Report, Volume II of II

Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

Contents

Volume I

- **Part 1: Front Matter**
  - Transmittal Letter
  - Executive Summary
- **Part 2: Biological Assessment and Recommendations**
- **Part 3: Implementation Plan**
- **Part 4: Economic Assessment**

Volume II

- **Part 5: Appendixes**
  - **A: Comments related to Spokane River UAA**
    - A1: Summary of and Responses to Comments Received on Draft Spokane River UAA (Issued June 2004)
    - A2: Summary of and Responses to Comments Received on Revised Advisory Committee Draft Spokane River UAA (Issued August 2004)
    - A3: Letter from Washington Department of Ecology (July 8, 1998)
  - **B: Checklist of UAA Elements**
  - **C: Summary of Data Sources Used to Support Spokane River UAA**
  - **D: Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses**
    - D1: Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses Report
    - D2: TMDL Model Parameters for Updated Next Level of Treatment Table
    - D3: Additional Charts of LTI CE-QUAL-W2 Modeling Results for Year 2001
  - **E: Economic Analysis Background Materials**
    - E1: Land Application of Reclaimed Water
    - E2: Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent
    - E3: Rate Analysis City of Spokane
    - E4: Spokane County Preliminary Evaluation of Land Application

– **F: Advanced Wastewater Treatment Technology Evaluation Workshop (August 24, 2004)**

– **G: Resumes of Spokane River UAA Project Team**

Appendix A

Comments Related to Spokane River UAA

APPENDIX A

Comments related to Spokane River UAA

This appendix includes the following sections:

A1 Summary of and Responses to Comments Received on Draft Spokane River UAA (Issued June 2004)

A2 Summary of and Responses to Comments Received on Revised Advisory Committee Draft Spokane River UAA (Issued August 2004)

A3 Letter from Washington Department of Ecology (July 8, 1998)

Appendix A1

Summary of and Responses to Comments Received on Draft Spokane River UAA (Issued June 2004)

APPENDIX A1

Summary of and Responses to Comments Received on Draft Spokane River UAA (Issued June 2004)

Responses to comments received on the Draft Spokane River UAA report were completed on August 12, 2004, and posted to the website at http://www.spokaneriveruses.net/documents/Spokane_UAA_AppA.pdf.

Response to Comments Received on Draft Spokane UAA

Commentator	Section	Subsection or Page	Paragraph	Comment	Response
Ecology – Melissa Gildersleeve	G	-	-	Before responding to the individual questions, we would like to take a moment to clarify where we are with the current UAA analysis. It is becoming obvious to us that we need to be more direct and less open-ended in our conversations with you to avoid giving you an overly optimistic assessment of the potential for the uses or criteria to be changed in the Spokane system. If we had to make a determination today based on the UAA report submitted to Ecology, we would conclude that trout spawning is an existing and attainable use for the river, and that trout rearing is an existing and attainable use of the reservoir. We would also conclude that there is no sound basis for assuming that trout would not be relying on the hypolimnion of the reservoir during the summer, and we find that rearing would be better protected by maintaining oxygen conditions throughout the entire reservoir as near to saturation as possible. And finally, without a technical evaluation of the opportunities to improve water quality by altering the hydropower operations on the system, we must be additionally optimistic in assessing the attainable uses and water quality conditions.	Open and direct conversations continue to be welcome and encouraged. Conclusions in the UAA also support the determination that spawning is an existing and attainable use for the river and that rearing is an existing and attainable use for the reservoir. The primary distinction is that the UAA attempts to establish appropriate temporal and spatial resolution of when and where these uses (and other uses such as cool and warm water species spawning and rearing) are occurring (or may occur under attainable conditions), and appropriate DO criteria to protect those uses. We agree that the hypolimnion may play an important role for trout rearing and foraging in the reservoir, particularly for existing or future stocked fish. We have provided additional analyses relating to where suitable conditions for these fish occur in the hypolimnion, both now and under attainable conditions, and how much suitable volume that represents (see sections 3.3.2 and 4.2.2). We have identified this as a subcategory of use and recommended DO criteria specific to the upper and lower portions of the hypolimnion (see section 5.2.3 and 5.2.4). We certainly agree that changes in hydropower operations might significantly affect water quality. Additional discussion of hydropower considerations has been provided in sections 4.1.1 and 4.2.1.
Ecology – Melissa Gildersleeve	G	-	-	We did not find sufficient analysis to support the contention that fish would not spawn in the area of the reservoir that currently comprises the hypolimnion. While this is a reasonable assumption, the UAA must be more complete in its evaluation of the various species that inhabit the reservoir and their spawning patterns – with a focus on the depths, seasons, and substrate characteristics. For example, species may be using the portions of the hypolimnion for spawning during the winter and early spring when conditions are generally favorable. Improvements in light penetration due to better control on sediments and algal growth, increased oxygen due to better control of BOD and nutrients from both point and nonpoint sources, and alternative flow patterns through the hydropower facilities may change current limiting conditions in what is now the hypolimnion.	We have added additional habitat information for species that have been observed in Long Lake Reservoir. Nearly all of the cool- and warm-water species observed in Long Lake Reservoir spawn in the spring within shallow or nearshore littoral zones. Additional biological information and analysis is provided in section 3.3.3 and Table3-7. In terms of potential future responses in the reservoir from control of point and non-point sources and altered hydropower operations, additional information and analysis is provided in section 4.2.
Ecology – Melissa Gildersleeve	G	-	-	The term “natural conditions” is used in two ways when we refer to Lake Spokane: (1) When implementation of the water quality standards is discussed (such as the TMDL or permitting issues) we consider natural conditions to be the lake (as formed by the dam) without anthropogenic pollution sources. (2) When rule revision (for instance a use change or a variance) is discussed in the context of removing designated uses, the natural conditions are considered to be the condition of the waterbody without human influences – including dams or other hydrologic modifications. This interpretation is necessary to remain in compliance with the federal UAA regulations at 40 CFR 131.10(g)(4).	Washington’s current standards state that where natural conditions are less than the criteria, natural conditions shall constitute the criteria with no measurable decrease (±0.2 mg/l). Although neither the temperature nor the DO standards were developed with lakes/reservoirs in mind, Ecology recognizes that the “natural condition” (plus the small 0.2 mg/l incremental allowance for human degradation) does not completely address stratified conditions such as those commonly found in lakes and reservoirs. Even more fundamentally, reservoirs are man-made waterbodies that are not “natural”. Thus, applying the “natural conditions” language of the water quality standards to dams or other hydrologic modifications is not appropriate. Federal UAA regulations at 40 CFR 131.10(g)(4) recognize that dams are not natural, and therefore, allow incorrectly designated uses to be modified, as appropriate.
Ecology – Melissa Gildersleeve	G	-	-	The report does not contain an analysis of the invertebrates that are either present in the hypolimnion now, or that may be present if human sources of pollution were remedied. We had suggested in a previous meeting that it would be very important to identify the highest – most sensitive – uses that could be attained in the hypolimnion in the absence of human sources of water quality degradation. The report only makes the circular argument that in waters that are devoid of oxygen the species present would only be those with a high tolerance to hypoxic conditions.	Additional information and analysis regarding existing and attainable macroinvertebrate uses in the hypolimnion have been added (see sections 3.3.3 and 4.2.3 and Table 4-1).

Commentator	Section	Subsection or Page	Paragraph	Comment	Response
Ecology – Melissa Gildersleeve	G	-	-	A further evaluation of the substantial and widespread social and economic effects is needed if an argument to change uses is based on cost. This question calls out the differences between how information is considered when implementing the standards and when setting the standards. When the standards are implemented, for instance in an AKART (all known, available, and reasonable treatment) determination the cost effectiveness approach, sometimes called the "knee of the curve" approach, is frequently used to determine permit requirements. When setting the standards, water quality criteria are based on biological risk without consideration of cost. Cost concerns sometimes comes into consideration through the allowance of provisions such as mixing zones or compliance schedules. When use changes or variances are considered the federal regulations require that an assessment of substantial and widespread economic and social impacts be conducted if attainability is limited based on the ability to control pollution.	It is our understanding that federal regulations only require one of the six factors under 40 CFR 131.10(g). Thus, human caused conditions that cannot be remedied (factor 3) and hydrologic modifications in which restoration is not feasible (factor 4) can be implemented independently from the substantial and widespread social and economic impact factor (factor 6) if appropriate in a given circumstance. A recent precedent for this is the Chesapeake Bay UAA. In this case, EPA cited factor 1 (natural conditions) and factor 3 (human-caused conditions) as its bases to modify designated uses via establishment of new subcategories and applicable DO criteria. Factor 3 was cited because analyses had been done showing that application of state-of-the-art treatment for point sources and reasonable expectations regarding control on nonpoint sources would not provide attainment of designated uses and criteria. Thus, it was determined human caused conditions could not be remedied. A substantial and widespread social and economic impact analysis was not conducted, nor was this factor cited as a necessary basis for use changes or criteria establishment.
Ecology – Melissa Gildersleeve	G	-	-	Potential Criteria Table This table over simplifies the discussion that we included in our letter. The letter described possible approaches that might be acceptable if certain conditions could be demonstrated in the UAA. These demonstrations have not yet occurred. For example, there has been no reasonable or acceptable demonstration that trout will not be relying on the cool waters in the hypolimnion for holding during the summer, thus the inference that oxygen may be acceptably lowered to 4-5 mg/l is not an appropriate assumption.	Further discussion and detail regarding recommended criteria and their application is provided in sections 5.1 and 5.2.
Ecology – Melissa Gildersleeve	G	-	-	Ecology did not move forward with its proposal to revise the state's dissolved oxygen criteria. The old Class AA, Class A, and Class B freshwater oxygen criteria were just incorporated into the new use categories. Thus the 2002 white paper was not used as the basis for the current (new) standards. The white paper was used, however, in developing our last letter to you on possible use-based oxygen levels that we may be able to view as protective if the UAA could demonstrate that alternative uses represent the highest attainable uses for the system. In understanding the 2002 white paper it is important to recognize that Ecology would not support relying on the one-day minimum values alone or the 30-day average minimum values alone. They act in tandem to ensure that conditions would remain fully protective. It is also important to realize that we dropped this topic because we could not get key stakeholders such as EPA comfortable with the use of these two metrics given the limitations of current field monitoring programs. Thus, any UAA that uses these metrics will need to provide some assurance that the outcome would indeed ensure that the average minimum oxygen concentration would be met along with the one-day minimums. Ecology did not develop an implementation method for converting the 30-day and 1-day minimums into effluent limits or TMDL loading targets since the proposed criteria were dropped from the state's rulemaking. The criteria would need to be met at the time of the year that the use exists or would likely exist if human sources of water quality degradation were alleviated.	Thank you for the clarification. We have taken this into account as we evaluated sub-categories and applicable criteria for the river and reservoir. See Sections 5 and 6 for our specific recommendations and how they might be implemented.
Ecology – Melissa Gildersleeve	G	-	-	DO criteria [should not] be set at what can be achieved with the highest level of treatment and nonpoint source control. As mentioned above, water quality criteria are set based on biological risk and not on cost of attainment. Ecology's draft guidance at present would in some cases allow the water quality criterion to be set based on attainability. In these cases attainability would be based on one of the six criteria specified in 40CFR131.10(g), not on the degree of pollution control as referenced in your question. However, as we mentioned at the meeting, USEPA has expressed some concerns with the particular approach specified in the guidance, and we will be speaking with them soon to determine whether attainability based on 40CFR131.10(g) can in some cases be used to set a waterbody specific criterion. Until that issue has been resolved it would be prudent to expect that a waterbody-specific criterion should be based only on biological risk without considerations of attainability.	The numeric criteria recommended in Section 5 are all biologically based. We have recommended a narrative criterion for the lowest portion of the hypolimnion (representing about 12% of the reservoir volume during worst-case conditions in August). This narrative approach emphasizes maximizing the volume of suitable conditions in the hypolimnion via the next level of treatment and control of nonpoint sources. See previous response regarding economic and social impacts analysis.

Commentator	Section	Subsection or Page	Paragraph	Comment	Response
Ecology – Melissa Gildersleeve	G	-	-	Applicable technical rationale behind other Region 10 standards (that have been approved by Region 10 EPA) [should not] be applied to this system. Information from other recent standards changes that EPA has approved can help give context to the standards approval process, but this information is unlikely to affect decisions made in Washington. Our experience with EPA and standards approvals indicates that each state is evaluated and treated separately based on state-specific situations. Just because EPA approved a criterion in the past does not mean that they would approve it today if it was submitted to them. Changes in EPAs understanding about the impact of parameters such as dissolved oxygen and temperature occur, and thus they will not a criterion in Washington just because they have approved similar criterion in Idaho. Recent court cases and rulemakings in Oregon along with Washington's process of developing proposed oxygen criteria have further raised EPAs awareness on the importance of maintaining oxygen rich waters.	We appreciate this comment. We provide examples from other states and EPA regions in this UAA report to provide important context and precedent in sections 2.2.2 and 2.3. We understand that Ecology and EPA Region 10 will decide the outcome of this process based on their own considerations.
Ecology – Melissa Gildersleeve	G	-	-	The application of the Spokane Tribal standards needs to be determined with Spokane Tribe and the USEPA. Any change in uses or criteria resulting from the Spokane UAA must be protective of downstream uses and criteria as specified in the Washington Water Quality Standards. A change in Washington's standards, even through a UAA process, does not change the Tribe's standards or alter the obligation to meet those standards.	We appreciate this comment and understand that downstream standards must be considered in the UAA, TMDL and FERC relicensing processes. Consideration of downstream standards is discussed in Section 6.3. In addition, the City of Spokane (one of the UAA Sponsors) has requested a meeting with Tribal Government Officials. This meeting is pending Tribal Review of the Draft UAA.
Ecology – Melissa Gildersleeve	G	-	-	Ecology strongly reiterates the recommendation that you coordinate with the Avista relicensing process. Information such as PM&Es could prove valuable in determining the attainable conditions of the waterbody. As discussed earlier, changes in uses must be based on the criteria set in 40CFR131.10(g). In addition, a UAA addresses a **waterbody** (not a specific discharger or group of dischargers), and as such must examine, as much as possible, all human effects on the waterbody. This means that in order to fully evaluate attainability for a use change in an area such as the Spokane River and Lake Spokane where the water quality is impacted by humans, Ecology must know the whether the dams could be removed, or whether their operations or structures could be modified to improve water quality without causing substantial and widespread economic and social effects to the local area. As we discussed, some of this information might be available in the FERC relicensing process.	We are coordinating with AVISTA. Additional discussion of hydropower considerations has been provided in sections 4.1.1 and 4.2.1.Unfortunately the AVISTA licensing process is under a different schedule than the development of the UAA and different from the TMDL. Nonetheless, potential protection, mitigation, and enhancement measures (PM&Es) associated with relicensing process that have been identified (as of June 2004) have been evaluated in the context of defining attainable uses in sections 4.1.1 and 4.1.2. Although we recognize the need to consider widespread, economic and social impacts when evaluating the ability to attain water quality standards, a social and economic study was not conducted because it was not cited as a necessary basis for use changes or criteria establishment. Sections 4.1 and 4.2 provide the factors that are the basis for the proposed use change. The UAA sponsors have committed to undertaking a social and economic study, if appropriate, following a biological assessment. Dam removal, modification and operation changes are under FERC licensing jurisdiction. The licensing process is not on the same schedule as UAA or TMDL. An integrated approach to these regulatory processes would be welcome. In the interim, potential protection, mitigation, and enhancement measures (PM&Es) associated with relicensing process that have been identified (as of June 2004) have been evaluated in the context of defining attainable uses in sections 4.1.1 and 4.1.2
WDFW – Chris Donley	3.2			Table 3-1 – Deep creek is only intermittent in portions of the basin. It is an excellent trout stream in areas where there is surface flow. It is very common in this area to have streams that flow in and out of the ground.	Thank you for the clarification. Corrected in revised UAA in section 3.2.3.
WDFW – Chris Donley	3.2	3.2.1	5	"spawning habitat consist of small patches…" This statement is not applicable to the upper river. The report from NHC made this statement, but applied it to the lower river below Monroe Street. The opposite is actually true for the upper portion of the Spokane River. There are large areas of spawning gravel that are critical to year class recruitment. Please omit the referred to citation. NHC in the instream flow document identifies the critical spawning areas and the approximate size.	Thank you for the clarification. Corrected in revised UAA in sections 3.2.1 and 3.2.3.

Commentator	Section	Subsection or Page	Paragraph	Comment	Response
WDFW – Chris Donley	3.2	3.2.1	8	Upriver Dam to Nine Mile Dam The document characterizes this reach as limited in data. This is not entirely accurate. The reach from Upriver to Monroe street has little to no available data, but the reach from Monroe Street to Nine Mile Dam does. WDFW provided data to you for this reach. These two reaches should be separated. They are completely different in terms of aquatic habitat, aquifer inflow and fish populations. The fish population between Upriver and Monroe Street is an unknown. However, Avista does stock rainbow trout in this reach and there are observations of wild rainbows. The overall population for this reach appears to be dominated by native cyprinids and catostomids. The Monroe Street to Nine Mile Dam reach has an excellent trout population. It has been well documented by WDFW and Avista that there is a naturally reproducing population of rainbow trout and mountain whitefish in this reach. The densest population of rainbow trout in the Spokane River occurs in this reach. The document asserts that the river, " alternates between lotic and lentic environments". This is inaccurate; the amount of "Lake" habitat in this stretch is limited in comparison to the free flowing stretches. Regardless of how the reaches are broken out this is a mischaracterization of the habitat. The only major "lake" type habitat is the Nine Mile pool. I suggest that this be broken into a separate reach and characterized using the WDFW data that was provided for this portion of the river.	Thank you for the clarification. Corrected in revised UAA in section 3.2.3.
WDFW – Chris Donley	3.2.	3.2.2	4	Last sentence. Taken out of context. There is no argument that non-natives have a competitive advantage in elevated water temps, but there are no non-native species in this reach of the river exhibiting competitive advantage. The only non-native species in this reach is brown trout, and they are present in low numbers. This indicates that the habitat conditions are not conducive for them to establish a large competitive population.	Thank you for the clarification. Deleted from revised UAA in section 3.2.
WDFW – Chris Donley	3.2.	3.2.2	7	Higher concentrations of DO are not counterintuitive when you consider that 95% of the reach is **free flowing** with considerably more water than the upstream reach. Break the reach into two reaches and it may be easier to characterize the increase in DO.	Thank you for the clarification. Corrected in revised UAA in section 3.2.2..
WDFW – Chris Donley	3.2	3.2.3	Table 3.3	Omit following species – golden trout, dolly varden, arctic grayling. There is a potential native strain of kokanee in the Little Spokane River.	Thank you for the clarification. Corrected in revised UAA in Table 3-4.
WDFW – Chris Donley	3.2	3.2.3	10	"However, non-native species have been introduced…" This quote is appropriate for the river as a whole, but there several reaches of the river that are dominated by cold/cool water native species, that while densities are probably lower than historical, the fishery has not changed significantly in the last five decades. The upper river and the reach below Monroe Street are two examples of the cold/cool water fisheries. While it would be convenient to dismiss these populations they do in fact exist and are providing recreational and ecological benefits.	Thank you for the clarification. Corrected in revised UAA in section 3.2.3..
WDFW – Chris Donley	3.2	3.2.3	13	"furthermore, a WDFW…" Genetics have not been completed on this stretch of river. The findings you have attributed to me are relevant to the reach below Monroe Street. It is true that the genetics below Monroe Street are unclear, but the initial findings do not indicate, " …that this population has not been heavily influenced by other populations". The initial findings do not indicate whether their was or was not influence from other populations. The end all be all to this point is, there isn't enough known about the genetics of wild rainbow to draw any conclusions at this time.	Thank you for the clarification. Corrected in revised UAA in section 3.2.3.
WDFW – Chris Donley	3.2	3.2.3	16	What WDFW 2003 document states fish per mile? WDFW may have extrapolated data from CPUE to infer densities by square meter, but no scientifically valid, statistically sound population estimates have been conducted. Please omit the citation and sentence it is not scientifically valid.	Thank you for the clarification. Corrected in revised UAA in section 3.2.3.
WDFW – Chris Donley	3.2	3.2.3	24	Upriver Dam to Nine Mile Dam – again the breakout of reaches leads to confusion. To adequately describe management activities, it needs to be more clearly illustrated where fish are stocked in the river and when. The fishery in this section should be considered **cold/cool** not cool/warm	In section 3.2.2 we have changed the description of the riverine reach to be a cool- and cold-water fishery. This includes the Upriver Dam to Nine Mile Dam section.

Commentator	Section	Subsection or Page	Paragraph	Comment	Response
WDFW – Chris Donley	3.2	3.3.3		Under heading Rainbow Trout pp. 3-29 – spawning and rearing are definitely limited in Lake Spokane, but WDFW stocking eliminates these from being critical life stages for supplemented trout populations. Trout are commonly found to inhabit pelagic habitat. The stock of fish stocked in Lake Spokane are almost strictly zooplanktivorous/insectivorous allowing for their ability to utilize pelagic areas efficiently. Lake Roosevelt that has similar littoral and pelagic habitat supports a successful stocked rainbow fishery.	Although we agree that the WDFW rainbow trout stocking program might eliminate rearing from being critical life stages for stocked populations, our recommendations include protecting rearing requirements for wild rainbow trout and other cold- and cool-water species. In terms of where trout may be rearing, we thank you for your input. Corrected in revised UAA in section 3.3.3.
Spokane Tribe – Chris Butler	ES	ES-3		In this case [the Spokane Tribe] disagrees with the mixed fishery and … with limiting the cold water aquatic life. This is a salmonid fishery which is a cold- and cool-water fishery. By increasing temperature will further increase the temperatures down stream, which is already in violation during the late summer months to our water quality standards. By eliminating the cold-water you are eliminating a population of E.P.T. macroinvertebrates which is also needed for salmonid rearing.	We agree that the fishery in the riverine reach (upstream from Long Lake Reservoir) is better characterized as a mixed fishery supporting cold- and cool-water species; this has been changed in the revised UAA in section 3.2.3. The fishery in Long Lake Reservoir can still be more accurately characterized as a cool- to warm-water fishery based on WDFW population surveys conducted in 2001 (see new Figures 3-14 and 3-15). The UAA does not propose to increase actual temperatures, decrease actual DO levels, or eliminate any cold-water aquatic life. Its primary objective is to reconcile the existing and attainable uses (fishery and macroinvertebrate) with the correct water quality criteria (uses and criteria). While there are clearly salmonids present, to characterize the system as a salmonid fishery is not a complete description of the entire fishery. Although the draft UAA did not yet contain recommendations, the revised UAA recommends *higher* levels of DO during critical salmonid spawning periods in riverine reaches in recognition that this critical life stage deserves to be well protected (see sections 5.1.1 and 5.1.4).
Spokane Tribe – Chris Butler	ES	ES-4		Research shows that with the other species that you are trying to identify as a mixed fishery don't require the high levels of DO for survival. By keeping the salmonid species as your target for DO levels you will be protecting the other species. By utilizing other species for DO levels you are not protecting salmonids and wiping out their ability to sustain a population.	Although the proposed sub-category of use recognizes a mixed fishery, in fact, salmonids continue to drive the recommended DO criteria during specific life stages (spawning and rearing) because these remain the most sensitive species (see sections 5.1.1, 5.1.2, and 5.1.4).
Spokane Tribe – Chris Butler	ES	ES-5		You can not ignore salmonids i.e. mountain white fish, kokanee, and resident chinook, they are and will always be receiving washouts from Lake Coeur d'Alene. Landlocked salmon and kokanee will always be present in Lake Spokane as they are present in Little Falls pool as well. These species have been observed spawning in Tshimikain Creek which is located at the Eastern tribal boundary. The Sherman Creek Hatchery, Spokane Tribal Hatchery, and The Lake Roosevelt Land Development Association releases 1,000,000 kokanee and 500,000 rainbows a year into Lake Roosevelt and the Spokane arm. Kokanee are observed and captured trying to access Little Falls Dam in order to reach their spawning grounds. It is not just Western Washington that is protective of anadromous runs, our water quality standards are protective of it also. Reason being that one day the tribe would like to see the runs returned	While there are limited washouts of salmonids (chinook and kokanee) from Coeur d'Alene Lake, these individuals do not appear to make up a sustainable, reproducing population in the Spokane River (see section 3.2.3 and Table 3-4). The kokanee in Long Lake Reservoir appear to be migrants of the stocked fish that have moved down the Spokane River from Coeur d'Alene Lake and are not reproducing within the reservoir (see Section 3.3.3). That is not to say that native salmonids are not present in the system, but water quality criteria are typically set to protect critical life stages (spawning and rearing) of self-reproducing fishery populations. Downstream fishery populations sustained by successful hatchery releases of kokanee and rainbow trout should be protected to every extent possible. The recommendations from this UAA are consistent with the potential that anadromous runs might return, in that salmonid spawning and rearing uses continue to drive the proposed site-specific sub-categories and criteria. In addition, if anadromous runs are restored in the project area, the periods in which they would be migrating through Long Lake Reservoir (fall and spring) do not coincide with periods of lowest DO.
Spokane Tribe – Chris Butler	ES	ES-6		You are referencing the tribal governments many times throughout this document, meaning it sounds as if you have been getting our input from the beginning of this UAA. I have had one consultation with CH2MHill in which can be summed up as; yes we have water quality standards, no we are not interested lowering them. Other than this to my knowledge the tribe has not been consulted with during the development of this analysis.	When the sponsors asked for meetings with the Spokane Tribe, tribal technical staff said that it wanted to see the draft UAA before scheduling those meetings. Our comments in the draft UAA did not mean to imply that tribal coordination has been ideal. The sponsors recognize the importance of the Tribe's input and meeting the tribal water quality standards. The sponsors also recognize that consultation with the Spokane Tribe must be on a government to government basis and not as part of a broad based citizen involvement program or strictly on a staff to staff basis. The City of Spokane (one of the UAA Sponsors) has requested a meeting with Tribal Government Officials, pending Tribal Review of the Draft UAA. It is clear that conditions in the river and reservoir continue to require additional source control of nutrients beyond current levels, the sponsors are committing to further watershed improvement including the next level of treatment and participation in nonpoint source programs as appropriate and pursuit of conservation and reuse opportunities over time to accomplish the most effective clean-up of the river possible. This is discussed in more detail in section 6.2.

Commentator	Section	Subsection or Page	Paragraph	Comment	Response
Spokane Tribe – Chris Butler		Pg. 3-8 Table 3-3		Using your own words this paragraph should be raising a red flag that we are loosing native species due to human interaction and that things need to be done different in order to protect those species. Ie. Bull trout, kokanee, white sturgeon. Though your study by Zaroban et al 1999, says that the white sturgeon can handle "intermediate pollution." (A recent study by the Spokane Tribe and WDFW shows the numbers of sturgeon have been plummeting and that we are loosing spawning numbers and spawning grounds). There is not enough information to know all the limiting factors but we do know that there are large gaps in spawning recruitment. We know that longevity of white sturgeon leads to misinterpretation of the population. We know that dams, anadromous food resources lost, flow, temperature, turbidity, habitat diversity, and geomorphology are all apart of decreasing the population, and everyone of these is human caused (Upper Columbia White Sturgeon Recovery Plan 2002). This means you should be placing the White Sturgeon as a SENS species.	Thank you for your comments, particularly regarding White Sturgeon. White sturgeon were included in this table because of the sighting of one individual that washed down from Coeur d'Alene Lake. Although various studies classify sturgeon sensitivity, we have re-classified sturgeon as SENS to be conservative in Table 3-4.
Spokane Tribe – Chris Butler		3-24		You know as well as I do you don't make assumptions, you only state the facts. This comes across simply as a way of trying to per sway people of being in favor of lowering DO and temperature standards.	While it is true that no pre-1915 fishery studies are available for Long Lake Reservoir, reservoir fishery populations typically go through a series of changes through time as non-native species are introduced. No ecosystem remains static and as a reservoir system matures, there is typically a succession from native species to non-native species as native species are reduced through predation, competition, or other interactions. Given that the Long Lake Reservoir fishery is dominated by non-native cool- and warm-water species (Figures 3-14 and 3-15), it appears that the typical reservoir maturation process has also occurred within Long Lake Reservoir, as well. While the UAA is attempting to determine the appropriate DO standard for the system, there is no recommendation to alter the current temperature standard (20°C).
Spokane Tribe – Chris Butler		Page 3-26, 3-27; Table 3-6		The header category for DO Preference bothers me, because no where in that column do you talk about preference. All you mention is tolerated levels of which some seem a little extreme. I guess it would be dependent upon whether or not the study you are referencing was done in a lake or whether it was done in an aquarium at a lab. You are ignoring all the salmonid species except rainbow trout when it comes to actually listing a **preference** for DO. The avoidance of Chinook and kokanee is unacceptable, as they are present in Long Lake Reservoir, Little Falls Pool, and Lake Roosevelt. These lower systems will always have washouts from Lake Coeur d'Alene, and when the anadromous runs return the standards need to be pre-set that will protect these species for both temperature and DO standards.	The header description for this column in Table 3-7 (formerly Table 3-6) has been changed.
Spokane Tribe – Chris Butler		3-30		Having 3 mg/L of DO in this sentence bothers me because a rainbow might be able to withstand short periods of 3 mg/L but if it was expected to thrive in these conditions you are mistaken. The way you should be considering this is as 0-4 mg/L is lethal because they tend not to feed at DO levels below 5 mg/L, 4-6 mg/L is stressed, and 7-9 mg/L is optimal conditions (Cherry, D.S.K.L. et. Al. 1977).	These are the conclusions of Bradbury et al. 1993, which was published by the Canadian Ministry of Fisheries and Oceans. Our recommendations recognize that fish typically avoid oxygen concentrations below 5 mg/l (section 5.2.4). We have provided additional analyses relating to where suitable conditions for these fish occur in the hypolimnion, both now and under attainable conditions, and how much suitable volume that represents (see sections 3.3.2 and 4.2.2). We have recommended DO criteria specific to the upper and lower portions of the hypolimnion (see section 5.2.3 and 5.2.4).
Spokane Tribe – Chris Butler		3-30		First of all the fish weren't removed they were extirpated. Little Falls Dam has adfluvial runs returning to it each year whether it is the washouts from Lake Coeur d'Alene or the kokanee that are released each year by the hatcheries and net pins.	Section 3.4.3 recognizes kokanee salmon as being supported in the reaches downstream of Long Lake Dam.
Spokane Tribe – Chris Butler		3-30		This comment is indicating a cooling trend as the water travels from Long Lake Dam through the Spokane Arm of Lake Roosevelt. I could not find any references in the report that supported your statement. However I did find a graph, which if you look close enough that it is a three way graph. Depth, temperature, and DO are located on the graph and from what I can see you were replacing DO surface measurements with temperature. July and August surface temperatures were between 21 and 23ºC, not 15 and 17ºC.	Thank you for the clarification. Corrected in revised UAA in section 3.4.2.
Spokane Tribe – Chris Butler		3-32		It is 1,000,000 kokanee and 500,000 rainbows that are stocked each year and it is supported by Bonneville Power Administration, (fish and wildlife mitigation dollars).	Thank you for the clarification. The information on downstream conditions and uses has been constrained to include primarily Little Falls Reservoir, as that is next immediate downstream waterbody from the project area.
Spokane Tribe – Chris Butler		4-7		Its not cool- and warm-water fishery. It's a cold- and cool-water fishery, and once again you can't ignore kokanee, salmon and white fish.	The revised UAA now refers to the riverine reach as a cool- and cold-water fishery (section 3.5.1). Based on relative abundance data, the reservoir is accurately characterized as a cool- and warm-water fishery (section 3.5.2). Although the proposed sub-categories of use for both reaches recognizes a mixed fishery, in fact, salmonids continue to drive the recommended DO criteria during specific life stages (spawning and rearing) because these remain the most sensitive species (see sections 5.1.1, 5.1.2, and 5.1.4).

Commentator	Section	Subsection or Page	Paragraph	Comment	Response
Spokane Tribe – Chris Butler	G			I felt that **Recommendations** and **Conclusions and Implementations** should have been in this draft. I would recommend changes be made to characterization of the area and incorporate that into any recommendations you have while recognizing the Tribal water quality standards directly downstream. I hope you understand the Tribal Water Quality Standards and what our main objective and goals are.	While we continued to work on the recommendations, conclusions and implementation section (the latest versions of which are included in this revised UAA), many stakeholders requested to see the existing and attainable information we compiled. In the interest of keeping this process as open as possible, we felt it was better to release the information as it becomes available to ensure that the UAA is based on the most accurate information possible.
Spokane Tribe – Chris Butler	G			**Reservoir Volume (percent).** This graph is simply stating the fact that we are drawing down the aquifer sooner each year to meet demands of population grow. At some point and time we need to start looking at reuse. I know the costs are through the roof (Bruce Ralls) but with a new facility coming in the future now is the time to make a difference in our water quality.	Figure 3-6 is independent of any drawdown operations. Instead, it simply relates typical volumes with the bathymetry of the reservoir to provide a quantitative measure of how much volume occupies shallower water when the reservoir is near full-pool in the summer (that is, 76% of the reservoir volume is contained within the upper 15 m of the reservoir where DO levels are not depressed). One of the primary objectives of the UAA is to protect existing and attainable uses of the Spokane River. The sponsors of this project are committed to continue to reduce loading to the Spokane River and continue clean up the system. The UAA will not result in any reversal of this trend.
Spokane Tribe – Chris Butler	G			**No anadromous use.** I have mentioned it before and I will do so again that the tribe would like to see anadromous runs return. So we have to protect the integrity of the water quality.	We appreciate this comment; see previous responses to anadromous fish comments.
Spokane Tribe – Chris Butler	G			Preliminary DO Recommendations For Sub-categories of Use (Table) I cannot support this idea if it signifies a drop from the already exceeded tribal and state water quality standards.	The recommended criteria in Chapter 5 represent a refinement of criteria to reflect existing and attainable uses where and when they occur. These criteria are generally expressed as a combination of 30-day minimum and 1-day minimum values that are protective of long-term and short-term uses. The current criterion of 9.5 mg/l, that is applicable at all times and all places in the reservoir because of the simple carry-over of class-based uses that are not existing or attainable (core salmonid spawning and rearing), is not and *cannot* be met under any circumstances. The UAA and TMDL processes will result in achievement of the best attainable water quality in the reservoir, and hence the best attainable water quality downstream from Long Lake Reservoir.
John Gross	G	-	-	I consider it a travesty of justice that good citizens are burdened with review of this sort of potentially damaging red herring when cleanup of the Spokane is a mandated public responsibility that the State of Washington agreed to in a 1998 settlement. … This document is a misguided effort to show that aquatic life uses occurring in the Spokane are not properly documented in the state's water quality standards and that criteria protecting these uses are, therefore, not appropriate… This document is an effort to erode cleanup efforts and codify the Spokane's impairments.	One of the primary objectives of the UAA is to protect existing and attainable uses of the Spokane River. The sponsors of this project are committed to continue to reduce loading to the Spokane River and continue clean up the system. *The UAA will not result in any reversal of this trend*. A secondary objective of the UAA is to ensure that cleanup targets are appropriate for the system. As many of the sponsors are stewards of public resources, they have a responsibility to ensure that local taxpayer money is spent wisely. Having a TMDL move forward that is based on incorrectly-applied targets means that even if every technically-feasible improvement to reduce or eliminate discharges were implemented (including seasonal land application), the current standards *cannot* be met. It is important therefore to look at all contributions to DO impairment and to use resources appropriately to implement corrective actions that can achieve water quality targets.
John Gross	G	-	-	{Ecology and EPA] are not listed among your sponsoring group on your website, and , although it remains to be seen whether they will lend the slightest credence to this document, this effort so far is wanting in public involvement… In the event that this UAA effort somehow miraculously grows wings, you will be faced with public participation requirements that so far have been woefully lacking from your work.	Ecology and the sponsoring group continue discussions to resolve technical and legal questions. Public involvement was not detailed in the draft document because our public involvement specialists were continuing to compile the complete involvement history. This history includes meetings with the DO Advisory Group and the February public workshop. This information has been included in section 1.4. Additional public involvement is planned over the next year, including the necessary public involvement required in state regulations for standards changes.
John Gross	G	-	-	In an apparent attempt at irony, you term the group [of stakeholders] "diverse" although they share the common factor of being dischargers to the Spokane and include a large proportion of public agencies. Their stated goal… is a Clean Water Act provision and has been delegated by the EPA to the Department of Ecology for waters of the state… In accordance with that delegation Ecology underwent review and revision of the state's water quality standards… That would have been a far more appropriate forum in which to air your concerns with the standards… Please refer to WAC 173-201a [Section] 602 of the newly revised standards which included forty pages of site-specific water bodies and criteria.	All of the members of the sponsoring group live and work on the Spokane River and consider themselves local stakeholders that have a large personal stake in the health and quality of the river and reservoirs. These individuals have sponsored this study to ensure that the TDML is focusing on appropriate cleanup targets because they are charged with balancing the river and aquifer cleanup with fiscal responsibility. Many of the study sponsors provided comment to Ecology on the draft revised water quality standards in that public forum. Ecology's responsibility to promulgate water quality standards does not come with unlimited resources. Altering statewide standards is an onerous process that Ecology has provided to local stakeholder hands via the UAA processes. Unfortunately, the statewide change from a class-based system to a use-based system was an excellent opportunity to assign appropriate use-based criteria, which could not be realized fully because of state resource limitations. Thus, Section 602 of the revised standards is generally a reiteration of former class-based standards (on a site-specific basis) within the use-based system.

Commentator	Section	Subsection or Page	Paragraph	Comment	Response
John Gross	G	-	-	The document goes to some length, at undisclosed public expense, to assert that existing uses on the Spokane are equivalent to attainable uses. If this were the case, however, Sections 303(c) and 303(d) of the Clean Water Act would not be so pertinent to the issue at hand… You make the case that for nearly three decades [the fact designated uses are not existing uses] has escaped our attention despite lawsuits filed and settled, and considered revisions to pertinent state and federal law open to public comment.	The sponsors of this study are committed to implementing the next level of treatment to continue improvement trends seen over the last 25 years. The ultimate goal is that the system can be removed from the 303(d) list as being impaired. The "next level of treatment" is currently defined as that level of treatment being achieved by the Rock Creek Plant, operated by Clean Water Services in Washington County OR. This plant discharges to the Tualatin River. This plant achieves perhaps the highest quality effluent in the region, and this treatment technology would represent a 99 percent removal of phosphorus for dischargers to the Spokane River. Ultimately, the "next level of treatment" will require that the treatment meet the standard defined under the State Water Quality Act for "All Known, Available and Reasonable" methods of treatment, AKART. While the legal history on the Spokane River is rich, this analysis specifically addresses current TMDL processes and targets, and considers the newly revised water quality standards, including application of the UAA provisions that are being implemented elsewhere in the nation under EPA programs.
John Gross	G	-	-	You tell us that pollution control may increase the quality of the Spokane but that physical conditions will limit cold water biota. The assertion is difficult to believe given the tremendous runs of anadromous fish that once inhabited the Spokane and managed to deal with these limitations. The effort to codify the Spokane as a septic system does not pass muster and it is misguided work on the required TMDL underway…. We are all aware that we can provide far better wastewater treatment than direct discharge to the river.	The constraints that currently limit cold water biota include the physical reservoir system and its operations. When the anadromous runs were present, the reservoirs were not in place and the salmon were very likely thermally-adapted to warmer temperatures common to Eastern Washington than those stipulated under the current statewide criteria. To characterize this effort as codifying the Spokane as a septic system neglects the fact that the relative contribution of any of the dischargers to the Spokane River is less than 8 percent during drought conditions. Further, thank you for recognizing the efforts that have been made over the last 25 years to restore the system to its current state. These efforts include improving the City's CSO program (Section 1.3.4), as well as commitments to implement the next level of treatment. This level of treatment represents state-of-the-art technology for nutrient removal. Removing discharges from the river has also been evaluated. This option does not provide any additional benefit to the river's water quality over the next level of treatment.
John Gross	G	-	-	The fundamental assertion of your document is that because aquatic life in the Spokane is struggling and impaired, we should grace this condition…[this] is not a morally defensible reason to write these uses to extinction, as we did with historic life uses of the Spokane and Columbia…. Figures 1-2 and 1-3 of your document indicate better water quality through time in the Spokane; what is it that encourages you to reverse this trend?	The UAA never asserts that we should grace struggling and impaired aquatic life, nor does it recommend any backsliding of water quality improvements. *The UAA will not result in any reversal of water quality improvements because sponsors will continue to be engaged in the TMDL process and are committed to implementing the next level of treatment.*
John Gross	3.2	3.2.3	-	Please consider review of your fisheries section by a fisheries biologist.	We continue to solicit input to our technical information so that the analysis is as accurate and thorough as possible. Thank you for the clarification. Our fisheries biologists (who have been extensively involved throughout this process) have reviewed and addressed this information throughout the revised UAA.
John Gross	1.2	1.2.1	3	I fail to see the goal of "to be financial stewards of public monies such that these resources are spent on effective and achievable cleanup objectives" to be implemented in any fashion. In fact… [I] feel like the sponsoring group and the citizens of this area got shellacked…. It is not the responsibility of the Spokane dischargers or their consultants to write or revise water quality standards. So, please cash your checks and leave TMDL development to resource managers and true stakeholders.	Ecology has responsibility to promulgate water quality standards, subject to EPA approval. As noted above in an earlier response, Ecology is resource constrained and, thus, technical analyses for altering statewide standards (which is justifiably onerous process) will in most cases be conducted by stakeholders affected by water quality standards that may be inappropriate via the UAA processes.
John Gross	4.2	4.2.3	1	This section predicts the dire consequences we can expect in our fishing prospects should we *reduce* BOD loading to lower Spokane.	Section 4.2.3 has been revised to be clearer. If the reservoir moves more toward an oligotrophic system, biological productivity could either increase or decrease; associated effects to the existing fisheries community are uncertain.

NOTE: G = General comment not related to specific UAA section.

Appendix A2

Summary of and Responses to Comments Received on Revised Advisory Committee Draft Spokane River UAA (Issued August 2004)

APPENDIX A2

Summary of and Responses to Comments Received on Revised Advisory Committee Draft Spokane River UAA (Issued August 2004)

Responses to comments received on the Draft Spokane River UAA report were completed on November 28, 2004.

APPENDIX A2

Response to Comments Received on August 11 Draft Spokane River UAA

Comments are grouped into the following broad categories:

- General Comments
- Downstream Surface Water Quality Comments
- Avista Corporation (Avista) Relicensing Comments
- Social and Economic Impacts Comments
- Total Maximum Daily Load (TMDL) Implementation Comments
- Washington State and U.S. Environmental Protection Agency (EPA) Standards Comments
- Other Case Studies Comments

Specific comments are then addressed within the following technical categories:

- Biological (Fish and Macroinvertebrate) Comments
- Limnology Comments
- Modeling Comments
- Recommended Criteria Comments
- Other Specific Technical Comments

General Comments

Commentator	General Comments	Response
Ecology – Melissa Gildersleeve	Thank you for the opportunity to review the August 2004 draft of the Spokane River and Long Lake Reservoir Use Attainability Analysis (UAA). As we have discussed at prior meetings, in order to proceed with changes to our water quality standards, the use attainability analysis needs to meet the federal regulations and needs to contain enough scientific rigor to support the removal of a use. In general, we do not find that our previous comments have made an impact on the approach taken for this UAA [Ecology correspondence: May 23, 2003; May 13, 2004; July 8, 2004]. ***A*** While this is troubling, we are still hopeful that the final product will be one that meets state and federal water quality regulations and can serve as the basis for adjusting any incorrectly designated uses in the Spokane system. The information in the draft UAA seems to support the position that, with the exception of salmonid spawning as a designated use for the lower segments of the reservoir, the uses currently designated for the Spokane River system appear well placed. Based on the information provided, only minor fine tuning through setting more tailored spawning and rearing windows seems supportable at this juncture. While we support this form of fine tuning, we do have numerous concerns regarding the approach taken in the draft UAA: • All states and tribes must set standards and control pollution sources in a manner that meets the downstream tribe or state's standards. The uses and criteria established in a UAA must meet the Spokane Tribe's standards, regardless of the conclusions in the UAA. While the tribe could voluntarily choose to modify its standards on the basis of the UAA, Washington cannot use the UAA to override the promulgated standards of the Spokane Tribe. ***B*** • The dams and their ability to influence water quality need to be incorporated in the UAA analysis. The UAA cannot simply state that their effects are what you would expect and that they preclude uses. If dams are exerting a negative influence, then an analysis in conformance with 40 CFR 131.10(g)(4) needs to be included. ***C*** • The document revolves around assumptions that have not been demonstrated to be valid for the system. These include assumptions that food may be limited for fish, and that there would be no significant water quality benefits from dam alterations. Assumptions that are used as the basis for a use change need to be supported with scientific data or studies. ***D*** • The document paraphrases both state water quality standards and the federal UAA rules in ways that change their meaning. ***E*** • We are not inclined to support using a narrative goal statement as the sole criteria for protecting the resources of the hypolimnion in the reservoir. To support a biologically-based UAA, we need at least to see numeric criteria that would allow the water to be used as thermal refugia and short-term foraging habitat, as well as to provide for a more diverse macroinvertebrate community. Saying that the fish have plenty of other places to inhabit so they don't need the hypolimnion is not an adequate basis to support a rule change. ***F*** • There needs to be more information to support the timing windows used to apply the spawning criteria. Based on an abbreviated examination of the cited references, the timing windows recommended do not seem to match the actual spawning periods. We support using the annual average spawning and emergence dates for establishing the spawning through emergence window. • There needs to be more consideration of existing and attainable uses. Kokanee, cutthroat trout, chinoook salmon, and mountain whitefish are not adequately addressed. ***G*** Given the short review time for this draft document, we have not reviewed all of the key references. We will do this as part of our review of the final UAA. Instead, we have focused on providing detailed comments on items that need to be corrected as well as on areas that need additional information. When we initially commented on this project, we encouraged the proponents to pursue the economic hardship provisions of the UAA rules. While we can possibly make some small changes to the standards based on a biological basis alone, it is unlikely to offer any significant relief from the standards. Even if a defensible UAA for the state's waters is developed, however, the UAA is unlikely to be approved if either the Spokane Tribe or the EPA are not supportive. ***H*** We look forward to the final UAA and to the satisfactory completion of this project. I have enclosed additional and more detailed comments. Please let us know if you have any questions or if you need any of our comments clarified.	***A***-We have appreciated the input and communication provided by the Washington Department of Ecology (Ecology) in this process to date. We believe we have responded completely to all previous written comments (for example, see Appendix A in the August report and Appendix A1 in this final report). We have made substantive modifications in overall approach and scientific support and content in relation to Ecology's comments. Although we have not agreed with Ecology on all issues, we have provided detailed responses to all comments. We also note that the proposed surface water quality standards pending at EPA do not include a true "use-based" standard for the Spokane River or Long Lake Reservoir because they are simple carry-over uses from the "class-based" system. Ecology has neither attempted to validate the legitimacy of these carry-over uses and criteria nor established use-based standards specific to reservoirs. These are the fundamental reasons that this Spokane River and Long Lake Reservoir Use Attainability Analysis (Spokane River UAA) is needed. We agree that this Spokane River UAA needs to meet regulatory requirements and contain adequate rigor to support use refinements. We believe that this final document accomplishes those objectives. ***B***-Ecology overstates the language of 40 CFR 131.10(b), which is as follows: "In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters." The modeling conducted by both Ecology and Limno-Tech, Inc. (LTI) has demonstrated that implementation of the proposed next level of treatment scenario (NLoT scenario) in this Spokane River UAA will increase dissolved oxygen (DO) in reservoir releases to the maximum extent that proven wastewater treatment processes are capable of achieving. Control of nonpoint sources and a broader watershed approach, including Avista relicensing, are needed for any further improvement in the downstream Spokane Tribe DO standard. Aeration of the reservoir or its releases may ultimately be appropriate (see Part 3, Implementation Plan). Aeration would provide for the attainment of downstream surface water quality standards. All of these approaches, which are based on a coordinated, watershed-based solution, are discussed in the final Spokane River UAA report. On the other hand, Ecology's modeling has also demonstrated that its proposed TMDL (Ecology, 2004e) will not meet the Spokane Tribe's downstream DO standard in the reservoir. Finally, we note that the Spokane Tribe has not designated the Spokane River as "impaired" in the area for which it has adopted standards. ***C***-The draft versions of the Spokane River UAA report included extensive discussion of the dams and their effects on surface water quality. This final Spokane River UAA report includes additional analyses regarding the dams and the reasons why it is appropriate for this Spokane River UAA to assume that the dams will not be removed. As you know, dam removal has been removed as an option for the hydroelectric facilities on the Columbia River. Potential operational changes associated with relicensing the dams and the likely effects on surface water quality have also been included in the Spokane River UAA. 40 CFR 131.10(g)(4) is cited as one regulatory basis for the recommended surface water quality standards modifications in this Spokane River UAA. ***D***-Food limitations are not cited as a basis for any use changes. Habitat limitations are the primary reasons for use refinements. These conclusions are supported with scientific data and studies (see Part 2, Sections 3 and 4). ***E***-Ecology has not cited any specific examples of such paraphrasing in the Spokane River UAA report. Without a more specific comment, it is not possible to respond other than to note that we believe that the regulatory basis for the recommendations in this Spokane River UAA is sound and defensible. ***F***-The narrative approach proposed does not apply to the vast majority of the hypolimnion. It only applies to the small portion at the very lowest depths closer to the dam (only 12 percent of total reservoir volume). In addition, this final Spokane River UAA recommends that the narrative approach for this small portion of the reservoir should include long-term goals of maintaining DO levels as high as possible, and higher than 4.0 milligrams per liter (mg/L) on a spatially averaged basis. Implementation of this Spokane River UAA will lead to average DO in the very lowest depths of the hypolimnion closer to the dam being greater than 4.0 mg/L. Using 4.0 mg/L as a goal is consistent with the goal established in the TMDL for the Brownlee Reservoir hypolimnion (Idaho Department of Environmental Quality [IDEQ] and Oregon Department of Environmental Quality [ODEQ], 2004). That TMDL has been approved by EPA. As described in the Spokane River UAA, depth, temperature, and bottom substrate conditions likely will continue to limit macroinvertebrate diversity in this portion of the hypolimnion (see Part 2, Section 4.4.3). Finally, the analysis in the Spokane River UAA makes it apparent that

Commentator	General Comments	Response
		the attainable numeric DO criteria in the remaining 88 percent of the reservoir will protect all existing and attainable aquatic life uses. ***G***-We have included additional discussion on these species in this final Spokane River UAA. ***H***-The sponsors want Spokane River UAA-based standards that are rationally established for this highly altered system. The sponsors agreed at the beginning of the process to do an economic study once biologically based standards were in place. Substantial additional information has been included in this final Spokane River UAA regarding costs of compliance with Ecology's Draft TMDL (2004e) and with the standards recommended in this Spokane River UAA (see Part 4, Economic Assessment). We have also added considerable analysis related to the attainability of the proposed DO criteria in this final Spokane River UAA. This analysis concludes that the proposed criteria are, in fact, attainable with the NLoT and reasonable control of nonpoint sources through implementation of best management practices (that is, the NLoT+25 percent NPS BMPs scenario, see Part 2, Section 5.3). The cost differential between compliance with our proposed biologically based criteria compared to Ecology's proposed approach in the Draft TMDL (2004e) is an order-of-magnitude difference. We also understand the importance of including the Spokane Tribe and EPA in this process.
EPA, Office of Water, Region 10 - David Ragsdale	Thank you for the opportunity to provide comments on the draft Long Lake UAA. Although EPA has tracked development of this project, we are deferring to provide detailed comments at this time. EPA hopes the UAA proponents will address the technical and procedural issues raised by Ecology and the Spokane Tribe. To date, the draft UAA has not changed to address many of the state's comments and achieving compliance with the downstream tribal standards has been ignored. The direction of the UAA has instead continued on a course that is unlikely to be supportable by EPA, Ecology or the Tribe as a mechanism for adjusting the uses of Long Lake. It is my perspective that a UAA based on changing the currently designated biological uses will not result in any significant change in associated water quality criteria. Such a change was the rational behind the Spokane River dischargers funding this project. At the incept of this project I expressed (in public meetings at Spokane Falls Community College and during the initial UAA advisory committee meetings) that it should be determined very early in the analyses whether adjusting uses of the River and/or Lake based on biology would result in any meaningful relief for the dischargers. "Relief" being changing the water quality criteria associated with designated uses such that some loading of pollutants to these water bodies from the point sources could be justified. The UAA does not now support more than the original supposition that salmonid spawning in lower Long Lake may be the only non-existing or non-attainable designated use… Thank you again for soliciting public input on this project.	The Spokane River UAA has demonstrated that the existing and attainable uses are in fact quite different than the current designated uses. The vast majority of the reservoir does not support salmonid spawning. In addition, the reservoir does not support "core" salmonid rearing, for which it is also designated. The reservoir is, in fact, a mixed fishery, with warm- and cool-water species being dominant. Thus, a new subcategory of use for the reservoir, as described in the Spokane River UAA, is much more accurate and descriptive of existing and attainable uses. There are also substantial habitat constraints limiting salmonid uses in the river upstream of Long Lake Reservoir. Thus, the subcategory of use defined in this Spokane River UAA for that reach is also more descriptive of the existing and attainable uses. The DO criteria recommended in this Spokane River UAA will protect these more accurate uses. In addition, the cost of compliance with these Spokane River UAA-recommended uses and criteria are an order-of-magnitude lower than the excessive costs associated with Ecology's approach to compliance with the existing arbitrary DO criterion of 0.2 mg/L delta DO (also see above responses).
WDFW - Chris Donley	I do not have any substantive comments on the fish end of things for the UAA. It appears that most of the current data cited is accurate. Thank you for the opportunity to comment on this draft of the UAA. I will include substantive comments on the final draft of the UAA.	We appreciate the information, data, and previous comments provided by the Washington Department of Fish and Wildlife (WDFW) during this Spokane River UAA process.
Lincoln Loehr	My comments are based just on a quick review of the executive summary, and also the answers provided by Ecology in their September 2004 "Frequently Asked Questions About Protecting Oxygen in the Spokane River." I noted that questions and answers addressed the issue of who was doing the UAA and why. I think it is a fair answer that Ecology should have done UAAs for every waterbody in the state before they assigned them to the original classes, and that in switching to the Use Based standards, Ecology should have done UAAs then. The facts are, Ecology never did UAAs and consequently there are waterbodies that could have their actual and existing uses better described. Ecology will not do UAAs and instead puts the onus on affected parties to undertake. The public needs to realize this. The public may perceive this as self-serving, but they need to realize it is the only way the issue can be addressed. Sadly, it's also a fact that Ecology has not made the use of UAAs simple, nor have they allowed any changes to uses for waterbodies to-date. In fact, the agency is still trying to write basic guidance on how to do them. The TMDL is developed to try to meet a certain standard. The UAA is developed to see what the existing and attainable uses are, and also to identify what site-specific criteria are appropriate to protect those uses. I understand that there is public resistance to site-specific criteria. The public sees such efforts as weakening environmental protection. This leads me to my next point. What is the technical basis behind our current dissolved oxygen standards? The answer is, Ecology can't find what technical basis was offered when the standards were developed. The standards pre-date the formation of the Department of Ecology. I will provide a copy of correspondence to that effect. Since the state had no technical basis behind their standards, it is interesting to note that EPA has freshwater dissolved oxygen criteria and they are not single numbers, but a range of numbers covering different situations. I have attached a summary of the EPA criteria. In 1998 I asked the State to go through rulemaking to remove the existing DO standards and to replace them either with EPA's criteria or with other scientifically based values. Ecology did start a dissolved oxygen review and was moving towards revisions, but ultimately pulled the proposed revisions from their final rule. Hence, we still have dissolved oxygen standards that are more than three decades old, for which the original technical basis behind them is unknown and unknowable. We do have EPA criteria that are	The Ecology letter cited was subsequently provided by Mr. Loehr. It is included as Appendix A3.

Commentator	General Comments	Response
	less stringent. The proposed site-specific standards for the Spokane River and the Long Lake Reservoir do not appear to me to conflict with the EPA's approach to dissolved oxygen criteria.	
	I also note that the UAA and the proposed site-specific standards take into consideration different applications over the water column. This approach is quite appropriate for waterbodies such as lakes, reservoirs and even the ocean. Deeper waters naturally have less dissolved oxygen because they are removed from the source of oxygen and the available dissolved oxygen is gradually utilized by the biota. Unfortunately, DOE's regulations do not provide a sensible means for implementing dissolved oxygen standards, other than the provision that where the natural condition is lower, then the natural condition is the standard. In reality, Ecology generally makes comparisons to the numbers in the standards and fails to make meaningful evaluations of the natural conditions. Lake standards for dissolved oxygen avoid the dilemma by not having specific numbers. I have reviewed dissolved oxygen data and temperature data from over 50 lakes that Ecology has recently published, and they routinely exhibit thermal stratification in the summer, resulting in surface waters far in excess of the numeric temperature standards and deeper waters that do not meet the dissolved oxygen standards. Stratification, and differences associated with the natural phenomenon are normal and the UAA and proposed site-specific standards correctly accommodate this. The existing state standards fail to accommodate this. The proposed UAA and site-specific standards are superior to the State's existing, simplistic and wishful standards.	
	I noted on page ES-14 of the executive summary that additional modeling will be conducted to determine if removal of point source flows from the river might adversely affect DO conditions in the river or the reservoir. Such modeling is important because a cure for a problem that only compounds the problem would be a costly mistake. It is quite possible that meeting a TMDL's requirements, by getting discharges out of the river, could produce a counter-intuitive result of making the problem worse. In fact, I have another example where removing the discharges would make the river worse which should also be recognized.	An additional model run was made with point source flows removed. However, the results of that run were deemed unreliable. A final run was made with the flow from the City of Spokane's treatment plant set to zero and with other point source flows retained with their concentrations set to zero. This final run also did not accurately capture the effects of the point source flows removed. The model needs to be refined before this much-needed run can be made.
	In the 1990's, Ecology was looking at developing a TMDL for metals for the Spokane River. The river had elevated metals associated with historic mining practices in Idaho. Ecology was considering ratcheting the metals levels down in the permits for the dischargers to the Spokane River. The metals standards are hardness dependent formulas. The mistake Ecology made was that they looked at a single, low hardness value for the river, applied it to the formulas and then had single value metals standards that they worked with. That process lost sight of the fact that the standards themselves were not single fixed values, but were instead a metals and hardness relationship. I noted that the dischargers had harder water because their source water was ground water. With clean metals sampling and hardness sampling, the dischargers were able to show that they were meeting the hardness dependent standards at the end of pipe. Therefore, the dischargers were actually adding assimilative capacity for metals to the river.	We agree that the issue of metals toxicity warrants additional consideration and analysis by Ecology before Ecology takes any further action on the TMDL.
	I presented the above analysis to Ecology personnel and their first reaction was, "that can't be right!" Because it is counter-intuitive, Ecology's first reaction was understandable. Ecology had a spreadsheet model evaluating metals and flow inputs to the river. I asked them to use their model to evaluate the river under two different situations. One was to have all the dischargers greatly increase in volume, while keeping the same metals and hardness concentrations. The other was to have all the dischargers get out of the river. I challenged them to tell me which condition was better for the metals in the river, relating to the hardness dependent metals standards. Within a few hours Ecology called back to say I was right.	
	I share this story because it relates to the dissolved oxygen TMDL, the UAA and the site-specific criteria development. If Ecology moves forward with the TMDL, based on the existing dissolved oxygen standard, without any refinement to reflect the better science and understanding that is available now in the UAA and site-specific criteria proposal, it is likely that the dischargers will, at great cost, be forced to get the discharges out of the river as the most feasible means to comply. The modeling may or may not show that this will be beneficial to dissolved oxygen because of the loss of flow. I can say with great confidence, right now, that modeling Ecology is already familiar with confirms that if the dischargers got out of the river, the river would be worse off for metals because of the reduced hardness of the river.	

Downstream Surface Water Quality Comments

Commentator	Downstream Surface Water Quality Comments	Response
Spokane Tribe – Chris Butler	I have decided that instead of picking apart certain areas of the report I would comment on the entire report as a whole. In the beginning Linda and Thomas visited the tribe to share with us the UAA process and to ask a few questions. One of the questions asked was "would the tribe consider adjusting our water quality standards" specifically lowering the levels for Dissolved Oxygen (D.O.). Our answer was no, because we believe that our water quality standards protect all aquatic species. The Spokane River has always been an intricate part of the Spokane tribe and we have to do everything we can to protect that. We also commented that we would be opened minded to anything you put in-front of us provided that it protects our efforts and resources down stream. With that in mind your recommendations and implementations are not attaining our water quality standards down stream. Even if given a number of years to achieve your goals our water quality standards downstream of the dischargers would still not be met. I personally wanted to try and understand how everything worked through the process of waste water treatment plants (WWTP) in order to have a better understanding. So we were given a tour of the Spokane's WWTP and the whole the process was explained. I even went to the advanced WWTP meeting that the Department of Ecology (DOE) had put together for the dischargers. I personally don't believe that the next level of treatment (NLoT) that you are considering is enough. There is newer technology out there that removes phosphorus even further than the treatment options you are considering. It was recognized as a problem in the 70's as per court and still remains an issue with the current population growth in the Spokane and N. Idaho areas. These solutions you propose are quick fix problems that will only temporarily and partially fix the problem. The low D.O. is nothing new. Your own reports (Spokane River Water Quality Monitoring Program, Annual Data Summary, 1999-2002, prepared for Avista Utilities, prepared by **CH2MHILL**) show how the tribe's water quality standards are not being met. My own monitoring, (still pending) shows levels of D.O. at 3.83 mg/L at 4 meters at the eastern boundary. The nutrient loading resulting in low D.O. needs to be curtailed. We are going to great effort to maintain a cold and cool water fishery. This includes releasing 500,000 rainbow trout and 1,000,000 kokanee a year into the Spokane River and Lake Roosevelt. This has been taking place since July 1988 (Tim Peone, Pers. Comm.). The 2002 creel survey reports 2,224,856 ± 151,288 (95% C.I.) angler hours on the Spokane River and Lake Roosevelt (Lee, still pending). Lowering D.O. levels would greatly diminish work done (fishery mitigation, fishery restoration), over the last 16 years and make our efforts seem futile. I don't believe that focusing on the upper hypolimnion to the surface for continued water quality improvements will solve all the problems. The problem starts with sediment oxygen demand (SOD) at the bottom of the lake and biological oxygen demand (BOD) from fall plankton senescence. If nutrient loading is reduced, your SOD and BOD will be lowered which will increase D.O. levels from the sediments to the surface. This will then increase our down stream D.O. levels in tribal waters. It is sad to say that the burden is put on the point-sources rather than the non-point sources. But it is well known that it is easier to control the point-sources than it is non-point sources no matter the cost. This means that current dischargers need to stop looking at the river as a means of disposal and start looking at new technology that will allow opportunities in reuse. I would like to thank you for allowing me the time to make comments.	We recognize the importance of the Tribe's standards and the value of the river to the Tribe in general. As described in the draft versions of the Spokane River UAA, we are aware that there are times when the Tribe's DO criterion of 8.0 mg/L is not met downstream of Long Lake Dam. Our Spokane River UAA report has included some of the results of modeling that LTI has conducted as a subcontractor to CH2M HILL. This modeling was performed using Ecology's CE-QUAL-W2 surface water quality model. This modeling has shown that the NLoT scenario proposed by the point sources, along with a reasonable expectation of nonpoint source controls of phosphorus (that is, the NLoT+25 percent NPS BMPs scenario), will achieve the same benefits as removing the point sources from the river. Ecology's modeling results show the same outcome. Furthermore, modeling done by both LTI and Ecology has shown that the proposed Draft TMDL (Ecology, 2004e) will not meet the Tribe's DO standard. We believe that the ultimate resolution of the issue of meeting the downstream DO standard of the Tribe must involve open and honest discussions related to realistic expectations and outcomes of the TMDL and the Spokane River UAA as they pertain to the goals and standards of the Tribe. We also believe that the aeration option discussed in the Spokane River UAA provides for the attainment of Tribal DO standards. See also response to comment B above in the "General Comments" provided by Ecology – Melissa Gildersleeve. We conducted a wastewater treatment technology workshop that included the best national and regional experts on the subject of phosphorus treatment. The summary memo of that workshop is included in this final Spokane River UAA as Appendix F. These recognized experts concluded that meeting Ecology's target of 0.01 mg/L total phosphorus (TP) is not feasible with any technology other than reverse osmosis (RO). The capital cost to implement RO technology for the City of Spokane alone would be several hundred million dollars. As noted above, there is no substantive benefit related to increasing DO levels from going beyond the NLoT+25 percent NPS BMPs scenario. One of the more substantial concerns that we have with the Draft TMDL (Ecology, 2004e) is that Ecology does not even mention the fact that their own analyses show that their proposed TMDL will not meet the Tribe's DO standards. It does not seem appropriate for Ecology to criticize the Spokane River UAA in this regard while, at the same time, neglecting to disclose that its own proposed TMDL fails to meet the Tribe's DO standards. We sincerely believe that the ultimate resolution of these complicated issues will involve not only this Spokane River UAA and an appropriate watershed-based TMDL, but also the Avista relicensing and other critical watershed processes that are underway. All parties need to be open and honest in these proceedings. We believe that we have been open and honest. See response to Comment B above in the "General Comments" provided by Ecology – Melissa Gildersleeve. The Draft TMDL (Ecology, 2004e) fails to include both point and nonpoint source discharges. This is contrary to the regulatory and case law requirements. The Spokane River UAA, on the other hand, provides a plan that includes controls related to point and nonpoint sources.
Ecology – Melissa Gildersleeve	**ES-14, Downstream Issues**. No allowance exists for not meeting the downstream water quality standards of other states or tribes, and Washington cannot use a UAA to change the downstream standards of another jurisdiction. The cost considerations that exist internal to a state also do not override the standards downstream states or tribes. While conditions may indeed improve, the tribal standards are not predicted to be attained using the next level of treatment and 25% control of nonpoint sources. Only the Spokane Tribe can agree to change its criteria for the river. This is a big hurdle for the UAA, as the Tribe would need to determine that it is willing to change their criteria to accommodate the UAA. This is our understanding, and we have never heard of EPA resolving this type of dispute in the favor of the upstream state or tribe. The proponent should be working closely with EPA and the Spokane Tribe to ensure their support.	See responses to the Spokane Tribe's comments above. Also, we note that EPA approved a DO criterion for the Spokane River in Idaho (daily minimum of 6.0 mg/L) that is less stringent than the current Ecology criterion of 8.0 mg/L for the Spokane River in Washington.
Ecology – Melissa Gildersleeve	**6-3, Downstream Issues.** Even if the proponents proposal makes conditions better downstream, NPDES permits are not to be written that cause a violation of the Tribe's downstream standards. Additionally, standards are not to be adopted that would interfere with attaining downstream uses and criteria, thus even if Ecology supports UAA-based changes, it is imperative that the Tribe also support them to the extent that they would be willing to change or somehow waive their own criteria. As we noted at the beginning of this process, the need to meet the Tribe's standards (current or modified based on agreement with the UAA) appears to be a very critical issue. We are not sure what other options exist, but we are reasonably certain we could not reduce the stringency of our state criteria if it would violate the tribal water quality standards. We strongly recommend the proponents work closely with the Spokane Tribe and EPA Region 10 to determine if they are supportive of the UAA's conclusions.	See responses to the Spokane Tribe's comments above.

Avista Relicensing Comments

Commentator	Avista Relicensing Comments	Response
Ecology – Melissa Gildersleeve	**Page ES-4, first paragraph.** While it may not be feasible to restore the system, when developing a UAA document there needs to be more basis then the opinion of the proponents. There must be some obvious reasons why the proponents believe the system cannot be restored that can be included. How big are they? How much power is produced? Where is the power used? What is the local payroll? In other words, what factors exist that would convince a skeptical reviewer that is unfamiliar with the system to agree that the dams cannot or should not be removed and the system restored?	Additional information has been added to the final Spokane River UAA regarding the presence and operation of the dams (see Part 2, Section 4.1).
Ecology – Melissa Gildersleeve	**Page ES-4, second paragraph.** The PM&Es were not developed as part of the UAA. Why should they be considered a surrogate for a determination of all feasible controls? Provide a linkage to the analysis that is used as the basis for the concluding they will not allow the water body to support spawning and non-core rearing. Remove the inference that non-core is related to a pristine headwater system. This is not correct. The use was developed primarily to apply to larger main stem rivers – similar to the Spokane River.	We did not say that the protection, mitigation, and enhancement measures (PM&Es) define all feasible controls. However, until the relicensing process has run its course, the PM&Es that are currently being discussed provide the best insight into future attainable conditions. Ecology's TMDL process is equally subject to the uncertainties associated with relicensing. We have previously told Ecology that the TMDL process should be deferred so that it is held concurrently with the relicensing process. Also, as noted above, we have added information regarding the dams and their operations. Specific definitions regarding what constitutes core versus non-core rearing are not provided in the current Ecology surface water quality standards. As part of Ecology's transfer of class-based designations to use-based designations, "core rearing" was applied to headwater systems that support extraordinary salmonid migration, rearing, spawning, and harvesting conditions. (For example, these conditions are found in relatively pristine headwater streams that were previously classified as Class AA waters.) "Non-core rearing" was applied to excellent salmonid migration, rearing, spawning, and harvesting conditions. (For example, these conditions are found in higher order streams downstream from pristine headwater streams that were previously classified as Class A waters.) Ecology has indicated that additional future guidance to determine what waters would be considered core versus non-core rearing water bodies might be based on consideration of the frequency and times of spawning, the extent and quality of rearing and spawning habitat, and the salmonid population density and diversity of the water bodies (Ecology, 2003). Until such time as Ecology defines core and non-core rearing and reexamines where and when these uses occur, Ecology's intended uses of these terms can only be described in the context of their previous class-based system.
Ecology – Melissa Gildersleeve	**ES-7, fourth paragraph.** Unless at least some analysis occurs, it cannot be assumed and should not be suggested that the dams are not remediable. The evaluation of PM&Es may need to be expanded if the designated uses are to be removed from the system under the federal rules. While it may be possible to grant a variance based on economic factors prior to evaluating the contributions the dams can make in determining the attainable uses, the federal rules have no provision that allows a lack of coordinated management of all human factors to be used as the basis for changing uses.	See above responses.
Ecology – Melissa Gildersleeve	**ES-10, second paragraph.** This first UAA test has not been adequately satisfied. No specific evaluation occurred on the ability to restore the system or operate the dams and reservoirs in a manner that would provide for the designated uses the proponent seeks to modify. The use is spawning and non-core rearing not excellent rearing. There is not basis provided for the assumption that there is a required distribution of habitats to provide for this designated use. Even the selection of the PM&E topics that are reportedly being considered in the dam relicensing demonstrate the potential exists to enhance this system. Additionally, the spawning and non-core use type exists now, so the dams do not "preclude" it; although, there may be a need to refine the criteria to better match the attainable condition once all the analyses for the dams and other sources have been completed.	See above responses.
Ecology – Melissa Gildersleeve	**ES-10, third paragraph.** The UAA needs to address how the system can be operated to support the use so even where natural conditions would have been worse, there is still a need to examine if human alterations can be made that exert a positive influence on protecting the designated uses. Further, spawning need not occur at every location in a river for the spawning use to be established. It is uncommon to have continuous spawning occurring throughout a river.	See above responses.
Ecology – Melissa Gildersleeve	**2-7, fifth paragraph, number 1.** TMDLs may examine the system without dams. The decision would be made based on what makes the most sense for that system and the parameter of concern.	This statement was taken from a written comment provided to us previously by Ecology (see comment from Ecology – Melissa Gildersleeve in Appendix A1 that states, in part, "This means that in order to fully evaluate attainability for a use change in an area such as the Spokane River and Lake Spokane where the water quality is impacted by humans, Ecology must know whether the dams could be removed, or whether their operations or structures could be modified to improve water quality without causing substantial and widespread economic and social effects to the local area."). Ecology has chosen in this Draft TMDL (2004e) to examine this system assuming the dams remain in place.

Commentator	Avista Relicensing Comments	Response
Ecology – Melissa Gildersleeve	**3-22, sixth paragraph**. It has been suggested in meetings with WDFW and the UAA contractors that the drawdown may be a key factor in the poor salmonid rearing populations in the reservoir. If macrophytes are not a problem, it is particularly important to evaluate whether the practice is unreasonably harming the potential use of salmonid rearing. This question needs to be addressed when considering what the attainable uses are.	If the drawdown did not occur, there likely would be improved rearing habitat. This is because the total volume of available habitat would be maintained at full pool level. Also, cold-water fish using the littoral zone would still have macrophytes for cover. However, this would not change the kinds of uses that are attainable because this Spokane River UAA already assumes salmonid rearing is an existing and attainable use.
Ecology – Melissa Gildersleeve	**4-3, last paragraph, habitat.** The dams and their ability to influence water quality needs to be incorporated in the UAA analysis. The UAA cannot simply state that their effects are what you would expect and that they preclude uses. If dams are exerting a negative influence, then an analysis in conformance with 40 CFR 131.10(g)(4) needs to be included. This analysis should answer questions like: What is the basis for assuming the system cannot be restored? What is the water quality and habitat improvements expected from applying all feasible structural and operational changes? How does this impact existing and attainable uses? The UAA here and elsewhere in the document cannot just assume the dams and their effects are permanent and be in concordance with the federal UAA requirements.	See above responses.
Ecology – Melissa Gildersleeve	**4-8, paragraph two.** While we appreciate the difficulty of addressing the hydropower issue, the UAA is not limited to actions that are in the control of the proponent. We cannot approve the UAA on the basis that the PM&Es chose or did not chose to examine certain options. Hopefully, even if the UAA report cannot reasonably assess the potential benefits from improved operation of the dams and reservoirs, the relicensing studies will eventually fill in the missing information and help determine if a use change can be supported through rulemaking.	See above responses.
Ecology – Melissa Gildersleeve	**4-8, seventh paragraph.** If there are summer operational changes that can improve conditions they need to be addressed as part of the UAA. They may also be unexpectedly included in the relicensing studies, so statements such as these are not sufficient in themselves. Why should a reviewer believe that there is no need for summer operational changes to protect water quality	See above responses.
Ecology – Melissa Gildersleeve	**4-14, third paragraph, first sentence.** The natural and hydroelectric limitations need to be considered separately.	The reference to natural conditions in this instance refers to physical characteristics of the river channel that has been impounded.
Ecology – Melissa Gildersleeve	**4-14, fifth paragraph.** No basis was provided to support the assertion that restoration to a free flowing river is not feasible or attainable.	See above responses.
Ecology – Melissa Gildersleeve	**5-5, last paragraph and first on next page.** We do not find that a sufficient basis was provided to support the position that the federal requirements for evaluating the impact of dams on use attainment has been included in the draft UAA.	See above responses.

Social and Economic Impacts Comments

Commentator	Social and Economic Impacts Comments	Response
EPA, Office of Water, Region 10 - David Ragsdale	Since it is unlikely the current direction of the UAA will result in obtaining the desired relief, I encourage the sponsors to reconsider investing any additional resources in this project. The proponents should instead conduct a detailed evaluation of the "social and economic impacts" of implementing wastewater treatment and reuse options necessary to achieve compliance with the wasteload allocations identified in the draft TMDL. This evaluation must also consider the need for restoring the quality of waters of the Spokane Tribe.	See responses above regarding the issue of relief. Economic analyses have been completed and are summarized in Part 4, Economic Assessment, with details in Appendix E.
Sierra Club – Rachael Osborn	At the August 17 UAA meeting, John Spencer suggested that the costs of removing effluent discharge from the Spokane River are estimated at $700-800 million dollars. Please provide the basis for this estimate.	This estimate was based on previous analyses done for the facilities plan. This cost has been reevaluated in light of the most recent Draft TMDL (Ecology, 2004e). The updated cost estimate is provided in Part 4, Economic Assessment, with details in Appendix E.
Sierra Club – Rachael Osborn	John Spencer also indicated that the UAA sponsors are prepared to move forward on an economic study. Please provide details about the purposes, scope of work, and timeline for this study.	Economic analyses have been completed and are summarized in Part 4, Economic Assessment, with details in Appendix E.

TMDL Implementation Comments

Commentator	TMDL Implementation Comments	Response
Ecology – Melissa Gildersleeve	**ES-8, third paragraph, second sentence.** What is the basis for assuming that all of the water associated with the point source discharges would leave the basin? Why wouldn't some of it return through subsurface flows as cooler water? Why couldn't the water be compensated for through greater discharges during the critical period from the reservoirs?	Analyses of effluent reuse in Part 4, Economic Assessment (with details in Appendix E) show that most of the wastewater from the City of Spokane would have to be reused out of the basin. For reasons stated in Part 2, Section 4, the CE-QUAL-W2 model will have to be modified to enable a reasonable evaluation of impacts on reservoir water quality of removing all point-source flows.
Ecology – Melissa Gildersleeve	**ES-8, fifth paragraph, second sentence.** This should be corrected to read, "would still remain in the 5-6 mg/l range". We also must note that this is still a great improvement from what currently exists, and that a greater proportion of the reservoir will remain at higher concentrations for a longer period of the summer season.	The correction has been made. For reasons provided in the final Spokane River UAA (see Part 2, Section 4.4.4) we believe that the oligotrophic SOD assumption is not a realistic one for this reservoir.
Ecology – Melissa Gildersleeve	**ES-14, TMDL Implementation**. The UAA is supposed to be used to establish the uses and criteria. If the proponents want the UAA to be based on economic and social impacts – where a cost benefit analysis can fit into the discussion to some extent – then it needs to be done outright. The UAA cannot be based on the expectation that 75% of the nonpoint sources will fail to use BMPs adequate to control their effects. The use of proven technology versus state-of –the-art technology is an economic issue, not a demonstration that human caused conditions cannot be remedied. Further, there is no reason at this point to assume that water quality would in fact be harmed by removing the dischargers from the river seasonally or that doing so is not actually a more cost effective long term strategy.	Economic analyses have been included in the final Spokane River UAA (see Part 4, Economic Assessment, with details in Appendix E). The regulatory basis for the recommended standards changes in this Spokane River UAA is not 40 CFR 131.10(g)(6). However, the economic analyses demonstrate that removal of the point sources is not a more cost-effective long-term strategy. The issue of proven versus state-of-the-art technology is not an economic issue. State-of-the-art technology has to do with what is possible given the application of science to the treatment of municipal wastewater. Ecology appears confused about this and fails to recognize that a technology must be proven before it is employed. Relying on unproven technology at great cost to the citizens of this region is neither environmentally nor economically appropriate. We did not state that greater than 25 percent control of nonpoint sources is infeasible. Rather, this degree of control is reasonable to expect and could be readily supported by stakeholders. On this point, the Spokane River UAA is much more optimistic than Ecology. Ecology's Draft TMDL (2004e) concludes that there is no reasonable assurance that nonpoint sources can be controlled at all, which is not an accurate conclusion. Ecology's conclusion that it cannot control nonpoint sources appears inconsistent with regulatory requirements, guidance, other states' TMDLs that have controlled nonpoint sources, and case law.
Ecology – Melissa Gildersleeve	**4-9, fifth paragraph.** Flows may be compensated by increased releases from the reservoir. It is not reasonable to assume that all of the dischargers' flows will be taken out of the watershed.	See previous response above.
Ecology – Melissa Gildersleeve	**4-14, first paragraph**. While complete reservoir recovery may take decades, significant improvements begin to occur in the first years that pollution rates are reduced. Ecology's modeling found oxygen may improve to 5-6 mg/l, not 5 mg/l and that the period of time oxygen remains above harmful levels declines.	We agree that improvement will occur as a result of the NLoT and nonpoint source controls (that is, the NLoT+25 percent NPS BMPs scenario). Ecology and LTI modeling has shown that there are no substantial further increases in DO levels if point sources are removed from the river.
Ecology – Melissa Gildersleeve	**4-14, second paragraph.** It is a mischaracterization to say that attainable uses are those that come with feasible and reasonable reductions in point and nonpoint sources. The federal rules create a more stringent test.	We did not say that these are the only considerations regarding attainability of uses. Instead we said that feasible and reasonable reductions in point and nonpoint sources must be considered. Certainly, while not specifically defined, feasibility and reasonableness are embedded in applicable federal regulations.
Ecology – Melissa Gildersleeve	**4-16, third paragraph.** There will need to be a very convincing argument behind the assumption that all the water would be removed from the basin and cannot be compensated for through increased releases from the reservoir for this argument to have much value.	This argument is not the basis for any of the recommendations in this final Spokane River UAA.
Ecology – Melissa Gildersleeve	**6-2, last paragraph.** Where there is uncertainty of being able to control nonpoint sources, EPA policy demands that point sources absorb all of the load reductions possible.	This comment is incorrect. EPA policy does not "demand that point sources absorb all of the load reductions possible." In fact, EPA's policy requires TMDLs to include nonpoint source loading allocations. (Guidelines for Reviewing TMDLs; EPA, 2002). Moreover, cases within the Ninth Circuit have acknowledged that nonpoint sources should be included in TMDLs (EPA, 1999).
Sierra Club – Rachael Osborn	We appreciate the UAA sponsors' commitment to reduce nonpoint source pollution affecting Spokane River and tributary water quality. Please provide details on the UAA sponsors' strategies, proposals and specific commitments to achieve non-point source reduction.	These would be defined through a broader watershed-based process. See the Executive Summary in Part 1 of this Spokane River UAA.
Sierra Club – Rachael Osborn	Please provide the City of Spokane's plan for upgrade of the SAWTP facility, including specifics about the City's timeline and strategies for phosphorous reductions. Please also provide details about how the City plans to pay for upgrading the plant, including funding sources and timing.	The City plans for upgrade to the SAWTP facility are contained in the "City of Spokane Wastewater Treatment Facilities Plan" and updates in the "Liquids and Solids Design Report." These reports are available at the City of Spokane Wastewater Management Division. The plans are to upgrade the plant to include final filtration for the removal of phosphorus. This will achieve between 95 and 99 percent phosphorus removal. Implementation of final filtration is scheduled to begin in 2010 and be online in 2012. The City plans to pay for the upgrades of the plant through funding of its capital improvement program (CIP) for wastewater facilities. This plan will be financed through (a) direct sewer revenues, (b) revenues collected in the stabilization fund, (c) bond proceeds, and (d) grants and loans from the State Centennial Clean Water Fund and State Revolving Loan Fund. Miscellaneous revenues will also contribute to the financing of the CIP. The CIP is available at the City of Spokane Wastewater Management Division.

Commentator	TMDL Implementation Comments	Response
Sierra Club – Rachael Osborn	Some of the UAA sponsor representatives have stated that they intend to move forward with reclamation and re-use of wastewater. Please provide us with re-use plans for each of the municipal dischargers and would-be dischargers, including timelines for implementation.	The City of Spokane owns and operates several municipal golf courses where treated wastewater might be reused for irrigation. Treated wastewater might also be injected into the aquifer, as is being done by LOTT (Lacey, Olympia, Tumwater, and Thurston County). Additional environmental and economic studies would be required before this type of water reuse could be implemented. Chapter 4 of Spokane County's Wastewater Facilities Plan (December, 2002), addresses conservation alternatives. The plan is located on the County's website. Additionally, the County must amend its facilities plan to evaluate reuse as part of its funding for the new sewage treatment plant.
Sierra Club – Rachael Osborn	Related to the above question, please provide copies of each water conservation evaluation and reclaimed water evaluation required by RCW 90.48.495 and 90.48.112, as prepared by the UAA sponsors who are subject to these statutory requirements.	The City of Spokane Comprehensive Water System Plan (November 2000) contains a chapter on water conservation. The plan and this chapter will be updated over the next 2 years with completion scheduled for 2006. This update will be consistent with the statutory requirements of the state water resources act and municipal water codes. The City of Spokane has a strong commitment to water conservation and has taken significant steps to improve on the management of its water resources through the installation of state-of-the-art source meters and the adoption of an inclining rate structure to charge more for users who use larger blocks of water. This rate structure is expected to return significant benefits in the reduction of per capita water use. Additional measures to achieve effective conservation will be assessed in the Comprehensive Plan Update. The Plan is available from the City of Spokane Water Department. Chapter 4 of Spokane County's Wastewater Facilities Plan (December 2002), addresses conservation alternatives. This plan is located on the County's website.
John Cross	I have prepared, and would be happy to forward, a more extensive comment letter addressing the technical merits of the August 11 draft of the UAA. However, it occurs to me that there is little point in attempting to further that dialogue. The UAA "stakeholders" are apparently going to pursue this effort, no matter how quixotic. So at this juncture, I would simply like to share with you some thought that I have previously passed on to some of the stakeholders. We are all aware that the Spokane River needs care. Native anadromous fish have been extirpated; legacy mining wastes prevent consumption of remaining fish and make primary contact with the river (swimming) a questionable practice; hydroelectric impoundments have altered flow, sediment transport, habitat, and water temperatures; shoreline development has claimed riparian habitat; water withdrawals are increasing and annual low flows are decreasing; and nutrient enrichment contributes to dissolved oxygen depletion. You are award that these are all known problems and they are being addressed at varying speed and intensity through various processes. The Department of Ecology has begun work on a dissolved oxygen TMDL. They are required by federal law and by settlement of the NWEA lawsuit in 1998 to develop this TMDL. Your clients, or "stakeholders," represent the major discharges to the Spokane and will be involved in this TMDL in some fashion. I would be surprised, and disappointed, to learn that this is news to any of you. However, rather than join the TMDL development responsibly, you seek to change the rules of the game. We can agree to disagree on this particular assessment of your effort but it is true that for at least six years (since 1998) this TMDL has been approaching. You attempted to explain your rationale to me (in your response to comments on the earlier draft UAA) by claiming that an objective of the UAA is "to ensure that cleanup targets are appropriate for the system." You further claim that Ecology's responsibilities "do not come with unlimited resources." So, I am disturbed by your insistence on continued attempts to change the rules of the game rather than work within the existing framework as laid out by federal and state law. Furthermore, I understand that the "stakeholders" are mounting a new lobby attempt to convince Ecology to delay TMDL development. I would like to take this opportunity to lobby you and your clients to join TMDL development responsibly and begin actual and tangible clean up work on the river. Since the issue of limited resources is of interest to you, I think you would be interested to know that the resources of your clients are generally limited as well. I have repeatedly requested information from some of the stakeholders regarding their budgets for the UAA and the source of funding for these budgets. I have received no information at all on this point and, despite three requests of Spokane County for this and other information, have no response at all from that stakeholder. Perhaps the County, now having a point of contact for UAA comments, will change that. And perhaps you would be interested in restoring my faith in public disclosure and sharing information on the budget for the UAA and sources of funding. Thank you in advance. Finally, it appears form the response to comments on the earlier UAA draft that you and your clients are not addressing water quality standards of the Spokane Tribe. Again, I would be surprised and disappointed to learn that you are not aware that the Tribe has water quality standards with EPA approval for Clean Water Act implementation. EPA will require that Washington's proposed water quality standards and the TMDL incorporate provision to meet Spokane Tribal water quality standards. Your UAA and the TMDL also require EPA approval. It is overwhelmingly clear that your clients' resources are best spent on responsible TMDL development and implementation.	See responses to other general comments above.

Washington State and EPA Standards Comments

Commentator	Washington State and EPA Standards Comments	Response
Ecology – Melissa Gildersleeve	**Page ES-3, fourth paragraph, first sentence.** The federal regulation on UAAs does not contain a "reasonable" clause.	See previous response above.
Ecology – Melissa Gildersleeve	**Page ES-3, fifth paragraph.** The basis is not clear for the assumption that fish passage barriers created by the dams cannot be corrected. It is also not clear what the assumed "required distribution of habitats necessary to support excellent migration, rearing and spawning" is, or what it is based on. If this is supposed to be a comparison to the state standards then it is in error. The state adopted non-core rearing as a sub characterization of the aquatic life use for the Spokane. This river is obviously not core rearing, though it may have the potential to be core rearing again – this is an attainability question. The question that will need to be addressed is whether the river provides non-core salmonid rearing along with spawning. The reference to "excellent" quality is an artifact of our old standards where Class A waters were generally described as being excellent. However, those standards did not say that the spawning, rearing, and migration use had to be excellent.	See previous response above.
Ecology – Melissa Gildersleeve	**ES-9, fifth paragraph.** We find no basis for the statement that the existing uses of the Spokane River do not fit into existing categories. There appears to be nothing unique about the biological assemblage in this system as compared to other rivers throughout the state of similar size without access for anadromous species. All or almost all lower main stem waters are a mixed fishery. The spawning and non-core rearing use as well as the redband trout use type seem quite appropriate for this river based on the current information and analysis. This is the type of water body we were considering when we established these two use categories. This does not mean that we oppose setting unique life stage timing elements as special conditions in the standards for a river, but we need to clarify that use types in the standards are broad enough to cover the Spokane as well.	The current designated use is inappropriate, not only because it is an inland and mixed fishery, but also because the salmonid uses are limited by habitat considerations associated with the presence of the dams and the water temperature conditions. Ecology's expectations for its salmonid and redband waters, as characterized by its statewide water temperature criteria, are not consistent with the overall existing and attainable Spokane River conditions. See also previous responses above regarding the presence of the dams.
Ecology – Melissa Gildersleeve	**ES-11, whole page**. The suggestion is made that if the reservoir is not core rearing then it does not fit into existing categories and so an entirely new category is created. This position appears to be necessary to try to move away from the narrative criteria for lakes that do not allow more than a 0.2 mg/l change from natural levels, regardless of the use category assigned. The standards do not state that the use is "extraordinary salmonid migration, rearing, spawning, and harvesting" only that the water bodies that are assigned to Class AA are "extraordinary".	The Spokane River UAA does not claim or suggest that just because the reservoir does not support core rearing that other categories are not appropriate. The reservoir does not fit into any other category for a variety of compelling reasons: 1) it supports predominantly a cool- and warm-water fishery, 2) the fishery is not composed of indigenous warm-water species, 3) spawning of native salmonids is not an existing or attainable use, 4) it is not a natural lake, and 5) its highest attainable salmonid use is a put-and-take rainbow trout fishery. Ecology has stated that its current surface water quality standards do not properly address reservoirs such as this. Ecology does not seem inclined to address this on a statewide basis in time to influence this proposed TMDL (Ecology, 2004e). Therefore, there is no alternative other than to address Long Lake Reservoir on a site-specific basis.
Ecology – Melissa Gildersleeve	**ES-13, third paragraph.** We do not share the opinion that the standards were not developed with lakes/reservoirs in mind. The standards recognize the great sensitivity of lakes to changes in input parameters. The allowance for the 0.2 mg/l change is to avoid having to disallow all human activities which would degrade oxygen conditions but to otherwise come as close as possible to protecting the best potential oxygen conditions across depths in lakes and reservoirs. We also disagree with the opinion that applying the natural conditions language to dams or other hydrologic modifications is not appropriate. The equivalent condition of a natural input scenario is valid for both natural lakes as well as ones created by humans. The federal UAA regulations allow incorrectly designated uses to be modified based on a very wide range of human and natural conditions, it is not correct to infer that since dams are on the list then the protection of the reservoir to the same high degree as a natural lake is inconsistent with the federal rules.	We agree that reservoirs deserve protection. However, it is the existing and attainable uses that must be protected. An arbitrary criterion of a 0.2 mg/L change in DO levels is not necessary to protect existing and attainable uses for the reservoir.
Ecology – Melissa Gildersleeve	**1-1, fourth paragraph, first sentence**. While not prohibited by the federal regulations, UAAs are not specifically geared to defining uses on a reach basis. Ecology has noted previously that we generally do not support trying to break up uses at a reach level. This creates a potential patchwork of criteria that will be problematic to implement in permits and programs, and because uses commonly move over time among and between reaches due to fluctuations in habitat conditions and population size.	In general terms, we agree. This is why we recommend that the river reach (RM 96 to RM 58) be considered a single reach, even though there are dams and associated run-of-river reservoirs in this reach.
Ecology – Melissa Gildersleeve	**1-1, fourth paragraph, third sentence.** A UAA does not define site-specific criteria. The term site-specific criteria has a very specific use in the federal water quality standards program. We view what the UAA is trying to do as a form of use refinement (similar to establishing a new subcategory) rather than site-specific criteria. The effort to describe the biological community and the various life stages in greater temporal detail is not the same as demonstrating that those species or life stages are more tolerant of some environmental condition.	The use of the term "site-specific criteria" is appropriate in this instance because we do not seek to establish a statewide criterion associated with a statewide subcategory of use. The subcategories and criteria recommended in this Spokane River UAA are specific to this river and reservoir. Our approach is identical to that used for the Chesapeake Bay UAA (EPA, 2003b). In that case, EPA and the various states did not establish subcategories and criteria that will be used anywhere outside of that system.
Ecology – Melissa Gildersleeve	**1-3, second paragraph.** The standards establish special provisions for lakes that account for the fact that conditions change with depth. Thus it is incorrect to say the standards do not differentiate uses or criteria for different locations or depths in a reservoir. The decision was to retain the same approach in the standards under the new system as we had used under the prior Lake Class. This approach recognizes the unique sensitivity of lakes and reservoirs and allows only very minor degradation from human activities.	See previous responses above.

Commentator	Washington State and EPA Standards Comments	Response
Ecology – Melissa Gildersleeve	**2-1, second and third paragraphs.** Even though the appropriate federal rule language is shown below, the UAA discussion suggests uses can be removed if they cannot be supported using technology-based controls. This is not true. The federal rules are focused on the determination that controls more stringent than technology-based standards would be required and the imposition of such alternative control requirements would result in substantial and widespread social and economic impact.	The Spokane River UAA report does not state or suggest that uses can be removed only if they cannot be supported by technology-based controls. The report correctly states that the regulations stipulate that attainable uses are those that, **at a minimum**, can be achieved with technology-based controls. The phrase "at a minimum" is not defined by EPA regulations or policy. In this Spokane River UAA, we have recommended a degree of control that goes far beyond the minimum technology-based controls for point sources. And these controls would be at a substantial cost to those point sources. There is no promulgated technology-based control for phosphorus. Any rational assessment would conclude that the proposed degree of control (about a 99 percent treatment efficiency) is a major commitment to the highest attainable improvements in surface water quality.
Ecology – Melissa Gildersleeve	**2-4, second paragraph, last sentence.** Class B was not intended to apply to waters used for spawning. Saying it was not intended to fully protect spawning suggests we can decide not to fully protect an existing use, which we cannot do under the federal regulations.	The wording was changed in the text in response to this comment.
Ecology – Melissa Gildersleeve	**2-4, third paragraph, last sentence.** The parenthetical sentence is incorrect. The Lake Class criteria did not allow any change from natural levels, not even 0.2 mg/l. This needs to be fixed in Table 2-2 as well.	These changes were made.
Ecology – Melissa Gildersleeve	**2-5, fourth paragraph, second sentence**. Lakes are mentioned in several locations in the standards. Most important to this UAA is where it is mentioned along with the temperature and dissolved oxygen criteria in WAC 173-201A-200. In the old standards, the definition was key to the use of the Lake Class category.	The wording was changed in the text in response to this comment.
Ecology – Melissa Gildersleeve	**2-6, Table 2-3, river portion.** The note associated with the column on dissolved oxygen criteria contains errors. The 0.2 mg/l allowance is cumulative for all human sources of oxygen depression and it is not plus or minus but only minus. This mistake occurs throughout the document.	These changes were made.
Ecology – Melissa Gildersleeve	**2-6, Table 2-3, reservoir portion.** The 9.5 mg/l criteria is not established for lakes. WAC 173-201A-200(d)(ii) establishes that "For lakes, human actions considered cumulatively may not decrease the dissolved oxygen concentration more than 0.2 mg/l below natural conditions."	This is a major ambiguity in the revised surface water quality standards. It is explicit that a 9.5 mg/L DO level applies to core water bodies, and that Long Lake Reservoir has been roll-over designated as a core water body. There is no language in the standards that makes it evident, legally or otherwise, that Long Lake Reservoir is **not** subject to the core DO criterion of 9.5 mg/L.
Ecology – Melissa Gildersleeve	**2-6, Table 2-3, Note.** It should be made clear that the note is the author's opinion, it is not a provision of the state standards. This is not based on any apparent technical or biological analysis. This is a far more complex issue than can be appropriately addressed in single sentence footnote. However, we find the use of the surrogate natural condition (no upstream pollution) to be entirely consistent to the concept of providing the highest degree of protection to natural lakes when used for reservoirs.	The footnote was deleted to make it clear that this language is not taken from the Washington surface water quality standards.
Ecology – Melissa Gildersleeve	**2-7, eighth paragraph**. As noted previously, it is incorrect to say that Ecology did not develop the oxygen standards with lakes in mind. There may be some better way to apply criteria to lakes, and we are open to considering alternative approaches, but the lakes and reservoirs were specifically incorporated through a specific provision in the standards. The criteria adjust to the thermal and oxygen profiles and thus ensure the uses will be fully protected within the attainable condition of reservoirs and lakes.	The lead-in phrase has been deleted in response to this comment.
Ecology – Melissa Gildersleeve	**4-1, first paragraph.** The federal regulations for conducting a UAA to remove designated uses is more demanding then described here as feasible and reasonable reductions. It is critical that the audience reading this UAA understand how demanding the federal government requirements are for removing a designated use.	See previous response above.
Ecology – Melissa Gildersleeve	**4-5, seventh paragraph.** The non-core rearing component of the standards is not for "relatively pristine headwater systems" and is not described as supporting "excellent salmonid migration, rearing, spawning, and harvesting". Thus an artificial target has been created to make the comparison. The river fits well in the category of spawning and non-core rearing, and may also fit in the category of redband trout habitat. The UAA can try and create more temporally tailored (life-stage based) criteria for application to the river without trying to create an argument that the existing use types are not applicable. For the river at least, the UAA is promoting a refinement of a broader subcategory.	See previous response above.

Other Case Studies Comments

Commentator	Other Case Studies Comments	Response
Ecology – Melissa Gildersleeve	**2-8, comparison to other Region 10 developments**. A UAA is supposed to be a science-based evaluation, not a review of past policy determinations or undocumented criteria. The evolution of thought on a topic such as the effects of oxygen is not necessarily reflected through changes in state standards. For example it was not until Washington attempted to adopt average-base oxygen criteria that EPA began to critically question whether it would be effectively implemented and became concerned that the technology was not ripe for this type of criteria. Moreover, the court recently ruled against the Oregon criteria for protecting fish embryos as being under protective, even though it was approved by EPA. Similarly, the fact that Idaho has been waiting for years to get its seasonal cold-water fishery use reviewed by EPA, suggests that the approach was not received warmly.	Part 2, Section 2 of the Spokane River UAA report is not intended to provide a scientific basis for our Spokane River UAA recommendations. It is simply included to provide some context and perspective on other developments in the region. We recognize that the recommendations in this Spokane River UAA are specific to the Spokane River.
Ecology – Melissa Gildersleeve	**5-10, second paragraph**. This statement appears to be incorrect. In conversations with EPA about the Brownlee Reservoir TMDL, they have said that the criteria are being required to be attained in the hypolimnion and that a load allocation is even being given to the dams, which is designed to achieve that goal.	The information on the Brownlee Reservoir TMDL has been further clarified in the text (see also the discussion of this TMDL in Part 2, Section 5.2.4 as it pertains to the lower hypolimnion of Long Lake Reservoir). Important notes for this case study (IDEQ and ODEQ, 2004) include: "Dissolved oxygen concentrations in Brownlee Reservoir need to increase substantially (by more than 4 mg/L in some conditions), in order to meet the SR-HC TMDL target of 6.5 mg/L for support of salmonid rearing/cold water aquatic life. Brownlee Reservoir is a narrow, deep channel with a relatively short retention time. The deep sections of the reservoir, below the thermocline, are well below the photic zone and provide little growth potential. These deep layers (the hypolimnion) are relatively stagnant during stratification and experience little if any circulation or recharge during the summer months…" "Both the metalimnion and the epilimnion offer greater potential for habitat than the hypolimnion. The middle layers of the reservoir (the metalimnion and the epilimnion below the immediate surface layers) provide adequate temperature conditions throughout much of the summer. During late summer and early fall, cold water tributaries provide refugia for cold-water species living in the reservoir. These upper layers (the upper column of the metalimnion and the lower volume of the epilimnion) represent the portion of the reservoir most likely to support aquatic populations. Improvements in dissolved oxygen in these areas will therefore provide greater, more immediate benefits to aquatic life within the reservoir. These areas have been targeted directly as high priorities for improvements in dissolved oxygen. Areas of the hypolimnion known to experience low dissolved oxygen … are located well below the photic zone of the reservoir, [thus] these deep waters represent less of a viable habitat than do the waters above the hypolimnion. Because of this, they have been targeted as a secondary priority for dissolved oxygen improvement…" "For this reason, the hypolimnetic waters will take longer to meet water quality standards. Sustained reductions over time have been shown to have a positive effect on hypolimnetic waters in other systems and have been projected to occur in Brownlee Reservoir through modeling, but time frames are lengthy, extending many years in some cases…." "In an overall assessment of the immediate benefits, it is obvious that improvements projected to occur in hypolimnetic waters will act to better support designated uses. The dissolved oxygen concentrations, without application of the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets, consistently drop to lethal concentrations, well below 3 mg/L. In all cases with application of the total phosphorus target the dissolved oxygen concentration stayed near or above 3 mg/L…"

Biological (Fish and Macroinvertebrate) Comments

Commentator	Biological (Fish and Macroinvertebrate) Comments	Response
Ecology – Melissa Gildersleeve	**Page ES-3, first paragraph.** No evidence is provided of true genetic adaptation, and it is equally if not more likely that the population has been constrained to narrow windows of time and spatial distribution without genetic alteration. The inference of genetic adaptation needs to be removed unless it can be supported by sound scientific analysis demonstrating the species have higher temperature optimum and tolerances than their ancestors or other populations throughout the region. Behavioral adaptation in this context also infers that the species were able to remain healthy and viable by altering their use of the environment. This has also not been shown. A biological response to stimuli is not the same as biological adaptation.	These statements in the Spokane River UAA report were taken from written, scientific materials and are appropriately placed in the text. We made some minor modifications within the body of the report. However, the issue is not highly pertinent to the overall objective or outcome of the Spokane River UAA report.
Ecology – Melissa Gildersleeve	**Page ES-3, third paragraph, first sentence.** The UAA is not using the terminology in the revised state standards that describes self-reproducing populations appropriately. The concept is not directed towards, or limited to, portions of streams or rivers where spawning and all other life stages occur. It describes populations that would persist naturally and is used to differentiate put-and-take fisheries. If fish spawn in one area and rear in another, that rearing area is still occupied by a self-reproducing population.	We added some other specific information related to differentiating lacustrine habitats from riverine habitats that more specifically separate out the spawning discussions in a broad sense so they are related to those habitats where salmonids would actually spawn (riverine segments).
Ecology – Melissa Gildersleeve	**Page ES-3, third paragraph, last sentence**. Behavioral adaptation is a survival strategy but is not a replacement for healthy conditions. Behavioral adaptation occurs under all environmental conditions but continues right up to the point that the species is extirpated from the system. The concept here is used as if everything is fine because the fish behaviorally adapt to the stress of warm water, fine sediments, and low oxygen. Adaptation in this context often means they leave the main stem or become isolated in refugia for part of the year. This might have some value if it can be shown the populations are not diminished in health because these behavioral adaptations are so effective. If true for the Spokane, then this would be a good point to make, but it needs to be supported with data.	The key point we are making about the river reaches is that water temperature is limiting the composition of aquatic species in most reaches, along with other habitat constraints in the reservoir sections of this overall "river" reach. Nonetheless, it is the cold-water species use that serves as the basis for the DO criteria we have recommended for the entirety of this river reach.
Ecology – Melissa Gildersleeve	**ES-4, fourth paragraph.** Provide the technical evaluation of the impact of operational changes that will maximize cool water in the system and its impact on dissolved oxygen. The discussion on the limits to improving spawning is confusing. Spawning occurs in the late winter and spring season when oxygen levels are generally very good. Other factors such as low flows and dewatering, or excess sedimentation may be the limiting factors for spawning. It is also at least equally plausible that poor recruitment due to adverse summer conditions is a factor in limiting spawning. The UAA may be intended by the proponents to address concerns over meeting the oxygen standards, but in order for the UAA to be approved, the analysis must go beyond this one issue to remove or modify the designated uses.	This sentence has been clarified in the final Spokane River UAA.
Ecology – Melissa Gildersleeve	**ES-4, sixth paragraph, last sentence.** How does this relate to the attainable condition? What is the range of gravels used to describe spawning gravels for the various species of fish that use the system – rainbow trout, cutthroat trout, kokanee, chinook, and mountain whitefish? How does this compare with the range identified in the literature and the way these fish use lake and reservoir systems with otherwise high quality habitat?	We provided additional information regarding size of spawning sediments.
Ecology – Melissa Gildersleeve	**ES-5, fifth paragraph.** We disagree that 5 mg/l and 20°C is suitable and find much higher oxygen levels to be supportable in the scientific literature as being preferred. Since we find fault with this assumption, we find particular trouble with its use in analyzing the health of the reservoir and the relative contribution of the point sources to impairing that health. This concern is further compounded by the use of spatial and temporal averaging across the volume of the reservoir.	The text recommends less than 20°C and greater than 5.0 mg/L DO concentration. In this suitable volume, under current conditions DO concentrations average 6.7 mg/L and temperatures average 18.1°C.
Ecology – Melissa Gildersleeve	**ES-6, second paragraph, last sentence.** This suggests without supporting evidence that low oxygen levels are not influencing the macroinvertebrate population, and suggests that the species have adapted to low oxygen conditions. This latter inference is not supported in the document and the term "adapted" should be eliminated. The macroinvertebrate community <u>might</u> fully reflect the potential community for that type of substrate, and those species <u>may</u> be very tolerant of low oxygen conditions, but that is not an example of adaptation.	The macroinvertebrate diversity has likely reached its capability given substrate conditions and water temperatures. Modifying DO levels will not change either of these constraints measurably.
Ecology – Melissa Gildersleeve	**ES-6, third paragraph, first sentence.** Fish abundance and health is also related to water chemistry and physical habitat conditions, not just productivity and stability.	This has been addressed within the document. See Part 2, Section 3.3.3.
Ecology – Melissa Gildersleeve	**ES-6, third paragraph, first sentence.** In our meetings with the contractor and WDFW the agency's fish biologist stated that they recognized the natural contingent of cold water fish that come from spawning populations in upstream waters, and that they want a stocked rainbow trout fishery that holds over for more than one or two years. This is not a put-and-take fishery in the traditional sense, where the fish are either harvested by people or they die.	This is still a put-and-take management strategy and does not change the spawning potential within the reservoir.
Ecology – Melissa Gildersleeve	**ES-6, sixth paragraph.** The fact that conditions in the reservoir are too stressful at present to support a healthy cold water fish population, and that WDFW conducts stocking to <u>supplement rainbow trout populations</u> does not eliminate spawning and rearing as being a life stages that need to be supported. With further water quality and habitat improvements it may be that, the reservoir will serve as a moderately healthy rearing habitat. If this reflects the attainable use then the UAA would need to identify it for protection. Further, the argument is incorrectly made that a "self-reproducing" population needs to support all life stages in a single location. It is very common for different life stages to occur in different location in lake and riverine systems. The population is considered self-reproducing if it would persist if humans were removed from the picture, even though they do not always spawn, rear, and over-winter in a single location.	The Spokane River UAA recognizes that trout rearing in the reservoir is an attainable use. The recommended designations and DO criteria reflect that recognition. We have recognized that trout that may be spawning elsewhere (for example, in the Little Spokane River) may use the reservoir for rearing. The reference to "self-reproducing" is only to illustrate that the reservoir does not support one of the four life stage habitats needed (spawning). Cold-water spawning is not occurring and not likely to occur within the lacustrine reach. It is likely that substrate conditions are limiting this within the riverine and transitional area as well.
Ecology – Melissa Gildersleeve	**ES-7, first paragraph.** If stocked fish are small juveniles they will of course feed exclusively on insects and zooplankton. However, if the system supports adult and subadults, their diets will change such that they will feed on small fish as well.	This comment is acknowledged and further supported within the body of the Spokane River UAA report.

Commentator	Biological (Fish and Macroinvertebrate) Comments	Response
Ecology – Melissa Gildersleeve	**ES-7, second paragraph.** The discussion focuses only on trout, but there may be other species that use the deeper portions of reservoirs where conditions are cold and oxygenated. The argument is somewhat circular. It suggests that the hypolimnion can remain hypoxic because the fish will not use the very stressful hypoxic waters if there is less stressful condition in higher strata. Further, the suitable volume concept masks the actual patterns of oxygen and temperature such that an evaluation of the risks posed by the assumption is problematic. Averaging warm supersaturated water with deeper oxygen limited waters is not reasonable. It assumes the benefits of supersaturation compensate for the harm of residing at lower oxygen levels.	The conditions regarding stratification within the reservoir are not unique to Long Lake Reservoir. The lowest DO levels are found within the deepest parts of the reservoir. This is a very small percentage of the total reservoir volume (only 12 to 17 percent) depending on the scenario. Trout appear to use the uppermost strata throughout the season, with intermittent trips deeper, presumably to feed. Low DO levels during stratification are expected within these types of systems. We have not averaged supersaturated water with low DO-level water to derive the "suitable volume." The "suitable volume" is based on the volume where water temperature is less than 20°C and DO is greater than 5.0 mg/L.
Ecology – Melissa Gildersleeve	**ES-7, fifth paragraph.** While it appears that this will not be found to be a core salmon and trout rearing reservoir, there will need to be a sound scientific rationale for changing it.	See Part 2, Section 5.2 for the rationale used in the Spokane River UAA.
Ecology – Melissa Gildersleeve	**ES-8, second paragraph.** The concept of suitable volume has not been demonstrated to be an effective measure of habitat quality in reservoirs. We have concerns with the spatial and temporal averaging that it uses. It does not address issues such as alleviation of lethal conditions in the hypolimnion and does not characterize the absolute changes in oxygen concentrations that may be serving as the limiting factors for fish and other aquatic life. Suitable volume has been incorporated as a replacement for the numeric criteria established to protect fully fisheries uses in the state water quality standards. This compounds the tactical problems with basing so much of the UAA on this untested approach. Why is a suitable volume of 20°C and 5 mg/l no better than a suitable volume of 18°C and 7 mg/l? Why was the 5 mg/l value chosen instead of a fully protective value? Why was it chosen instead of a chronic lethal threshold value? There is no scientific basis provided that can be used to support the premise that a fully protective reservoir condition is based on maximizing the "suitable volume". This concept with refinement may actually have some merit, but the UAA does not demonstrate its strength or provide research references that document its defensibility. Ecology will need a sound scientific foundation in order to move forward with this concept.	The growth and survival of fish are highly dependent on water temperature and the availability of food (Hughes and Grand, 2000). It is recognized that these conditions are not uniform throughout the lacustrine portion of Long Lake Reservoir. (That is, the CE-QUAL-W2 model provides a 2-dimensional view of reservoir temperature and DO levels. Therefore, specific microhabitat conditions along the shorelines are not delineated.) However, the CE-QUAL-W2 model does provide a reasonable characterization of overall macrohabitat availability. Thus, the "suitable volumes" derived from the model are expected to be of the correct order of magnitude. In addition, the focus of the model interpretation is on the conditions in the upper hypolimnion. The habitat conditions become progressively more homogenous with increasing depth. The basis for the water temperature and DO values chosen as suitable is provided in Part 2, Table 3-7 for rainbow trout.
Ecology – Melissa Gildersleeve	**ES-8, fifth paragraph, last sentence.** The attainable substrate condition throughout much of the hypolimnion may limit the type of species to those that have wide tolerances to oxygen, but if this is not true then a greater diversity of species can potentially exist at 5-6 mg/l than at 2-4 mg/l.	Benthic macroinvertebrate communities are not likely to become significantly more complex or diverse under improved deep-water DO conditions due to water temperature and habitat limitations. This is discussed in Part 2, Section 4.4.3.
Ecology – Melissa Gildersleeve	**ES-8, sixth paragraph.** The analysis is not done at the species/genus level thus is biased against an accurate analysis of diversity. At the family level, we would expect chironomids and oligochaetes to dominate these soft-bottom environments regardless of the dissolved oxygen concentration. However, the family Chironomidae is a very large family with members that respond to eutrophication stress. In fact, Hilsenhoff Biotic Index scores for chironomids range from 1 (most intolerant to organic pollution) to 10 (most tolerant to organic pollution). The members of the class Oligochaeta also vary among an organic pollution gradient.	It is not necessary to be able to distinguish these organisms at the species level. (This is not normally done because of the substantial extra effort for that level of taxonomic identification.) The chironomids and oligochaetes that are there now likely will continue to dominate the profundal benthos because of habitat limitations, specifically substrate and water temperature conditions. Even if there were to be an increase in diversity within these groups, there would not be a discernable benefit to fish in the reservoir because fish will not preferentially feed at these depths.
Ecology – Melissa Gildersleeve	**ES-9, second paragraph, first sentence.** We do not support the focus on the planted rainbow trout fishery. There are naturalized populations of other stocks and species using the reservoir, and no clear evidence is provided to suggest these are populations cannot be made more robust with better controls on water conditions.	The focus is on rainbow trout since they are a cold-water native species, they are the most widely distributed to provide an indicator for change, and the impacts to rainbow trout would likely be similar to those for other cold-water fishes.
Ecology – Melissa Gildersleeve	**ES-9, third paragraph.** The use of the suitable volume concept does not provide a clear picture of where, when, and the extent of improvements by averaging a broad range of temperature and oxygen conditions. In addition, without a sound research-based rationale for its use we cannot support the assumption that the benefits to aquatic species are inconsequential. The focus on stocked rainbow trout only is also not appropriate.	See above responses.
Ecology – Melissa Gildersleeve	**ES-10, table ES1.** We find that the criteria values themselves are adequate to protect the uses that are targeted in the UAA for the river, but we are concerned that the UAA has not adequately demonstrated why fall spawning should not be explicitly protected and why spring spawning protection should end in May. Additionally, even though EPA Region 10 approved Oregon's average-based oxygen criteria, they were strongly opposed to Washington's approach. Oregon also limits the use of average-based criteria to where sufficient monitoring data exists to develop the average; otherwise, a more restrictive single daily minimum value is applied. The shorter averaging period proposed in the UAA, compared with the one used in Ecology's draft standards proposal, may help mitigate some of this concern. However, we expect there will still be concern that due to the lack of reliable monitoring technology to verify compliance with the 30-day average minimum oxygen concentration regulation of the water body will be based only on the 1-day minimum value. Perhaps because this is a TMDL/UAA combination project, there may be an opportunity to use modeling as a basis for overcoming this objection. We note this since the EPA objections were strong enough to persuade Ecology not to move ahead with our rule proposal. The proponents need to understand that this is likely to be a substantial issue for the EPA.	The uppermost riverine reach of the reservoir possibly provides suitable spawning habitat for brown trout (Part 2, Table 3-7). Similar to other trout species, brown trout require gravels in well-oxygenated waters, but are relatively more tolerant of pollution and turbidity (Part 2, Table 3-7). Brown trout are a non-native species in this system that spawn mid- to late September to November (Donley, 2004, pers. comm.). To protect potential brown trout spawning activities, ***for Long Lake Reservoir (riverine), a 1-day minimum DO value of 8.0 mg/L should be applied between mid-September and November*** (Part 2, Figure 5-4b). The dominant spawning areas coincide with areas already protected by winter uses. Therefore, the recommended winter DO reservoir criterion (***1-day minimum DO value of 8.0 mg/L should be applied between October and June***; see Part 2, Sections 5.2.5 and 5.2.2) provides protection for brown trout fall spawning. Regarding reliability of monitoring, there has been extensive application of continuous DO monitoring throughout the U.S., including in Oregon and Idaho. As with any such devices, the instrumentation must be properly installed, calibrated, and maintained. The U.S. Geological Survey has established reliable procedures and is collecting defensible data (for example, in the Tualatin River in Oregon [Rounds and Wood, 2001]). The CE-QUAL-W2 model that has been used throughout the northwest for DO TMDLs, including the Spokane River system, produces continuous output data that can be directly compared to average-based criteria. (Again, see the EPA-approved Tualatin River TMDL [Rounds and Wood, 2001]).

Commentator	Biological (Fish and Macroinvertebrate) Comments	Response
Ecology – Melissa Gildersleeve	**ES-11, last paragraph.** It is not appropriate to compare the macroinvertebrate populations from streams to that of a lake in suggesting the use is not being met. If the UAA is going to claim that the food supply is less for fish in a lake, it needs to be specific to the Spokane Reservoir and there must be a scientific evaluation that shows this. Fish often move to lakes and reservoirs because they can take advantage of a larger prey base and thus use them to accelerate their growth rates, so the reasons for suggesting the opposite condition exists in the Spokane River system needs to be scientifically defensible.	There are separate discussions of macroinvertebrates in the Spokane River (RM 112 to RM 58) and Long Lake Reservoir (RM 58 to RM 34) sections of the Spokane River UAA. Site-specific data are used where available.
Ecology – Melissa Gildersleeve	**ES-12, Recommended Uses**. It is not clear why cutthroat, kokanee, and mountain whitefish are not included for consideration.	The limited distribution and abundances of the remaining native salmonids and the extirpation of native anadromous fishes within the Spokane River system suggest a need to select cold-water species that can serve as an indicator for aquatic conditions within the Spokane River system. Redband rainbow trout (*O. mykiss gairdneri*) is a native subspecies of rainbow trout (*O. mykiss*; Behnke, 1992). They are distributed east of the Cascade Mountains within tributaries to the Columbia River (Wydoski and Whitney, 2003). WDFW 2004 examined the genetic structure of several populations of rainbow trout within the Little Spokane River. They suggested that isolated populations of resident native fishes are still found within the Little Spokane River system. Given the difficulties in differentiating the native strain of rainbow trout from those stocked within the system and the similarities in life history and habitat requirements (Behnke, 1992), rainbow trout will serve as a good cold-water species indicator of the fisheries within the main Spokane River.
Ecology – Melissa Gildersleeve	**ES-12, Table ES-2.** As with the recommendations for the river, we are concerned that the basis for the dates used to initiate the criteria are not clearly based on the temporal patterns of use by the biology. Our biggest concerns, however, relate to the criteria established for the hypolimnion. It is not clear that fish will not be trying to use the upper hypolimnion, and if they are then, 5 mg/l is not as protective as 6 or 8 mg/l. The basis for the recommendation is not well established. Even more so, the use of only a narrative in the lower hypolimnion is problematic. It would be very difficult to implement, and thus would not likely be implemented. At the very least the narrative should be accompanying a numeric criterion that will prevent lethal conditions. Numeric criteria such as a 30DADMin of 5mg/l and a 1DMin of 4.5 mg/l would support a wide range of macroinvertebrate species and prevent lethality in salmonids. It may also make sense to clarify that the criteria apply during stratified conditions.	When adopting water quality criteria to protect designated uses, the criteria must be based on sound scientific rationale (40 CFR 131.11[a]). States may adopt numeric and/or narrative water quality criteria (see 33 USC 1344[a]). The federal water quality standards regulation states that water quality criteria "are elements of State water quality standards, expressed as constituent concentrations, levels or narrative statements . . ." (40 CFR 131.3[b]). In establishing criteria, states may establish narrative criteria when numerical criteria cannot be established or to supplement numerical criteria (40 CFR 131.11[b][2]). Washington state's surface water quality standards currently contain narrative standards. See, for example, the "aesthetic values" criteria set forth in WAC 173-201A-200(b)(ii). The approach the Spokane River UAA has taken to establish the proposed narrative criteria is consistent with the regulatory requirements that require a scientific approach to setting criteria and that authorize the use of narrative criteria. Our recommendations are well supported. They are explained within the Recommendations section (Part 2, Section 5) and address these concerns. In addition, we have added a long-term goal of 4.0 mg/L for the lower level of the hypolimnion to avoid acute lethality for salmonids.
Ecology – Melissa Gildersleeve	**1-3, last paragraph.** Throughout the UAA the inference that species have adapted should be removed. Being restricted temporally and spatially and having potentially higher prespawning and developmental mortalities would not be forms of adaptation consistent with the biological protection objectives of the Clean Water Act.	The term adaptation has been removed except for where it was specifically stated in the cited material.
Ecology – Melissa Gildersleeve	**2-7, second paragraph.** We can find no scientific support for the assertion that brown trout are <u>substantially</u> more tolerant of warm water and low oxygen concentrations than other trout. This is common opinion but does not seem to be supported using scientific methods (Elliott, 1975, 1982; Mesick, 1995). The optimum and preferred ranges for brown trout, at least for temperature, appear essentially equal to that of rainbow trout species. The UAA needs to do a better job at describing the presence and potential use by cutthroat, kokanee, and chinook, which are native species. The UAA infers these are just juveniles that wash downstream from Lake Coeur d'Alene and do not take up residence. The UAA needs to have scientific information to back this up. Examination of the sizes of the fish found and the time of the years found, and not found, will help answer this question.	We stand by our references to brown trout tolerances as found within Part 2, Section 2.2.2. Descriptions and potential uses by fishes are detailed in Section 3.3.3. The size distribution of the fishes observed within the system is not completely documented. However, discussions on the use of the system by species provides a description of when and where the fishes may be found within the system, relative to critical DO parameters.
Ecology – Melissa Gildersleeve	**3-3, second paragraph.** Impacts to spawning would also influence summer juvenile and adult population numbers.	We agree.
Ecology – Melissa Gildersleeve	**3-5, seventh paragraph**. While these temperatures are not ideal, they create a fairly healthy environment for salmonids. Yet, the wording seems to leave the impression otherwise.	We removed the word "although" to remove any potential false suggestions.
Ecology – Melissa Gildersleeve	**3-6, second paragraph**. The UAA needs to better document the basis for the spawning period cited. The UAA should also include the calculations used for the surrogate ratio.	Spawning period descriptions are based on observations from local biologists, where available.

Commentator	Biological (Fish and Macroinvertebrate) Comments	Response
Ecology – Melissa Gildersleeve	**3-7, periphyton and macroinvertebrates.** How much of this sampling occurred in the section of the river with the highest temperatures? The results are applied widely in the report. It is predictive that the macroinvertebrate community will follow the water quality conditions, the key question is what is the highest attainable community? Abundance alone does not indicate that a water body is better or worse than another, because relatively intolerant taxa can be replaced by taxa that can tolerate a given stressor(s). Regarding references to the USGS (2003a) document: The low taxonomic richness of the Ephemeroptera, Plecoptera, and Trichoptera were not necessarily because of metals alone. In fact, the authors specifically say, "The brevity of sampling for this study did not . . . allow for determination of the most important stressors." The authors concluded that the low EPT scores were a result of poor water quality, but they did not venture to be any more specific than a combination of metals, PCB's, and temperature. The comparisons were made against three sites higher up in the watershed. Three reference sites only offer a qualitative comparison to the Spokane River sites.	Sampling locations are generally described and relationships to DO levels included where known. General discussions related to water temperatures are also included, where known. Further, discussions on attainability are related to habitat diversity and water temperatures, and these conditions are limited within lacustrine environments of the Spokane River system. Quantitative data are not generally available. However, such data are not likely necessary, since the species and their distributions and abundances are related to the limiting habitat parameters described previously.
Ecology – Melissa Gildersleeve	**3-8, fisheries, table 3-4.** What is the basis for listing the chinook and kokanee as non-native? There needs to be some figure or table that explains where these fish were found and when. Ideally, we want any information that helps us understand their age classes.	Native Chinook and steelhead runs are no longer found within the Spokane River subbasin. Isolated populations of hatchery reared and, perhaps, residualized chinook can be found within segments of the Spokane River system, and it is anticipated that these fish were outmigrants of stocked populations from Coeur d'Alene Lake (Donley, 2003, pers. comm.). Kokanee have been found within Long Lake Reservoir during recent surveys, although in small numbers (Osborne et al., 2003). Kokanee are native to isolated portions of the Little Spokane River system, and the population of these fish appear to be at severely depressed levels and restricted to the Chain Lake portion of the Little Spokane River system (Whalen, 2000). Further, Donley (2004, pers. comm.) stated that the Chain Lake population of Kokanee appears to remain depressed but stable, suggesting that the population remains within the Chain Lake area and the fishes are not moving into Long Lake Reservoir. Non-native kokanee were introduced into Coeur d'Alene Lake by Idaho Department of Fish and Game in 1937, and have been actively stocked within the lake since that time (Peters et al., 1998). Anderson and Soltero (1984, cited in Osborne et al., 2003) suggested that the limited kokanee found within Long Lake Reservoir are migrants of the stocked fish that have moved down the Spokane River from Coeur d'Alene Lake. However, these fish are not reproducing within the reservoir.
Ecology – Melissa Gildersleeve	**3-11, general comment.** For the discussions that follow, illustrate where each study occurred, what reaches were sampled, and whether they sampled for all species or only certain species. An absence of surveys is not an absence of fish.	The information from the studies was presented by reach and the site-specific information is available within the respective studies. Where available, DO-related discussions and the locations of fishes by general habitats are included. See Part 2, Section 3.2.3.
Ecology – Melissa Gildersleeve	**3-11, first paragraph, first sentence.** This statement appears to conflict with table 3-4. It appears that numerous cold-water species remain.	See above discussion related to chinook and kokanee salmon.
Ecology – Melissa Gildersleeve	**3-11 second paragraph, last sentence.** Strong populations of cutthroat upstream suggest restoration of this species may be very feasible as water quality conditions improve.	We agree. However, the populations tend to be stronger higher within the Spokane River system due to water temperature constraints. In addition, the species would not serve as an appropriate cold-water indicator for the lacustrine portion of Long Lake Reservoir due to habitat conditions.
Ecology – Melissa Gildersleeve	**3-11 third paragraph.** As noted previously, the report should not suggest genetic adaptation to degraded water conditions unless there is a scientific study demonstrating the fish have indeed altered their physiological response levels. This needs to be corrected throughout the study.	The term adaptation has been removed except for where it was specifically stated in the cited material.
Ecology – Melissa Gildersleeve	**3-14, second paragraph.** How does the study referenced pertain to the section of the river being discussed in the UAA?	The study relates to the influence of stocked rainbow trout on native fishes within the system.
Ecology – Melissa Gildersleeve	**3-14, third paragraph.** What is the basis for concluding no spawning occurs? A low density of spawning is hard to observe through sampling programs.	Discussions with local biologists support this assertion.
Ecology – Melissa Gildersleeve	**3-20, last paragraph**. "Suitable" is a problematic description of a monthly average oxygen concentration of 5 mg/l that is additionally applied as a volumetric average across a limnetic zone. Non-lethal, probably. Habitable, probably. However, not fully protective.	See above discussion on "suitable volume" and its relationship to rainbow trout within lacustrine environments.
Ecology – Melissa Gildersleeve	**3-21, first paragraph.** How does the definition used in the King County study of what is available habitat compare with the UAA report's definition of suitable habitat?	The King County study defined suitable habitat for chinook salmon to be DO levels greater than 4.0 mg/L and water temperatures to be from 16 to 18°C.
Ecology – Melissa Gildersleeve	**3-22, second paragraph.** What is the science behind the statement that macrophytes might be better integrators of environmental conditions? This suggestion seems unlikely except at the most course scale of analysis.	This was corrected to read "indicators" not "integrators."
Ecology – Melissa Gildersleeve	**3-23, sixth paragraph.** Are you sure the tested hypolimnetic species had a <u>preference</u> for hypoxic conditions; avoiding concentrations >2 mg/l?	This was reworded to read "tolerance" rather than "preference."
Ecology – Melissa Gildersleeve	**3-26, third paragraph, first sentence.** Why would this portion of the reservoir be limited to spawning by brown trout? Why is it not suitable for use by kokanee, rainbow, chinook, and whitefish?	We agree. This has been reworded to read: "The riverine reach of Long Lake Reservoir may provide good spawning habitat for brown trout but it is only believed to occur within the tailwaters of Nine Mile Dam (Donley, 2004, pers. comm.). Similar to other trout species, brown trout require gravels to spawn in well-oxygenated waters, but are relatively more tolerant of pollution and turbidity (see Table 3-7). Brown trout are non-native species in this system that spawn in mid- to late September to November."

Commentator	Biological (Fish and Macroinvertebrate) Comments	Response
Ecology – Melissa Gildersleeve	**3-26, third paragraph, last sentence.** WDFW has told us the reservoir is used as rearing habitat for migratory wild salmonids, and is also habitat for adult adfluvial fish populations. Their biologist believes the best salmonid habitat in the reservoir occurs in the lower portion of the reservoir where water quality issues seem to be the worst. WDFW supplements the trout population but notes there is also recruitment of wild salmonids from the Little Spokane River and the spawning that takes place below Nine Mile Dam.	A detailed description, including comments from a local biologist, on the uses of rainbow trout within the lacustrine portion of the reservoir is included in Part 2, Section 3.3.3.
Ecology – Melissa Gildersleeve	**3-28, Table 3-7, Surveys.** It is difficult to use this information without knowing more about the survey methods. For example, when the shoreline surveys conducted and what were was the ambient temperatures. Cold-water fish will be forced out of the near shore environment as the temperatures peak.	Discussions describing seasonal uses by fishes are included in Part 2, Section 3.3.3. Details of specific surveys are not always included and may not add additional information to the DO-level recommendations.
Ecology – Melissa Gildersleeve	**3-31, Table 3-7, Kokanee Spawning Preference.** This is the general pattern, but kokanee also spawn at great depths in reservoirs having suitable temperature and substrate conditions (see Jeric, 1996).	We agree. See Part 2, Table 3-7 for information on kokanee salmon.
Ecology – Melissa Gildersleeve	**3-34, third paragraph**. Is there a study to support the statement that prey are less abundant approaching the dam? Did someone examine the drift rates or make a determination that food was limited for fish near the dam?	These are conclusions within Bennett and Underwood, 1988.
Ecology – Melissa Gildersleeve	**3-34, fifth paragraph.** Is this reference examining preference or occurrence? Did Bradbury et al. find that fish sought out waters between 3-13 mg/l equally?	Reworded to read: "Raleigh et al. (1994, cited in Bradbury et al., 1999) suggested that rainbow trout appear to prefer (that is, tend to more frequently occur) in those portions of lakes where summer water temperatures are below 18°C with DO levels greater than 3.0 mg/L."
Ecology – Melissa Gildersleeve	**3-34, sixth paragraph.** We disagree with this concept that the fish would distribute themselves equally. The fish may just as likely concentrate into colder layers and thus the per fish area would be significantly less. In addition, the logic in the last sentence seems circular. The fish would not use the hypoxic cold layers, since non-hypoxic waters exist. Why wouldn't they benefit physiologically from being able to use cold hypolimnion waters with better (>5-6 mg/l) oxygen concentrations.	See discussion above regarding suitable habitat.
Ecology – Melissa Gildersleeve	**3-25, first paragraph**. Summarize the basis for why Soltero suggests the kokanee are stocked fish that washed downstream. In the attainability section explain why natural stocks would not colonize the reservoir and why planted fish cannot become self-sustaining in the watershed and use the reservoir for rearing and the upper reservoir for spawning.	See discussion above regarding kokanee within the reservoir.
Ecology – Melissa Gildersleeve	**3-38, fifth paragraph.** This statement infers that the non-free flowing reaches only contain planted cold-water species. The information presented does not provide clear support for such an interpretation.	Reworded to read "Thus, existing aquatic life uses can be described as a resident, interior fishery with a mixture of cold- and cool-water fish being predominant, and with free-flowing reaches also supporting a naturally reproducing cold-water rainbow trout population."
Ecology – Melissa Gildersleeve	**3-41, second paragraph, second sentence.** Ecology does not limit the concept of a self-reproducing population based on the site not being used for one or more life stages. The purpose is to distinguish planted populations that would not survive without human intervention (repeated stocking) from those that can naturally colonize and persist in a water body. Since our standards state that non-self reproducing populations are not considered as existing uses under our standards, this clarification is very important in the context of a UAA. Using the draft UAA report's definition, any site absent any of the four key life stages/habitats to support a species would not need to be protected for that species. This will not be an acceptable interpretation.	Reworded to read: "Within the lacustrine portion of the reservoir, stocked rainbow trout likely inhabit littoral habitats where food is more widely available and diverse, but there are likely patchy abundances of rainbow trout within the pelagic zone. The rainbow trout stocked in Long Lake Reservoir are almost strictly zooplanktivorous/insectivorous until they are adults, and may shift to piscivory to supplement their diet as they mature. The pelagic fishes likely spend most of their time within the epilimnion during stratification, but venture into the metalimnion or hypolimnion for short periods to feed. Warner and Quinn (1995) found that pelagic rainbow trout spent most of their time in the upper 3 meters (10 feet) during stratification, but made occasional, and brief, "dives" into deeper strata. Further, fishes in the Warner and Quinn (1995) study stayed primarily within the waters above the thermocline (10 to 20 meters [33 to 66 feet]) during stratification, even though these temperatures were recorded as high as 21°C."
Ecology – Melissa Gildersleeve	**3-41, second paragraph, last sentence.** The basis for describing the feeding habits of the particular species of rainbow trout stocked in Long Lake as being somehow unique is not clear. How this statement relates to other fish using or potentially using the reservoir is also not clear. There appears to be too much focus on the stocking program.	See above response.
Ecology – Melissa Gildersleeve	**4-5, third paragraph.** The statement that the recommendations will support anadromous fish if they return as well as wild stocks needs more support. Only part of the spring spawning and emergence window for rainbow trout is clearly used in setting the recommendations.	Under the lacustrine conditions that now exist within the system, our recommendations are supportive of attainable seasonal lacustrine uses. They are described in the Recommendations section (Part 2, Section 5).
Ecology – Melissa Gildersleeve	**4-6, fourth paragraph.** Spawning does not need to occur "throughout the reach" for spawning to be a protected use throughout the reach. Oxygen appears to well support spring spawning, so the issue in this case is whether other habitat factors limit spawning. Since some of these factors seem to be related to the design and operation of the dams and reservoirs, the question must be addressed in that context to be worth including in this discussion.	We agree. We replaced that sentence with "Thus, it is not expected that marginally improved DO conditions alone would either restore salmonid spawning within the riverine reaches where it is not currently occurring or substantially enhance it where it is occurring. Suitable substrate availability, temperatures, and competition within this modified environment are likely more important factors limiting spawning of rainbow trout (see Section 4.3.3)."
Ecology – Melissa Gildersleeve	**4-7, first paragraph.** Cold-water life already exists throughout the system so saying it cannot be restored seems peculiar. The focus on the "throughout" standard that has been created in the UAA is not consistent with the way species use natural water bodies and should not be a standard of performance for judging use attainment in an altered system. There is also inadequate documentation for the assumption that the habitats are so separated from one another and tributary systems that they are not viable habitat for cold-water species.	Reworded to read, "However, this improvement would likely not result in the restoration of cold-water aquatic life and salmonid spawning within the lacustrine portions of the river due to other limiting factors such as temperature and physical habitat."
Ecology – Melissa Gildersleeve	**4-7, last paragraph.** There appears to be a possibility that fall spawners currently exist and may be enhanced through fish passage construction as part of relicensing requirements. The UAA has not adequately addressed the issue of fall spawning species and how the criteria windows can be adequately defended as protecting this potentially attainable use or provided adequate evidence that the use is not attainable.	Fish passage was not addressed as part of this analysis. Nonetheless, fall spawning recommendations are included within the Recommendations section (Part 2, Section 5).

Commentator	Biological (Fish and Macroinvertebrate) Comments	Response
Ecology – Melissa Gildersleeve	**4-10, Trophic Status.** There is inadequate basis to hypothesize that in a system as productive as the Spokane that further improvements in controlling phosphorous might create a food limitation for fish. It has not been demonstrated that limiting the input concentrations in the mid summer period will cause a food shortage that would harm fish populations and create inferior growth rates.	Reworded to read: "Given that Long Lake Reservoir has stabilized to a mesotrophic status (Soltero et al., 1992), a decrease in phosphorus and resulting increases in DO levels might alter the future trophic status, but it is uncertain to what degree. Operational requirements of reservoirs create an unstable and, due to the lack of research, apparently unpredictable environment for definitively predicting how further nutrient reductions would affect the trophic status. If the reservoir was able to move toward a more oligotrophic system, the effects on biological productivity and the associated effects to the existing fisheries community would be uncertain."
Ecology – Melissa Gildersleeve	**4-10, Macrophytes.** What evidence is used to base the hypothesis on that there would be a decline in macrophytes and the decline would harm species?	Reworded to read. "The dense growth of macrophytes, particularly along the southern reservoir shoreline, currently provides stability to the shoreline and mitigates erosion. The shallow macrophyte beds that provide critical habitat for spawning and rearing for the dominant cool- and warm-water fish species are likely impacted more by reservoir operations within the lacustrine zone (May et al., 1988) than by additional, relatively minor, nutrient reductions given that the reservoir has apparently settled into a mesotrophic status (as described by Soltero et al., 1992). Further reductions in anthropogenically derived nutrients may or may not result in measurable impacts to macrophytes, since additional reductions would be minor given the history of the system."
Ecology – Melissa Gildersleeve	**4-10, Macroinvertebrates.** As with the discussions on Fish and Macrophytes the report takes too much speculative license by suggesting a healthier macroinvertebrate population would not benefit the fishery. The assumption that the population of macroinvertebrates will probably not improve anyway is troublesome. The internal SOD loading referred to is the result of human pollution and with control would be expected based on Ecology's modeling to substantially improve (to 5-6 mg/l) oxygen conditions in the hypolimnion. The assumption is made without any scientific foundation that two months of annual asphyxiation will not affect the biologic community. The UAA needs a strong scientific foundation in order to successfully get the uses changed. Another issue is that a scientific basis is not presented for why that cold-water fishes wouldn't need to be foraging in the cold hypolimnion, not the epilimnetic photic zone.	This was reworded to read: "The greatest diversity and density of macroinvertebrates occur in the littoral (inshore) zone, where light can penetrate and DO levels are not depressed. Because 50 percent of the total volume of the reservoir is within the euphotic zone, improvements in areas below the euphotic zone would not provide much benefit to the majority of the macroinvertebrate community. For those benthic macroinvertebrates in the euphotic zone, densities might already be high enough to support the large forage base for predators (Pfeiffer, 1985, cited in Parametrix, 2004). However, it is likely that reservoir operations limit the macroinvertebrate potential within this zone (May et al. 1988)."
Ecology – Melissa Gildersleeve	**4-11, fourth paragraph and Table 4.1**. Lake Roosevelt has significant issues with toxic substances accumulated in the benthos. Why would this be a good comparison? The comparison should be at the species level to evaluate diversity. At the family level we would expect chironomids and oligochaetes to dominate these soft-bottom environments regardless of the dissolved oxygen concentration. However, the family Chironomidae is a very large family with members that respond to eutrophication stress. In fact, Hilsenhoff Biotic Index scores for chironomids range from 1 (most intolerant to organic pollution) to 10 (most tolerant to organic pollution). The members of the class Oligochaeta also vary among an organic pollution gradient. At the family level you are generally comparing functional groupings and reflecting the feeding strategy (although we recognize there is functional variability within families as well). At the family level it is primarily an exercise of verifying that the same general types of organisms dominate similar reservoir substrate types. This may still be useful, however, if the UAA can show the sediment type is the attainable condition and that the species that would be found on the same substrate under better water quality conditions are ones with low oxygen sensitivity.	Long Lake Reservoir and Lake Roosevelt both receive toxic substances from upstream sources, including mining activities. According to Ecology's 2002-2004 integrated 305(b)/(303(d) report, Long Lake Reservoir is scheduled for a TMDL for PCBs, while Lake Roosevelt has been listed as needing a TMDL for mercury. The available data have been summarized as reported. The comparison is made for the purposes of looking at a local reservoir and the macroinvertebrates that occupy the deep water portion and to note that improvements within the seasonally stratified portion of the reservoir would not influence diversity. Given the difficulties of identifying these deepwater benthic species, it is common to only identify them to family, for chironomids, and to class, for oligochaetes. Sediments in Long Lake Reservoir are predominantly silts and clay (Part 2, Table 3-6), which do not support diverse macroinvertebrate communities such as those found in sandy riffle/pool complexes.
Ecology – Melissa Gildersleeve	**4-12, sixth paragraph.** The UAA has not demonstrated the highest attainable use is a put and take fishery for cold-water fish species. Much of the information provided would not allow Ecology to take this stance in a rule change.	This was reworded to read: "In terms of protecting rainbow trout that will be stocked in the future, increases in DO levels will likely not benefit these species. This is because these fish likely utilize the epilimnion and metalimnion for a majority of their needs. Only occasionally, and for short periods, did tracked rainbow trout venture into the deeper hypolimnion as observed by Warner and Quinn (1995) and James and Kelso (1995). The majority of food resources and water temperature needs for the fishes appeared to be available within the upper strata. Rearing habitat within covered and low-velocity areas is provided in the riverine and transitional sections of the reservoir. Adult trout will likely inhabit the same littoral habitats used for rearing because of food availability."
Ecology – Melissa Gildersleeve	**4-13, paragraph two.** Fish feed on benthic species in hypoxic areas of reservoirs as well, so it seems peculiar to suggest that adfluvial trout won't use the deep waters because prey will avoid these areas. It also does not address the issue of attainable conditions. Further, small trout may make only moderate use of some of the littoral areas because of predation risks by bass.	Because prey tend to avoid low DO conditions, and the majority of the prey-base is located within the upper strata, rainbow trout exposure to low DO levels is expected to be limited. However, it appears to occur in other systems (Warner and Quinn, 1995; James and Kelso, 1995). If DO conditions were improved in the open-water portion of the reservoir, additional, intermittent foraging might occur. However, this benefit is expected to be small given the trout's preference for easier prey in shallower environments with better feeding opportunities. Small fish are more likely to seek cover due to predation.
Ecology – Melissa Gildersleeve	**4-14, fourth paragraph, fourth sentence.** Spawning doesn't completely occur throughout any river we are aware of. This is not a test of whether the correct uses have been assigned.	This was reworded to read: "Thus, it is not expected that marginally improved DO conditions alone would restore salmonid spawning within the riverine reaches where it is not currently occurring (Donley, 2003, pers. comm.) or substantially enhance it in reaches, that is, tributaries, where it is occurring."
Ecology – Melissa Gildersleeve	**4-15, second paragraph, last sentence.** The UAA question is not whether spawning can be attained "throughout" the riverine reach.	See above response.

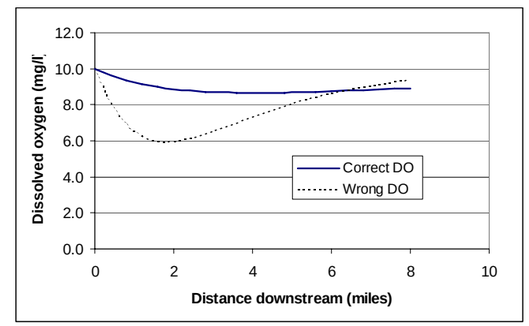
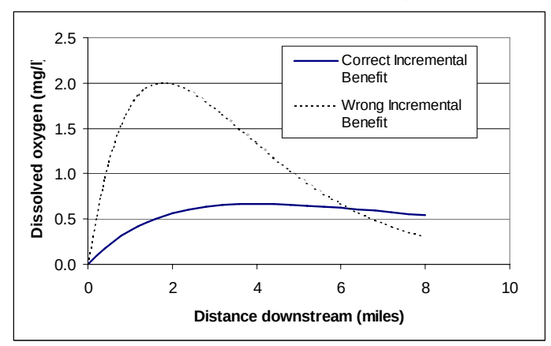
Commentator	Biological (Fish and Macroinvertebrate) Comments	Response
Ecology – Melissa Gildersleeve	**4-15, third paragraph, last sentence.** The draft UAA has not adequately documented that cold-water aquatic life will be limited in the river. There may be a portion of the river (just below the state line) that fits the description of a cool water dominated biota, but the rationale for the entire river seems inadequate at this point. It is not necessary to show that a completely unique use class exists to apply seasonal/life stage based criteria. If the UAA can reach the point of demonstrating what the highest attainable uses are, and recommend fully protective criteria for those uses, we will then find the best way to depict the recommended changes in a proposal for rulemaking. This may be through some uniquely named use, or it may be through application of one of the existing categories for aquatic life with the criteria adjusted for the water body using the special conditions provisions of our standards. There are other options as well. Ecology will want to take an approach that sets the best precedent for using the UAA results to modify the standards long term.	This is supported within the Recommendations section (Part 2, Section 5).
Ecology – Melissa Gildersleeve	**4-16, fourth paragraph.** As noted previously, the hypothesis that controls on nutrients will create food deficiencies in the system is too speculative to include in a UAA and should be backed up with science or removed.	This has been reworded to read: "Given that Long Lake Reservoir has stabilized to a mesotrophic status, a decrease in phosphorus and resulting increases in DO levels might alter the future trophic status. If the reservoir was able to move toward a more oligotrophic system, the effects on biological productivity and the associated effects to the existing fisheries community would be uncertain. The shallow macrophyte beds that provide critical habitat for spawning and rearing for the dominant cool- and warm-water fish species are likely impacted more by reservoir operations within the lacustrine zone than by additional, relatively minor, nutrient reductions given that the reservoir has apparently settled into a mesotrophic status. Further reductions in anthropogenically derived nutrients may or may not result in measurable impacts to macrophytes, since additional reductions would be expected to be minor given the history of the system."
Ecology – Melissa Gildersleeve	**4-16 last paragraph.** As noted previously, the comparison with Lake Roosevelt has some flaws. The lack of species level analysis and the fact that the sediment in Lake Roosevelt is impacted by toxics needs to be addressed in the analysis. This criticism does not mean that the conclusion is wrong, but that it needs to be shored up with more facts.	The comparison is made for the purposes of looking at a local reservoir and the macroinvertebrates that occupy the deep water portion and to note that improvements within the seasonally stratified portion of the reservoir would not influence diversity. Given the difficulties of identifying these deepwater benthic species, it is common to only identify them to family, for chironomids, and to class, for oligochaetes.
Ecology – Melissa Gildersleeve	**4-17, third paragraph.** The UAA would first need to prove that the reservoir only has the potential to be a put and take fishery before basing conclusions on the assumption that it is. The evidence suggests otherwise, and the goals of WDFW appears to be a supplemented fishery with year-round protection (multi-year survival) that also benefits native cold-water fishes.	Increasing the numbers of stocked fishes so that more fishes might survive the operational impacts of dams and predation risks to survive additional years does not mean that it is no longer a put-and-take managed reservoir. It is only a different strategy for put-and-take management.
Ecology – Melissa Gildersleeve	**4-17, fourth paragraph.** The use of the weighted monthly volumetric average has no apparent scientific basis, and the averaging blurs the absolute improvements possible. Since it does not relate to any studies we are aware of in the literature regarding fish health, it is also not a concept that we can support at this time. Fish may also be concentrating in more narrow zones than what is assumed by the "suitable volume" concept and thus even the estimates on the acre-feet available cannot be substantiated. This approach might have some value, but the available information does not demonstrate that it does and we would need a sound scientific basis to embrace such a concept.	See above discussions regarding the "suitable volume."
Ecology – Melissa Gildersleeve	**4-17, fifth paragraph.** If the hypothesis of "suitable volume" is valid, then it is not clear why the UAA is suggesting that conditions "will continue to favor cool- and warm-water species, and limit cold water aquatic life".	We have not claimed that "suitable volume" is the ideal habitat for cold-water species. This volume likely will provide sub-optimal conditions for stocked trout, but the reservoir will continue to favor cool- and warm-water species. These "suitable volume" conditions in the reservoir will be the highest attainable.
Ecology – Melissa Gildersleeve	**4-17, last paragraph.** Why wouldn't it be <u>biologically appropriate</u> to set the use type at the rearing-only use level in the state standards in the lower reservoir and apply the 0.2 mg/l depression from potential oxygen levels from upstream sources? There is nothing unique or unusual about lower main stem rivers and reservoirs having a mixed fishery.	It would not be biologically appropriate because it is not scientifically possible to attain the rearing-only criterion in the lower reservoir. The 0.2 mg/L change in DO level standard is arbitrary and has no biological basis or linkage to attainability of reservoir uses.

Limnology Comments

Commentator	Limnology Comments	Response
Ecology – Melissa Gildersleeve	**ES-5, sixth paragraph, second sentence**. The suggestion seems to be that the system has settled into its appropriate trophic condition. We disagree. The system will continue to change as input parameters are altered. With better controls on nutrients the system will stabilize at another trophic level just as well as it has at its current level. Further, the water quality conditions even within a similarly named trophic state can be quite different.	The system may continue to change. However, our analysis does examine what is attainable at the various treatment levels and what is protective of the critical life stages for various species.
Ecology – Melissa Gildersleeve	**ES-8, first paragraph, last sentence.** We do not support a suggestion that alleviating the algal blooms in the upper strata is bad because the oxygen concentrations, which reflect supersaturated conditions, will decline. This is because harmful nighttime depressions may follow these supersaturated conditions, and because most literature shows little if any benefits to such supersaturated conditions. Since this occurs in the warm surface layer, it is also an apples and oranges comparison. The oxygen appears likely to improve in the locations where the fish will mostly reside even though the absolute levels in the surface layer will go down.	We have not stated or suggested that lower DO levels due to lower algal productivity are “bad.”
Ecology – Melissa Gildersleeve	**ES-8, fourth paragraph.** Eliminate the comment about the system being stabilized. It would stabilize at alternative trophic states just as well. This seems to infer that it would be harmed from destabilization through controlling excess nutrients and increasing clean flows. The UAA needs to provide a scientific basis for demonstrating that the system would become nutrient limited if it is going to retain the assumption that cleaner water may hurt fish populations.	The statement is taken from Soltero et al. (1992). We have not stated, suggested, or assumed that cleaner water would hurt fish populations. This paragraph, in fact, goes on to note that the outcome is uncertain. Certainly there is a body of literature that has shown oligotrophication to adversely affect some species in some reservoirs, but we have not concluded that there will be adverse effects in Long Lake Reservoir.
Ecology – Melissa Gildersleeve	**ES-13, second paragraph, last sentence.** We do not support the use of a volume-weighted average across limnetic zones. The scientific basis for defending this recommendation has not been established, and it would be nearly impossible to implement. The boundaries would need to be established each time that sampling was to occur and a comprehensive network of sampling stations would be required to argue defensively that the zones were adequately averaged. We also disagree with the characterization that this is just an implementation step, when in fact it substantially changes the criterion. Just saying fish will move around and that conditions are always variable does not address whether or not using a volume-weighted average is consistent with the biological research and can be used to ensure full protection of the designated uses. This may be a cleaver approach that deserves to be studied further, but it remains undocumented at this point and thus does not appear defensible.	This comment implies that Ecology believes that monitoring/assessment for TMDL compliance needs be much more elaborate than that needed to establish the TMDL in the first place, which does not appear to be a reasonable or scientific approach. We believe that it is reasonable to assume that similar monitoring will be used for compliance as for the TMDL itself, perhaps supplemented by additional modeling. Ecology will not be able to more rigorously monitor compliance with a single value absolute DO criterion such as an 8.0 mg/L level everywhere at all times or with a relative DO criterion of a 0.2 mg/L change level everywhere at all times.
Ecology – Melissa Gildersleeve	**3-2, third paragraph.** What is meant by the statement that it functions like a lake. Does the flow stop entirely? Is the mean detention time greater than 15 days? Can the dams be operated to alter this condition? What is the attainable condition?	The backwater conditions created by the dams create a more lake-like condition (that is, slow waters, fine sediments, seasonal stratification, etc.). The wording has been changed to clarify this point.
Ecology – Melissa Gildersleeve	**3-5, fifth paragraph.** Why would lack of nuisance algal blooms be considered evidence oxygen is not being affected? If the value chosen for what is a nuisance is high, there could be considerable effects.	DO levels are affected by several factors including algal concentrations. Nuisance levels of algae can create supersaturation conditions (more than 100 percent saturation) during large algal blooms where photosynthetic oxygen production exceeds that which is released into the atmosphere (Maryland Department of Natural Resources [MDNR], 2004). The nuisance level for riverine periphytic algae cited by USGS in this report (USGS, 2003a) is taken from research conducted by Dr. Eugene Welch of the University of Washington. This level is not considered to be a “high” level, but in fact was based in part on avoidance of substantial DO effects.
Ecology – Melissa Gildersleeve	**3-18, second paragraph.** What about upstream sources of sedimentation? Why only focus on shoreline erosion?	This has been reworded to include upstream sources of sediment within the system.
Ecology – Melissa Gildersleeve	**3-21, second paragraph.** The inference is that it has settled into some stable climax state, when in fact it has been changing throughout the 80-year period as changes in pollution controls and water management have occurred.	See previous responses above.
Ecology – Melissa Gildersleeve	**3-21, fifth paragraph.** Suggesting that most reservoirs are eutrophic is not relevant to a UAA for a reservoir in the state of Washington. In addition, as noted, human pollution is the cause of most of the eutrophication.	The point is that this reservoir is not unique with regard to other reservoirs. We do note that cultural inputs as well as the location of the reservoir within the basin, relative to natural and man-caused nutrient inputs, are reasons for the expedited rates of productivity found in reservoirs across the country.
Ecology – Melissa Gildersleeve	**4-9, second paragraph.** This needs more explanation. We are of the opinion that the depth of the thermocline in Lake Spokane is partly determined by the heat budget and partly by the colder river water that moves through the interflow zone such that the thermocline would not move down in the water column if the clarity of the water increases.	This paragraph has been deleted.
Ecology – Melissa Gildersleeve	**4-13, fifth paragraph**. Why wouldn’t Lake Spokane have an even better flushing rate given its configuration and relatively shallow depths? How do the rates of accumulation compare in depth?	The main point of this paragraph and the quote above it is that Lake Washington’s recovery rate after removal of effluent loading was driven primarily by lack of hypolimnetic anoxia and the relatively short period of such loading. Lake Washington is a natural lake and Long Lake Reservoir is not. Several factors, including age, depth of outlet, water level fluctuations, drainage area, watershed area, and nutrient loading combine to differentiate natural lakes from reservoirs (Summerfelt, 1999). Loading and flushing rates tend to be higher in reservoirs (Summerfelt, 1999).

Commentator	Limnology Comments	Response
Ecology – Melissa Gildersleeve	**4-13, last paragraph**. Were most of the lakes in the study heavily developed? How do the lakes compare to Long Lake, which receives substantial point source pollution? Internal loading is important, but so is external loading. It is of course true that if ongoing sources are reduced or eliminated the relative contribution of internal loading will increase. It is also true that internal loading will continue to affect water quality long term, but such general relationships cannot be used to suggest the problems in Long Lake are substantially from internal loading.	The degree of development around the 17 lakes was not reported in Welch and Jacoby (2001, cited in King County, 2003), although all of these lakes were considered phosphorus-enriched to the extent that some form of treatment/management was undertaken (including diversion of stormwater, alum treatment, aeration, watershed protection, etc.). Of the 17 lakes examined, 14 were shallower than Lake Washington (and therefore, Long Lake Reservoir), and 8 of these lakes were unstratified. If anything, reference to these lakes would indicate a conservative approach to the importance of internal loading relative to Long Lake Reservoir. However, the point of this section of the Spokane River UAA report (Part 2, Section 4.4.4) was not to suggest that the problems in Long Lake Reservoir are substantially from internal loading, but rather to suggest that recovery due to further controls on external loading will likely not be manifested for decades. We recognize that conditions in the reservoir are affected by historical external loadings from point and nonpoint sources. The internal loadings that occur in the reservoir today are due in part to past external loadings. The internal loadings are nonetheless real and likely have affected (and will continue to affect) the DO levels by re-suspension of the deep, fine, organic particles during stratification turnover, water level fluctuations, and wind-driven hydraulics. We note that Ecology increased the phosphorus release rate from sediment by 10-fold in its latest calibration of the CE-QUAL-W2 model of the reservoir. We also note Ecology's argument in the Draft TMDL (Ecology, 2004a; Ecology, 2004e) that point sources primarily affect DO in the metalimnion of the reservoir while nonpoint sources primarily impact DO in the hypolimnion. Thus, control of nonpoint sources will be needed to substantially affect internal loadings.
Ecology – Melissa Gildersleeve	**4-16, fifth paragraph.** This paragraph seems to combine discussions relating to different limnologic regions of the reservoir. It is also not clear that with pollutant controls alone (no dam changes) that conditions would not improve to the extent that a wide range of macroinvertebrates could be supported in the hypolimnion (at 5-6 mg/l). Existing conditions are significantly worse than what appears to be potential. Such changes would also greatly increase the refugia value of the deep colder waters during middle of summer for fish species.	The hypolimnion DO range of 5.0 to 6.0 mg/L presumes an oligotrophic SOD rate, which is purely speculative.

Modeling Comments

Commentator	Modeling Comments	Response
Ecology – Melissa Gildersleeve	**Page ES-3, fourth paragraph, last sentence.** Model calibrations were actually less than 1 mg/l. While this does suggest that the absolute prediction may be slightly more or less, than what is predicted through modeling, the comparison between model runs is not subject to even this small degree of model error. In comparing scenarios using the model, any model assumptions that are less than perfect and produce predictive errors will be in the same direction, thus the accuracy of comparing different treatment scenarios would be even higher.	The mean DO error of 1.0 mg/L was taken from a paper written by the developers of the Spokane River model at Portland State University. This paper is cited in the Spokane River UAA report (Berger at al., 2002). Ecology has not provided documentation of lower calibration error. In any case, an error of 1.0 mg/L for DO is not unusual for complex systems such as this. For example, the root mean square (RMS) error of the CE-QUAL-W2 model developed by USGS for the Tualatin River in Oregon ranged from 1.1 to 2.3 mg/L for DO, depending on location (Rounds and Wood, 2001). The important point is that this error should be recognized, and the results of the various scenarios have to be interpreted with care and professional judgment. In the Draft TMDL (Ecology, 2004e), Ecology has used the model to judge compliance with a 0.2 mg/L DO deficit standard. Ecology has also interpreted the model as being able to accurately predict DO levels at all times and all places. The model accuracy is not amenable to this degree of rigor of application. In addition, it is not true that any errors in model assumptions will necessarily produce predictive errors in the same direction or of the same magnitude across comparative runs. See response below.
Ecology – Melissa Gildersleeve	**4-1, fourth paragraph.** As noted previously, the RMS is less than 1 mg/l, and the error level for predictions when comparing different control scenarios would be expected to be almost non-existent since any erroneous input assumptions would exert approximately equal effects on the predictions between multiple scenarios.	This comment is not valid as illustrated by the following simple example. In the charts below, a simple Streeter-Phelps calculation of DO in a river is shown for a case in which the biochemical oxygen demand (BOD) in the river is reduced from 10.0 to 5.0 mg/L via some form of control of BOD sources. The first chart shows the difference in absolute DO concentrations in the river using a "correct" BOD decay rate of 0.1 per day compared to a "wrong" value of 0.6 per day.  The second chart shows the incremental difference in DO depending on which decay rate is used. 

Commentator	Modeling Comments	Response
		It is clear that there is a very substantial relative error associated with using an erroneous input value. The error caused by the incorrect rate is 2.7 mg/L; the error in estimating the incremental benefit of reducing BOD is 1.3 mg/L. The relative error is smaller than the calibration error, but by no means negligible.
Ecology – Melissa Gildersleeve	**4-2, seventh paragraph.** If the UAA altered any other of the underlying input parameters for the model then it must be stated here.	Changes to input parameters are identified in this bullet in general terms. However, additional details are provided in Appendix D1 and Appendix D2.
Ecology – Melissa Gildersleeve	**4-3.** It appears that the model results did not include consideration of controls for human activities in Idaho. The UAA analysis is not limited by political jurisdiction. It is a federal requirement and tied to the rivers/resources affected. If the problems cross boundaries than so must the UAA. If due to a lack of cooperation or other factors information regarding the upstream waters and the potential remedies for human actions cannot reasonably be made, then conservative (in the direction of potentially erring in the direction of greater resource protection) assumptions need to be made regarding the potential benefits to water quality and uses.	The LTI modeling did account for controls for human activities in Idaho for the treatment scenarios. This was accomplished by using the uncalibrated Idaho model. See response below.
Ecology – Melissa Gildersleeve	**4-6, fifth paragraph**. It would be better if we had a calibrated Idaho model to assess the impacts at the Stateline. However, in addition to differences in scenario 1 dissolved oxygen inputs, there are also differences in phosphorus and BOD concentrations input at the Stateline that affect downstream conditions. The only way to resolve the differences in phosphorus and BOD concentrations input at the Stateline would be to calibrate the Idaho model. One way to assess the effects of phosphorus and BOD concentration differences between the scenarios would be to use the dissolved oxygen output from the Idaho model to re-define the Stateline boundary conditions for scenario 1 (i.e., 2001 measured conditions), then it would be possible to compare the effects of the 2001 “measured” Stateline concentrations and the Idaho model predicted concentrations.	We agree that calibration of the Idaho model would be desirable. We are aware that this affects parameters other than DO levels. This is an area of uncertainty not only for this Spokane River UAA but also for Ecology’s proposed TMDL (2004e). We have compared the results at the Washington-Idaho State Line monitoring station (Stateline) using both Ecology’s inputs and baseline inputs adjusted by the uncalibrated Idaho model. (See Figure D1-1-1.) Boundary conditions for the Washington model based on the uncalibrated Idaho model differ significantly from boundary conditions developed from field data (apart from effects of effluent changes), due largely to the relative sparseness of Stateline field data. The field data are the inputs for Ecology’s baseline Washington model run. The greatest discrepancy between boundary condition DO occurs during the spring months. The Ecology boundary condition during summer months also does not reflect the diurnal variation in DO predicted by the uncalibrated Idaho model. It is not possible at this time to determine which set of inputs is most representative or appropriate. However, as discussed in the Spokane River UAA report, DO monitoring at Stateline provides strong evidence that the DO criteria that are proposed in the Spokane River UAA are currently being met at Stateline. The calibrated Washington CE-QUAL-W2 model also shows that our proposed criteria will be met in the Spokane River segment (RM 96 to RM 58) downstream of Stateline using the NLoT scenario. This is a conservative (that is, protective) approach because the treatment scenario runs suggest lower DO values with the higher degrees of treatment in Idaho.
Ecology – Melissa Gildersleeve	**4-12, last paragraph**. We question the UAA’s assessment of lake dissolved oxygen improvements. Using a weighted average method to define the “suitable volume” for fish “averages out” parts of the lake that are predicted to improve the most. For example, the greatest change in dissolved oxygen under different point source loading scenarios is at and just below the thermocline. Without point source loading the dissolved oxygen concentrations are predicted to increase 1-3 mg/L in the upper two meters of the metalimnion or interflow zone which also has cooler temperatures than the epilimnion (i.e., potentially good fish habitat). Only those model segments of the model that represent the downstream 14 miles of the lake show this change. It would appear that being able to improve the dissolved oxygen by 1-3 mg/L in the two meters near the thermocline for 14 miles of lake would be a significant improvement in fish habitat?	Ecology does not provide the basis for the conclusion that DO will improve by 1.0 to 3.0 mg/L within that 2-meter band over a 14-mile reach. Our results (Part 2, Figures 4-3 and 4-4d) do not indicate that magnitude of improvement. However, we agree that incremental improvements in the metalimnion, interflow zone, and upper hypolimnion are important habitat considerations.
Sierra Club – Rachael Osborn	Please provide details about additional CE-QUAL-W2 modeling to be undertaken in conjunction with the UAA proposal. Do the UAA sponsors intend to do additional study of impacts downstream of Long Lake Dam?	All of the modeling that the sponsors have supported is fully described in the Spokane River UAA report and Appendix D. Discussion of the impacts downstream of Long Lake Reservoir can be found throughout the Spokane River UAA report.

Recommended Criteria Comments

Commentator	Recommended Criteria Comments	Response
Ecology – Melissa Gildersleeve	**4-16, second paragraph.** The existing criteria are based on the lowest oxygen concentration at any point in space and time (except arguably beyond 7Q10 flows) not a volumetric and temporal average. The UAA needs to address the absolute improvements. It should also examine the amount of time that more of the water body will be in compliance.	**Spatial:** In both the prior and current Washington surface water quality standards, DO criteria are expressed as 1-day minimum values. It appears that the standards are silent on the spatial interpretation of this minimum for DO. However, the salinity standards (WAC 173-201A-260) specify "where different criteria for the same use occurs for fresh and marine waters, the decision to use the fresh water or the marine water criteria must be selected and applied on the basis of vertically averaged daily maximum salinity." Because salinity differences in estuarine situations are analogous to thermal stratification in fresh water, it appears that a vertical-averaging approach for DO is not inconsistent with Washington standards. Support for the use of a spatially averaged monitoring approach is provided below. **Limnology texts**. This approach is also consistent with well-regarded limnology texts (for example, Wetzel, 1983), wherein volume-weighted averages are widely considered as the most representative estimate of the mass of dissolved oxygen (for example, in calculating hypolimnetic oxygen depletion rates, Ecology, 1998). **EPA's nutrient criteria guidance manual (2000)**. In EPA's nutrient criteria guidance manual (2000), Virginia's criteria Technical Advisory Committee (TAC) recommended that numeric nutrient criteria for phosphorus be applied either as a weighted-mean based on water mass, or as a mixed layer mean value (Appendix B of EPA, 2000). **Brownlee Reservoir TMDL.** This is consistent regionally with how the Brownlee Reservoir nutrients TMDL addressed DO deficits by evaluating each section (or zone) of the reservoir as a whole and presuming fully mixed conditions (IDEQ and ODEQ, 2004). **Behavior of aquatic organisms.** It is well known that fish and other aquatic organisms seek more optimal conditions over sub-optimal conditions when given a choice. For example, salmonids often find refugia in cooler pockets of smaller tributaries during warm summer months rather than remaining in warmer areas (EPA, 2003a). **Temporal:** In EPA's nutrient guidance (2000), the agency recognizes that because the timing of flows and stratification will vary from year to year, the controls of nutrients in the *surface* layer (emphasis added) are unpredictable except as a long-term average. (EPA is silent on controls in the hypolimnion. Perhaps it recognizes the inherent difficulties in controlling nutrients and low DO levels in passive areas of stratified systems [for example, well below typical interflow zones]). Vermont has taken this long-term average approach. Lake criteria have been set as seasonal or annual mean values rather than instantaneous "not to exceed" values (EPA, 2000). Additional analysis has been included in the Spokane River UAA that evaluates absolute improvements, as well as the amount of time that more of Long Lake Reservoir will be in compliance. This analysis (which reflects 2001 conditions) shows that the existing 9.5 mg/L lake criterion (applied everywhere at all times) is exceeded greater than 45 percent of the time (Part 2, Figure 5.3). The 0.2 mg/L delta criterion (applied everywhere at all times) is exceeded greater than 60 percent of the time (Part 2, Figure 5-3). In contrast, the biologically based criteria recommended in the Spokane River UAA are consistently met throughout the epilimnion, metalimnion, and upper hypolimnion.
Ecology – Melissa Gildersleeve	**5-1, last paragraph.** The UAA should include a suggestion for how to overcome the concern regarding the lack of field monitoring technology. This was a key reason many stakeholders, including EPA, did not support Ecology's proposal to use an average oxygen criteria. Can modeling be used to set up control values for daily grab samples, can a worse case week window be identified to target confirmation monitoring, or could a protective strategy be established to monitor in depth if some input values change that would alter the TMDL model predictions of compliance, etc?	Continuous DO monitoring occurs routinely to meet criteria and targets that are expressed as time-weighted averages. Although the technology certainly exists, monitoring may be more resource-intensive than current programs. To support the Chesapeake standards, EPA Region 3 (2003d) has suggested that any limitations in direct monitoring be addressed by more intensive monitoring programs, where feasible, or by the use of statistical methods to assess attainment. The example EPA Region 3 provides is the use of cumulative distribution functions where criteria attainment is expressed as a percent volume of DO of a particular use habitat that meets or exceeds applicable criteria. For the Spokane River system, the existing modeling also provides information about probable future conditions that can be confirmed with additional monitoring. Finally, the Canadian Ministry of Water Land and Air Protection in British Columbia specifies two-number criteria (instantaneous minimum and 30-day mean values) to ensure that fluctuations do not go lower than the instantaneous minimum criterion (Government of British Columbia, 1997).

Commentator	Recommended Criteria Comments	Response
Ecology – Melissa Gildersleeve	**5-3, fifth paragraph.** We would be looking to apply the spawning criteria from the average start to completion dates of the spawning through emergence period.	Based on available data collected in the Spokane River system, April and May bracket average dates of spawning and emergence (Avista, 2000a; Parametrix, 2003; Northwest Hydraulic Consultants, Inc. [NHC] and Hardin-Davis Inc. [HDI], 2004). Avista (2000a) concluded that "specific dates, standardized time periods after spawning, or degree-day thresholds would not be reliable predictors of fry emergence on their own." Thus, in our August Draft Spokane River UAA report based on empirical data collected by Avista in 1997, 1998, 1999 (Avista, 2000a), and 2003 (Parametrix, 2003) we concluded that the core spawning period is generally considered to be between April and May, with limited fry emergence occurring in early June during years with cooler water temperatures. Under the assumption that delayed emergence until June is controlled by a combination of high flows and cooler water temperatures, higher DO values are expected such that extending spawning criteria during these periods is not warranted. For example, DO levels during years associated with late emergence in June and with water temperatures near 13°C should be within the 10.5 to 11.0 mg/L DO range (Ecology, 2004c).
Ecology – Melissa Gildersleeve	**5-3, last paragraph.** Except for needing more support for the windows of time used to apply the recommended criteria values, we would agree that if applied correctly the values would be protective of the spawning use.	Comment noted.
Ecology – Melissa Gildersleeve	**5-4, fifth paragraph**. Except for needing more support for the windows of time used to apply the recommended criteria values, we would agree that if applied correctly the values would be protective of the rearing use.	Comment noted.
Ecology – Melissa Gildersleeve	**5-4 sixth paragraph.** Before being able to support the 8 mg/l daily minimum criteria, we would need more information to support the contention that there is a period of time where spawning of cold-water species is not an existing or likely potential use. This needs to particularly address the use or potential use by native fall spawning species (e.g., mountain whitefish, chinook, kokanee). Combining known reproductive patterns in the watershed or region with knowledge of other supporting habitat attributes (temperature, flow) may create a defensible basis.	See other responses related to the need for protection of kokanee and chinook. (In short, it is believed that these species are not using the mainstem Spokane River for spawning.) For whitefish, we have not found scientific data on DO requirements for spawning. In addition, the 8.0 mg/L DO criterion is consistent with the current Ecology DO criterion applicable to this season (and year-round). See Part 2, Section 2.2.2.
Ecology – Melissa Gildersleeve	**5-6, last paragraph and following discussion on uses.** The use of limnetic zones for applying criteria would be very problematic to implement due to the complexity of defining where they are during sampling events. It is also not very well demonstrated that the uses are really confined to specific zones, particularly under better water quality conditions. It is also not clear why many of the species found in the reservoir are not included in this discussion.	The definition of limnetic zones and applicable criteria in the Spokane River UAA would be relatively simple to determine during sampling events: • The euphotic zone is defined by light penetration • The boundary between the epilimnion/metalimnion and the hypolimnion (where the uses and criteria are proposed to change) is defined by the thermocline (-1°C per meter of depth) Both of these measurements are easily determined using Secchi depths and water temperature profile data. The boundary of the upper and lower hypolimnion is defined as that point where cold-water species would be found at DO levels greater than 5.0 mg/L. The recommended criteria group for a number of uses is based on the most sensitive life stage to be protected. For example, cool- and warm-water species rearing uses in the epilimnetic zone require lower DO levels than cold-water species rearing uses in the same area. Therefore, more stringent life stage requirements were incorporated into the recommended criteria. Identified uses within specific lake zones are defined based on available empirical data and literature information. Because we cannot prove a negative, additional aquatic surveys could not prove that uses are not confined to single zones. Implementation activities are expected to continue to improve the water quality in Long Lake Reservoir. Expected improvements to water quality conditions are expected to be only incremental. Therefore, fish behaviors will probably not change significantly. Other species in the reservoir (such as chinook and kokanee), are very limited compared to rainbow trout (which is used as an indicator species for cold-water fish) and other cool- and warm-water species (see Part 2, Figures 3-14 and 3-15).
Ecology – Melissa Gildersleeve	**5-9, first paragraph.** While it is true that the conditions in the cited study were more extreme and fish had to choose between lethal temperatures and hypoxic conditions, this is not sufficient basis to infer that the cold water at depth in Long Lake is not important. The discussion here would be fine if rewritten to seem less like a factual conclusion.	The study represents an extreme case that was cited to demonstrate that low DO levels are tolerated as an alternative to warm water temperatures. Because Long Lake Reservoir does not have these extreme water temperatures, DO targets have been based on more typical behaviors where refugia occur occasionally (not as a necessity for survival). We continue to believe that the lower hypolimnion in Long Lake Reservoir is important. The sponsors of this study have committed to improving DO conditions throughout the reservoir. However, we disagree that the lower hypolimnion could ever provide sustained, substantial habitat to any of the fish or other aquatic species that are known to currently, or could possibly, inhabit the reservoir. In EPA's nutrient criteria guidance, it is recognized that "most, if not all, lakes have been impacted by human activities to some degree" and that reference conditions should realistically represent either the least impacted condition or what is considered to be the most attainable condition (EPA, 2000). This is consistent with the British Columbia approach, which recognizes that oxygen in stratified systems is naturally depressed,

Commentator	Recommended Criteria Comments	Response
		so DO criteria should be applied to surface and near-surface waters with site-specific objectives for deeper layers (Government of British Columbia, 1997). Our approach recognizes the importance of all of the layers of the reservoir during stratification. However, it distinguishes those layers by existing uses. We believe that occasional foraging and refuge from warmer surface water layers would be adequately protected by ensuring that upper hypolimnion DO levels remain above 5.0 mg/L.
Ecology – Melissa Gildersleeve	**5-10, fourth paragraph.** As noted previously, we do not believe that a narrative statement with such a broad goal would be realistically implemented. We believe it needs to at least include numeric criteria that would provide broad protection for a range of macroinvertebrates and prevent lethal conditions for fish that may need to seek refuge in the hypolimnion. There is no clear basis for distinguishing the upper from the lower hypolimnion for establishing biologically-based criteria, and it is questionable why 5 mg/l would be considered fully protective of the upper hypolimnion given that higher oxygen concentrations would be more protective and may also be attainable.	We believe that implementation of such a narrative criterion actually provides a great deal of flexibility in how point and nonpoint sources continue to implement controls that minimize the volume of water with DO levels below 5.0 mg/L. Using a narrative criterion means that, as future feasible technologies are available to point and nonpoint sources and these technologies can be shown to increase DO levels in the reservoir, they should be implemented to be in compliance with the criteria. We have modified the Spokane River UAA to include a numeric target of 4.0 mg/L in the lower hypolimnion. The intention is to have a measurable target in conjunction with a quantifiable volume. See also response to Ecology Comment ES-12 Table ES-2. Available data for the lake (water temperatures and population densities) indicate that fish do not require the low volume of water in the lower hypolimnion as a survival refugia, given the large volume of "suitable water" in the epilimnion, metalimnion, and upper hypolimnion. In addition, Long Lake Reservoir is a deep, dark reservoir. Given these physical constraints, broad protection for a range of benthic macroinvertebrates is not necessary. The 5.0 mg/L value for the upper hypolimnion is a conservative number given the current and attainable uses in the upper hypolimnion. Higher DO values are always better. However, in stratified systems, DO limitations are simply a reality.
Ecology – Melissa Gildersleeve	**5-10, sixth paragraph.** Where spawning is not a potential use the recommendation for a Winter oxygen criteria of 8 mg/l appears protective of the remaining potential uses.	Comment noted.
Ecology – Melissa Gildersleeve	**6-1, Implementation.** As noted previously, the lack of research supporting the application of the criteria as a monthly volume weighted average makes its approval very unlikely. This is made more problematic by the challenge that it would be to implement it in the real world. Further, diversity of conditions can occur above a "not to be exceeded" minimum value as well as it occurs within a volumetric average, so recognizing systems are not uniform is not really a basis for using the average.	See response to Ecology comment 4-16, second paragraph**.**

Other Specific Technical Comments

Commentator	Other Specific Technical Comments	Response
Ecology – Melissa Gildersleeve	**ES-2, last paragraph**. The role of the numerous point source dischargers should be included in the discussion of human factors that have altered the system and its fisheries.	The Executive Summary has been modified and no longer discusses this topic. Discussions elsewhere in the document clearly recognize the role of point sources in surface water quality issues. For example, following point source treatment upgrades in 1978, the percentage of hypoxic volumes in Long Lake Reservoir decreased from 66 to 17 percent. Soltero et al (1982) calculated that, prior to the point source treatment upgrades in 1978, the volume of reservoir that was less than 5.0 mg/L was 66 percent, while 46 percent of the reservoir was classified as anaerobic (less than 1.0 mg/L). Following point source treatment upgrades, these percentages improved to 15 percent and less than 5 percent, respectively (Soltero et al., 1982) (see Part 2, Section 3.3.2 and Figure 1-2).
Ecology – Melissa Gildersleeve	**ES-5, second paragraph**. Mixing is not entirely prevented. This should say, "Restricts the mixing of the upper and lower layers".	Change incorporated.
Ecology – Melissa Gildersleeve	**ES-7, sixth paragraph.** The modeling or basis for this assumption needs to be included in the UAA.	See Part 2, Figure 4-2.
Ecology – Melissa Gildersleeve	**ES-9, Recommendations, principles.** Suggest that you replace words like "should" with "were". These should clearly be read as your operating principles. They are not necessarily appropriate or consistent with state and federal regulations. For example, we would be unlikely to set multiple aquatic life designated uses for the same location, and the federal regulations are focused on protecting attainable uses as well as those in existence since 1975.	These operating principals are entirely consistent with federal regulations in both the Clean Water Act, as evidenced by both EPA's UAA guidance document and standards handbook (EPA, 1983; EPA, 1994), Ecology's recent Draft UAA guidance document (2004b), and the Chesapeake Bay program UAA (EPA, 2003d). Multiple aquatic life designated uses for the same location under different seasons are the backbone of use definitions. The entire focus of the Spokane River UAA is to define the attainable and existing uses that need to be protected.
Ecology – Melissa Gildersleeve	**1-2, second paragraph.** While the study can choose to examine only part of the river, doing so is problematic. The pollution sources and modifications upstream of Coeur d'Alene Lake must be considered in the UAA in determining the attainable uses. Similarly, any uses or criteria established through the UAA must protect downstream uses and criteria below Long Lake Dam.	The geographic scope of the Spokane River UAA was decided by stakeholder consensus in 2003. There was explicit recognition that Idaho sources upstream from the state boundary needed to be included in the analysis. Pollution sources and modifications upstream from Coeur d'Alene Lake have already been addressed as part of the Idaho cleanup process. Downstream uses are discussed in detail in the Spokane River UAA in response to earlier Ecology comments.
Ecology – Melissa Gildersleeve	**1-3, fifth paragraph, last sentence.** This seems to suggest human influences are only a minor component. This position has not been defended in the UAA and should be removed. As acknowledged in the UAA, the system once supported healthy fish populations, and the alterations by point and nonpoint sources, dams, and withdrawals appear to be at the root of the habitat limitations that exist today.	Ultimately, water temperatures and physical habitat constraints (both of which have been altered by dams and other permanent modifications) limit the determination of what might be currently attainable, independent of point and nonpoint sources. (See Part 2, Section 4.) Anadromous fish runs were extirpated by downstream projects. Ecology has noted that both the Spokane River and Long Lake Reservoir support healthy populations of resident salmonids (based on the salmonid stock status data incorporated by reference in the Statewide Strategy to Recover Salmon; Washington State, 1999).
Ecology – Melissa Gildersleeve	**3-3, fourth paragraph.** The point sources pass along proportionally greater levels of pollutants than the natural waters. They in fact make up most of the phosphorus loading according to the TMDL analysis.	Ecology has concluded in the Draft TMDL (2004a; 2004e) that point sources of phosphorus have a proportionally greater effect on metalimnion DO levels while nonpoint sources of phosphorus have a proportionally greater effect on hypolimnion DO levels. Ecology's calculations of relative loads in the proposed TMDL (Ecology, 2004e) show only the summer season loads. Because the nonpoint source loads are the greatest during spring runoff, Ecology's characterization of the relative contributions in this comment and the proposed TMDL (Ecology, 2004e) is incomplete and misleading.
Ecology – Melissa Gildersleeve	**3-4. Chemical conditions.** The discussion uses primarily old data, isn't there any recent data?	This discussion includes older data to evaluate existing uses that have occurred any time since 1975. More recent data are summarized in the Spokane River UAA, and have been presented in detail in the Pollutant Loading Assessment (Ecology, 2004a) and USGS (2003a).
Ecology – Melissa Gildersleeve	**3-10, second paragraph**. Point sources should be included in the list of human causes for alteration to the system.	Comment noted. See response to Ecology comment 1-3, fifth paragraph, last sentence.
Ecology – Melissa Gildersleeve	**3-19, fourth and fifth paragraph.** Is 19°C a monthly average? Be sure to explain what the averaging period is for your monitoring results for both dissolved oxygen and temperature.	Data used to develop water temperature and DO isopleths are monthly averages of available monitoring data (Ecology, 2004c).

Commentator	Other Specific Technical Comments	Response
Ecology – Melissa Gildersleeve	**3-20, fifth paragraph, last sentence.** EPA has made nutrient controls a national priority. This statement should be removed unless it can be made more relevant to the purpose of this particular UAA.	Recognizing its importance, USGS had focused resources on the Spokane River. The conclusions of USGS are based on extensive monitoring and are included as background for this particular system and Spokane River UAA, particularly in the context of defining what the existing uses are from physical, chemical, and biological perspectives. While EPA has identified sedimentation, pathogens, and nutrients as its top national priorities, nutrient control is ranked fourth out of the top 10 goals of the federal water quality strategy: "Provide technical support to states and tribes for developing and adopting nutrient criteria and biological criteria" (EPA, 2003c). Interestingly, focusing on appropriate uses is ranked seventh on this same list: "Provide technical support, outreach, training and workshops to assist states and tribes with designated uses, including use attainability analyses and tiered aquatic life uses" (EPA, 2003c).
Ecology – Melissa Gildersleeve	**3-24, fourth paragraph**. Why was a Secchi disk reading from 1992 used? This is quite a simple and common metric. What was unique about the 1992 reading that makes it suitable for describing the lake in general? Secchi depth changes with changing algal densities and turbidity levels over time and throughout the year. This needs to be brought back in the discussion about what the attainable condition is likely to be.	This was cited in reference to Soltero et al. (1992), which is one of the most comprehensive studies completed at Long Lake Reservoir. More recent Secchi depth measurements collected by Ecology in 1999 report a mean depth of 5.2 meters (17 feet) (range of 2.7 to 8.5 meters [9 to 28 feet]; Ecology, 1999). In comparison to other lakes within Washington, Secchi depths of 5 to 6 meters (16 to 20 feet) appear to be among the best 1 percent in the state (Ecology, 2004f). As water quality conditions improve in Long Lake Reservoir, Secchi depths would be expected to increase. As discussed in Part 2, Section 4.4.2, it is possible that improvement in light penetration due to improved sediment and algae management may change current limiting conditions in what is currently the hypolimnion. Typically, Secchi depth measurements increase as the trophic state improves (the current average Secchi depth of about 5 to 6 meters [16 to 20 feet] in Long Lake Reservoir is already greater than the Secchi depth in most reservoirs and lakes in Washington [Gilliom, 1984]). For example, Lake Washington Secchi depths improved from a minimum of 0.8 meter (30 inches) to a maximum of 7.6 meters (25 feet) following phosphorus reductions of 77 percent (King County, 2004b).
Ecology – Melissa Gildersleeve	**3-35, fifth paragraph**. Whose water quality standards were 8.5 mg/l? The state standard was 8 mg/l and the Spokane Tribe did not have standards then.	Heaton et al. (1993) incorrectly believed the Washington Class A standard was 8.5 mg/L. Because this study is cited and the information is attributed to the authors, the statement was not corrected. However, the author's error was noted in the Spokane River UAA.
Ecology – Melissa Gildersleeve	**3-36, Table 3.8.** It is fine to show the data this way (medians and percentiles), but it cannot be compared with the criteria established in the state standards or the Spokane Tribe's standards. All we can say using this table is that in 2001, the state's dissolved oxygen criteria were exceeded more than 50% of the time from July through September, and temperature criteria exceeded less than 10% of the time. For the "All Data" category why would you combine daily maximums with daily minimums in developing an average? This doesn't make sense to us and adds confusion to the issue for reviewers that don't know what "all data" means.	All data were included to be complete and thorough, as well as to demonstrate that the downstream effects of conditions in Long Lake Reservoir are generally above the state's and the Spokane Tribe's criteria the majority of the time (both on a seasonal and a diurnal basis). The statistical information is provided as a framework for evaluating the data, particularly as broken out by season. As noted previously, EPA nutrient guidance (2000) is consistent with current Section 303(d) listing guidelines where "an excursion that occurs less than 10 percent of the time… may be considered acceptable." See additional discussion of downstream issues presented above.
Ecology – Melissa Gildersleeve	**5-1, fourth paragraph, last sentence**. What is a "regular non-point source discharge"?	The "regular nonpoint source discharges" phrase has been restated to more accurately reflect the diffuse nature of most nonpoint source discharges such as stormwater.

Appendix A3

Letter from Washington Department of Ecology (July 8, 1998)

APPENDIX A3

Letter from Washington Department of Ecology (July 8, 1998)

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
P.O. Box 47600 • Olympia, Washington 98504-7600
(360) 407-6000 • TDD Only (Hearing Impaired) (360) 407-6006

July 8, 1998

Mr. Lincoln Loehr
Environmental Analyst
Heller, Ehrman, White and McAuliffe
6100 Columbia Center\701 Fifth Avenue
Seattle, WA 98104-7098

Dear Mr. Loehr:

I am writing in response to your June 12 letter concerning our state standards for dissolved oxygen. As I discussed with you on the phone, we do not have supporting information on the technical basis for our existing criteria.

This last year I personally went through all of the files stored at Ecology and downtown in the state central archives. I examined these files with the intent to document the basis for our various water criteria. Little information exists in general regarding the water quality standards. This leaves me with the disappointing conclusion that the archive staff decided these records were not historically critical and had them destroyed. All I found in relation to dissolved oxygen was a comment letter sent by a pulp mill stating the need to allow some human degradation beyond natural levels in marine waters during periods of upwelling.

The existing dissolved oxygen criteria thresholds have existed in the state standards as far back as 1967 and is the oldest copy of the standards in my possession. The criteria has never been expressed other than an absolute threshold value, even though many other criteria have been and continue to include averaging periods. Let me know if you have any further questions or issues needing clarification (360) 407-6477.

Sincerely,

Mark Hicks

Mark Hicks
Water Quality Standards

MPh:mh

Shared.../section/wm/mark/loehr1.doc

Appendix B

Checklist of UAA Elements

APPENDIX B

Checklist of UAA Elements

Washington Department of Ecology's (Ecology's) Draft Use Attainability Analysis Guidance (2004b) suggests that the elements in Table B-1 be included in a use attainability analysis (UAA) submittal. These requirements are consistent with U.S. Environmental Protection Agency (EPA) requirements for defensible UAA documentation (EPA, 1983) and have formed the basis of the Spokane River and Long Lake Reservoir UAA (Spokane River UAA) project since its inception.

TABLE B-1
Checklist of UAA Elements

UAA and Aquatic Habitat Checklist Elements (in Ecology, 2004b)	UAA Section Where Element is Located
General Watershed Information	See TMDL Subbasin Assessment (Ecology, 2004a)
Physical Information	Spokane River UAA Part 2, Section 3.2.1: Physical Conditions (Spokane River) Spokane River UAA Part 2, Section 3.3.1: Physical Conditions (Long Lake Reservoir)
Biological Parameters	Spokane River UAA Part 2, Section 3.2.3: Biological Conditions (Spokane River) Spokane River UAA Part 2, Section 3.3.3: Biological Conditions (Long Lake Reservoir)
Chemical Parameters	Spokane River UAA Part 2, Section 3.2.2: Chemical Conditions (Spokane River) Spokane River UAA Part 2, Section 3.3.2: Chemical Conditions (Long Lake Reservoir)

References

U.S. Environmental Protection Agency (EPA). 1983. Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses.

Washington Department of Ecology (Ecology). 2004a. Final—Spokane River and Lake Spokane (Long Lake) Pollutant Loading Assessment for Protecting Dissolved Oxygen. Publication No. 04-03-006. October 2004.

Washington Department of Ecology (Ecology). 2004b. Draft Use Attainability Analysis Guidance for Washington State, Version 1.0. May 2004.

Appendix C

Summary of Data Sources Used to Support UAA

APPENDIX C

Summary of Data Sources Used to Support UAA

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Av	1	Paper		x	x							x					Fisheries Assessment of the Upper Spokane River	Bailey and Saltes	Jun-82	x							x	x			
Av	2	Paper				x	x					x					An Evaluation of the Fisheries Potential of the Lower Spokane River: Monroe Street Dam to Nine Mile Falls Dam	Kleist	Sep-87	x							x		x		
Av	3	Paper		x								x					Population Dynamics and Factors Affecting Rainbow Trout in the Spokane River	Bennett and Underwood	Feb-88	x							x				
Av	4	Paper						x				x					Factors Limiting the Fish Community with Emphasis on Largemouth Bass in Long Lake, Spokane County, Washington	Bennett, D. and D. Hatch	May-91	x							x				
Av	5	Electronic/ Paper		x	x							x					1997-1999 Upper Spokane River Rainbow Trout Spawning and Fry Emergence Study		Jun-00	x											
Av	6	Electronic/ Paper				x	x					x					Spokane River Creel Survey: 1996, 1997, and 1999		Jun-00	x											
Av	7	Electronic/ Paper		x	x	x	x				x	x					Initial Information Package for the FERC Relicensing of the Spokane River Hydroelectric Project		Jul-02	x											
Av	8	Electronic/ Paper	x	x	x	x	x	x				x					Spokane River and Coeur d'Alene Fisheries Bibliographic Database		Apr-03	x											
Av	9	Electronic/ Paper		x	x	x	x									x	Scoping Document 1		May-03	x											
Av	10	Electronic/ Paper	x	x	x	x	x	x			x						Final Phase 1 Report, Water Quality Data Compilation Spokane River Licensing Project		Jul-03	x											
Av	11	Electronic		x	x	x	x					x					Draft Fisheries Meeting Summary		Jan-03	x											
Av	12	Electronic		x		x						x					Study Plan, Habitat Use, Spawning Distribution and Movements of Rainbow Trout in the Spokane River, Spokane River Hydroelectric Project, FERC Project No 2545		Apr-03	x											
Av	14	Electronic	x								x						Final Study Plan, Water Temperature Study, Spokane River Hydroelectric Project		May-03	x											
Av	15	Electronic/ Website	x	x	x	x	x	x			x	x					Avista FERC Website		Jul-03	x											
Av	16	Electronic	x	x	x	x	x	x								x	Draft Coeur d'Alene Lake and Spokane River Designated Beneficial Uses and Other Water Quality Related Issues		Apr-03	x											

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Av	17	Electronic		x		x						x					Final Study Plan Fish Habitat Instream Flow Assessment, Spokane River Hydroelectric Project, FERC Project No. 2545		Jul-03	x											
Av	18	Electronic		x	x	x	x	x			x					x	Final Study Plan Water Budget and Identification of Beneficial Uses, Spokane River Hydroelectric Project, FERC Project No. 2545		Apr-03	x											
Av	19	Electronic		x	x	x	x	x			x	x			x		Spokane River Hydroelectric Project Relicensing, Summary List of Ongoing Information Gathering Activities		Jun-03	x											
Av	20	Electronic		x	x	x	x	x			x	x				x	Spokane River Hydroelectric Project Terrestrial Resources Summary Description of Existing Conditions and Identification of Data Gaps based on Currently Available Information Sources		May-03	x											
Av	21	Electronic/ Raw Data							x		x						Unpublished monitoring data collected from Long Lake Dam tailrace and Little Falls tailrace between 1999-2001.		Jun-04	x								x			
Av	22	Electronic	x	x				x								x	Spokane River Hydroelectric Project, Phase 2 Erosion Assessment	Earth Systems and Parametrix	Mar-04	x											
Av	23	Electronic		x	x	x	x	x			x						Phase 2 Spokane River Water Temperature Report	Golder and HDR	Jan-04	x											
Av	24	Electronic	x	x	x	x	x	x			x	x			x		Spokane River Summary of Potential PM&Es		Jun-04	x											
Av	25	Electronic	x	x	x	x	x	x			x	x			x	x	Instream Flow and Fish Habitat Assessment	NHC and Hardin Davis	Apr-04	x											
Av	26	Electronic		x	x	x	x					x					Rainbow Trout Spawning Survey 2003 (Draft Report)	Parametrix	Oct-03	x											
Av	27	Electronic						x			x	x	x			x	Summary Review, Lake Spokane Drawdown Effects to Fish and Aquatic Habitat	Parametrix / Weitkamp	Nov-03	x											
Av	28	Electronic/ Paper		x	x	x	x	x						x			Spokane River Water Quality Modeling Update, Spokane River Hydroelectric Project, Water Resources Work Group Meeting	HDR	Jul-04	x											x

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Av	28	Paper		x	x	x	x	x			x				x	x	Informal Draft, Spokane River Hydroelectric Project, FERC No. 2545, Application for New License, Major Project—Existing Dam, Vol. II, Part 1 of 2, Applicant-Prepared Preliminary Draft Environmental Assessment. *Anticipated public release February 2005.*		Feb-05	x											
Av	29	Electronic/ Paper				x	x	x			x	x					A General Assessment of Aquatic Resources on the Lower Spokane River Reservoirs	Pfeiffer, D.	1985	x											
CCA	1	Paper	x								x						Water Quality Monitoring in the Extreme Upper Reach of the Spokane River During Low Flow Summer Conditions August/September 1992		Nov-92		x										
CCA	2	Paper	x								x						City of Coeur d'Alene Spokane River Translator Values, Phosphorus & Ammonia		Jan-01		x										
CCA	3	Electronic/ Paper/ Data	x	x	x						x			x			Data Assessment Technical Memorandum		Aug-01		x										
CCA	4	Electronic/ Paper/ Data	x	x	x						x			x			Spokane River Model Calibration Results		Nov-01		x						x	x			
CCA	5	Electronic/ Paper/ Data	x	x	x						x			x			Spokane River Scenario Modeling Results		Dec-01		x										
CCA	6	Electronic	x	x							x						Raw Data (Water Quality, Flow, Temperature, etc.)		Varies		x										
CS	1	Electronic				x					x						Spokane, Washington Report on Sewage Disposal	Butler	Jul-33			x									
CS	2	Electronic			x			x		x	x						Quality of Surface Waters, June 1959-July 1960.		Jun-61							x		x			
CS	3	Electronic						x			x						A Preliminary Investigation of the Low Dissolved Oxygen Concentrations that Exist in Long Lake located near Spokane, Washington	Cunningham and Pine	Jan-69			x									
CS	4	Electronic			x	x	x	x			x						Water Quality Report		Apr-71			x						x			
CS	6	Electronic						x			x						Cultural Eutrophication of Long Lake, Washington	Soltero, Gaspirino, Graham	Jan-75			x									
CS	7	Electronic		x	x	x	x	x			x						Water Quality Trend Analysis: The Spokane River Basin	Yake	Jul-79			x						x			

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
CS	8	Electronic						x			x						The Effect of Continuous Advanced Wastewater Treatment by the City of Spokane on the Trophic Status of Long Lake, Washington, during 1979		Oct-80			x					x	x			
CS	10	Electronic						x			x						The Effect of Continuous Advances Wastewater Treatment by the City of Spokane on the Trophic Status of Long Lake, Washington, during 1980		Jul-81			x					x	x			
CS	11	Electronic						x			x						Water Quality Data for the Lower System between January and June of 1981		Aug-81			x					x				
CS	12	Electronic						x			x			x			Wasteload Allocation Study, Supplemental Report for Phosphorus Allocation		Dec-81			x						x			
CS	13	Electronic					x	x			x						Water Quality Data for the Lower System between October and December of 1981		Feb-82			x					x				
CS	14	Electronic					x	x			x						The Effect of Seasonal Phosphorus Removal by the City of Spokane's Advanced Wastewater Treatment Plant on the Water Quality of Long Lake, Washington	Soltero, Nichols, Cather	Jul-82			x					x				
CS	15	Electronic/ Paper					x	x			x						The Cause(s) of Continued Hypolimnetic Anoxia in Long Lake, Washington Following Advanced Wastewater Treatment by the City of Spokane		Aug-82			x					x				
CS	16	Electronic					x	x			x						Water Quality Data for the Lower System between April and June of 1982		Aug-82			x					x				
CS	17	Electronic					x	x			x						Water Quality Data for the Lower System between July and September of 1982		Nov-82			x					x				
CS	18	Electronic			x	x	x				x		x				Water Quality of the Upper Spokane River and Evaluation of Methods for Measurements of the Effect of Effluent Upon Primary and Secondary Producers	Funk, W.H., H.L. Gibbons, R.M. Duffner, T. Notestine, and T. Nielson	Jan-83			x					x				

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
CS	19	Electronic	x	x	x	x	x	x			x						Methodology for Assessing the Initiation Date of Chemical Phosphorus Removal at Spokane's Advanced Wastewater Treatment Plant According to Predicted Spring Runoff	Mires and Soltero	Feb-83			x					x					
CS	20	Electronic					x	x			x						Water Quality Data for the Lower System between January and March of 1983		May-83			x					x					
CS	21	Electronic					x	x			x						Methodology for Assessing the Fall Termination Date of Chemical Phosphorus Removal at Spokane's Advanced Wastewater Treatment Plant		Jul-83			x					x					
CS	22	Electronic					x	x			x						Water Quality Data for the Lower System between April and June of 1983		Aug-83			x					x					
CS	24	Electronic					x	x			x						The Effect of Seasonal Alum Addition (Chemical Phosphorus Removal) by the City of Spokane's Advanced Wastewater Treatment Plant on the Water Quality of Long Lake, Washington, 1983	Soltero, Nichols, Cather, McKee	Jul-84			x					x					
CS	25	Electronic		x	x	x	x	x			x						Water Quality Improvement as a Result of Advanced Wastewater Treatment		Dec-84			x						x				
CS	26	Electronic					x	x			x						Water Quality Data for the Lower System between June and December of 1984		Feb-85			x					x					
CS	27	Electronic					x	x			x						Water Quality Data for the Lower System between January and June of 1985		Aug-85			x					x					
CS	28	Electronic					x	x			x						Variable Initiation and Termination of Alum Addition at Spokane's Advanced Wastewater Treatment Facility and the Effect on the Water Quality of Long Lake, Washington, 1985	Soltero, Appel, Sexton, Buchanan	Jul-86			x					x	x				
CS	29	Electronic/ Paper					x	x			x			x			Verification of Long Lake Water Quality as Predicted by the Phosphorus Attenuation Model		Jul-93			x					x					
CS	30	Electronic				x					x						Memo Report-7Q10 Flow Calculations		Jan-95			x										
CS	31	Electronic		x		x					x						Memo Report-Effect of Upriver Dam on Low Flows at Spokane		Jan-95			x										

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
CS	35	Electronic			x	x	x	x			x			x			Upper Spokane River Model: Boundary Conditions and Model Setup, 1991 and 2000		Nov-01			x					x	x			
CS	36	Electronic			x	x	x	x			x			x			Upper Spokane River Model: Model Calibration, 2001		Jan-03			x					x	x			
CS	37	Electronic			x	x	x	x			x			x			Upper Spokane River Model: Model Calibration, 1991 and 2000		Jan-02			x					x	x			
CS	38	Electronic/ Paper			x	x	x	x			x			x			Upper Spokane River Model: Boundary Conditions and Model Setup, 2001		Dec-02			x					x	x			
CS	39	Electronic/ Paper	x	x							x			x			Upper Spokane River Model in Idaho: Boundary Conditions and Model Setup for 2001		Apr-03			x	x				x				
CS	40	Electronic/ Paper					x				x						Combined Sewer Overflow Monitoring		May-80			x									
CS	41	Electronic								x						x	UAA/TMDL Implementation Cost Assessment	Henron L.	Nov-04			x									
Eco	1	Paper						x			x						Preliminary Investigation of the Low Dissolved Oxygen Concentrations that Exist in Long Lake Located near Spokane Washington		Jan-69									x			
Eco	2	Paper			x	x	x	x			x						Status Report on Water Pollution in the Spokane River		Mar-70									x			
Eco	3	Paper	x	x	x	x	x	x			x						An Analysis of Water Quality in the Spokane River	Stude	Aug-71								x	x			
Eco	4	Paper		x	x	x	x	x			x						Water Quality Status Report Spokane River Basin, Initial Basin Assessment and Recommended Monitoring Program		Jan-72									x		x	
Eco	5	Paper	x	x	x	x	x	x			x			x			Data Report for the Spokane River Basin Model Project		May-73									x		x	
Eco	6	Paper	x	x	x						x	x	x				Biological Impact of Combined Metallic and Organic Pollution in the Coeur d'Alene Spokane River Drainage System	Funk and others	Jun-73								x	x			
Eco	7	Paper					x	x			x						Chemical and Physical Characteristics of a Eutrophic Reservoir and its Tributaries: Long Lake, Washington	Soltero	Oct-73								x	x			
Eco	8	Paper					x	x			x						Chemical and Physical Characteristics of a Eutrophic Reservoir and its Tributaries: Long Lake, Washington II	Soltero	Mar-75								x	x			

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information													
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Eco	11	Paper					x	x			x						The Zooplankton Dynamics of a Eutrophic Reservoir: Long Lake, Washington		Jan-79									x			
Eco	12	Electronic/ Paper						x			x						The Recent Blue-Green Algal Blooms of Long Lake, Washington	Soltero and Nichols	Jan-81									x			
Eco	13	Paper			x	x	x	x			x			x			Spokane River, Wasteload Allocation Study, Phase I	URS	Apr-81									x			
Eco	15	Paper			x	x					x						An Examination of the Nutrient and Heavy Metals Budget in the Spokane River Between Post Falls and Hangman Creek	Yearsley	Sep-82									x		x	
Eco	16	Paper			x						x		x				Baseline Study to Determine the Water Quality and the Primary and Secondary Producers of the Spokane River, Phase I	Gibbons, Funk, Duffner, Nielsen, Notestine	Oct-82								x	x			
Eco	17	Paper		x	x	x	x	x			x			x			The Spokane River Basin: Allowable Phosphorus Loading	Harper Owes / Patmont, Pelletier, Singleton, Soltero, Trial, Welch	Sep-87								x	x			x
Eco	18	Paper						x			x					x	Lake Spokane Phase I Restoration Project - Appendices	Soltero, Sexton, Wargo, Geiger, Robertson, Bolstad, Buchanan, and Johnson	Jan-92									x			
Eco	19	Paper						x	x		x	x				x	Baseline Water Quality Data for Selected Lakes and Streams on the Spokane Indian Reservation, Including the Spokane River Arm of Lake Roosevelt and Little Falls Reservoir	Heaton, Peone, and Scholtz	May-93								x	x			
Eco	20	Paper		x	x	x	x	x			x			x			Comparison of Non-Point Source Phosphorus Loading to the Spokane River from its Headwaters to Long Lake, Washington, with That Used in the Spokane River Attenuation Model	Soltero, Appel, Sexton, Buchanan	Jul-93			x					x	x			
Eco	21	Paper		x	x	x	x	x			x	x					Literature Review for Spokane River Focused Natural Resource Damage Assessment		Jul-97									x			
Eco	22	Paper	x	x	x	x	x	x			x						Concepts for Monitoring Water Quality in the Spokane River Basin, Northern Idaho and Eastern Washington		Jan-98									x			

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information													
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Eco	23	Paper			x						x						Spokane River/Aquifer Interaction Project Groundwater Data Report		Feb-00									x			
Eco	24	Paper								x		x				x	Listed Fish Species Life Histories for Washington State		Jul-00									x			
Eco	25	Paper		x	x	x	x	x			x	x	x				Ecological Risk Analysis of Elevated Metal Concentrations in the Spokane River, Washington	Kadlec	Nov-00									x			
Eco	27	Electronic/ Paper		x	x	x	x				x			x			Spokane River and Long Lake Total Maximum Daily Load Study Data Summary Report		Jan-02									x			
Eco	28	Electronic		x	x	x	x	x		x	x					x	Draft Implementation Plan for the Revisions to Chapter 173-201A WAC, Water Quality Standards for Surface Waters of the State of Washington		Dec-02									x			
Eco	29	Electronic/ Paper								x	x					x	Evaluating Criteria for the Protection of Freshwater Aquatic Life in Washington's Surface Water Standards. Dissolved Oxygen.	Hicks, M.	Dec-02									x			
Eco	30	Electronic/ Paper			x	x	x	x			x			x			Draft Spokane River and Lake Spokane (Long Lake) Pollutant Loading Assessment for Protecting Dissolved Oxygen	Cuisimano	Feb-04									x			
Eco	31	Electronic/ Paper					x	x			x						Further Investigation as to the Cause and Effect of Eutrophication in Long Lake, Washington	Soltero, Gaspirino, Graham	Jul-74								x	x			
Eco	32	Electronic/ Paper		x	x	x	x	x			x						Focus: Dissolved Oxygen in the Spokane River and Long Lake		Jun-02									x			
Eco	33	Electronic			x						x						Dissolved Oxygen in the Spokane River Downstream from Inland Empire Paper Company with Recommendations for Waste Load Allocations for Biochemical Oxygen Demand		Sep-94									x			
Eco	34	Electronic								x	x					x	Focus: Changing the Surface Water Quality Standards from a "Class-Based" to a "Use-Based" Format		Dec-02									x			
Eco	35	Electronic								x	x					x	Focus: Water Quality Antidegradation Implementation Plan		Dec-02									x			
Eco	36	Electronic								x	x					x	Focus: Revised Temperature Criteria for Fresh Water		Dec-02									x			
Eco	37	Electronic								x	x					x	Focus: Revised Dissolved Oxygen Criteria for Fresh Water		Dec-02									x			

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information													
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Eco	39	Electronic								x	x					x	Focus: Overview of the Water Quality Standards Revisions		Dec-02									x			
Eco	40	Electronic								x	x					x	Focus: Miscellaneous Revisions (ammonia criteria, regulation of dams, tools, and minor edits)		Dec-02									x			
Eco	41	Electronic								x	x					x	Focus: Criteria for Agricultural Water Supply		Dec-02									x			
Eco	42	Electronic								x	x					x	Focus on Proposed Changes to Water Quality Standards		Jan-03									x			
Eco	43	Electronic								x	x					x	Draft Rule-Making Criteria Documentation as required by the Administrative Procedures Act RCW 34.05		Dec-02									x			
Eco	44	Electronic								x	x					x	Crosswalk between 9/97 Current Standards and 12/02 Proposed Standards (WAC 173-201A)		Dec-02									x			
Eco	45	Electronic								x	x					x	Responsiveness Summary		Jul-03									x			
Eco	46	Electronic								x	x					x	Proposed Dissolved Oxygen Criteria Decision Process for Ecology's Proposed Rule		Dec-02									x			
Eco	47	Electronic								x	x	x				x	Evaluating Standards for Protecting Aquatic Life in Washington's Surface Water Quality Standards Temperature Criteria		Dec-02									x			
Eco	48	Electronic								x	x					x	Water Quality Standards for Surface Waters of the State of Washington (New)		Dec-02									x			
Eco	50	Electronic								x	x					x	Proposal to Restructure the Standards to a Use-Based Format Decision Process for Ecology's Proposed Rule		Dec-02									x			
Eco	51	Electronic								x	x					x	Water Quality Standards for Surface Waters of the State of Washington (Old)		Nov-97									x			
Eco	52	Electronic/ Paper					x	x			x		x				The Effect of Continuous Advanced Wastewater Treatment by the City of Spokane on the Trophic Status of Long Lake, Washington	Soltero, R.A., D.G. Nichols, G.P. Burns, and L.R. Singleton	Jul-79			x					x	x			
Eco	53	Electronic/ Paper			x	x	x	x			x					x	Chemical Analysis and Toxicity Testing of Spokane River Sediments Collected in October 2000		Jul-01									x			

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Eco	54	Electronic/ Paper			x	x	x	x									Spokane River/Aquifer Interaction Project Results, May-November 1999	CH2M HILL	Jul-01									x			
Eco	55	Electronic/ Paper			x	x	x	x			x			x			Data Summary: Spokane River and Lake Spokane (Long Lake) Pollutant Loading Assessment for Protecting Dissolved Oxygen	Cuisimano	Aug-03									x			
Eco	56	Electronic/ Paper						x		x	x	x					Mercury in Edible Fish Tissue and Sediments from Selected Lakes and Rivers of Washington State		Jun-03									x			
Eco	57	Electronic/ Paper						x		x	x	x					Survey of Chemical Contaminants in Ten Washington Lakes		Sep-94									x			
Eco	58	Electronic/ Paper		x	x	x	x				x						Cadmium, Copper, Mercury, Lead, and Zinc in the Spokane River: Comparisons with Water Quality Standards and Recommendations for Total Maximum Daily Loads		Jan-94									x			
Eco	60	Electronic/ Paper				x					x					x	Spokane Wastewater Treatment Plant Class II Inspection	Hallinan	Aug-81			x						x			
Eco	61	Electronic/ Paper						x			x	x					Analysis of Fish Tissue from Long Lake (Spokane River) for PCBs and Selected Metals		Nov-02									x			
Eco	62	Electronic/ Paper			x	x	x	x			x						Department of Ecology 1993-94 Investigation of PCBs in the Spokane River		Feb-95									x			
Eco	64	Electronic/ Paper			x	x	x	x			x			x			Continued Investigation of Eutrophication in Long Lake, Washington: Verification Data for the Long Lake Model		Jun-76									x			
Eco	65	Electronic/ Paper		x	x	x	x	x			x			x			Phosphorus Attenuation in the Spokane River	Harper-Owes / Patmont, Pelltier, Harper	Jun-85									x			x
Eco	66	Electronic/ Paper								x	x						Little Spokane River Study--Final Report		Nov-91									x			
Eco	67	Electronic/ Paper				x	x	x			x	x	x			x	Lake Spokane Phase I Restoration Project: Assessment of Various Nutrient Sources and Macrophyte Growth in Long Lake and Feasibility of Various Source Control Measures	Soltero, Sexton, Wargo, Geiger, Robertson, Bolstad, Buchanan, and Johnson	Jul-92								x	x			
Eco	68	Electronic	x	x	x	x	x	x				x					Meeting notes with Ecology and WDFW	Donley	Mar-04									x	x		

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Eco	69	Paper			x	x	x	x	x		x					x	Metals Concentrations in Spokane River Sediments Collected with USGS in 1998		Aug-99							x		x			
Eco	70	Electronic								x						x	Draft Use Attainability Analysis Guidance for Washington State		May-04									x			
Eco	71	Electronic/ Raw Data		x	x	x	x	x			x						Downloads of water quality data.		Nov-03									x			
Eco	72	Electronic/ Paper						x			x	x					Long Lake Fish Tissue Sampling Supplement		Apr-02										x		x
Eco	73	Paper			x	x	x	x			x			x		x	Oral and written communication with Spokane TMDL Advisory Group	Merrill, K.	Jul-04									x			
Eco	74	Paper								x						x	Memorandum from Kahle Jennings (Ecology) to Chehalis Basin Partnership. Subject: Comparison of Dissolved Oxygen Criterion for Washington State and Idaho. August 27, 2004.	Jennings K.	Aug-04									x			
Eco	75	Electronic								x						x	Guidelines for the FY 2006 Water Quality Program Funding Cycle. Appendix H: Median Household Income Table.		Jul-04									x			
Eco	76	Electronic								x						x	Financial Hardship Analysis Form		Nov-04									x			
Eco	77	Electronic								x						x	Dissolved Oxygen in Lake Whatcom: Trend in the Depletion of Hypolimnetic Oxygen in Basin I, 1983-1997		May-98									x			
Eco	78	Electronic								x	x					x	Draft Total Maximum Daily Load to Restore and Maintain Dissolved Oxygen in the Spokane River and Lake Spokane (Long Lake)		Oct-04									x			
Eco	80	Website								x						x	Water Right Information		Nov-04									x			
Eco	81	Electronic								x						x	Letter to Lincoln Loehr regarding Washington State dissolved oxygen standards	Hicks, M.	July-98									x			
Eco	82	Electronic						x		x	x						Water Quality Assessments of Selected Lakes Within Washington State		Jul-01									x			
Eco	83	Electronic								x						x	Washington's Water Quality Management Plan to Control Nonpoint Sources of Pollution: Volume I		Aug-04									x			
Eco	84	Electronic						x		x	x						Trophic Lake Census of Washington State Lakes by Satellite Imagery		Mar-04									x			

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information													
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
EPA	1	Electronic								x						x	Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses		Nov-83											x	
EPA	2	Electronic								x	x					x	Lake and Reservoir Bioassessment and Biocriteria Technical Guidance Document		Jan-04											x	x
EPA	3	Paper								x	x					x	Tools for Assessing Lake Eutrophication in the Puget Sound Region, Washington. In Lakes and Reservoir Management.	Gilliom, R.J.; EPA 440/5/84-001	1984											x	x
EPA	4	Paper								x						x	Water Quality Standards Handbook, 2nd edition	EPA 823-B-94-005a	1994											x	
EPA	5	Electronic								x						x	EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards		2003											x	
EPA	6	Electronic								x						x	Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability	EPA 903-R-03-004	2003											x	
EPA	7	Paper								x						x	Strategy for Water Quality Standards and Criteria: Setting Priorities to Strengthen the Foundation for Protecting and Restoring the Nation's Waters	EPA-823-R-03-010	Aug-03											x	
EPA	8	Electronic								x						x	Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs	EPA-822-B00-001	Apr-02											x	
EPA	9	Paper								x						x	Combined Sewer Overflows: Guidance for Financial Capability Assessment and Schedule Development		Mar-97											x	
EPA	10	Paper								x						x	Winchester Lake and Upper Lapwai Creek TMDL, Final		Feb-99											x	
EPA	11	Website								x						x	Federal Appeals Court Upholds Landmark Clean Water Decision; Ruling upholds EPA's authority to address Garcia River, other waterways polluted by runoff.		1999											x	
EPA	12	Website								x						x	Region 10 TMDL Review Guidelines		Jan-02											x	
EPA	13	Electronic								x	x					x	Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity, and Chlorophyll *a* for the Chesapeake Bay and its Tidal Tributaries	EPA 903-R-03-002	Apr-03											x	

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
IDEQ	1	Paper	x										x				Macrobenthic Communities in the Coeur d'Alene Lake System	Winner	Jul-72				x				x				
IDEQ	2	Paper	x	x	x	x	x	x			x						Good Water? A Study of the Coeur d'Alene-Spokane River Region	Flaherty	Jan-73				x				x				
IDEQ	3	Paper	x	x	x	x	x	x			x						River Basin Water Quality Status Report, Spokane River Basin		Jul-75				x							x	
IDEQ	4	Paper	x	x	x	x	x	x			x						Water Quality Assessment, Kootenai, Clark Fork, Pend Oreille, Spokane River Basins		Nov-76				x							x	
IDEQ	5	Paper	x								x						Attached Algae Biomass (Periphyton) at Water Quality Trend Stations, 1978 and 1979		Jan-79				x								
IDEQ	6	Paper		x							x						Water Quality Studies of the Spokane River between Coeur d'Alene, Idaho, and Post Falls, Idaho, 1978-1979	Yearsley	Jul-80				x							x	
IDEQ	7	Paper		x							x						An Assessment of Algal Productivity in Spokane River Waters Collected from Lake Coeur d'Alene to Post Falls, Idaho, May-October 1980		Mar-81				x							x	
IDEQ	8	Paper		x							x						Flow Characteristics and Water Quality Conditions in the Spokane River, Coeur d'Alene Lake to Post Falls Dam, Northern Idaho	Sietz and Jones	Oct-81				x			x	x	x			
IDEQ	10	Paper		x							x						Water Quality Studies of the Spokane River between Coeur d'Alene, Idaho, and Post Falls, Idaho, 1988		Aug-89				x							x	
IDEQ	11	Paper		x								x					Spokane River Fishery Evaluation	Davis	May-91				x								
IDEQ	12	Paper		x							x						Physical and Chemical Water Quality of the Spokane River Outlet Reach of Lake Coeur d'Alene, Kootenai County, Idaho, 1990 and 1991		Mar-92				x					x			
IDEQ	13	Paper		x							x						Low Flow Plant Growth Nutrient, Chlorophyll and Dissolved Oxygen Monitoring of the Spokane River, Idaho		Jul-92				x								
IDEQ	14	Paper	x									x					Population Dynamics, Food Habits, Movement and Habitat Use of Northern Pike in the Coeur d'Alene Lake System, Idaho		Sep-92				x	x							
IDEQ	15	Paper	x								x	x	x		x		Beneficial Use Attainability Assessments of Streams in the Lake Coeur D'Alene Basin, Idaho		Jan-93				x								

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
IDEQ	16	Paper		x	x						x						Spokane River (Idaho Reach) Water Quality Concerns at a Glance		May-93				x								
IDEQ	17	Paper		x	x						x			x			Diel Dissolved Oxygen Monitoring of the Spokane River, During Extreme Low Flow, Kootenai County, Idaho, 1992		Feb-94				x								
IDEQ	18	Paper	x	x	x						x			x			A Phased Approach Total Maximum Daily Load for Total Phosphorus for the Spokane River in Idaho		Dec-94				x								
IDEQ	20	Paper			x	x	x	x				x					1998 Fish Consumption Survey Spokane River, Washington		Nov-98				x					x			
IDEQ	21	Paper	x	x	x	x	x	x			x						Local Stakeholder Concerns Regarding Spokane River Dissolved Oxygen Issues		May-01				x								
IDEQ	23	Electronic/ Paper	x	x	x	x	x	x			x						Occurrence and Transport of Cadmium, Lead, and Zinc in the Spokane River Basin, Idaho, and Washington, Water Years 1999-2001		Jan-03				x			x					
IDEQ	24	Electronic/ Paper	x	x	x	x	x	x			x						Summary of Surface-Water-Quality Data Collected for the Northern Rockies Intermontane Basins National Water Quality Assessment Program in the Clark Fork-Pend Oreille and Spokane River Basins, Montana, Idaho, and Washington, Water Years 1999-2001	Beckwith	Apr-03				x			x					
IDEQ	25	Electronic	x								x						Total Maximum Daily Load for Dissolved Cadmium, Lead, and Zinc in the Coeur d'Alene River Basin, Response to Comments		Aug-00				x								
IDEQ	26	Electronic	x								x						Administrative Record Index Coeur d'Alene Basin TMDL		Aug-00				x								
IDEQ	27	Electronic	x								x						Coeur d'Alene Lake Management Plan		Sep-96				x								
IDEQ	28	Website								x	x						Snake River – Hells Canyon Total Maximum Daily Load (TMDL)	DEQs (Idaho and Oregon)	Jul-03				x								
IDEQ	29	Electronic								x	x	x				x	Fish Names and Sensitivity to Water Temperature		Apr-03				x								x
IDEQ	30	Electronic/ Paper								x	x	x	x	x		x	Final Snake River – Hells Canyon Total Maximum Daily Load (TMDL)	IDEQ and ODEQ	Sep-04				x							x	x
IDFG	1	Partial Paper		x	x	x	x					x					Federal Aid to Fish and Wildlife Restoration		May-80					x							
IDFG	2	Paper	x	x								x					Idaho Fisheries Management Plan		Jan-86					x							

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
IDFG	3	Partial Paper		x	x	x	x					x					Federal Aid in Fish Restoration		Aug-87					x							
IDFG	4	Paper	x									x					Federal Aid in Fish Restoration		Sep-95					x							
IDFG	5	Paper		x	x	x	x					x					Federal Aid in Fish Restoration		Apr-96					x							
IDFG	6	Paper		x	x	x	x					x					Federal Aid in Fish Restoration		Feb-97					x							
IDFG	7	Paper	x									x					Angler Behavior Studies		Sep-99					x							
IDFG	8	Electronic			x	x	x	x								x	Conservation Strategy for Spokane River Basin Wetlands		Jun-99					x							
IDFG	9	Electronic	x	x												x	Conservation Strategy for Northern Idaho Wetlands		Jun-97					x							
IDFG	10	Electronic								x		x					Status of Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*) in the United States: 2002		Feb-03					x							
IDFG	11	Website/ Raw Data	x	x						x		x					Historical fish stocking for all fish types from 1967 through 2004, Spokane River.		2004					x							
O	1	Electronic								x	x						Spokane Tribe of Indians Surface Water Quality Standards		Mar-03												x
O	2	Electronic			x	x								x		x	Finite-Element Modeling Of The Spokane-Rathdrum Prairie Aquifer From Stateline To The Little Spokane River		Apr-03												x
O	3	Electronic								x	x	x					Physical Habitat Use and Water Quality Criteria for Redband Trout and Bull Trout Associated with the Hells Canyon Complex		Jan-03												x
O	4	Paper								x		x					Native Trout of Western North America.	Behnke, R.J.	1992												x
O	5	Paper								x	x				x		Management of Artificial Lakes and Ponds	Bennett, G.W.	1962												x
O	6	Electronic								x						x	Return to the River-2000, Chapter 5: Status of Freshwater Habitats		Jan-00												x
O	7	Paper								x		x					Fishes in Kansas, 2nd ed.	Cross, F.B. and J.T. Collins	1995												x
O	8	Electronic/ Paper															The Water Environment: Algal Toxins and Health		Jan-81												x
O	9	Paper								x	x					x	Mixing Inland and Coastal Waters	Fischer, H.B., E.J. List, R.C.Y. Koh, J. Imberger, and N.H. Brooks	1979												x
O	10	Paper	x	x	x	x	x	x	x		x	x					Memo: Readers of First Draft Intermountain Province Subbasin Plan		Aug-03												x

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
O	11	Electronic							x			x					Spokane Tribal Hatchery', Project No. 1991-04600, (BPA Report DOE/BP-00004731-1)	Peone	Mar-03												x
O	12	Electronic							x		x	x			x	x	Preliminary Lake Roosevelt Fisheries Evaluation Program. 2000 Annual Report	Spokane Tribe of Indians (Lee, Scofield, Pavlik, Fields)	Nov-03												x
O	13	Paper										x					Natural Lakes and Large Impoundments. In Inland Fisheries Management in North America, 2nd edition.	Hayes, D.B., W.W. Taylor and P.A. Soranno	1999												x
O	14	Electronic								x		x					Life History Characteristics of Freshwater Fishes Occurring in Newfoundland and Labrador, with Major Emphasis on Lake Habitat Characteristics	Bradbury, C., M.M. Roberge, and C.K. Minns	1999												x
O	15	Paper								x			x				Increase Abundance and Depth Distribution of Pelagic Crustacean Zooplankton During Hypolimnetic Oxygenation in a Deep, Eutrophic Alberta Lake	Field, K.M. and E.E. Prepas	1997												x
O	16	Paper								x	x	x	x				Fundamentals of Ecology, 2nd edition	Odem, E.P.	1959												x
O	17	Paper								x	x						Fundamentals of Limnology, 3rd edition	Ruttner, F.	1969												x
O	18	Paper															Freshwater Fishes of Canada	Scott, W.B. and E.J. Crossman	1973												x
O	19	Paper								x			x				Freshwater Invertebrates of the United States, 2nd edition	Pennak, R.W.	1978												x
O	20	Paper								x		x					Fishes of Idaho	Simpson, J. and R. Wallace	1982												x
O	21	Paper								x	x						Water Quality - Prevention, Identification, and Management of Diffuse Pollution	Novotny, V. and H. Olem	1993												x
O	22	Paper								x	x		x				Monitoring Freshwater Benthic Macroinvertebrates and Benthic Processes: Measures for Assessment of Ecosystem Health	Reice, S.R. and M. Wohlenberg	1993												x
O	23	Paper								x			x				An Introduction to the Aquatic Insects of North America, 3rd edition	Merritt, R.W. and K.W. Cummins	1996												x

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
O	24	Paper								x	x					x	Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs, and Watersheds for Sustainable Use	Morris, G.L. and J. Fan	1998													x
O	25	Electronic	x									x					Coeur d'Alene Tribe Fish, Water, and Wildlife Program Supplementation Feasibility Report on the Coeur d'Alene Indian Reservation	Peters, R., A.J. Vitale, and K. Lillengreen	1998													x
O	26	Paper								x						x	Practical Use of Biological Statistics. In Inland Fisheries Management in North America, 2nd edition	Ney, J.J.	1999													x
O	27	Electronic								x	x					x	Assessing the TMDL Approach to Water Quality Management	National Academy of Sciences	2001													x
O	28	Electronic								x						x	Agenda Item B, Rule Adoption: Water Quality Standards, Including Toxic Pollutants Criteria	ODEQ	2004													x
O	29	Paper								x	x					x	The Dynamics of Density-Stratified Reservoirs. In G.E. Hall ed. Reservoir Fisheries and Limnology	Wunderlich, W.O.	1971													x
O	30	Paper								x		x					Inland Fishes of Washington	Wydoski, R.S. and R.R. Whitney	1979													x
O	31	Paper								x	x						The Prediction of River Water Temperatures	Smith, K.	1981													x
O	32	Paper								x	x						Limnology	Wetzel, R.G.	1983													x
O	34	Electronic							x		x	x					Measurement of Lake Roosevelt Biodata in Relation to Reservoir Operations	Griffith, J.R., A.C. McDowell, and A.T. Scholtz	1991													x
O	35	Paper								x		x					Predation Risk and Importance of Cover For Juvenile Rainbow Trout in Lentic Systems	Tabor, R.A. and W.A. Wurtsbaugh	1991													x
O	36	Paper								x	x						Contaminant Transport in Surface Water. In Handbook of Hydrology.	Huber, W.C.	1992													x
O	37	Paper															Freshwater Biomonitoring Using Individual Organisms, Populations, and Species Assemblages of Benthic Macroinvertebrates. In Freshwater Biomonitoring and Benthic Macroinvertebrates.	Johnson, R.K., T. Wiederholm, and D.R. Rosenberg	1993													x
O	38	Electronic							x								Measurement of Lake Roosevelt Biodata in Relation to Reservoir Operations	Voeller, A.C.	1993													x

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
O	39	Paper								x	x						Stream Water-Temperature Sensitivity to Weather and Bed Parameters	Sinokrot, B.A. and H.G. Stefan	1994												x
O	40	Paper								x		x					Stocking for Sport Fisheries Enhancement. In Inland Fisheries Management in North America, 2nd edition.	Heidinger, R.C.	1999												x
O	41	Paper								x	x	x	x				Land and Reservoir Habitat Management	Summerfelt, R.C.	1999												x
O	42	Paper								x		x					Classification of Species Attributes for Pacific Northwest Freshwater Fishes	Zaroban, D.N., M.P. Mulvey, T.R. Maret, R.M. Hughes, and G.D. Merritt	1999				x								x
O	43	Electronic								x	x						Retention and Internal Loading of Phosphorus in Shallow, Eutrophic Lakes	Sondergaard, M., J.P. Jensen, and E. Jeppesen	2001												x
O	44	Paper								x			x				A Guide to Freshwater Invertebrates of North America	Voshell, J.R. Jr	2002												x
O	45	Electronic								x	x						Lake Washington Existing Conditions Report	King County	2003												x
O	46	Paper								x		x					Inland Fishes of Washington, 2nd edition	Wydoski, R.S. and R.R. Whitney	2003												x
O	47	Electronic								x	x						Lake Sammamish Water Quality: Thermal Stratification, Dissolved Oxygen, and Transparency in Lake Sammamish	King County	2004												x
O	48	Website								x	x						The Lake Washington Story	King County	2004												x
O	49	Paper								x						x	Agreement signed in Elwha dam removal.	Casper Star-Tribune, Associated Press	Aug-04												x
O	50	Website/ Raw Data								x		x					Fishbase		2004												x
O	51	Paper								x						x	Port Angeles: Memo-signing paves way for dam removal project	Gawley, B., Port Angeles Peninsula Daily News	Aug-04												x
O	52	Electronic/ Website								x						x	Social Impacts in Environmental, Social and Economic Impacts of Dams. Accessed in November 2004.	International Development Studies Network	2004												x
O	53	Electronic/ Website								x						x	Natural Resource Year in Review – 1996. Publication D-1182. Accessed in November 2004.	National Park Service	May-97												x

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
O	54	Electronic								x						x	Draft Fifth Plan	Northwest Planning and Conservation Council	Oct-04												x
O	55	Electronic/ Website								x						x	American Field Guide Teacher Resources: Salmon vs. Dams, The Dam Removal Debate on the Elwha River	PBS	2004												x
O	56	Electronic/ Website								x						x	Committee on Dam Decommissioning	United States Society on Dams	2004												x
O	57	Electronic								x						x	Spokane County Preliminary Evaluation of Land Application	HDR	Sep-04						x						x
O	58	Website								x						x	Poverty: 1999	US Census Bureau	May-04												x
O	59	Paper								x						x	State of Washington Irrigation Guide	US DA, SCS	1990												x
O	66	Website								x						x	Local Area Unemployment Rate	US Bureau of Labor Statistics	Nov-04												x
O	67	Website								x							American Factfinder Data Sets	US Census Bureau	Nov-04												x
O	68	Electronic								x						x	Promulgation of the Chesapeake Bay DO Standards	Maryland Department of Natural Resources	Dec-04												x
O	69	Electronic								x						x	Ambient Water Quality Criteria for Dissolved Oxygen, Overview Report	Government of British Columbia	Feb-97												x
O	71	Paper								x						x	Physiological Ecology Meets the Ideal Free Distribution: Predicting the Distribution of Size-Structured Fish Populations Across Temperature Gradients	Hughes, N.F. and T.C. Grand	2000												x
O	72	Paper								x						x	Movements and Habitat Preference of Adult Rainbow Trout (Onchorhyncus mykiss) in a New Zealand Montane Lake	James, G.D. and J.R.M. Kelso	1995												x
O	73	Paper								x							Quantification of Hungry Horse Reservoir Water Level Needed to Maintain or Enhance Reservoir Fisheries, Methods, and Data Summary: 1983-1987	May, B., S. Glutting, T. Weaver, G. Michael, B. Morgan, P. Suek, J. Wachsmuth, and C. Weichler	1988												x
O	75	Electronic								x						x	U.S. Rules Out Dam Removal to Aid Salmon	New York Times	Dec-04												x

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information													
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
O	77	Paper								x						x	Horizontal and Vertical Movements of Telemetered Rainbow Trout (*Onchorhyncus mykiss*) in Lake Washington	Warner, E.J. and T.P. Quinn	1995												x
O	78	Website								x						x	Washington Climate Summaries	Western Regional Climate Center	May-04												x
O	79	Electronic/ Paper								x						x	Final Issue Paper, Dissolved Oxygen 1992-1994 Water Quality Standards Review	ODEQ	Jun-95												x
O	80	Electronic								x						x	Statewide Strategy to Recover Salmon, Extinction is Not an Option		Sep-99												x
SCo	1	Electronic			x	x	x	x								x	Habitat Map, Spokane County Comprehensive Map		2004						x						
SCo	2	Electronic/ Paper			x	x	x	x			x					x	Water Quality and Water Quantity, Spokane County		Jul-96						x						
SCo	3	Electronic								x						x	Spokane County Wastewater Financial Analysis Scenarios	Dunlap, T.	Nov-04						x						
Univ	1	Paper					x	x			x						An Investigation as to the Cause and Effect of Eutrophication in Long Lake, Washington	Soltero, Gasperino, Graham	Jul-73								x				
Univ	2	Paper	x	x			x	x			x	x	x				An Integrated Study on the Impact of Metallic Trace Element Pollution in the Coeur d'Alene-Spokane Rivers-Lake Drainage System	Funk, Rabe, Filby and others	Aug-75								x				
Univ	3	Paper							x	x	x	x	x				Carbon and Nitrogen Stable Isotope Assessment of the Lake Roosevelt Aquatic Food Web	Black, Barlow, and Scholtz	Jan-03								x				
Univ	4	Website								x						x	Washington State University, Water Research Center		Jul-03								x				
Univ	5	Electronic/ Website								x						x	Various files with direction to academic resources		Jul-03								x				
Univ	6	Paper			x							x					Effects of Fluctuating Flows on the Population Dynamics of Rainbow Trout in the Spokane River of Idaho	Underwood and Bennett	Jan-92								x				
Univ	7	Electronic/ Paper				x	x	x			x		x				Response to the Spokane River Periphyton Community to Primary Sewage Effluent and Continued Investigation of Long Lake	Soltero, Gasperino, Williams, Thomas	Jul-75								x				
Univ	10	Electronic/ Paper			x	x	x	x			x		x				Response of the Spokane River Diatom Community to Primary Sewage Effluent	Williams and Soltero	Jan-78								x				

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information														
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
Univ	11	Electronic/ Paper			x	x	x	x			x						Impact of Combined Sewer/Stormwater Overflows on the Spokane River, Washington	Soltero, Humphreys, Sexton	Oct-90								x				
Univ	13	Website						x			x						A Water Quality Model of the Spokane River-Long Lake System Using CE-QUAL-W2	Berger, C.J., R.L. Annear, and S.A. Wells	2002								x				
Univ	14	Paper		x							x	x	x			x	Aquatic Ecology of the Spokane River Between Coeur d'Alene and Post Falls, Idaho, 1980	Falter and Mitchell	Jan-82								x				
USGS	1	Electronic/ Paper	x	x	x	x	x	x				x	x				Summary of Information on Synthetic Organic Compounds and Trace Elements in Tissue of Aquatic Biota, Clark Fork-Pend Oreille and Spokane River Basins, Montana, Idaho, and Washington, 1974-96		Jan-96							x					
USGS	2	Electronic/ Paper	x	x	x	x	x	x			x	x					Concentrations of Selected Trace Elements in Fish Tissue and Streambed Sediment in the Clark Fork-Pend Oreille and Spokane River Basins, Washington, Idaho, and Montana, 1998		Jan-98							x					
USGS	3	Website/ Paper		x	x	x	x				x	x	x				National Water-Quality Assessment-Northern Rockies Study Unit (NROK)		Jun-03							x					
USGS	4	Website/ Raw Data		x	x	x	x				x	x	x			x	USGS Data Download Site for Spokane River, 1998-1999 Data		Jan-99							x					
USGS	5	Electronic/ Paper		x	x	x	x				x	x	x				Ecological Indicators of Water Quality in the Spokane River, Idaho and Washington, 1998 and 1999	MacCoy and Maret	Sep-03							x					
USGS	6	Electronic		x	x	x	x	x	x		x						River Discharge and Water Quality Data Download		2003							x					
USGS	7	Electronic	x	x	x	x	x	x		x	x					x	Water Quality in the Northern Rockies, Intermontane Basins, Idaho, Montana, and Washington		2004							x					
USGS	8	Electronic								x				x			Modeling Water Quality in the Tualatin River, Oregon, 1991-1997, USGS Report WRI 01-4041.	Rounds and Wood	2001							x					
WDFW	1	Electronic		x	x	x	x	x				x				x	Draft Spokane River Subbasin Summary	Whalen	Nov-00										x		
WDFW	2	Electronic						x			x	x					2001 Warmwater Fisheries Survey of Lake Spokane, Spokane and Stevens Counties, Washington	Osborne, Divens, and Baldwin	Apr-04										x		

Summary of Data Sources Used to Support UAA

Filing Information			Geographic Location								Data Type						Document Information													
																				Av	CCA	CS	IDEQ	IDFG	SCo	USGS	Univ	Eco	WDFW	EPA	O
Source Abr.	Source Number	Format	C d'A Lake / Basin	Post Falls	Upper Falls	Monroe	Nine Mile	Lake Spokane	Lake Roosevelt	Other	Water Quality/Limnology	Fisheries	Invertebrates	Modeling	Recreation	Other (Habitat, Regulatory, etc.)	Name	Author (if appropriate)	Date	Avista / Washington Water Power	City of Cd'A	City of Spokane	IDEQ	IDFG	Spokane County	USGS	Universities	Washington Dept. of Ecology	WDFW	USEPA	Others
WDFW	3	Electronic						x		x		x					Little Spokane River Rainbow Trout, Genetic Information	Loxterman	May-04										x		
WDFW	4	Electronic/ Paper			x	x	x	x				x					Meeting notes from meeting with Chris Donley, WDF&W District Biologist	Donley	Jun-03										x		
292		COUNT	46	81	92	89	102	108	10	119	183	78	26	26	7	99				29	6	37	29	12	4	13	53	92	7	22	78

Appendix D

Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses

APPENDIX D

Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses

This appendix includes the following sections:

D1 Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses

D2 TMDL Model Parameters for Updated Next Level of Treatment Table

D3 Additional Charts of LTI CE-QUAL-W2 Modeling Results for Year 2001

Appendix D1

Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses

Report

Support of Use Attainability Analyses

Appendix D1 of Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses

Prepared for:

CH2M HILL

November 15, 2004

Limno-Tech, Inc.
Excellence in Environmental Solutions Since 1975
Ann Arbor, MI

Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses

Prepared for: CH2M HILL

Purchase Order 73235

November 15, 2004

ACKNOWLEDGEMENTS

Limno-Tech, Inc. Project Officer: David Dilks

Limno-Tech, Inc. Project Manager: Joseph Helfand

TABLE OF CONTENTS

D1. EXECUTIVE SUMMARY D1-1

D1.1. SPOKANE RIVER CE-QUAL-W2 MODEL D1-1
- D1.1.1 CE-QUAL-W2 ..... D1-1
- D1.1.2 MODEL IN IDAHO D1-1
- D1.1.3 MODEL IN WASHINGTON D1-1

D1.2. POST-PROCESSING D1-3
- D1.2.1 POST-PROCESSOR APPLICATION 1 ..... D1-3
- D1.2.2 HYPOLIMNION DEFINITION D1-4
- D1.2.3 POST-PROCESSOR APPLICATION 2 ..... D1-4
- D1.2.4 TIME SERIES D1-4
- D1.2.5 VERTICAL PROFILES FOR AUGUST 17TH D1-5
- D1.2.6 TIME SERIES BY DEPTH D1-5

D1.3. SCENARIOS D1-6
- D1.3.1 EXISTING LOADS D1-6
- D1.3.2 "ORIGINAL" NEXT LEVEL OF TREATMENT D1-6
- D1.3.3 POINT SOURCE LOADS OUT OF RIVER D1-6
- D1.3.4 POINT SOURCE LOADS AND FLOWS OUT OF RIVER D1-6
- D1.3.5 RELATIVE EFFECTS D1-6
- D1.3.6 UNLOT D1-7
  - D1.3.6.1 UNLOT SCENARIO 1 ..... D1-7
  - D1.3.6.2 UNLOT SCENARIO 2 ..... D1-7
  - D1.3.6.3 UNLOT SCENARIO 3 ..... D1-8
  - D1.3.6.4 UNLOT SCENARIO 4 ..... D1-8

D1.4. RESULTS D1-9
- D1.4.1 POINT SOURCE LOADS OUT OF RIVER D1-9
- D1.4.2 RELATIVE EFFECTS D1-10
- D1.4.3 UNLOT D1-16
  - D1.4.3.1 MINIMUM DAILY DO FOR SEGMENTS 155, 167, AND 183 ON AUGUST 17 ..... D1-16
  - D1.4.3.2 DEPTH CONTOUR CHARTS D1-19
  - D1.4.3.3 TIME SERIES CHARTS D1-25

D1.5. REFERENCES D1-34

LIST OF FIGURES

Figure D1-1-1. Dissolved Oxygen Concentration by Day for the Spokane River from 2001 Idaho Stateline Boundary Study D1-2
Figure D1-4-1. Dissolved Oxygen for Segment 155 ..... D1-9
Figure D1-4-2. Dissolved Oxygen for Segment 167 ..... D1-9
Figure D1-4-3. Dissolved Oxygen for Segment 183 ..... D1-10
Figure D1-4-4. Hypolimnion Algae Levels by Scenario by Hours of Day D1-12
Figure D1-4-5. Hypolimnion Algae Levels by Scenario by River Segment D1-13
Figure D1-4-6. Hypolimnion Algae Levels by Scenario by Days of Year D1-14
Figure D1-4-7. Hypolimnion DO Levels by Scenario by River Segment D1-15
Figure D1-4-8. Hypolimnion DO Levels by Scenario by Days of Year D1-16
Figure D1-4-9. Minimum DO Profiles, by Depth for Segment 155 ..... D1-17
Figure D1-4-10. Minimum DO Profiles by Depth for Segment 167 ..... D1-18
Figure D1-4-11. Minimum DO Profiles by Depth for Segment 183 ..... D1-18
Figure D1-4-12. DO Contour at 5 meters for Segment 155, Scenario 1 ..... D1-19
Figure D1-4-13. DO Contour at 5 meters for Segment 155, Scenario 2 ..... D1-19
Figure D1-4-14. DO Contour at 5 meters for Segment 155, Scenario 3 ..... D1-20
Figure D1-4-15. DO Contour at 5 metersfor Segment 155 , Scenario 4 ..... D1-20
Figure D1-4-16. DO Contours for Segment 167, Scenario 1 ..... D1-21
Figure D1-4-17. DO Contours for Segment 167, Scenario 2 ..... D1-21
Figure D1-4-18. DO Contours for Segment 167, Scenario 3 ..... D1-22
Figure D1-4-19. DO Contours for Segment 167, Scenario 4 ..... D1-22
Figure D1-4-20. DO Contours for Segment 183, Scenario 1 ..... D1-23
Figure D1-4-21. DO Contours for Segment 183, Scenario 2 ..... D1-23
Figure D1-4-22. DO Contours for Segment 183, Scenario 3 ..... D1-24
Figure D1-4-23. DO Contours for Segment 183, Scenario 4 ..... D1-24
Figure D1-4-24. Minimum Daily DO Concentrations Segment 63 ..... D1-25
Figure D1-4-25. Minimum Daily DO Concentrations Segment 2 ..... D1-26
Figure D1-4-26. Minimum Daily DO Concentrations Segment 17 ..... D1-26
Figure D1-4-27. Minimum Daily DO Concentrations Segment 42 ..... D1-27
Figure D1-4-28. Minimum Daily DO Concentrations Segment 69 ..... D1-27
Figure D1-4-29. Minimum Daily DO Concentrations Segment 110 ..... D1-28
Figure D1-4-30. Minimum Daily DO Concentrations Segment 142 ..... D1-28
Figure D1-4-31. Minimum Daily DO Concentrations Segment 154 ..... D1-29
Figure D1-4-32. Thirty - Day Running Average Minimum DO Concentrations Segment 63 ..... D1-29
Figure D1-4-33. Thirty - Day Running Average Minimum DO Concentrations Segment 2 ..... D1-30
Figure D1-4-34. Thirty - Day Running Average Minimum DO Concentrations Segment 17 ..... D1-30
Figure D1-4-35. Thirty - Day Running Average Minimum DO Concentrations Segment 42 ..... D1-31
Figure D1-4-36. Thirty - Day Running Average Minimum DO Concentrations Segment 69 ..... D1-31

Figure D1-4-37. Thirty - Day Running Average Minimum DO Concentrations Segment 110 ..... D1-32
Figure D1-4-38. Thirty - Day Running Average Minimum DO Concentrations Segment 142 ..... D1-32
Figure D1-4-39. Thirty - Day Running Average Minimum DO Concentrations Segment 154 ..... D1-33

LIST OF TABLES

Table D1-3-1. Brief Specifications for Updated Next Level of Treatment D1-8

D1. EXECUTIVE SUMMARY

Limno-Tech, Inc., is assisting the Spokane River UAA Advisory Group in the development of site-specific dissolved oxygen criteria for the Spokane River and Long Lake Reservoir near Spokane, WA.

The Washington Department of Ecology has been developing Total Maximum Daily Loads to support attainment of dissolved oxygen standards in the Spokane River and its downstream impoundment, Long Lake Reservoir. The existing dissolved oxygen standard for Washington lakes allows for no man-made decrease in lake dissolved oxygen concentrations below natural levels. For purposes of management applications, "no decrease" has been defined as less than a 0.2 mg/L change in dissolved oxygen in any portion of the lake. Initial water quality model results have demonstrated that oxygen can be decreased by several mg/L in some of the deeper sections of Long Lake Reservoir. Subsequent analyses have indicated that attainment of the existing dissolved oxygen standard will require greater than 90% reduction in both point and nonpoint source loads to the Lake.

In response to this problem, the Spokane River UAA Sponsors Group was formed to provide the scientific and technical basis for appropriate designations of beneficial uses in the Spokane River and Long Lake Reservoir, and to recommend standards for the protection of existing and attainable uses.

LTI has applied the existing advanced State-approved CE-QUAL-W2 water quality models to evaluate the attainability of criteria. These models include a calibrated application to the Spokane River and Long Lake Reservoir in Washington, as well as an uncalibrated application in Idaho which is used to define the contribution of Idaho sources to dissolved oxygen depletion in Washington. LTI applied the models to evaluate a range of treatment scenarios, including "Next Level of Treatment" (which is defined as an effluent quality achieved by the Rock Creek plant, a tertiary plant operated by Clean Water Services in Hillsboro, Oregon), elimination of point source loads, and scenarios to illustrate the relative effects of removing particular load components. Model results were evaluated using LTI-developed software to provide a broad range of means of comparing water quality conditions to criteria, including spatial and temporal averaging and volume-weighting.

D1.1. SPOKANE RIVER CE-QUAL-W2 MODEL

D1.1.1 CE-QUAL-W2

CE-QUAL-W2 is a general purpose two dimensional (longitudinal-vertical), laterally averaged, hydrodynamic and water quality computer model that has been under development by the U.S. Army Corps of Engineers Waterways Experiment Station. The recently developed Version 3.1 was used in these studies. The hydrodynamic portion of the model predicts water surface elevations, velocities, and temperatures. The water quality portion predicts concentrations of constituents which may be inorganic suspended solids, phytoplankton, epiphyton, CBOD, ammonium, nitrate-nitrite, orthophosphate, labile dissolved organic matter, refractory dissolved organic matter, labile particulate organic matter, refractory particulate organic matter, total inorganic carbon, alkalinity, total iron, dissolved oxygen, or generic constituents.

D1.1.2 MODEL IN IDAHO

CE-QUAL-W2 model scenario applications were made to the Spokane River in the state of Idaho. The model locale is in northwestern Idaho from where the Spokane River originates in Coeur d'Alene Lake to the stateline between Idaho and Washington. The modeling period extended from Julian Days 10 to 365 of 2001. Constituents included in this model were inorganic suspended solids (1 group), phytoplankton (1 group), epiphyton (1 group), CBOD (4 groups), ammonium, nitrate-nitrite, orthophosphate, labile dissolved organic matter, refractory dissolved organic matter, labile particulate organic matter, refractory particulate organic matter, total inorganic carbon, alkalinity, and dissolved oxygen.

The model application in Idaho has not been calibrated. In these studies it has been used primarily to provide an upstream boundary condition for the model application in Washington (see below), under scenario conditions where the downstream effect of changing effluents into the Spokane River in Idaho is to be simulated. Boundary conditions for the Washington model application provided in this manner differ significantly from boundary conditions developed from field data (apart from effects of effluent changes), due largely to the relative sparseness of Idaho-Washington state line field data. This effect is illustrated in Figure D1-1-1.

D1.1.3 MODEL IN WASHINGTON

CE-QUAL-W2 model scenario applications were made to the Spokane River in the state of Washington. The model locale is in the northeastern part of Washington State and runs from the stateline between Idaho and Washington, downstream to the Long Lake Dam. The modeling period extended from Julian Days 74 to 304 of 2001 (March 15, 2001 through October 30, 2001). The "Riverine" portion of the model includes the pools of the Upriver Dam, the Upper Falls Dam, and Nine Mile Dam. The "Reservoir" portion is the Long Lake Reservoir. Constituents included in this model were inorganic suspended solids (1 group), phytoplankton (3 groups),

epiphyton (1 group), CBOD (6 or more groups), ammonium, nitrate-nitrite, orthophosphate, labile dissolved organic matter, refractory dissolved organic matter, labile particulate organic matter, refractory particulate organic matter, total inorganic carbon, alkalinity, and dissolved oxygen.

The model version used in these studies was modified by the Washington Department of Ecology and by Portland State University from an original calibration for the 2001 modeling period. Major changes included increasing algal groups from one to three, adding a CBOD group, changing epiphyton kinetic coefficients, and changing some boundary conditions. In addition, a "Run 1", which uses a blue-green algae settling rate of –2.0 m/d, and a "Run 2", which uses a blue-green algae settling rate of 0.01 m/d, were made available. These studies used only Run 1, which was recommended as being better able to reproduce field data than Run 2.

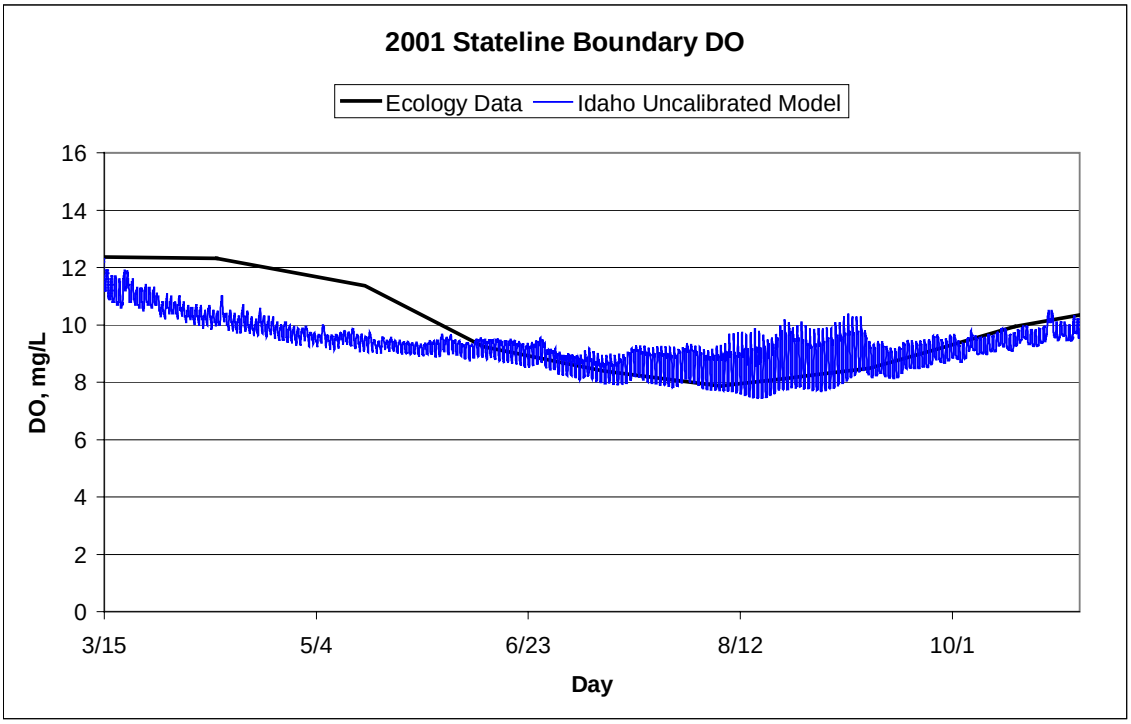


Figure D1-1-1. Dissolved Oxygen Concentration by Day for the Spokane River from 2001 Idaho Stateline Boundary Study

D1.2. POST-PROCESSING

CE-QUAL-W2 runs produced large amounts of output, as results were produced longitudinally by segment, vertically by layer, and through the modeling period at 0.5 hour intervals. As described below, several different types of post-processing of model results were used to appropriately average results and to display and compare them. For two of these types of post-processing, special database applications were created to implement the calculations.

D1.2.1 POST-PROCESSOR APPLICATION 1

The first post-processing program was created to calculate averages of model results in time and space, and compare these to water quality criteria. For volumes, the processor makes use of the geometric information contained in the model bathymetry input files, together with water surface elevations computed by the model at each time step. Six different averages are computed, four for selected individual segments and two for reaches.

Segments 9, 18, 40, and 51 in Idaho were processed. In Washington, segments 5, 10, 20, 36, 54, 57, 68, 82, 112, 124, 135, 142, 154, 159, 167, 178, 181, and 188 were processed. Reaches containing all model segments in the Idaho and Washington stretches were processed. For segments, the averages are:

1. The minimum DO of any layer in the segment, at any time step in the day.
2. The minimum from among all layers of the daily averages for each layer.
3. The minimum from among all time steps in a day, of the volume-weighted vertical average of the segment layers at each time step.
4. The average of all time steps in a day, of the volume-weighted vertical average of the segment layers at each time step.

For reaches, the averages are:

1. The minimum from among all time steps in a day, of the volume-weighted average of all layers and segments in the reach at each time step.
2. The average of all time steps in a day, of the volume-weighted average of all layers and segments in the reach at each time step.

For Long Lake Reservoir, during the July-September period, the above types of averages were applied separately to the epilimnion and hypolimnion layers, using the hypolimnion definition described below. Of all of the above types of averages, the first – minimum DO of any layer in the segment, at any time step in the day – is the most stringent in comparison with fixed DO criteria, so that was typically the one used.

D1.2.2 HYPOLIMNION DEFINITION

Comparison of model results to proposed criteria required definition of the metalimnion-hypolimnion boundary for all locations in the Long Lake Reservoir for the period July 1 through September 30. The model of the reservoir contains 35 segments. The period of time in which criteria may depend upon depth in the water column is 91 days. This corresponds to the need for over 3000 definitions of boundary depth, which are impractical to arrive at on an individual basis. The approach taken was to 1) perform a year-long CE-QUAL-W2 simulation, 2) sample the output to obtain vertical profiles of predicted temperature for a range of dates and locations in the reservoir, 3) visually define the location of the metalimnion-hypolimnion boundary for each sampled location and date, and 4) using the data from step 3, develop an empirical interpolating function to estimate the boundary depth for all needed dates and locations.

Temperature profiles were constructed for Segments 155, 160, 172, and 185 at bi-weekly intervals. The "textbook" definition of the metalimnion is the layer of maximum temperature change between the warmer upper layer and cooler lower layer. Working from this definition, the metalimnion-hypolimnion boundary was visually identified as the estimated inflection point between higher and lower rates of temperature change with increasing depth. The statistical software package TableCurve 3D was used to find an optimum interpolating equation to relate segment number, Julian date, and layer number of the boundary. The equation selected had the desirable properties of 1) lacking depth bias, with the arithmetic average of the errors between observed and predicted boundary layer depth less than 0.05m; 2) precision, with the predicted boundary layer within one layer of the observed 93% of the time; and 3) smoothness, with no discontinuities. This equation was then used in all instances, except for segment 154, to define the layers constituting the hypolimnion. Segment 154 is always considered to be an epilimnion segment.

D1.2.3 POST-PROCESSOR APPLICATION 2

A second post-processing program was created to generate segment volume-weighted vertically-averaged model results for DO and algae (sum of the three groups). Results are generated approximately hourly over a day, at one week intervals. The averages are calculated separately for the epilimnion and hypolimnion layers, where the hypolimnion exists according to the definition above.

D1.2.4 TIME SERIES

In time series post-processing, two types of time series were created from model results, for each of the Washington segments 2, 17, 42, 69, 110, 142, and 154. These series were:

1. The 30-day running average of minimum daily DO (in any layer of the segment) for the model period.
2. The minimum daily DO for each day in the period April through September.

D1.2.5 VERTICAL PROFILES FOR AUGUST 17TH

Vertical profile post-processing created profiles for August 17th, which had been identified as one of the most critical days in 2001. The profiles were created for Long Lake Reservoir segments 155, 167, and 183, in the upper, middle, and downstream parts of the reservoir respectively. The daily minimum DO was identified for each layer in the segment, and then plotted as a profile by depth below the water surface.

D1.2.6 TIME SERIES BY DEPTH

Time series by depth post-processing created charts for the July through September period (noon values for each day), for segments 155, 167, and 183, with lines representing several depth levels as well as the estimated location of the beginning of the hypolimnion layer (see above). More depth levels are represented as the reservoir deepens downstream. The 5 meter level is represented for segment 155. For segment 167 the 5, 15, and 20 meter levels are represented. For segment 183 the 5, 15, 20, 25, and 30 meter levels are represented.

D1.3. SCENARIOS

D1.3.1 EXISTING LOADS

The Existing Loads scenario used the calibrated model for the upper Spokane River in Washington, as set up by Ecology. The un-calibrated Idaho model was not used to provide boundary conditions at the State Line (the existing boundary conditions based on available measured data were used unchanged). The model was run for Julian days 74-304.

D1.3.2 "ORIGINAL" NEXT LEVEL OF TREATMENT

In this scenario, municipal (but not industrial) effluent concentrations were changed to correspond to a set of conditions termed Next Level of Treatment (later scenarios used an updated – and more stringent – Next Level of Treatment definition). Effluent flows were not changed from the Existing Loads scenario, except for the Spokane WWTP. The upstream boundary condition for the Washington model was created to match the downstream condition predicted by the uncalibrated Idaho model, which also had the Next Level of Treatment conditions applied for its municipal effluents. The boundary conditions created in this manner are significantly different from the Existing Loads boundary conditions, not only because of the change in effluents, but in large part because the model-based boundary conditions are provided at much greater time resolution than sample measurements-based boundary conditions.

D1.3.3 POINT SOURCE LOADS OUT OF RIVER

In this scenario, all point source pollutant loads (but not flows) were removed from the river. Boundary conditions at the state line were set from a file containing conditions used by Ecology in the their prior "No Point Source" simulation of the Idaho stretch. Point source pollutant loads were removed by zeroing out effluent concentrations of CBOD, NO3, NH4, PO4, and suspended solids.

D1.3.4 POINT SOURCE LOADS AND FLOWS OUT OF RIVER

In this scenario, all point source pollutant loads and flows were removed from the River. The un-calibrated Idaho model was used to set boundary conditions for the Washington model.

D1.3.5 RELATIVE EFFECTS

This set of scenarios looked at the relative effects on both DO deficit and algae concentrations (primarily in the hypolimnion of Lake Spokane) of removing point source and nonpoint source pollutant loads (but not flows) of BOD and P from the river. The un-calibrated Idaho model was run for each of the four combinations of conditions (plus the base case of not removing any loads), and its results were used for boundary conditions for the Washington model.

Inputs for these runs were created in the following manner:

- Removal of point source and non-point source P was done by zeroing concentrations of PO4 and setting the P content of CBOD concentrations to zero.
- Removal of point source and non-point source BOD was done by zeroing concentrations of CBOD and increasing PO4 concentrations commensurately to account for the P that had been in the CBOD compartment.

D1.3.6 UNLOT

An updated set of Next Level of Treatment conditions was defined and used in four scenarios, described below.

D1.3.6.1 UNLOT Scenario 1

This baseline scenario is identical to the Existing Loads scenario.

D1.3.6.2 UNLOT Scenario 2

In this scenario, all point source dischargers in the Idaho and Washington portions of the river discharge according to the concentrations and flows in the Updated Next Level of Treatment specifications. Non-point sources are unchanged. The uncalibrated Idaho model is used to provide boundary conditions for the Washington model.

Specifications for the Updated Next Level of Treatment are shown in Table D1-3-1. 5-day BODs were converted into ultimate BODs in the model inputs using existing model ratios. Total phosphorus was apportioned between organic phosphorus, modeled as a portion of the BOD concentrations, and phosphate phosphorus (PO4-P), modeled as a separate load constituent. Apportionment made use of the observation that the Rock Creek plant in Oregon, which has been used as the example facility for the capabilities of treatment processes, has approximately a 2:1 effluent ratio of average organic phosphorus to average phosphate phosphorus. To account for day-to-day variability, some model input concentrations were specified on the basis of both an average concentration and a coefficient of variation (standard deviation divided by the mean). In Table D1-3-1, “Rock Creek” refers to using the actual year 2000 time series data from the Rock Creek plant. “Calibration” (Calib.) refers to the existing year 2001 calibration model inputs.

Table D1-3-1. Brief Specifications for Updated Next Level of Treatment

Facility	CBOD5	BOD CV	TP	TP CV	NH3	Flow, MGD
Coeur d'Alene	2	0.6	0.06	0.6	Rock Creek	Calibration
Hayden	Calib.	na	Calib.	na	Calib.	Calibration
Post Falls	2	0.6	0.06	0.6	Rock Creek	Calibration
Liberty	2	0.6	0.06	0.6	Rock Creek	2, CV=0.12
Kaiser	CBODu = 8	0.15	0.06	0.6	0.1, CV=0.5	Calibration
IEPC	Calib.	na	0.2	0.3	Calib.	Calibration
Spokane WWTP	2	0.6	0.06	0.6	Rock Creek	65, CV=0.1

D1.3.6.3 UNLOT Scenario 3

In this scenario, point source discharges are the same as in Scenario 2, but non-point discharges have Phosphorus concentrations reduced by 25 percent from the baseline level. This was done by multiplying PO4 concentrations by 0.75 and setting the P content of CBOD concentrations to 75 percent of baseline.

D1.3.6.4 UNLOT Scenario 4

In this scenario, loads are the same as in the "Point Source Loads Out Of River" scenario, and the flow of the Spokane WWTP is set to zero.

D1.4. RESULTS

D1.4.1 POINT SOURCE LOADS OUT OF RIVER

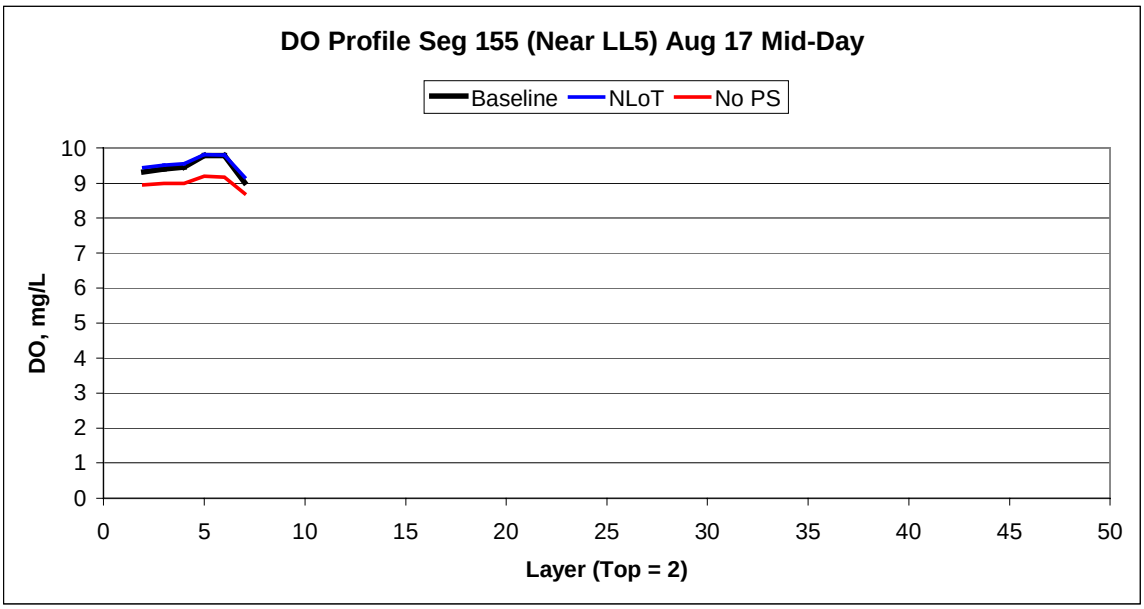


Figure D1-4-1. Dissolved Oxygen for Segment 155

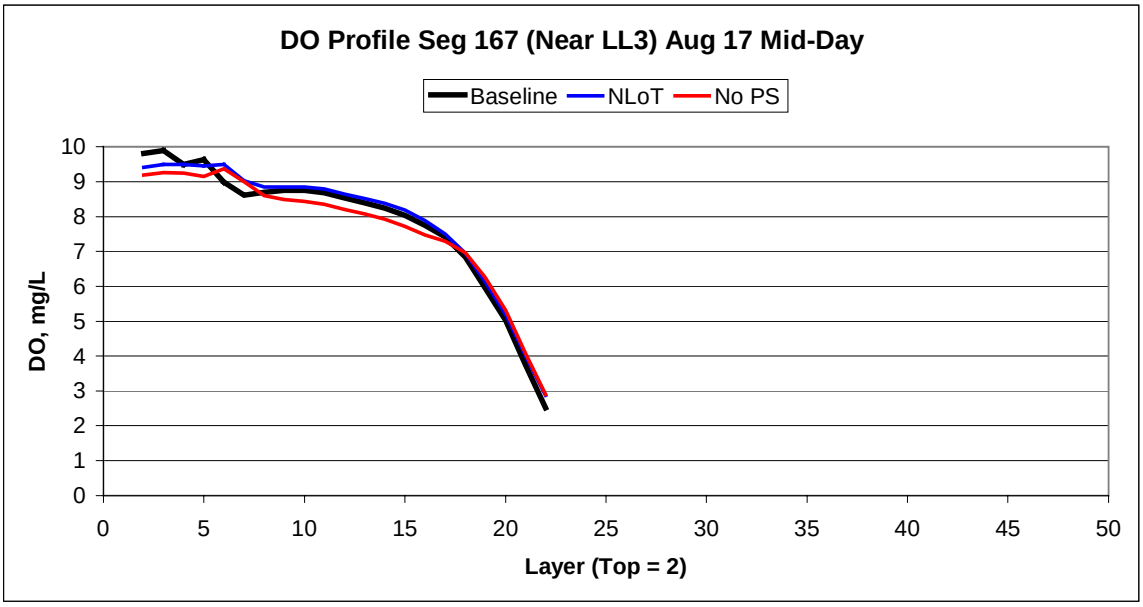


Figure D1-4-2. Dissolved Oxygen for Segment 167

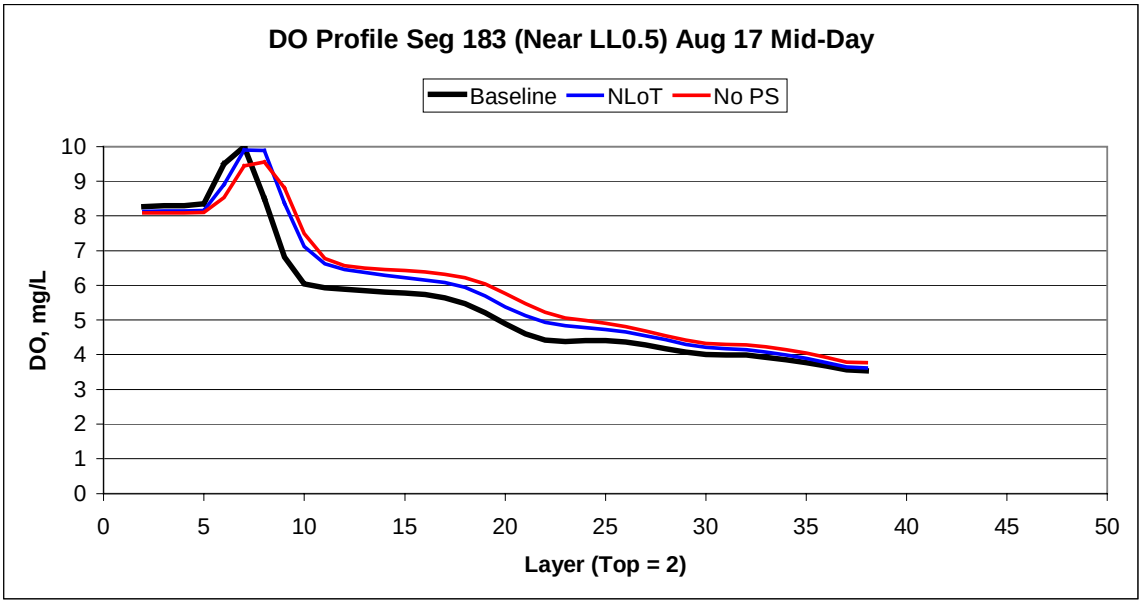


Figure D1-4-3. Dissolved Oxygen for Segment 183

D1.4.2 RELATIVE EFFECTS

In figures D1-4-4 through D1-4-8, several acronyms are used. They are:

- NPSP is non-point source phosphorus removed
- PSBOD is point source BOD removed
- NPSBOD is non-point source BOD removed
- PSP is point source phosphorus removed

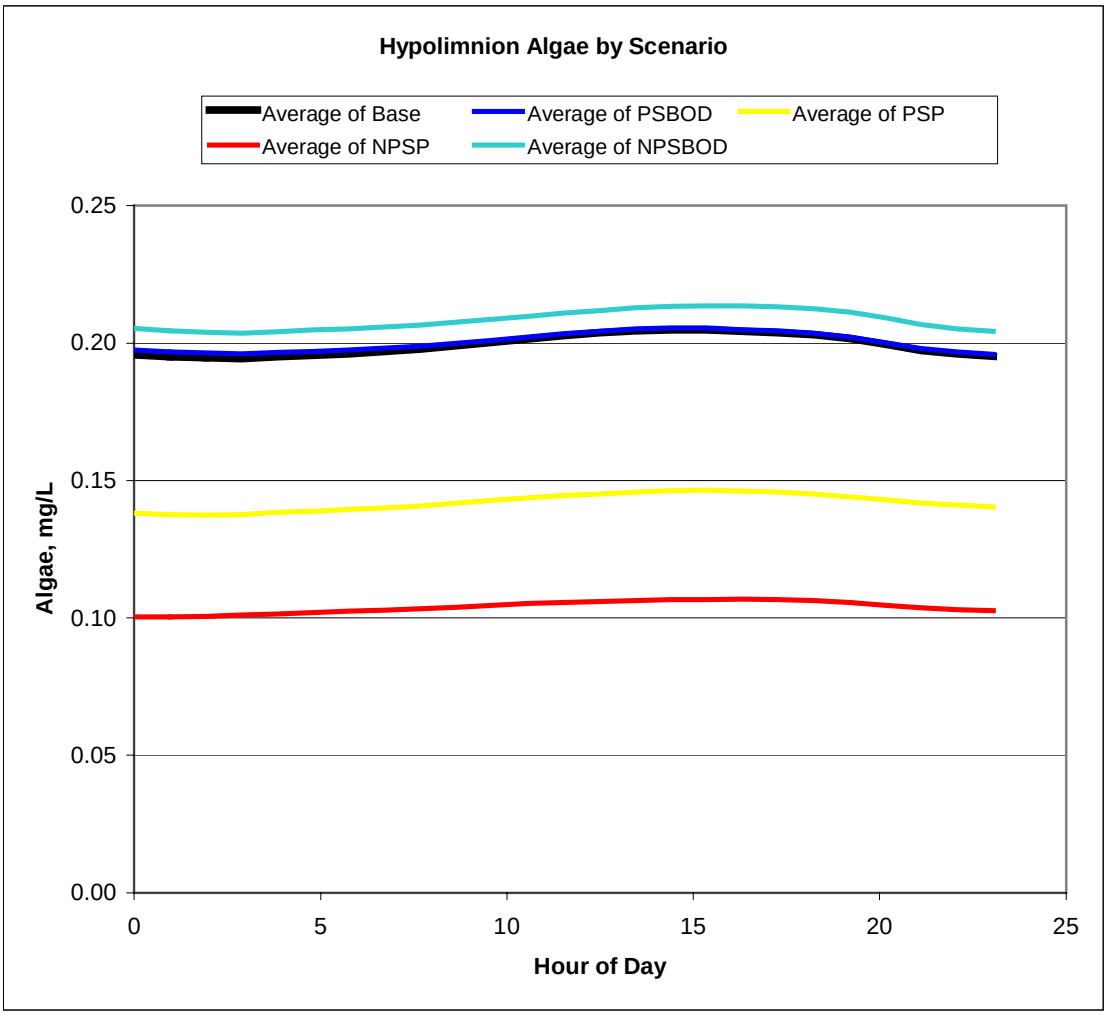


Figure D1-4-4. Hypolimnion Algae Levels by Scenario by Hours of Day

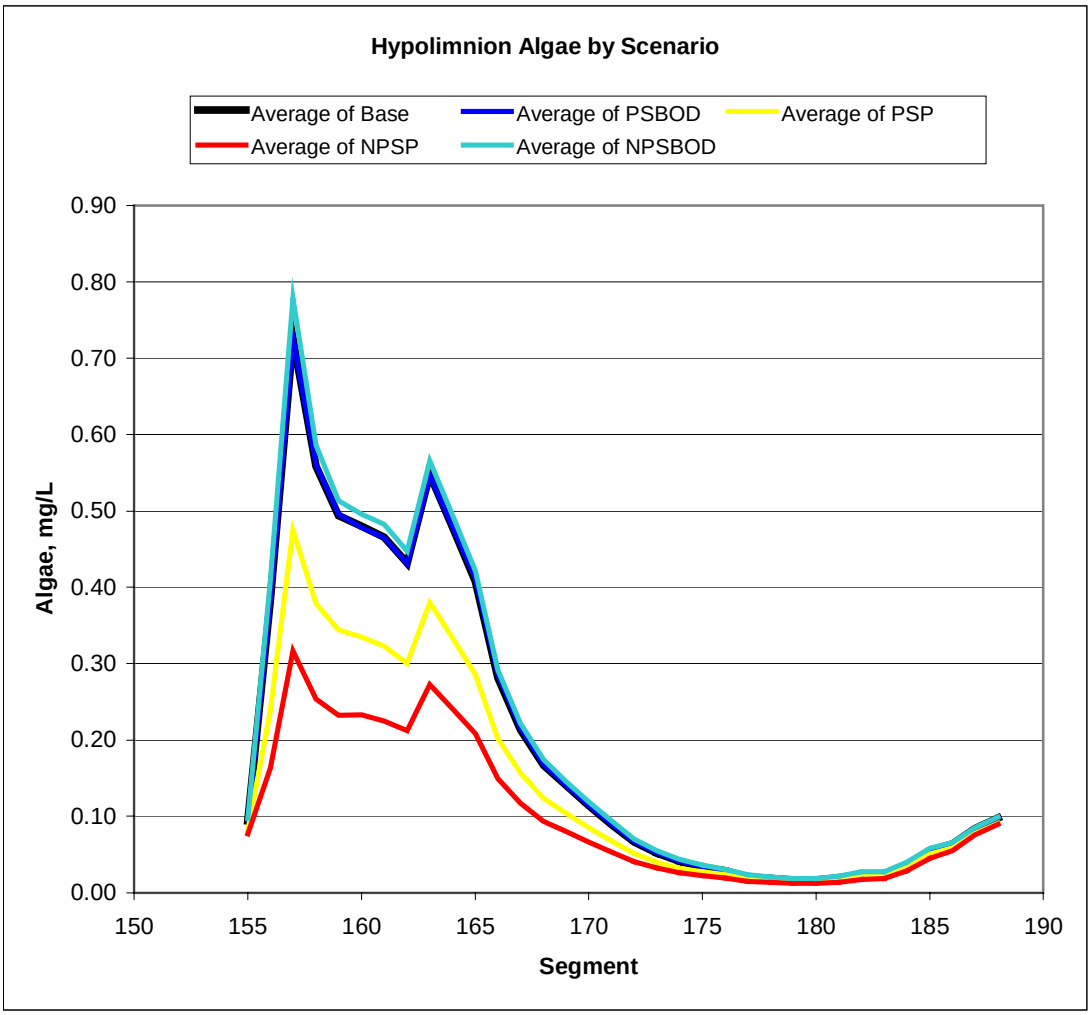


Figure D1-4-5. Hypolimnion Algae Levels by Scenario by River Segment

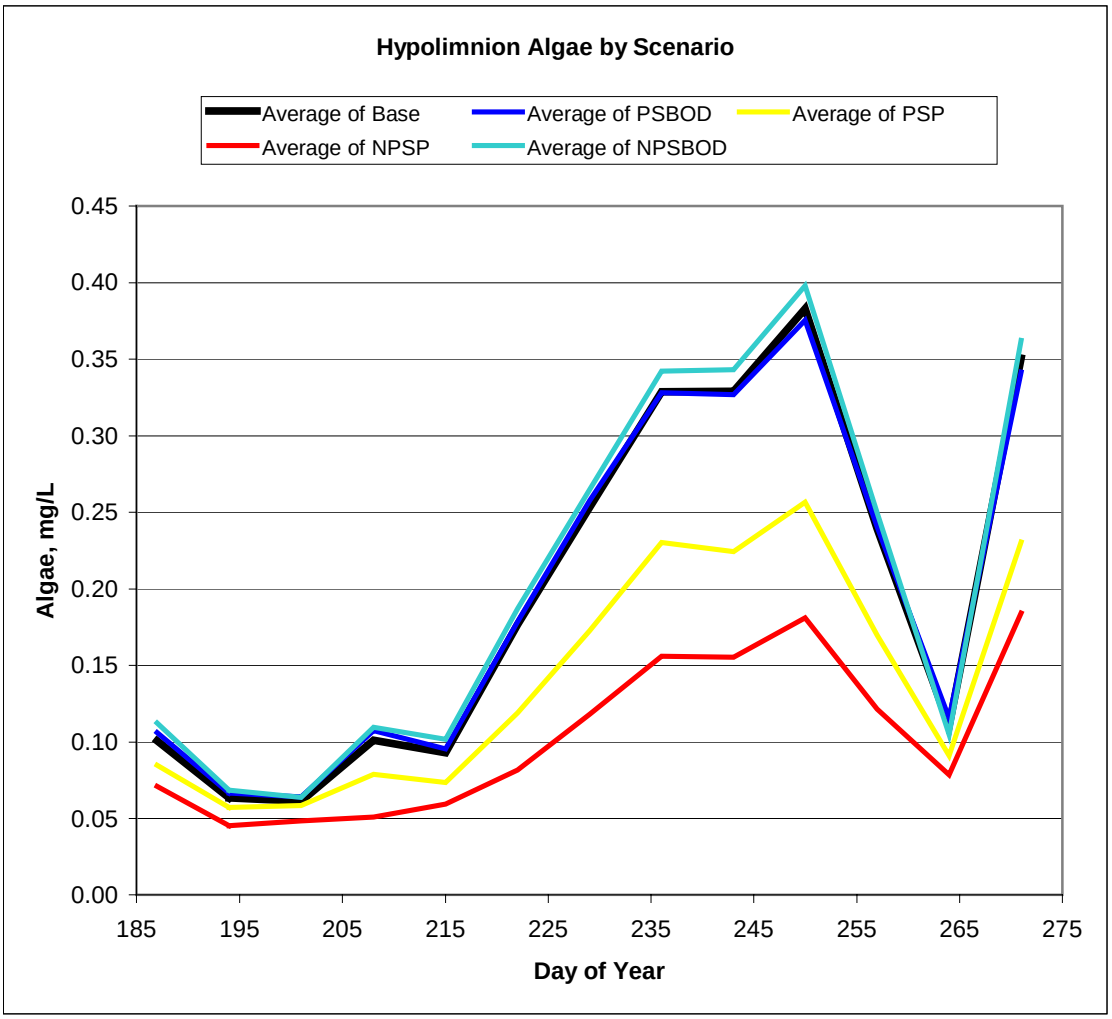


Figure D1-4-6. Hypolimnion Algae Levels by Scenario by Days of Year

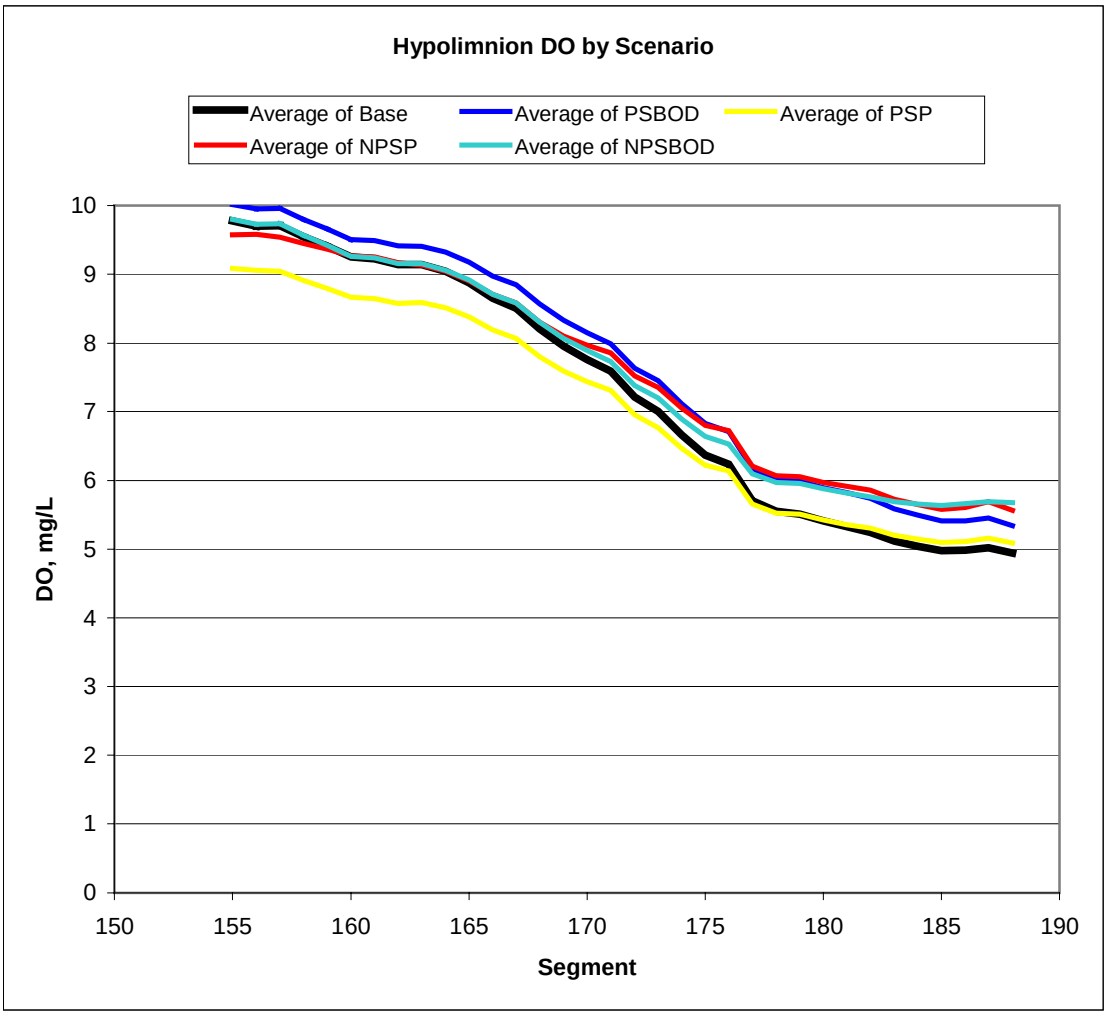


Figure D1-4-7. Hypolimnion DO Levels by Scenario by River Segment

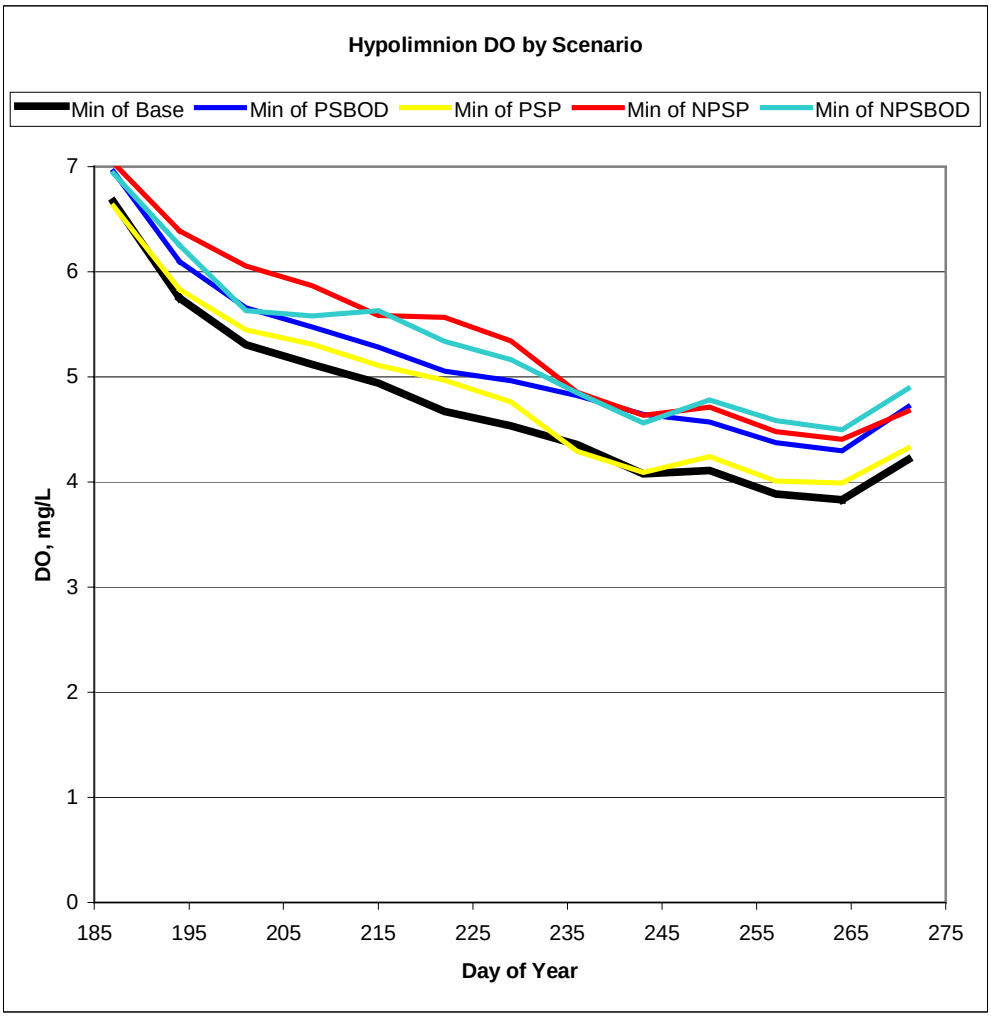


Figure D1-4-8. Hypolimnion DO Levels by Scenario by Days of Year

D1.4.3 UNLOT

D1.4.3.1 Minimum Daily DO for Segments 155, 167, and 183 on August 17

- **Scen 1.** Scenario 1-Baseline, or Base: Current flow and concentration conditions, using 2001 calibration year.
- **Scen 2.** Scenario 2-Next level of treatment (NLoT): For municipal discharges, defined for these initial model runs as future municipal effluent quality set equal to improvements observed at the Rock Creek treatment facility on the Tualatin River in Oregon (for example, discharges of 0.06 mg/L total phosphorus, about 99 percent treatment

efficiency). This run also used a 65 million gallons per day (mgd) flow for SAWTP to account partially for future growth and/or the County's proposed flow from a new plant.

- **Scen 3.** Scenario 3-NLoT+25 percent NPS BMPs: Identical to NLoT with an additional 25 percent reduction in nonpoint source loads through implementation of BMPs to control phosphorus loading (other nutrients will also probably be reduced as part of these BMPs but only phosphorus removals were modeled to be conservative).
- **Newer Scen 4.** Original Scenario 4-PS = 0 Concentration: Point source pollutant concentrations set to zero (point source flows remain in the river). Revised scenario 4 is point source pollutant concentrations set to zero (with flows remaining in the river) except for the City of Spokane discharge for which the flow was removed.

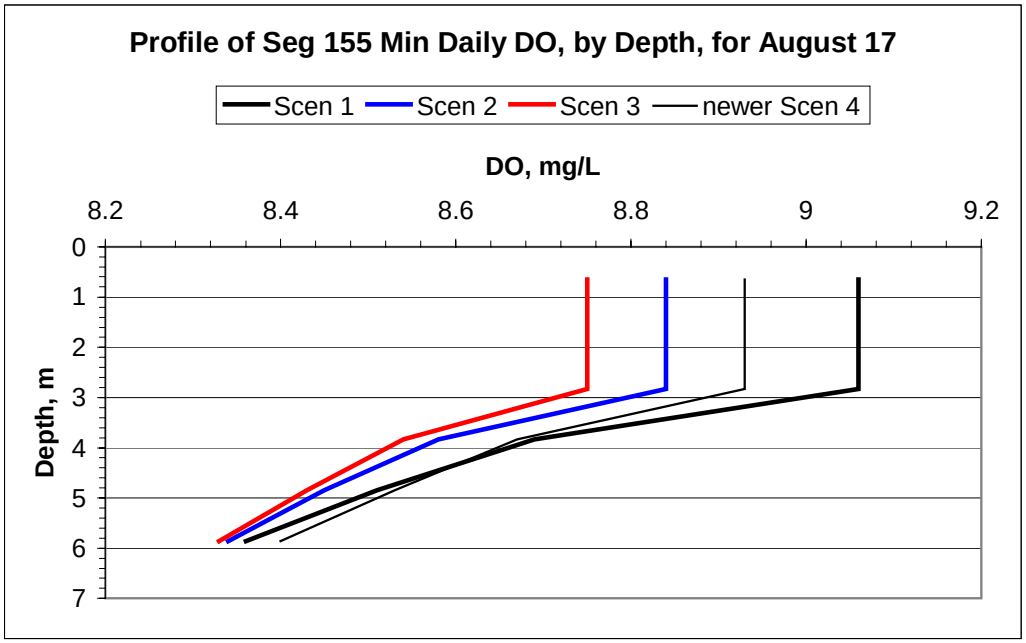


Figure D1-4-9. Minimum DO Profiles, by Depth for Segment 155

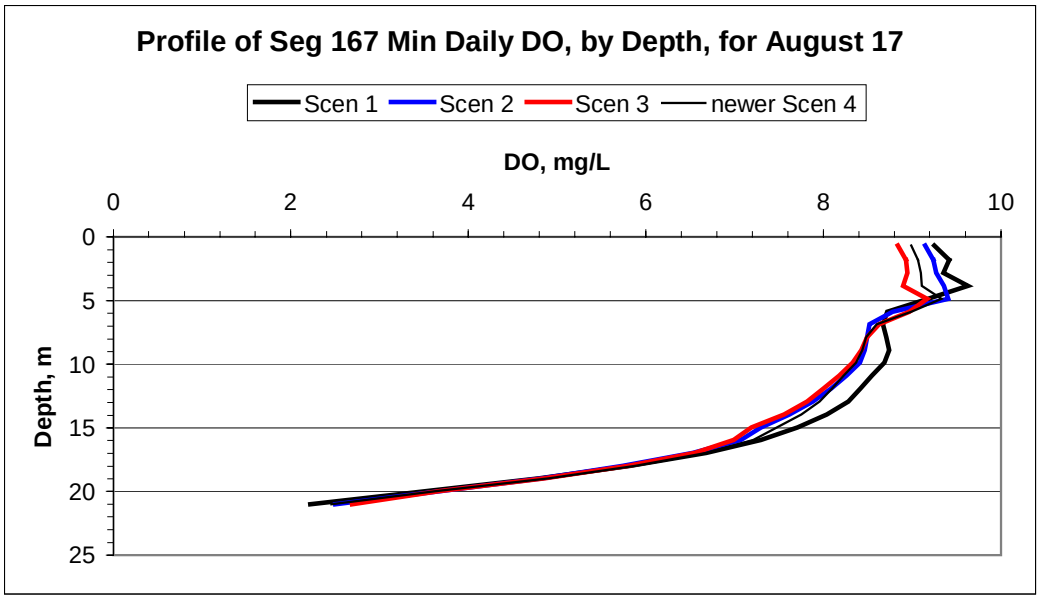


Figure D1-4-10. Minimum DO Profiles by Depth for Segment 167

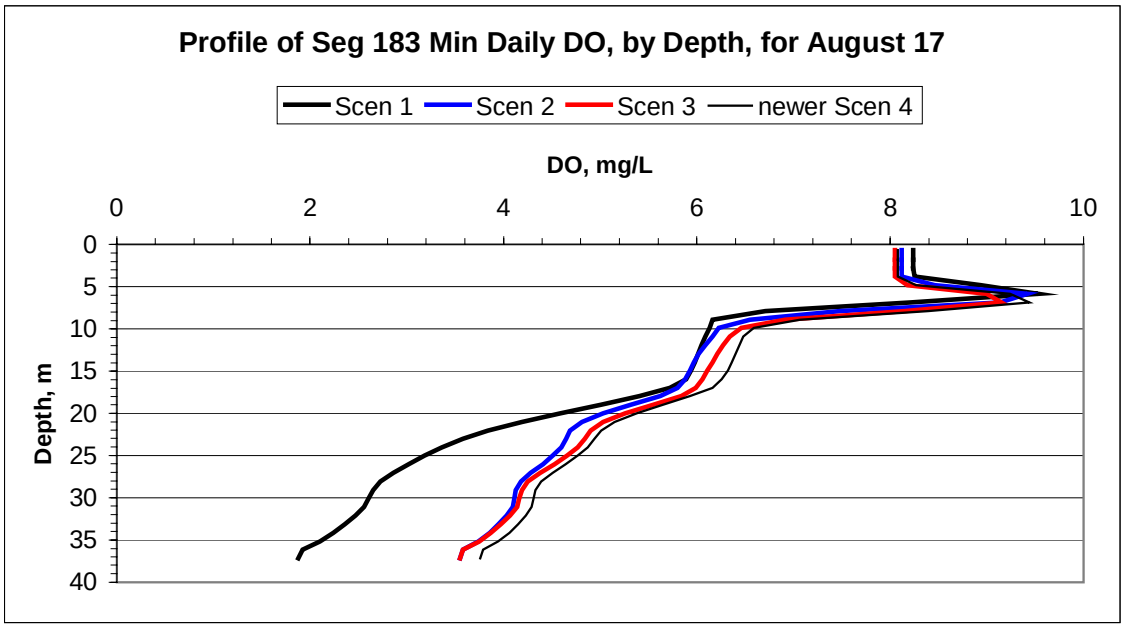


Figure D1-4-11. Minimum DO Profiles by Depth for Segment 183

D1.4.3.2 Depth Contour Charts

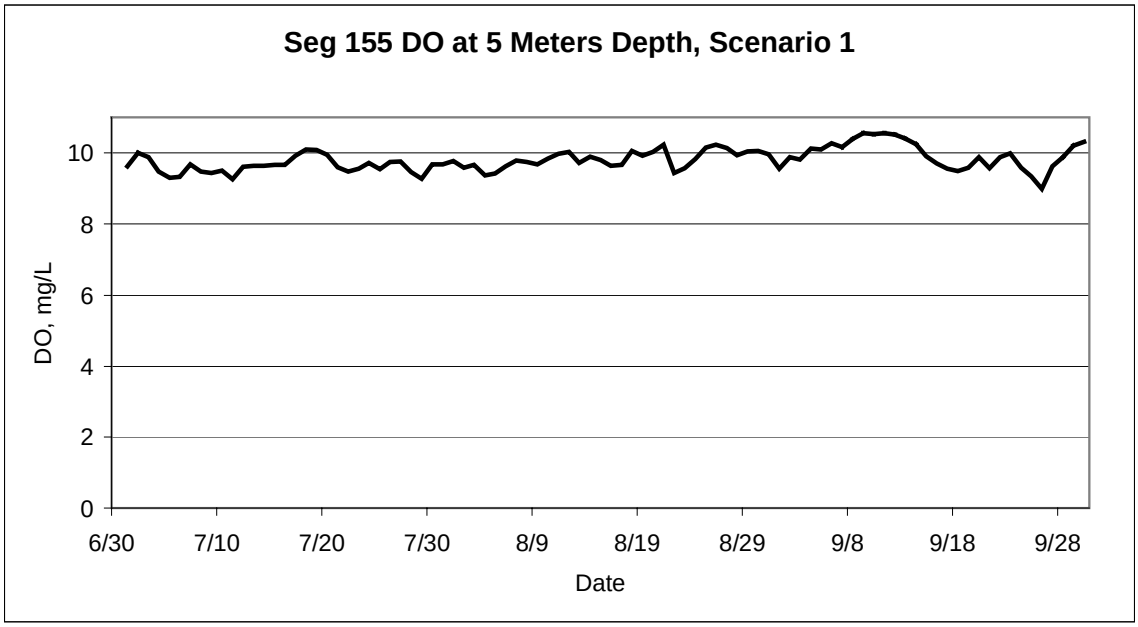


Figure D1-4-12. DO Contour at 5 meters for Segment 155, Scenario 1

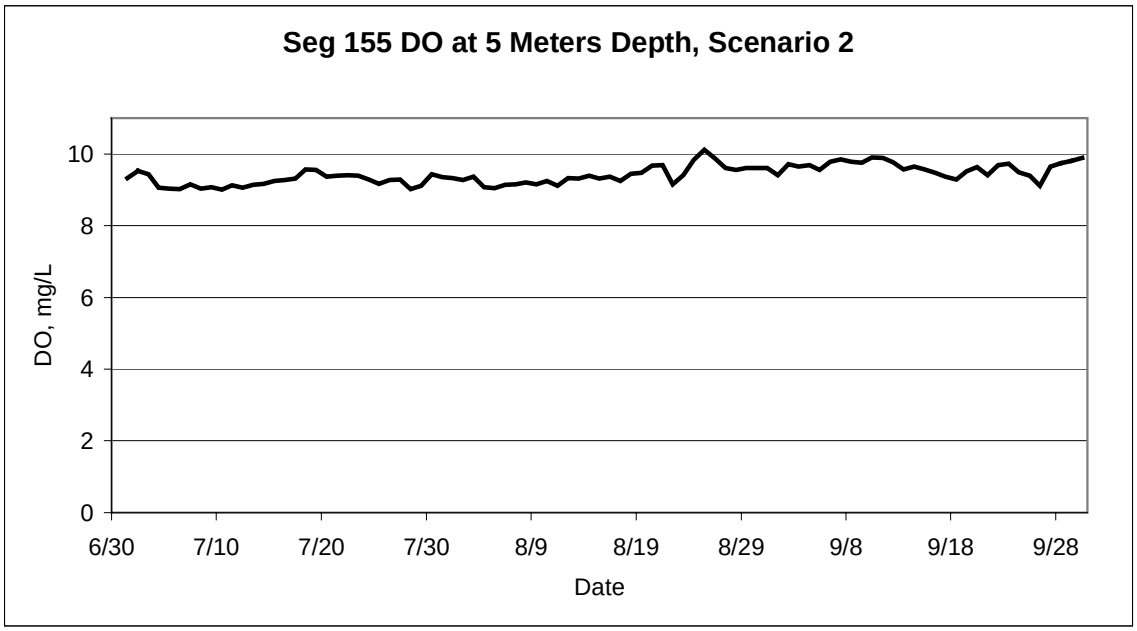


Figure D1-4-13. DO Contour at 5 meters for Segment 155, Scenario 2

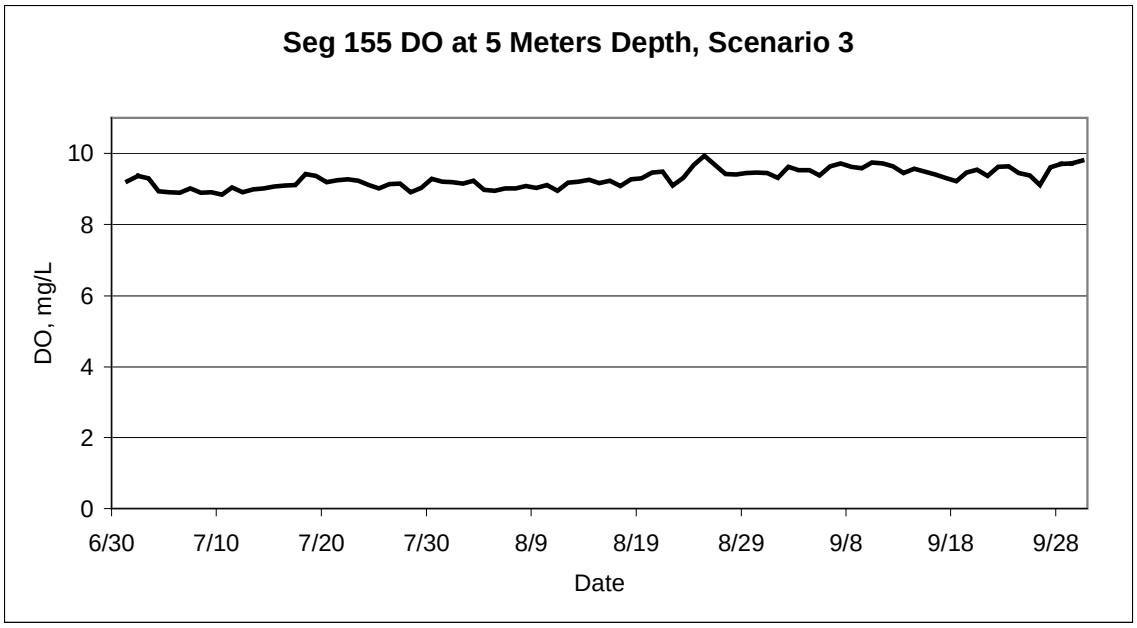


Figure D1-4-14. DO Contour at 5 meters for Segment 155, Scenario 3

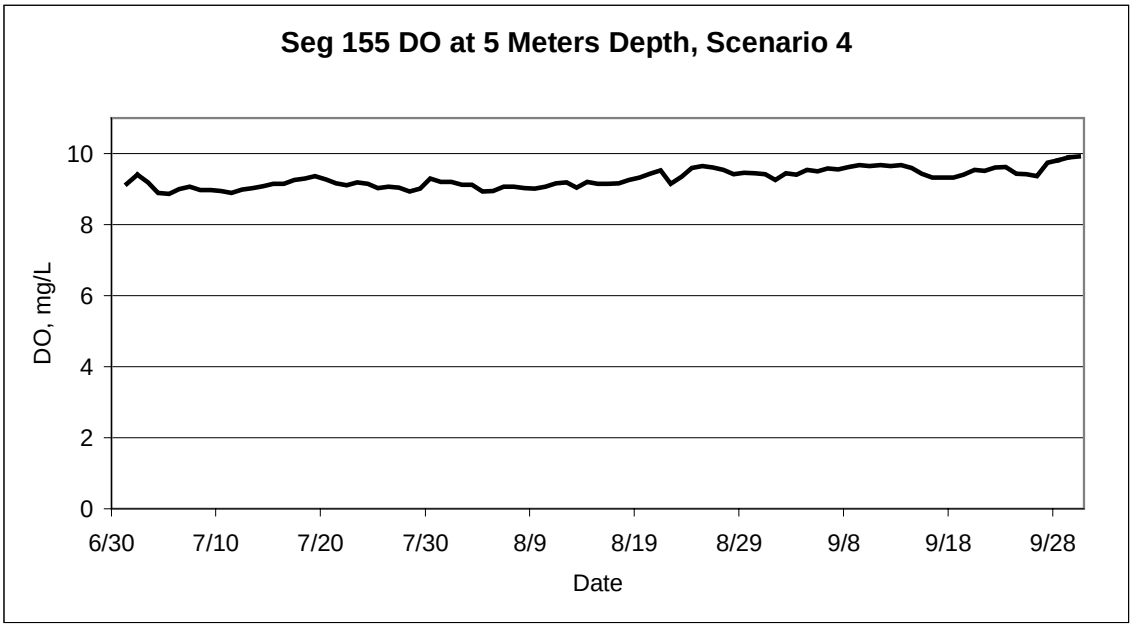


Figure D1-4-15. DO Contour at 5 metersfor Segment 155 , Scenario 4

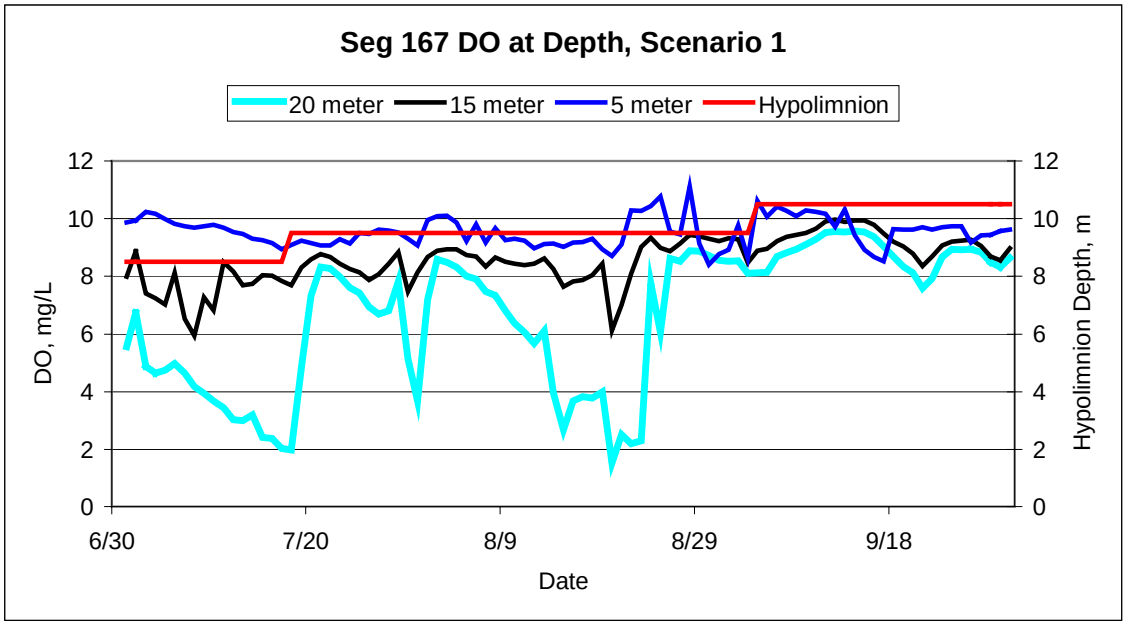


Figure D1-4-16. DO Contours for Segment 167, Scenario 1

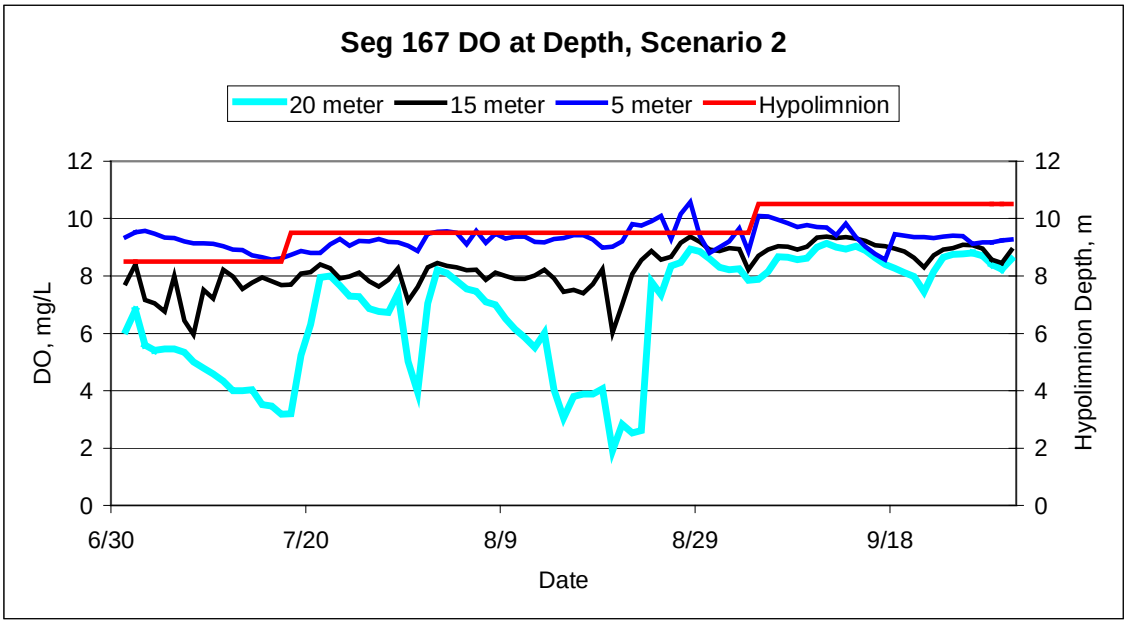


Figure D1-4-17. DO Contours for Segment 167, Scenario 2

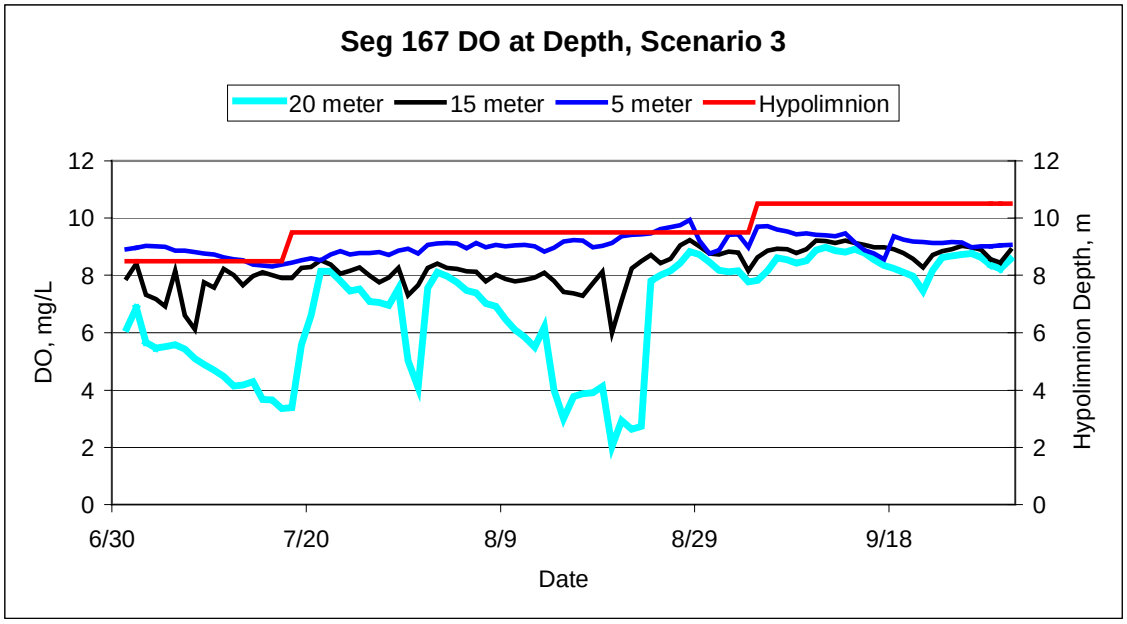


Figure D1-4-18. DO Contours for Segment 167, Scenario 3

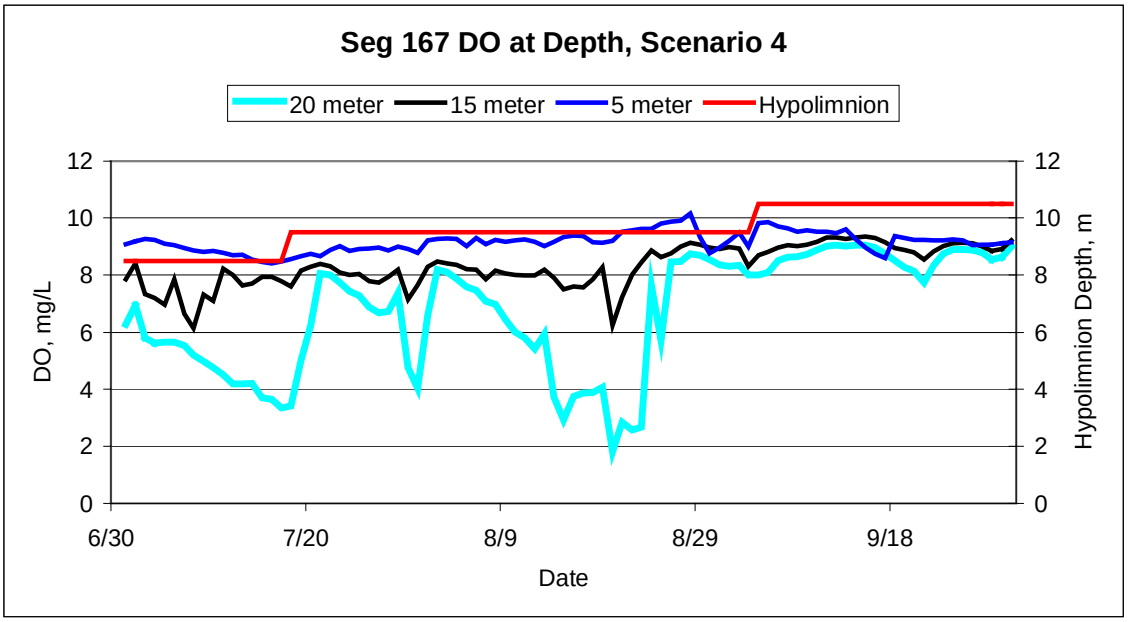


Figure D1-4-19. DO Contours for Segment 167, Scenario 4

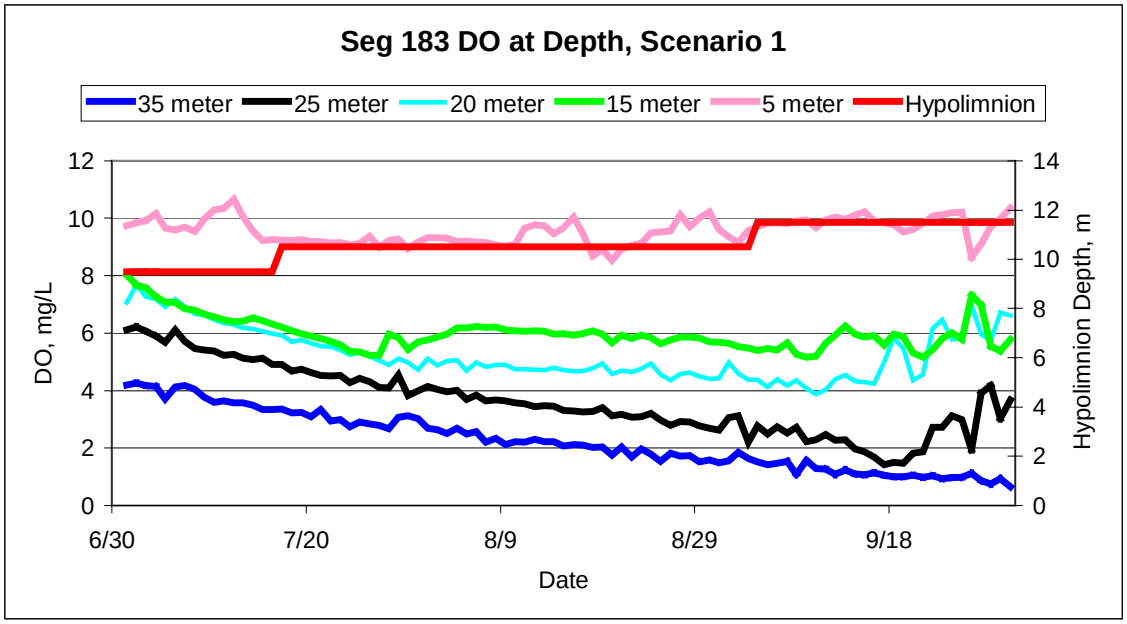


Figure D1-4-20. DO Contours for Segment 183, Scenario 1

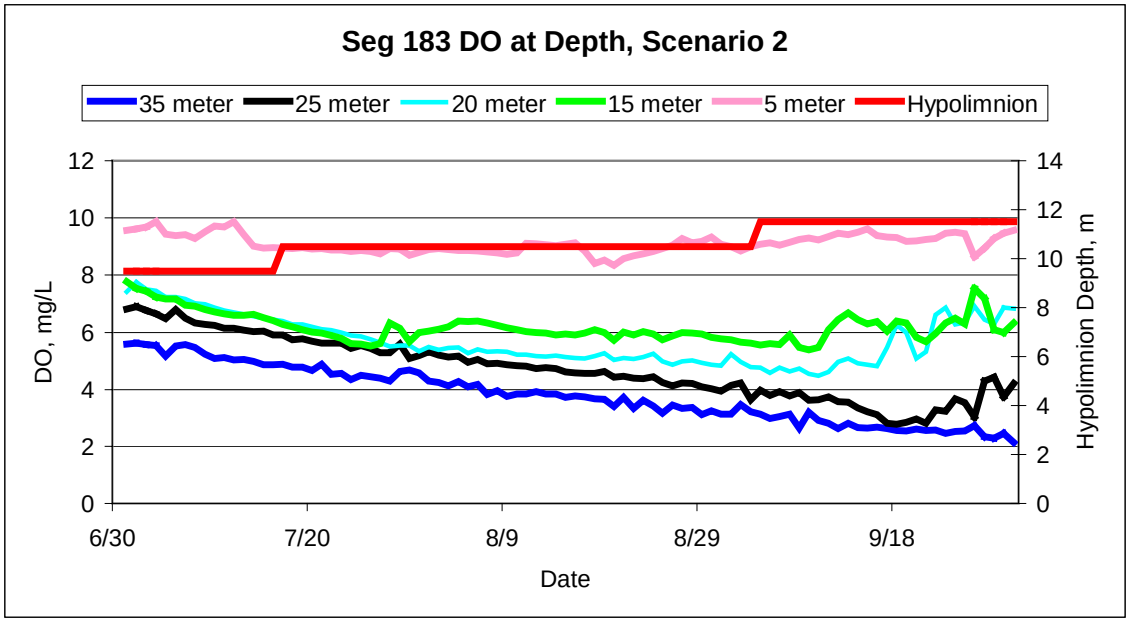


Figure D1-4-21. DO Contours for Segment 183, Scenario 2

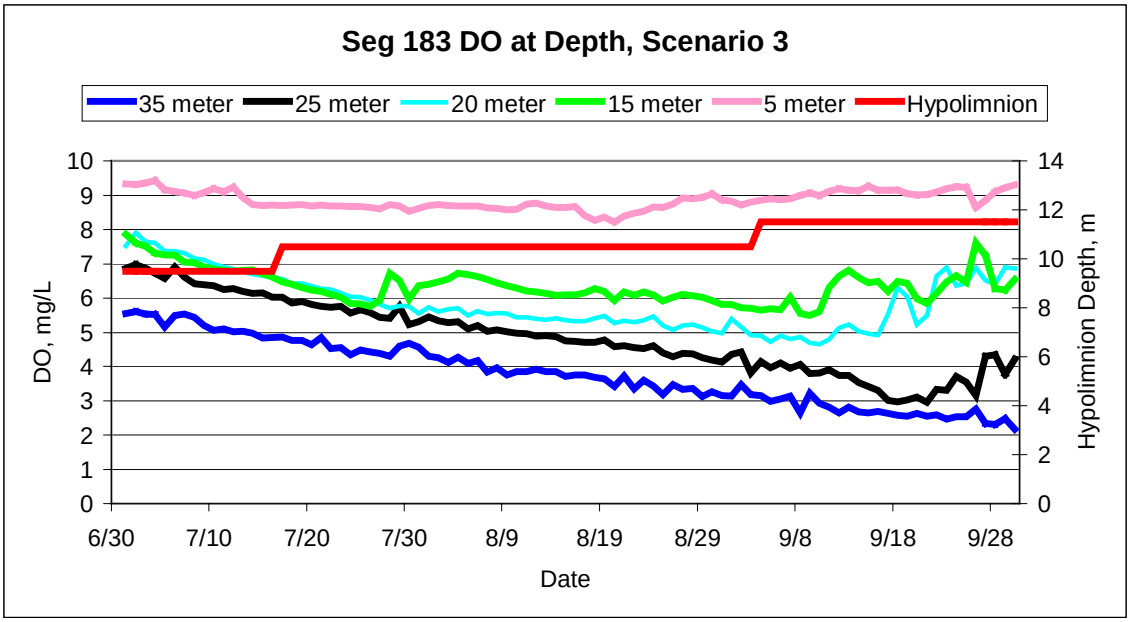


Figure D1-4-22. DO Contours for Segment 183, Scenario 3

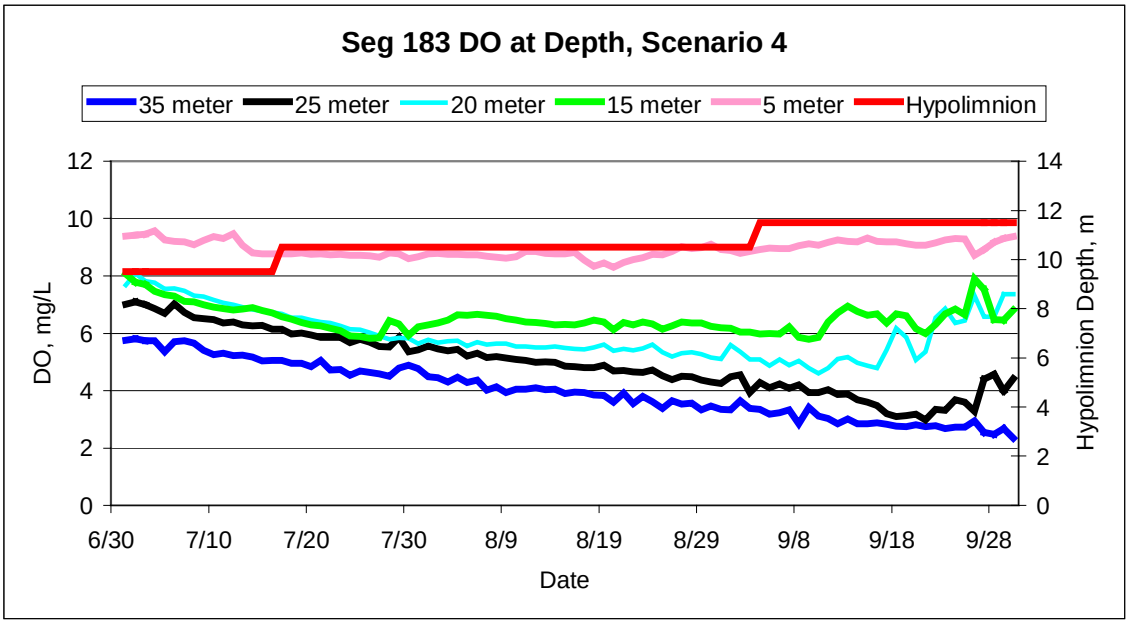


Figure D1-4-23. DO Contours for Segment 183, Scenario 4

D1.4.3.3 Time Series Charts

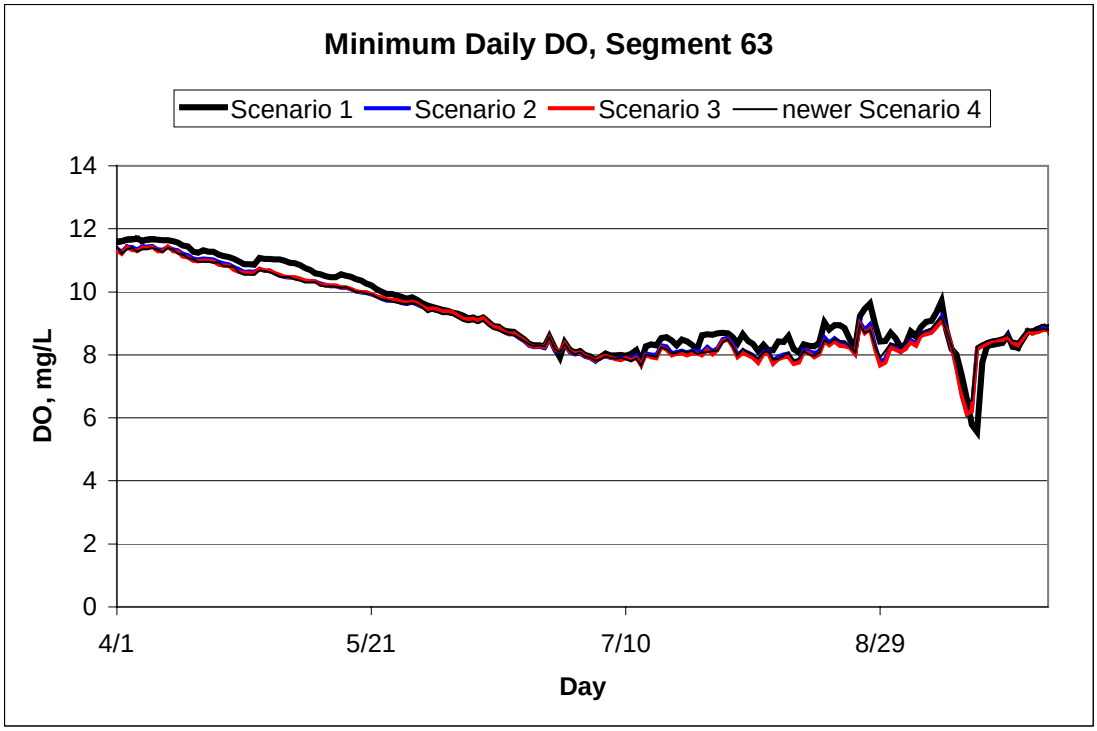


Figure D1-4-24. Minimum Daily DO Concentrations Segment 63

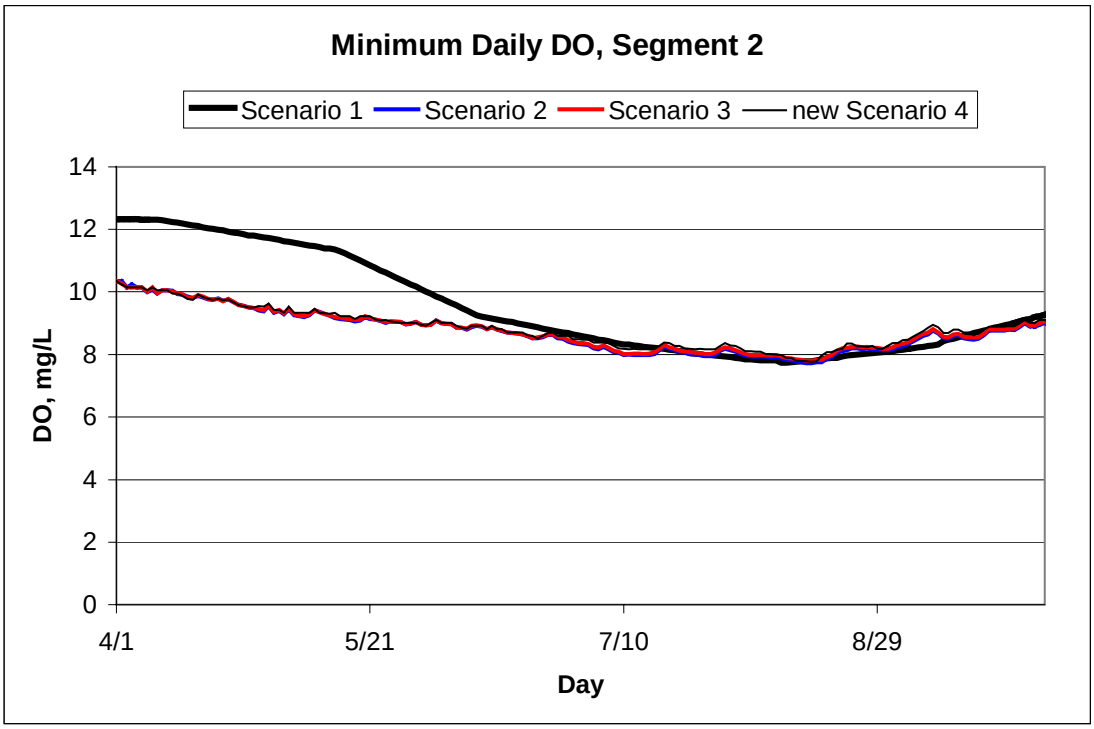


Figure D1-4-25. Minimum Daily DO Concentrations Segment 2

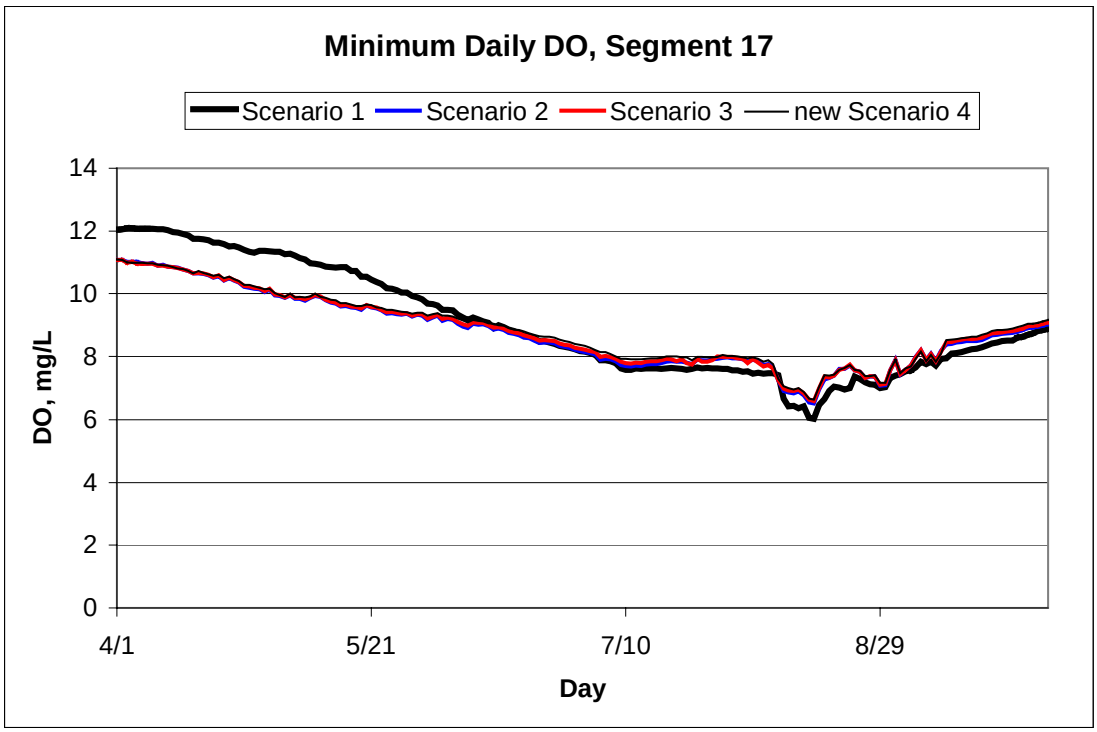


Figure D1-4-26. Minimum Daily DO Concentrations Segment 17

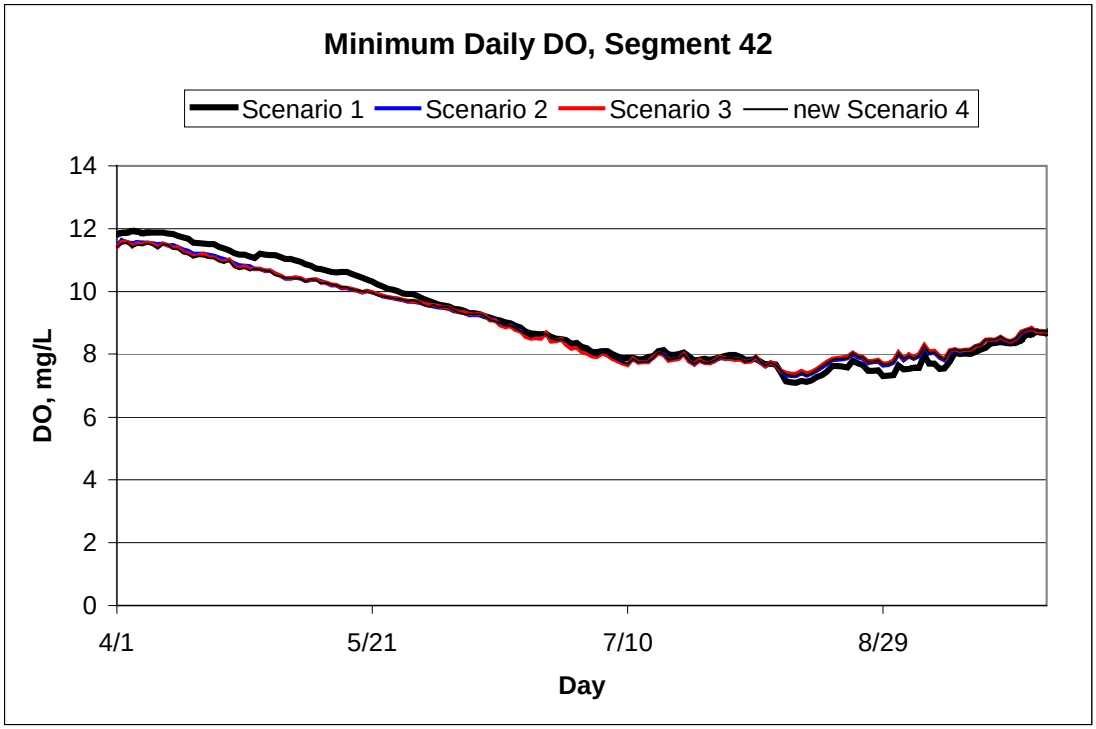


Figure D1-4-27. Minimum Daily DO Concentrations Segment 42

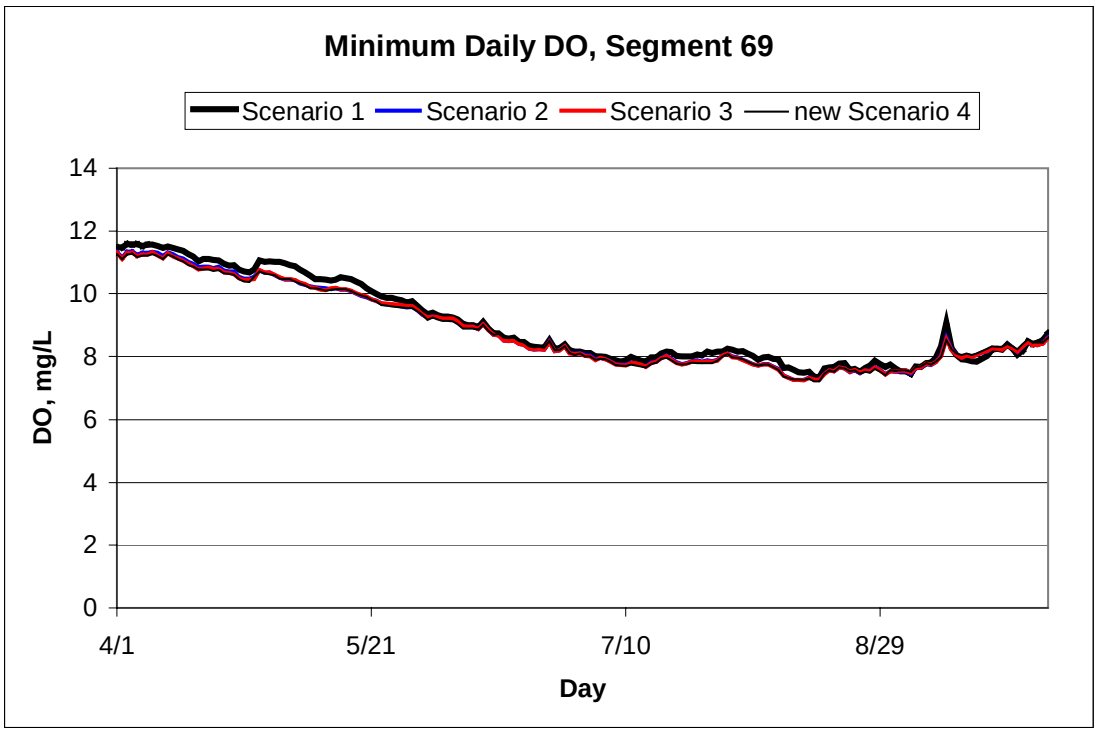


Figure D1-4-28. Minimum Daily DO Concentrations Segment 69

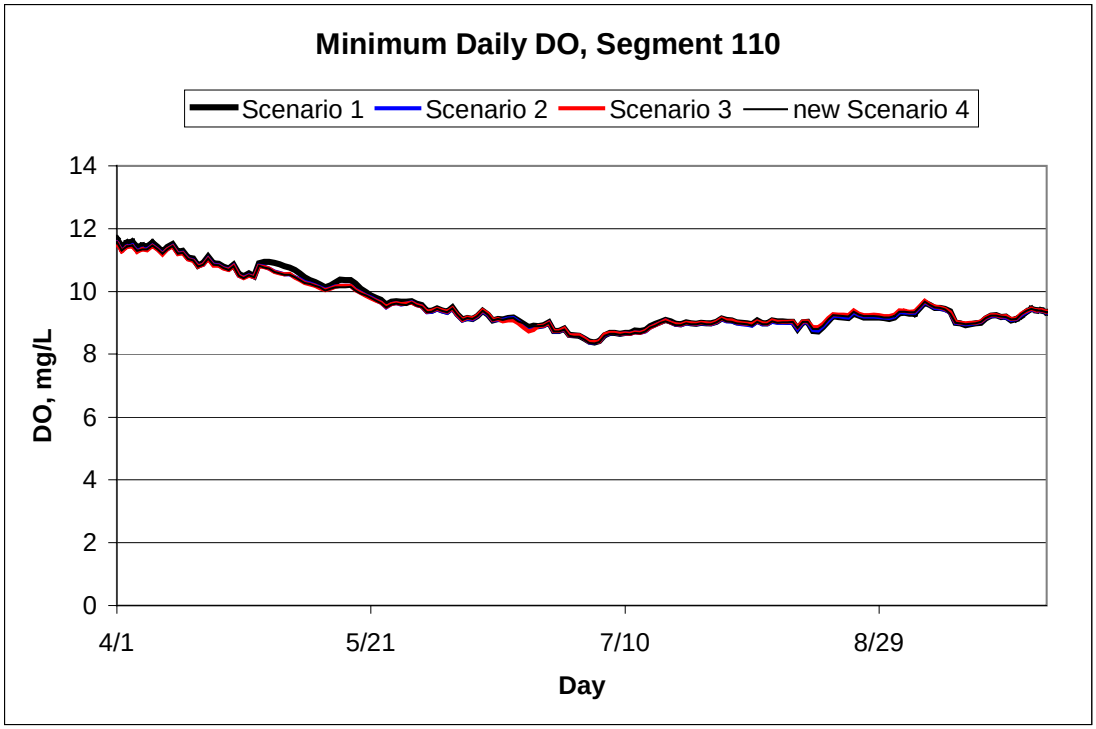


Figure D1-4-29. Minimum Daily DO Concentrations Segment 110

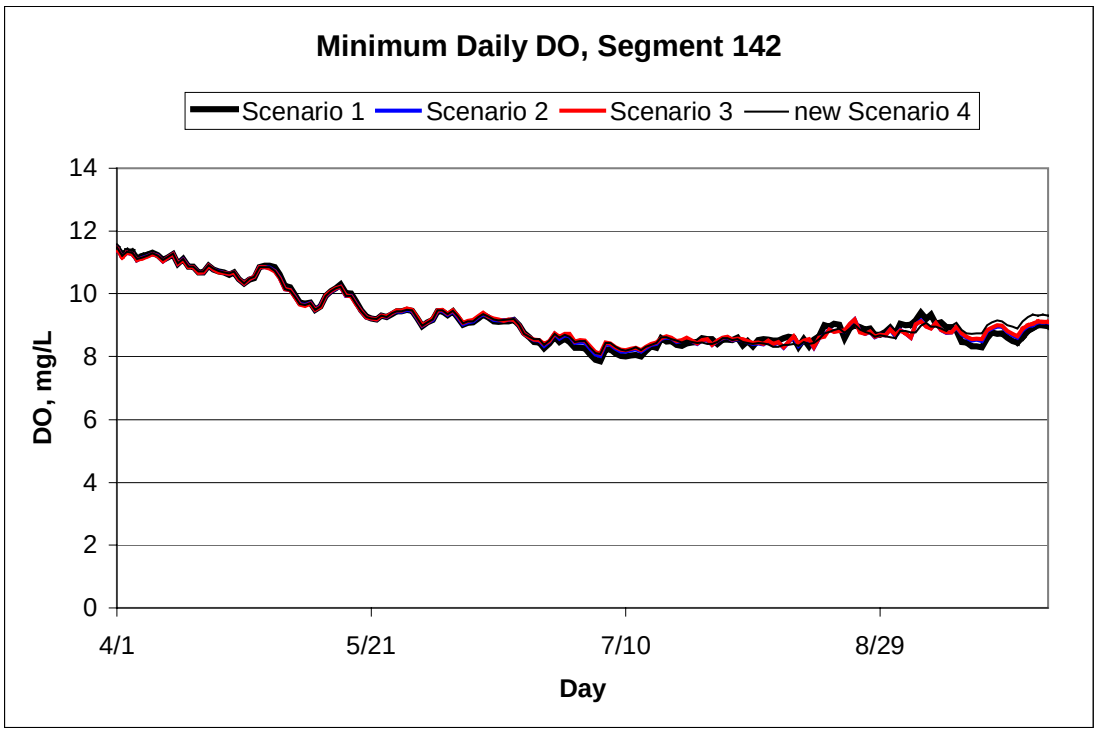


Figure D1-4-30. Minimum Daily DO Concentrations Segment 142

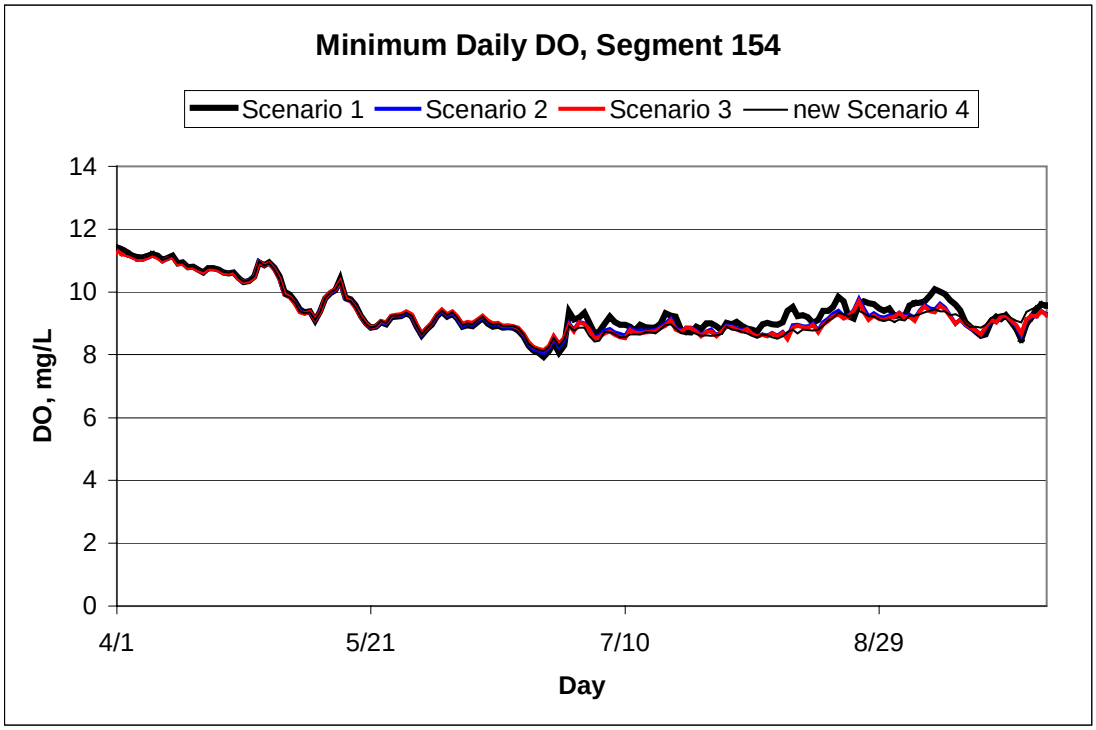


Figure D1-4-31. Minimum Daily DO Concentrations Segment 154

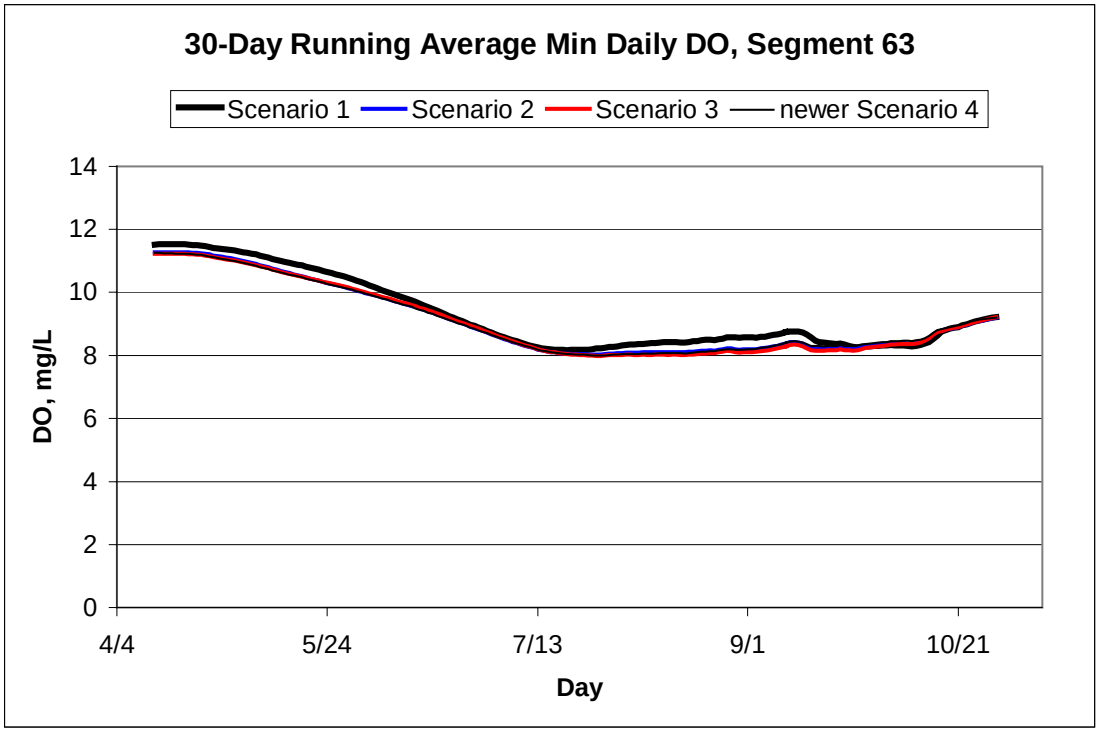


Figure D1-4-32. Thirty - Day Running Average Minimum DO Concentrations Segment 63

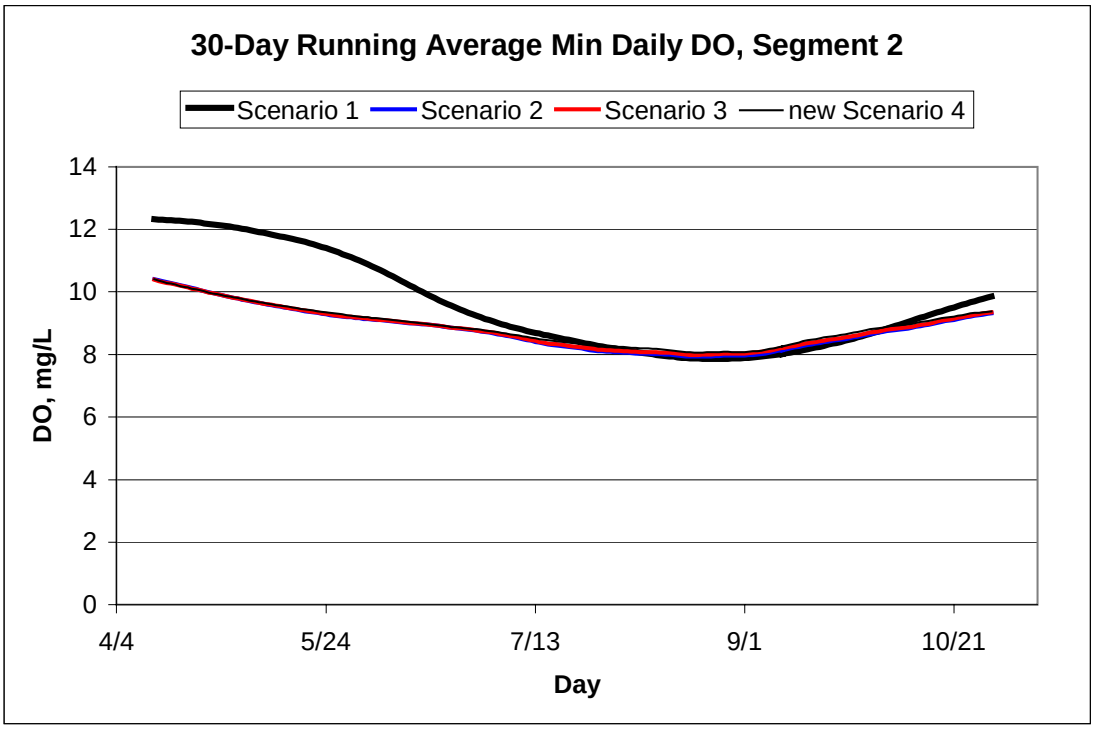


Figure D1-4-33. Thirty - Day Running Average Minimum DO Concentrations Segment 2

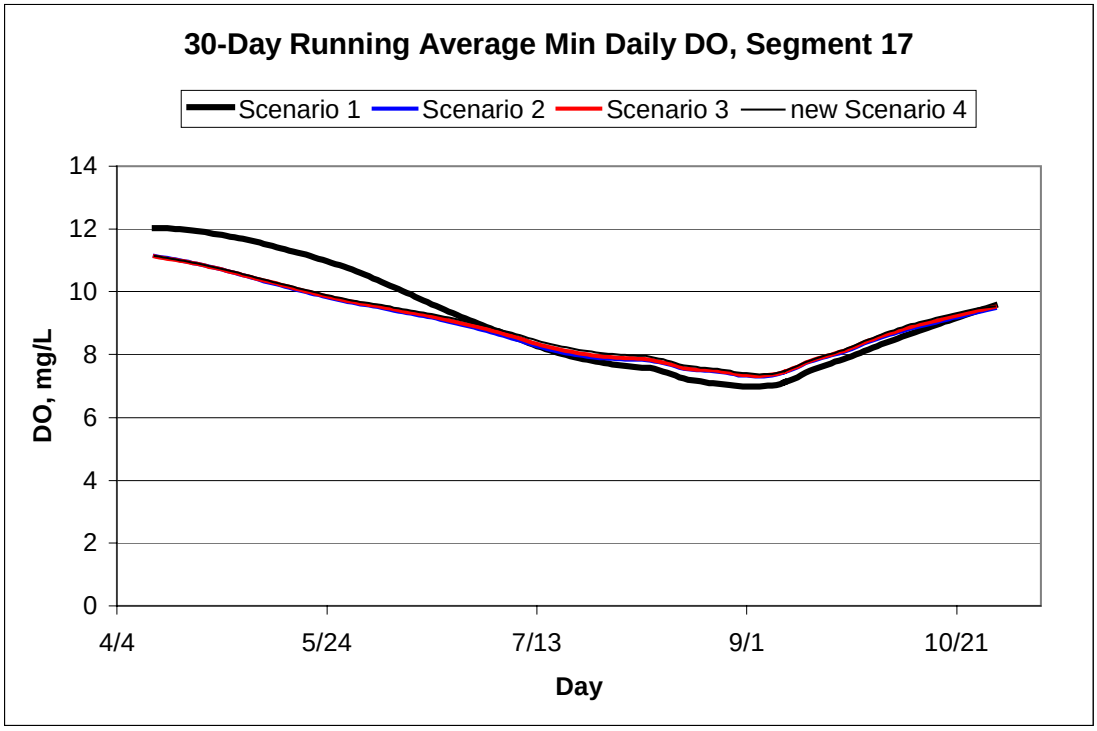


Figure D1-4-34. Thirty - Day Running Average Minimum DO Concentrations Segment 17

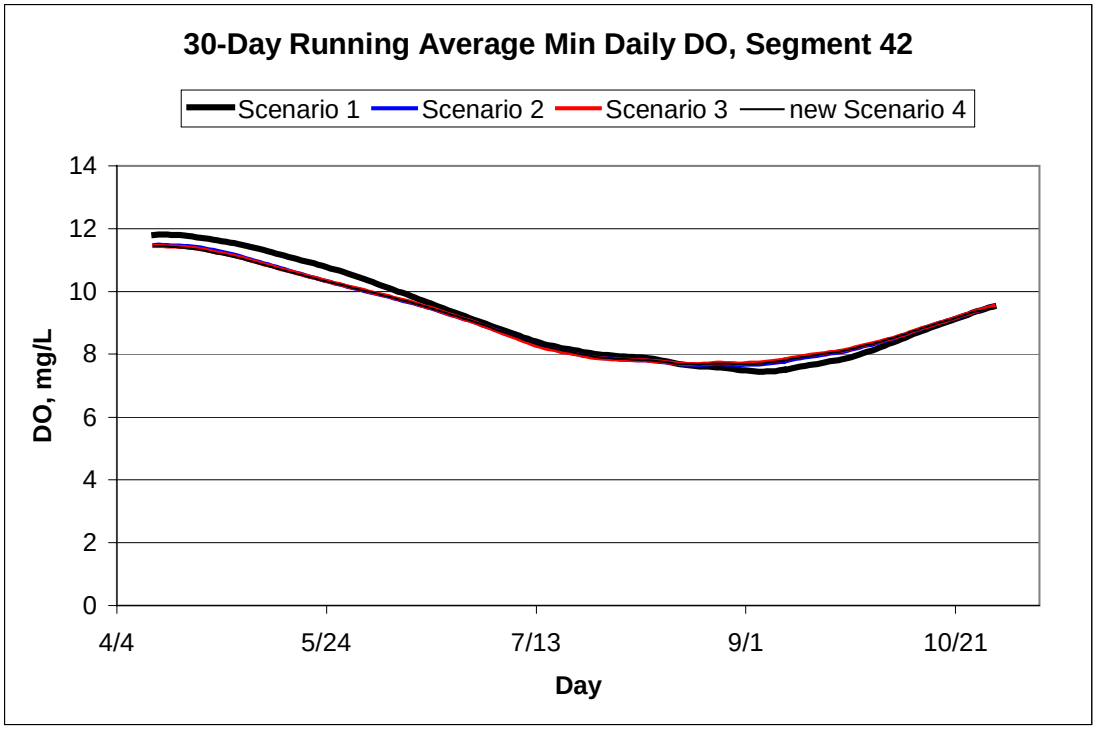


Figure D1-4-35. Thirty - Day Running Average Minimum DO Concentrations Segment 42

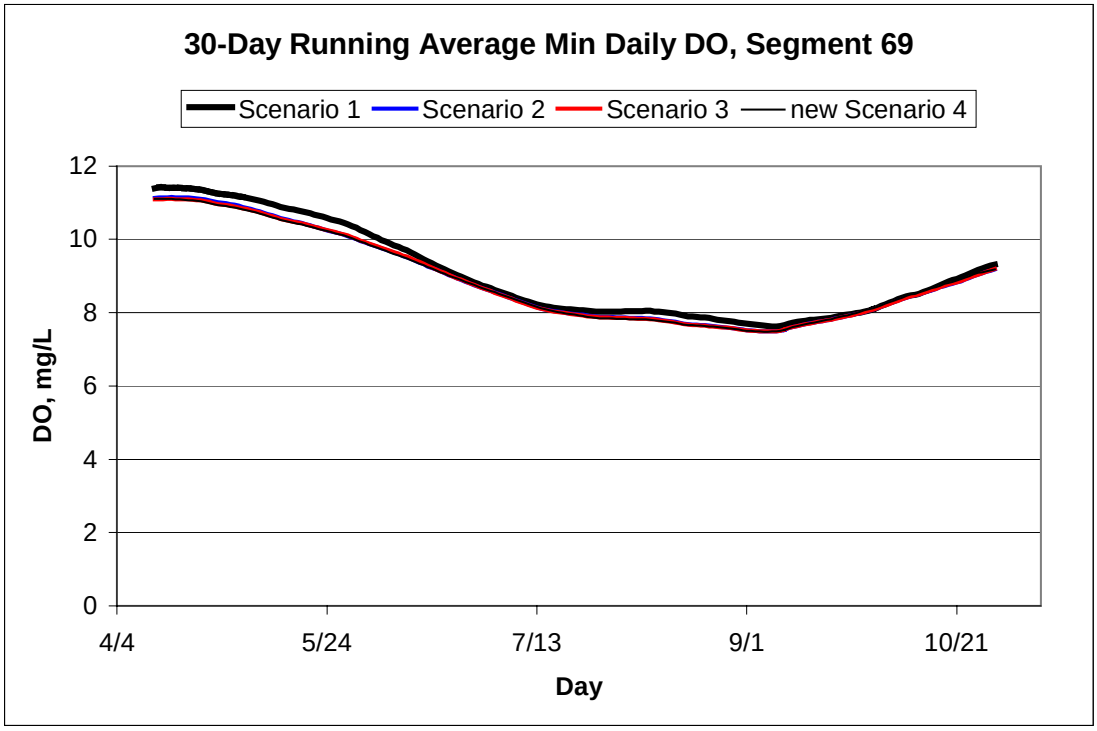


Figure D1-4-36. Thirty - Day Running Average Minimum DO Concentrations Segment 69

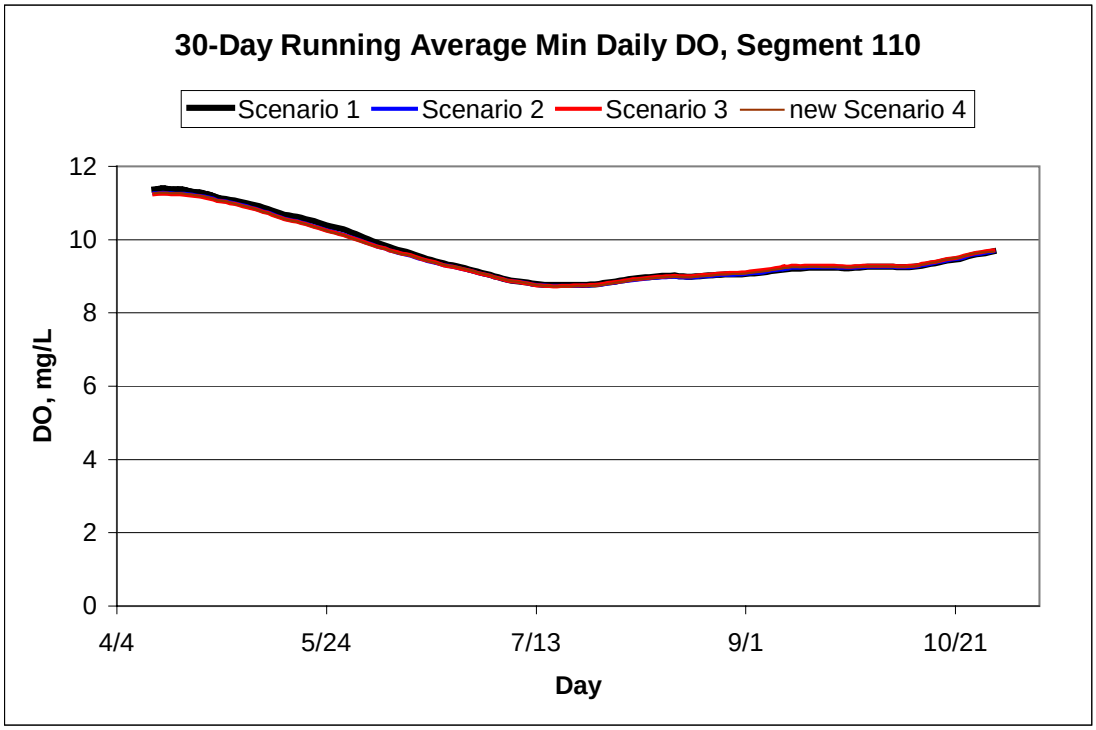


Figure D1-4-37. Thirty - Day Running Average Minimum DO Concentrations Segment 110

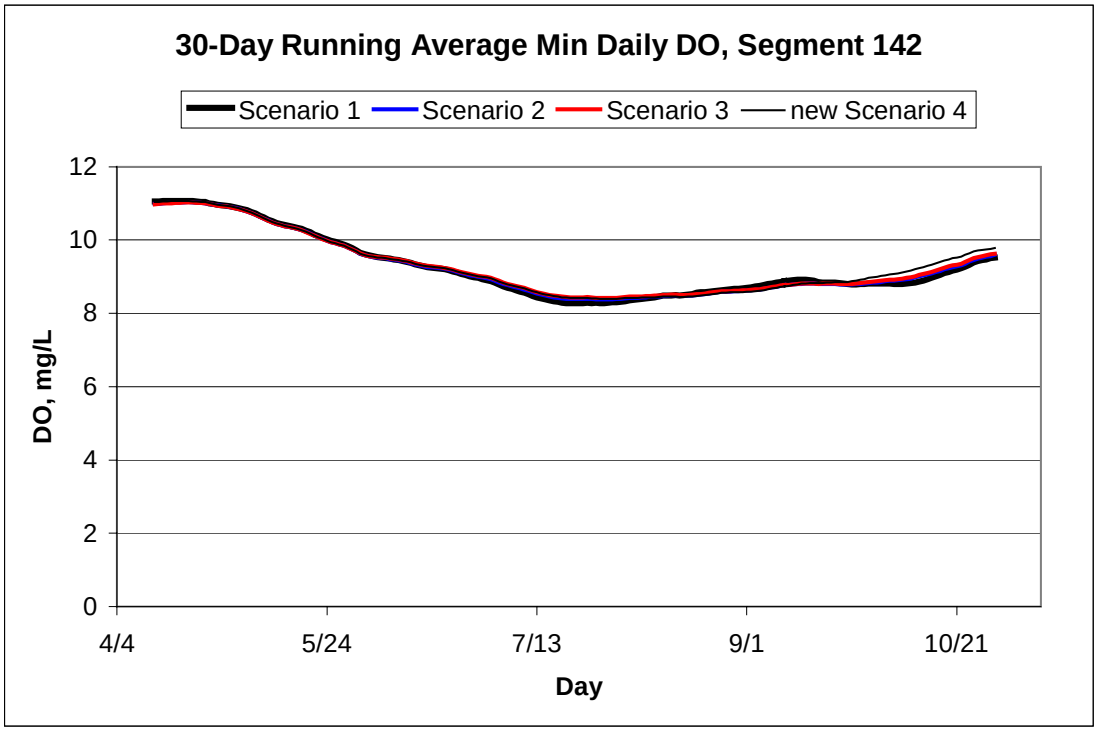


Figure D1-4-38. Thirty - Day Running Average Minimum DO Concentrations Segment 142

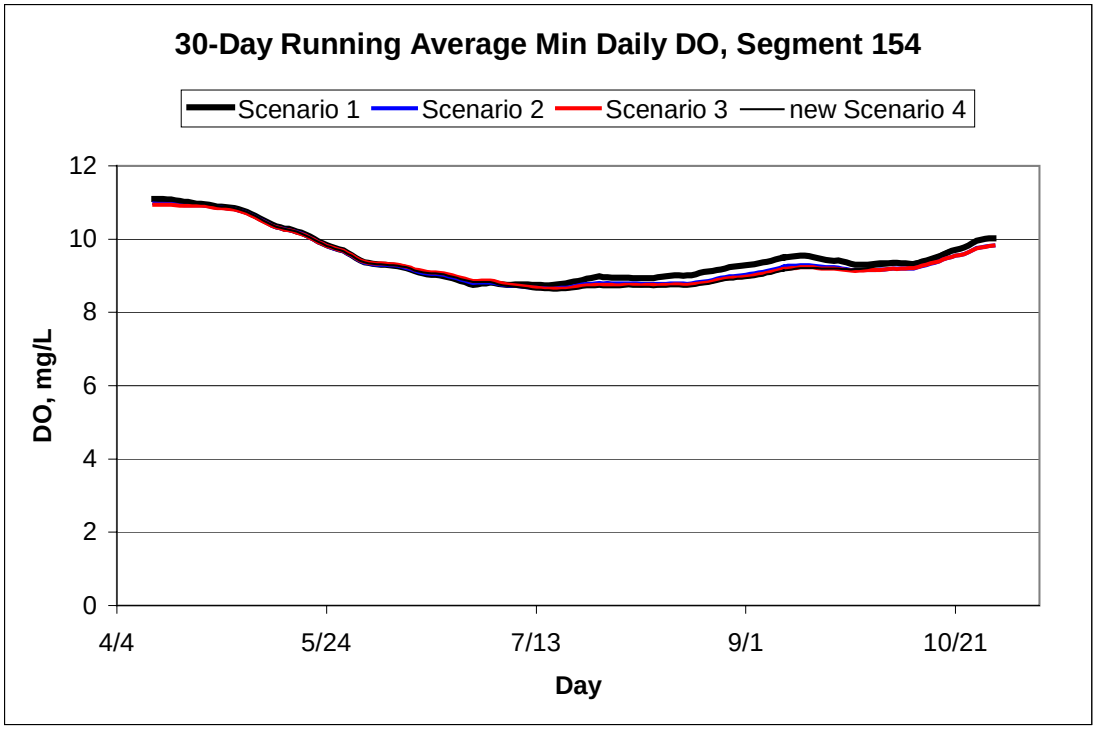


Figure D1-4-39. Thirty - Day Running Average Minimum DO Concentrations Segment 154

D1.5. REFERENCES

Cole, Thomas M. and Wells, Scott A. 2003. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.1 – User Manual – Draft Report. Instruction Report EL-03-1.

Berger, Christopher J. et al. 2002. Upper Spokane River Model: Model Calibration – Draft. Technical Report EWR-01-02.

Berger, Christopher J. et al. 2004. Review of Spokane River Model for Washington Department of Ecology. Technical Report EWR-01-04.

Slominski, Spencer et al. 2002. Upper Spokane River Model: Boundary Conditions and Model Setup, 2001. Technical Report EWR-04-02.

Wells, Scott A. et al. 2003. Upper Spokane River Model in Idaho: Boundary Conditions and Model Setup for 2001. Technical Report EWR-02-03.

Appendix D2

TMDL Model Parameters for Updated Next Level of Treatment Table

Table

TMDL Model Parameters for Updated Next Level of Treatment 7-6-04

Appendix D2 of Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

TABLE D2-1
TMDL Model Parameters for Updated Next Level of Treatment
7-6-04

Discharger	Phosphorous Total P	TSS	BOD	CBOD	Ammonia	Flow
City of Spokane and Spokane County Regional Plant	0.06 mg/L CV = 0.6	1.5 mg/L CV =0 .5	2 mg/L CV = 0.6: *create synthetic time series by using a CV of 0.6mg/L*	1.4 mg/L CV = 0.6	*Use the same concentration as used in the Next Level of Treatment*.	65 mgd (Average Dry Weather Flows) *Use existing flows to determine CV and generate a synthetic time series flows to average 65 mgd from April to October 30.*
Liberty Lake	0.06 mg/L	1.5 mg/L	2 mg/L	1.4 mg/L CV = 0.6	*Use the same concentration as used in the Next Level of Treatment*.	2 mgd *Use existing flows to determine CV and generate a synthetic time series flows to average 2 mgd*
Post Falls	0.06 mg/L	1.5 mg/L	2 mg/L	1.4 mg/L CV = 0.6		*Use current flows*
Coeur d'Alene	0.06 mg/L	1.5 mg/L	2 mg/L	1.4 mg/L CV = 0.6		*Use current flows*
Hayden Regional	0	0	0		0	0
Inland Empire Paper Company	0.2 mg/L *Create synthetic time series by using existing time series in the model to create a CV to average 0.2 mg/L*	*Use same data as in next level of treatment model run*	*Use same data as in next level of treatment model run*		*Use same data as in next level of treatment model run*	*Use same data as in next level of treatment model run*
Kaiser Aluminum	0.06 mg/L	12.5	8 mg/L Ultimate BOD		Ammonia = 0.1 Nitrate/Nitrate = 1.2	16.5 mgd variation of 2.5 mgd

Appendix D3

Additional Charts of LTI CE-QUAL-W2 Modeling Results for Year 2001

Figures

Additional Charts of LTI CE-QUAL-W2 Modeling Results for Year 2001

Appendix D3 of Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

APPENDIX D3

Additional Charts of LTI CE-QUAL-W2 Modeling Results for Year 2001

This Appendix includes the following charts:

- D3-1. Seg 167 DO at Depth of 5 Meters
- D3-2. Seg 167 DO at Depth of 15 Meters
- D3-3. Seg 167 DO at Depth of 20 Meters
- D3-4. Seg 183 DO at Depth of 5 Meters
- D3-5. Seg 183 DO at Depth of 15 Meters
- D3-6. Seg 183 DO at Depth of 20 Meters
- D3-7. Seg 183 DO at Depth of 25 Meters
- D3-8. Seg 183 DO at Depth of 35 Meters
- D3-9. Profile of Seg 155 Max Daily Temperature, by Depth, for August 17
- D3-10. Profile of Seg 167 Max Daily Temperature, by Depth, for August 17
- D3-11. Profile of Seg 183 Max Daily Temperature, by Depth, for August 17

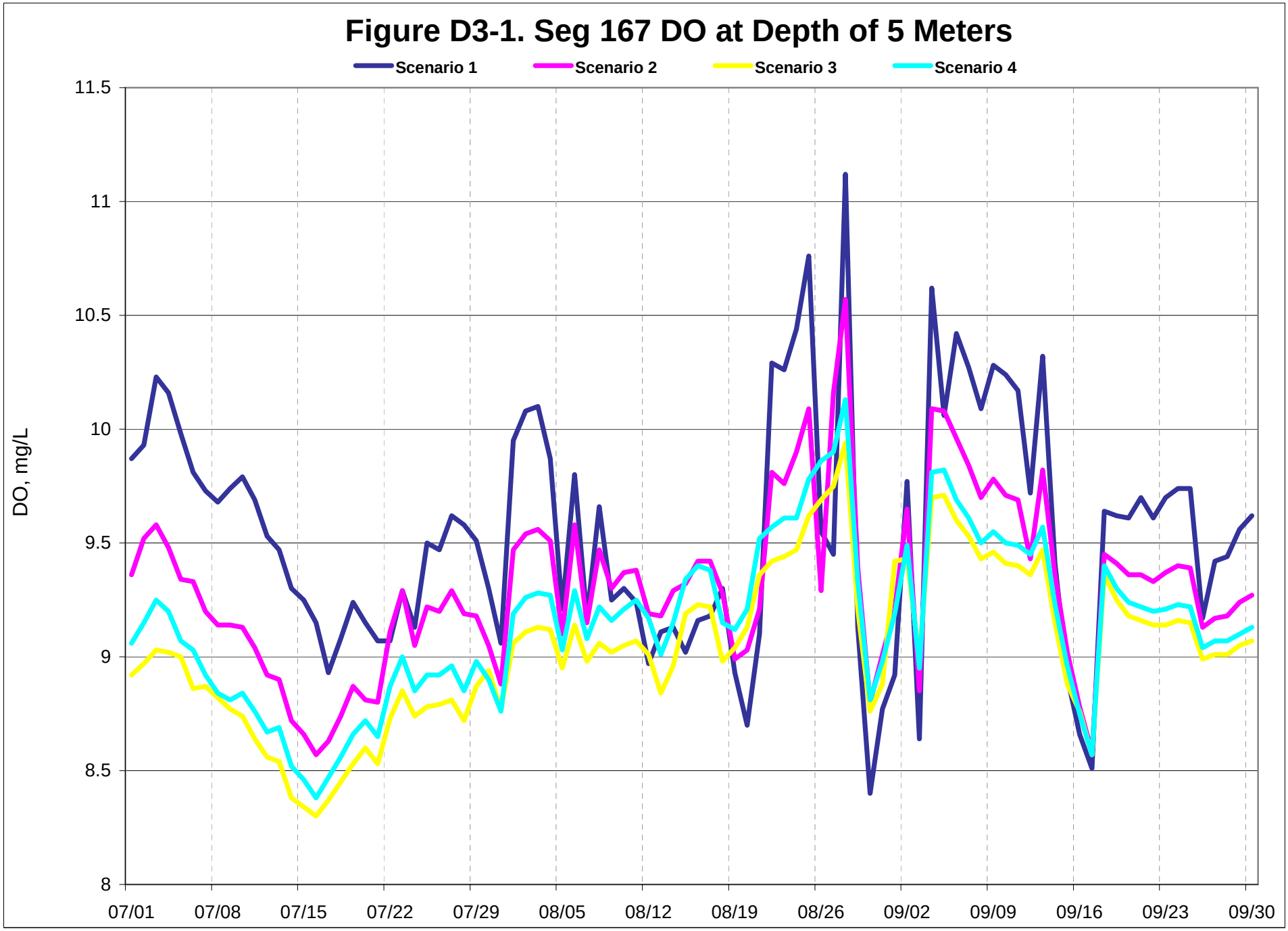


Figure D3-1. Seg 167 DO at Depth of 5 Meters
Scenario 1
Scenario 2
Scenario 3
Scenario 4
DO, mg/L
11.5
11
10.5
10
9.5
9
8.5
8
07/01
07/08
07/15
07/22
07/29
08/05
08/12
08/19
08/26
09/02
09/09
09/16
09/23
09/30

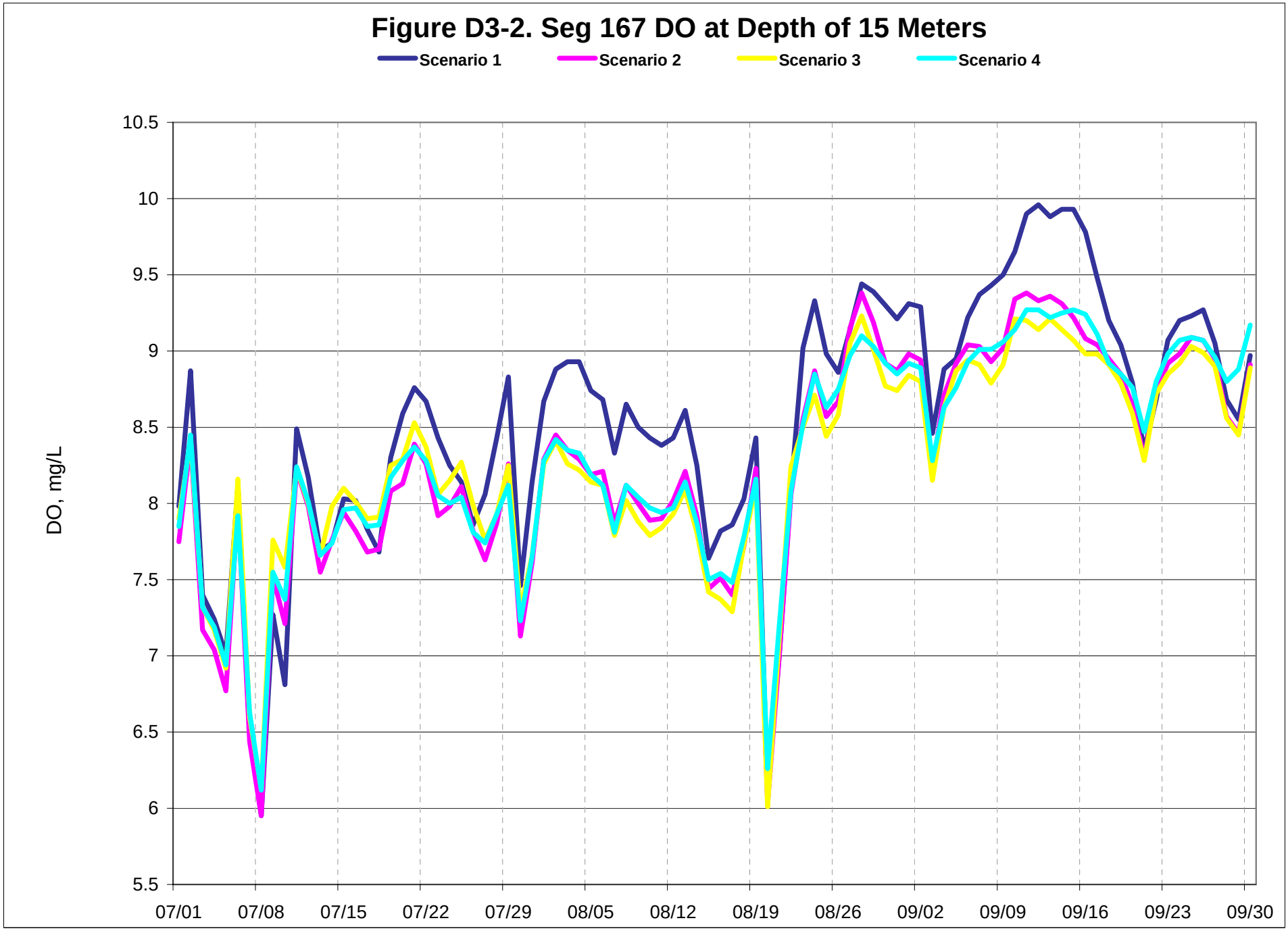
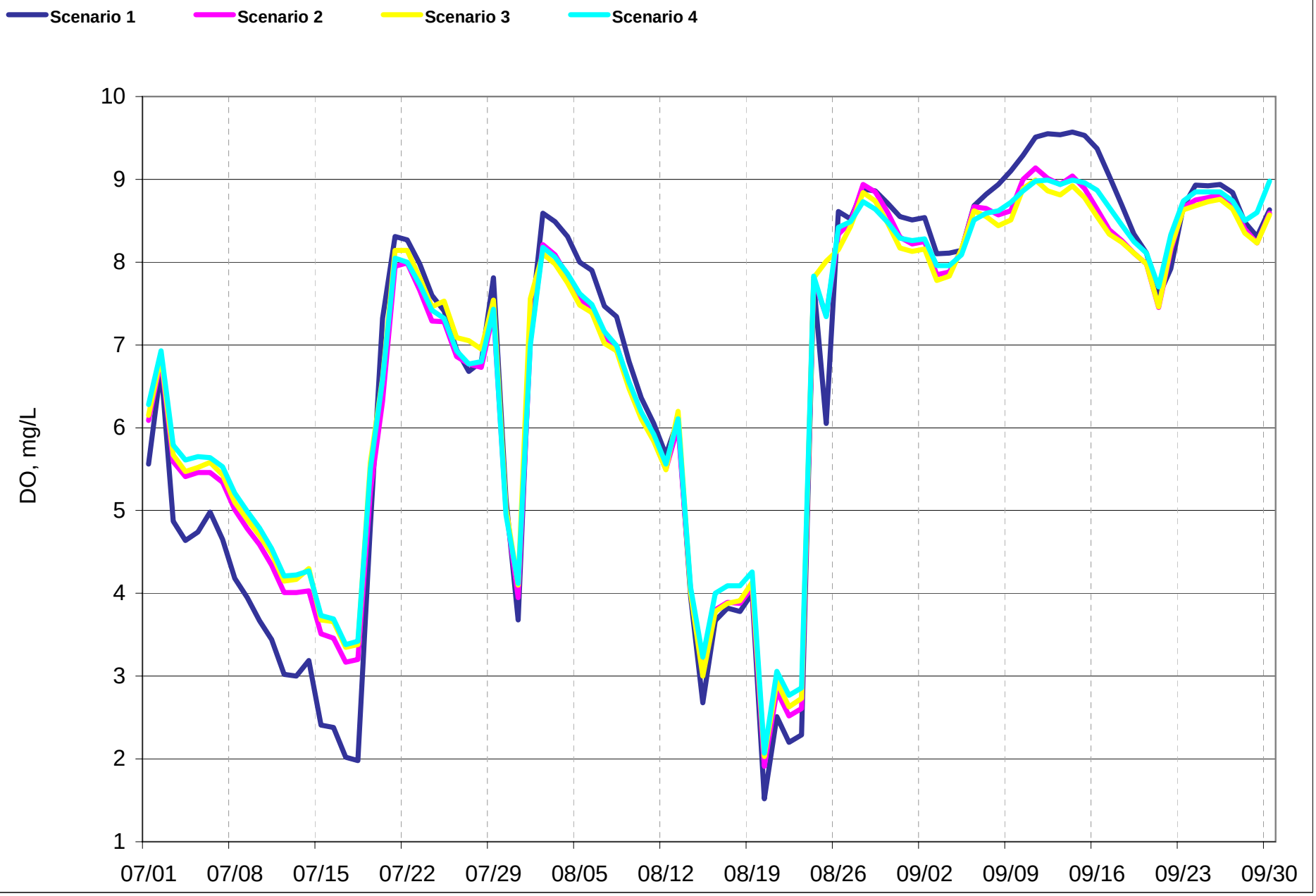


Figure D3-2. Seg 167 DO at Depth of 15 Meters
Scenario 1
Scenario 2
Scenario 3
Scenario 4
DO, mg/L
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
07/01
07/08
07/15
07/22
07/29
08/05
08/12
08/19
08/26
09/02
09/09
09/16
09/23
09/30

Figure D3-3. Seg 167 DO at Depth of 20 Meters



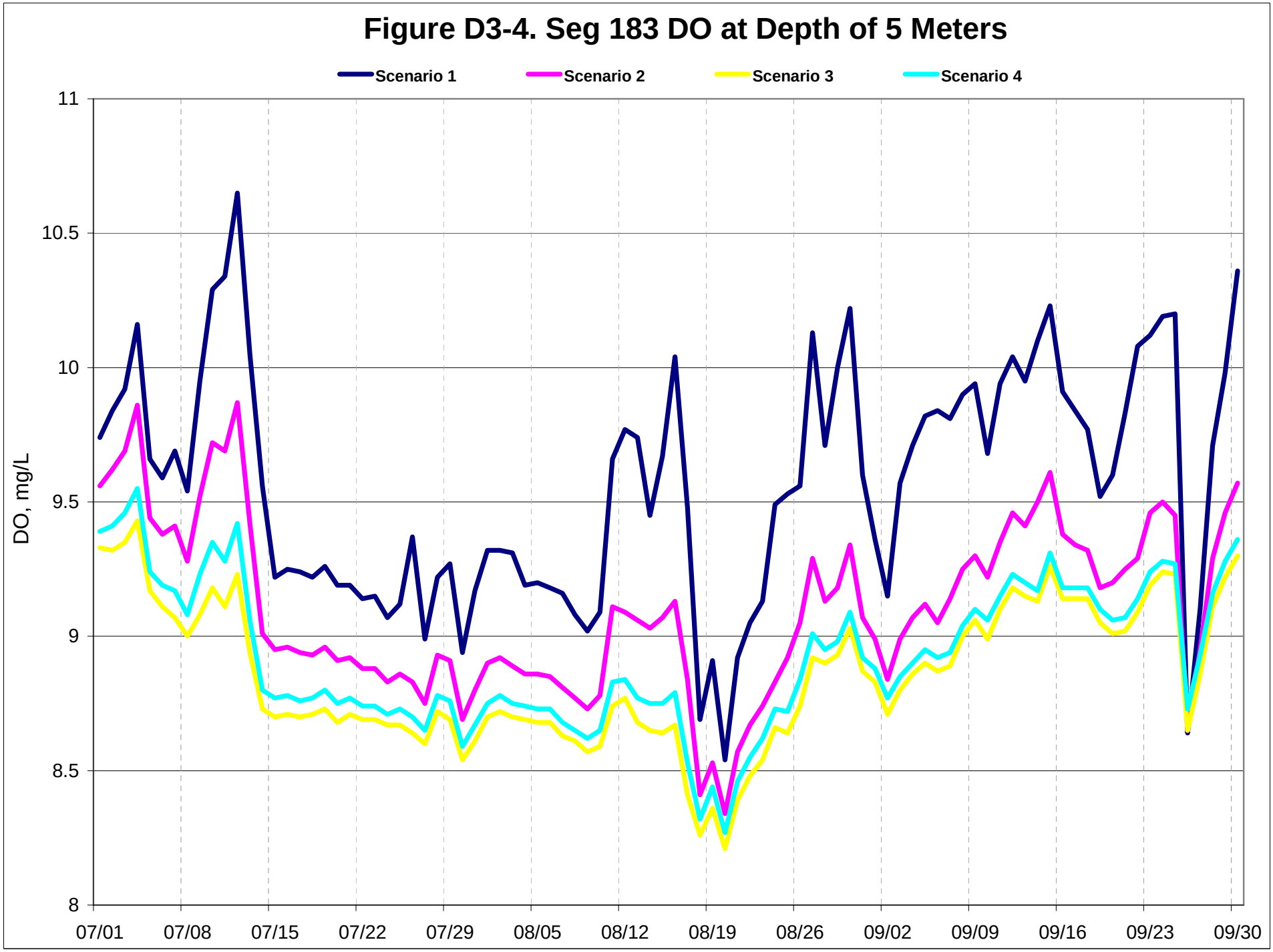
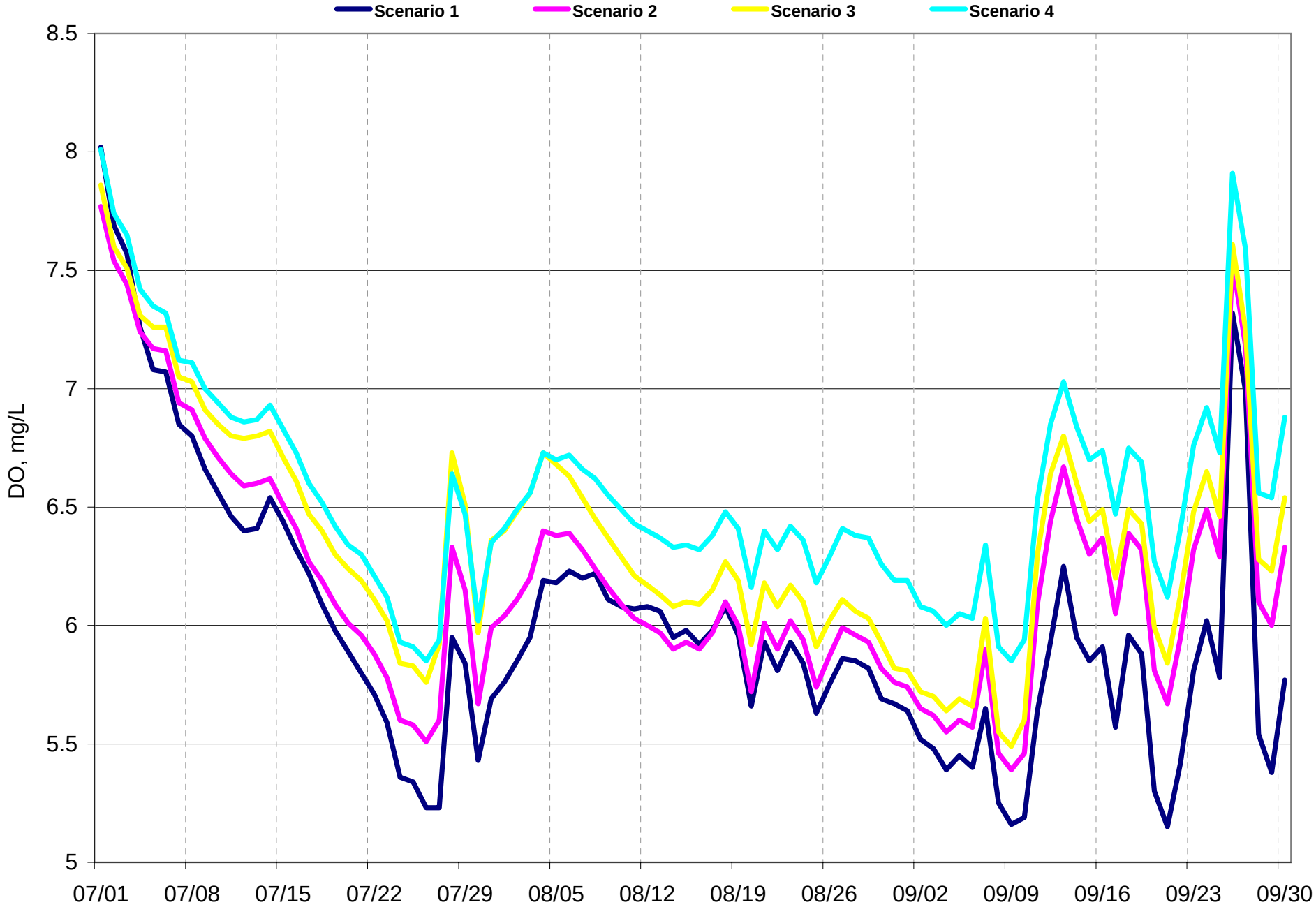


Figure D3-4. Seg 183 DO at Depth of 5 Meters
Scenario 1
Scenario 2
Scenario 3
Scenario 4
DO, mg/L
11
10.5
10
9.5
9
8.5
8
07/01
07/08
07/15
07/22
07/29
08/05
08/12
08/19
08/26
09/02
09/09
09/16
09/23
09/30

Figure D3-5. Seg 183 DO at Depth of 15 Meters



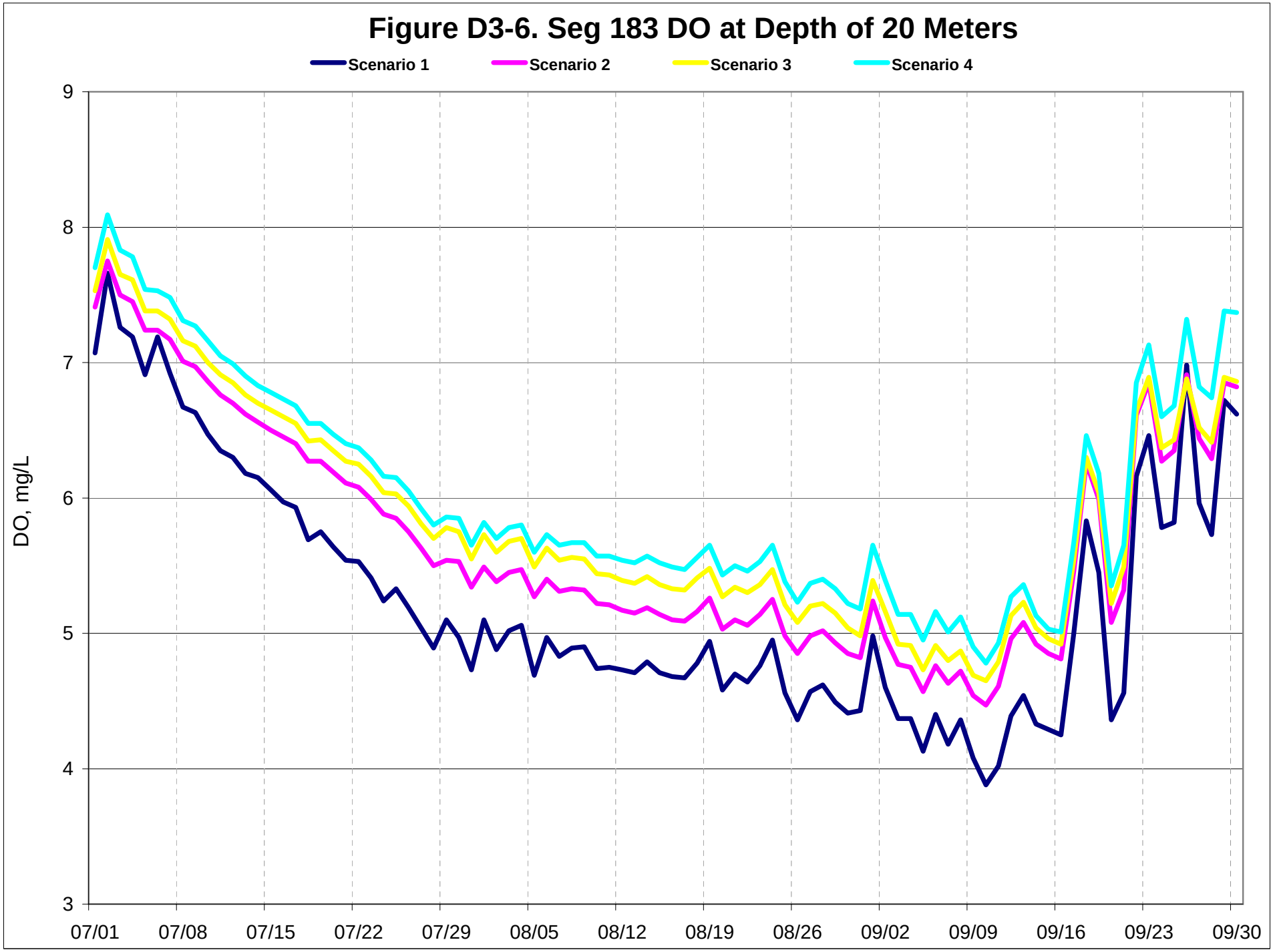


Figure D3-6. Seg 183 DO at Depth of 20 Meters
Scenario 1
Scenario 2
Scenario 3
Scenario 4
DO, mg/L
9
8
7
6
5
4
3
07/01
07/08
07/15
07/22
07/29
08/05
08/12
08/19
08/26
09/02
09/09
09/16
09/23
09/30

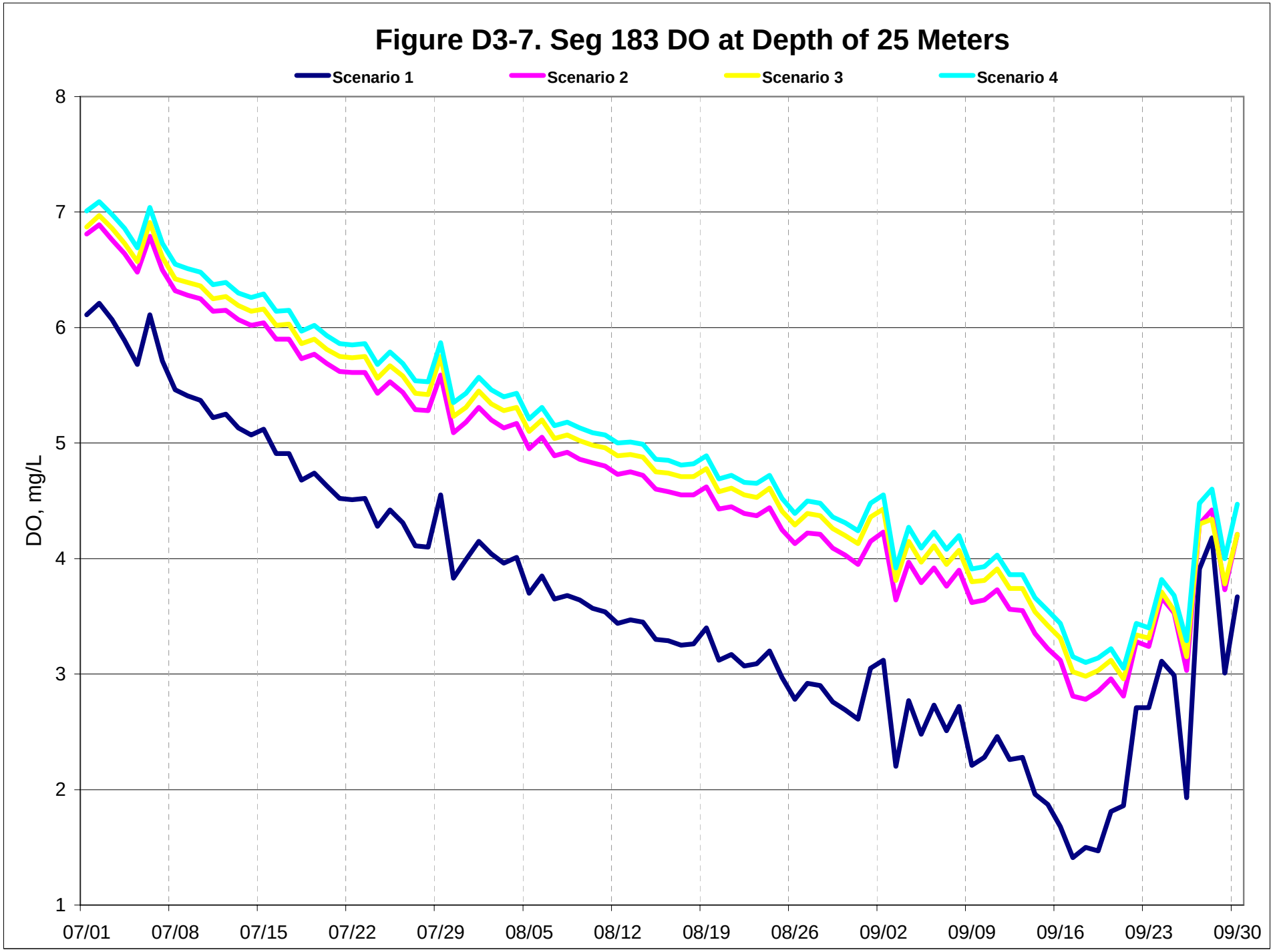


Figure D3-7. Seg 183 DO at Depth of 25 Meters
Scenario 1
Scenario 2
Scenario 3
Scenario 4
DO, mg/L
8
7
6
5
4
3
2
1
07/01
07/08
07/15
07/22
07/29
08/05
08/12
08/19
08/26
09/02
09/09
09/16
09/23
09/30

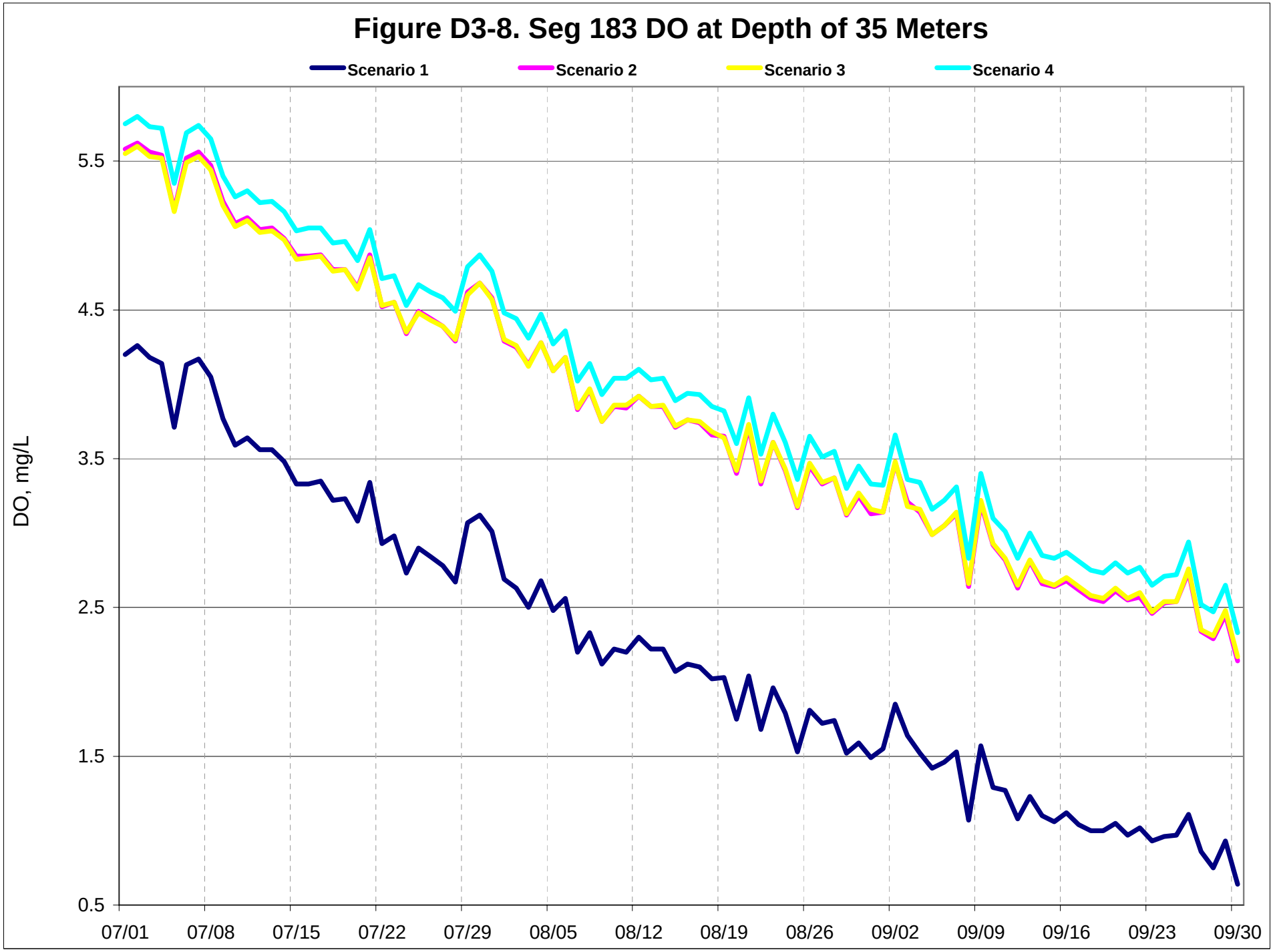


Figure D3-8. Seg 183 DO at Depth of 35 Meters
Scenario 1
Scenario 2
Scenario 3
Scenario 4
DO, mg/L
5.5
4.5
3.5
2.5
1.5
0.5
07/01
07/08
07/15
07/22
07/29
08/05
08/12
08/19
08/26
09/02
09/09
09/16
09/23
09/30

Figure D3-9. Profile of Seg 155 Max Daily Temperature, by Depth, for August 17

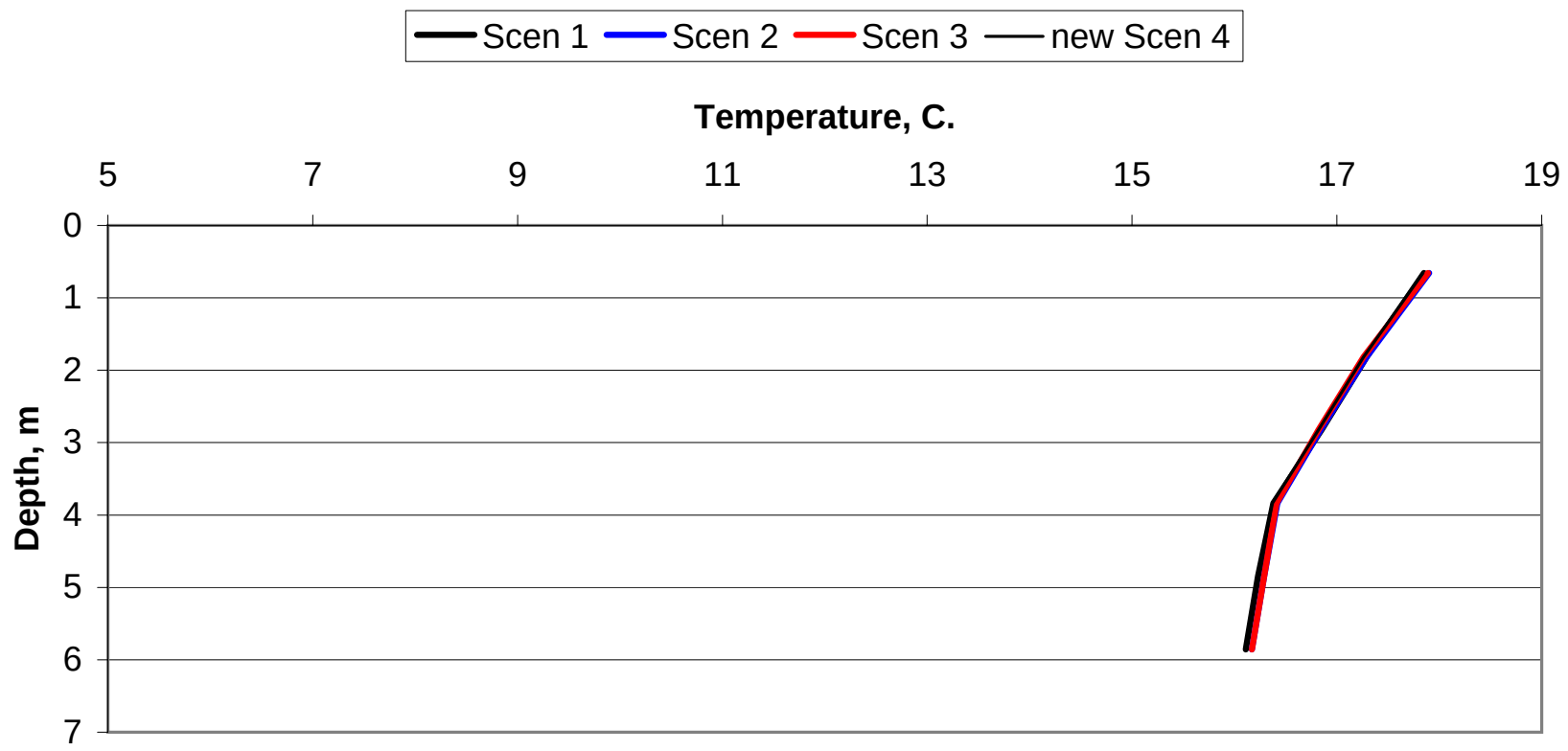


Figure D3-10. Profile of Seg 167 Max Daily Temperature, by Depth, for August 17

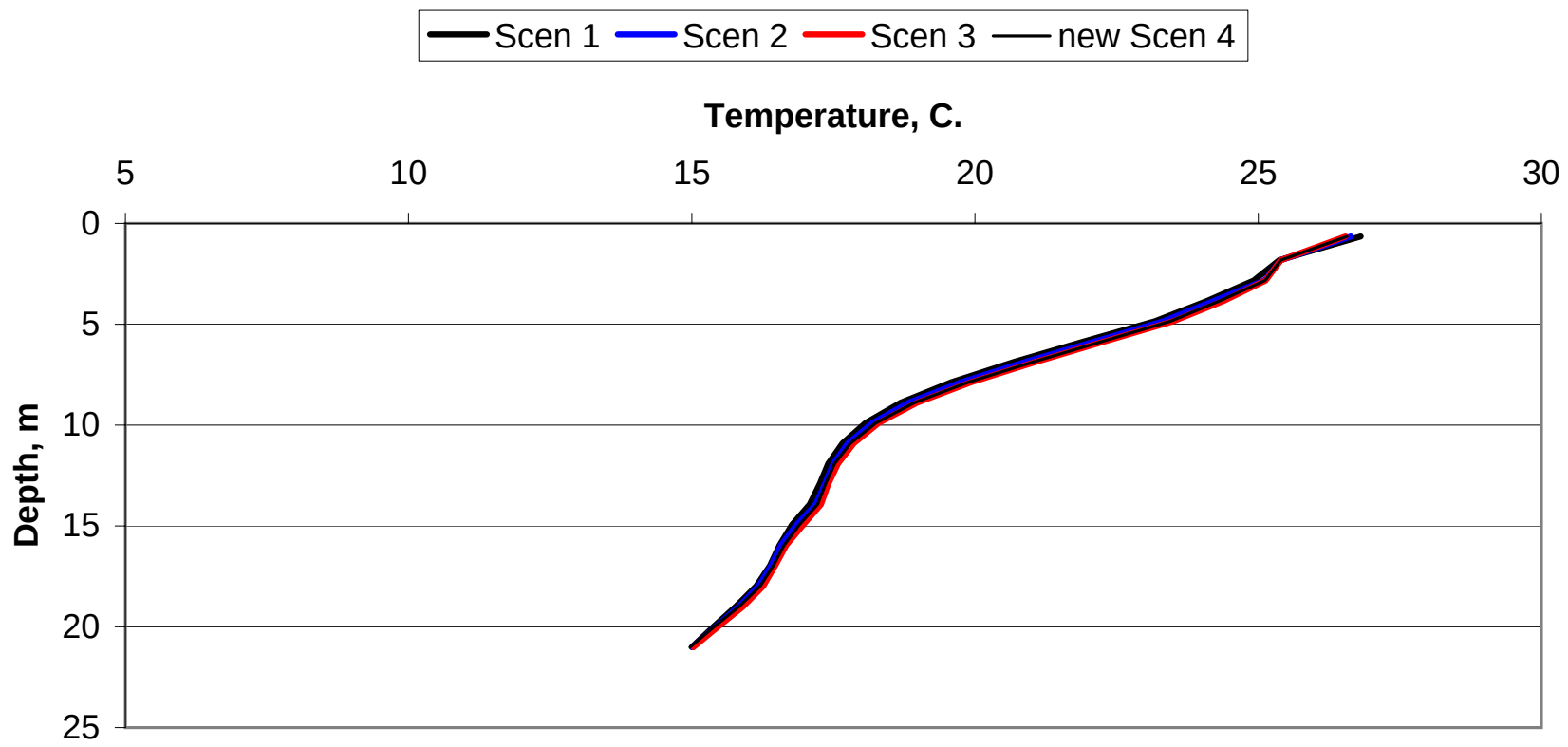
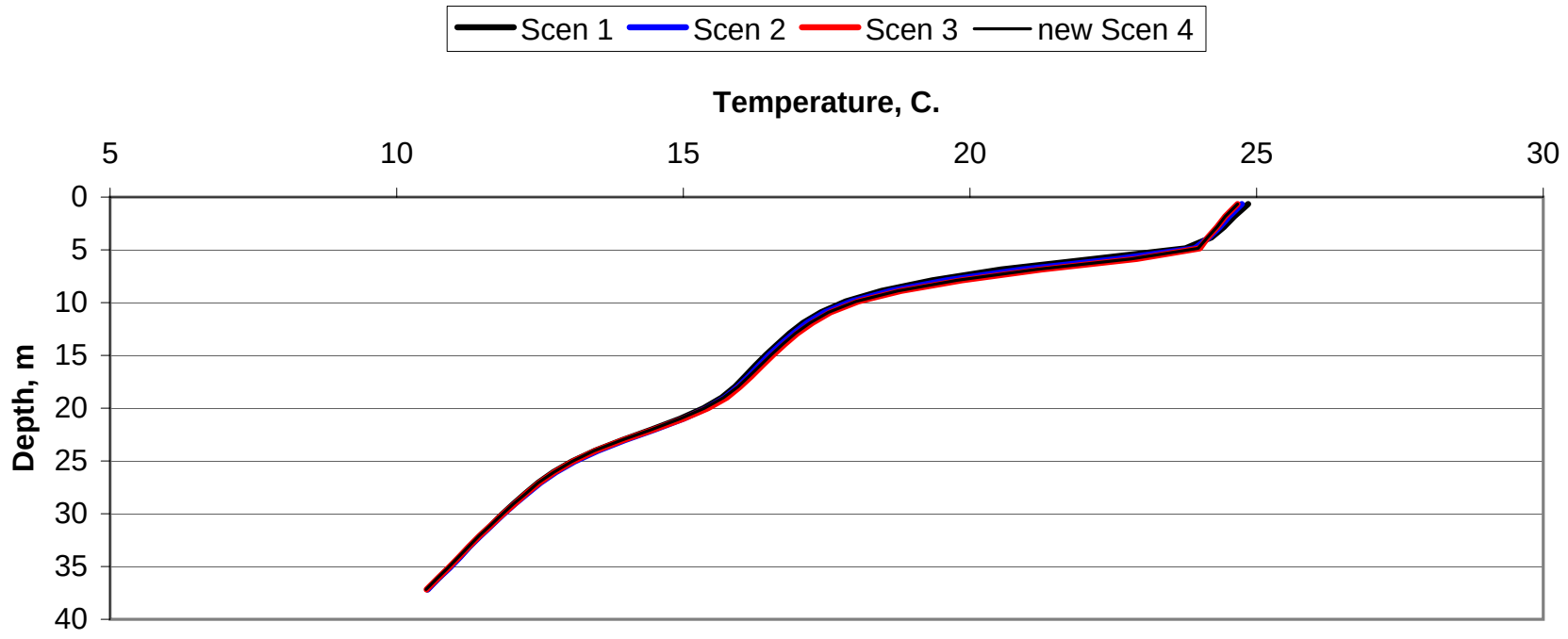


Figure D3-11. Profile of Seg 183 Max Daily Temperature, by Depth, for August 17



Appendix E

Economic Assessment Background Materials

APPENDIX E

Economic Assessment Background Materials

This appendix includes the following sections:

E1 Land Application of Reclaimed Water

E2 Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent

E3 Spokane Phosphorus Removal Costs

E4 Spokane County Preliminary Evaluation of Land Application

Appendix E1

Land Application of Reclaimed Water

Technical Memorandum

Land Application of Reclaimed Water

Appendix E1 of Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

Land Application of Reclaimed Water

PREPARED FOR: The City of Spokane

PREPARED BY: Daniel Ayers/CH2M HILL
Phil Johnson/CH2M HILL
Dick Haapala/CH2M HILL

DATE: November 18, 2004

E1.1 Introduction

Dissolved-oxygen and total phosphorus Total Maximum Daily Loads (TMDL) for the Spokane River are being prepared by the Washington Department of Ecology (Ecology). The City of Spokane is interested in land applying reclaimed water to eliminate the discharge of wastewater to the Spokane River in the summer months. This section analyzes the use of reclaimed water to produce agricultural crops. The land application system in this section differs from previous land application system evaluations in that wastewater flows will not be stored over the winter, but rather discharged to the river. This reduces the size and cost of the storage and irrigation system as less water needs to be stored and land applied, and more water is discharged to the river. The schedule for this project is to be on-line by 2012.

The agricultural land application system has been sized based on net irrigation requirements as published in the Washington Irrigation Guide. These irrigation application rates include sufficient amounts of water to leach soluble salts from the root zone of the crops. If the application of sufficient amounts of water to leach salts from the root zone is not allowed, then lower irrigation application rates are required, which require more land and irrigation equipment. The cost for this additional land and equipment is estimated to be $32 million.

E1.2 Regulatory Requirements

E1.2.1 Overview

Ecology along with the Washington State Department of Health jointly issues reclaimed water permits which govern reclaimed water generation and use. Washington Water Reclamation and Reuse Standards (Ecology, Publication #97-23, September 1997) provide guidance for best management practices for reuse applications as per requirements of Reclaimed Water Use, Chapter 90.46 RCW, and development of reclaimed water permit conditions. Reuse programs must also comply with state groundwater antidegradation policies (Water Pollution Control Act, Chapter 90.48 RCW and the Water Resources Act, Chapter 90.54 RCW) to protect the quality of the aquifer. Relevant reuse classes and allowable uses are summarized below.

E1.2.2 Classes and Allowable Uses of Reclaimed Water

Landscape irrigation of open public access areas such as golf courses, parks, playgrounds, and schoolyards requires Class A reclaimed water. Class A reclaimed water requires oxidation, coagulation, filtration, and disinfection treatment. The average monthly wastewater turbidity cannot exceed 2 nephelometric turbidity units (NTU), and no more than 5 NTU in any single sample. The median number of total coliform organisms in the wastewater after disinfection cannot exceed 2.2 per 100 milliliters, based on a 7 day sample period, and no more than 23 per 100 milliliters in any single sample.

Irrigation of food crops without contact of reuse water to the edible portion of the crop, and landscape irrigation of restricted public access areas such as cemeteries and freeway landscaping requires Class B reclaimed water. Class B reclaimed water requires oxidation and disinfection treatment. The median number of total coliform organisms in the wastewater after disinfection cannot exceed 2.2 per 100 milliliters, based on a 7 day sample period, and no more than 23 per 100 milliliters in any single sample.

Landscape irrigation of restricted public access areas such as cemeteries and freeway landscaping requires Class C reclaimed water. Class C reclaimed water requires oxidation and disinfection treatment. The median number of total coliform organisms in the wastewater after disinfection cannot exceed 23 per 100 milliliters, based on a 7 day sample period, and no more than 240 per 100 milliliters in any single sample.

Irrigation of non-food crops used for fodder, fiber, and seed, or food crops which undergo physical or chemical processing sufficient to destroy pathogens require only Class D reclaimed water. Class D reclaimed water requires oxidation and disinfection treatment. The median number of total coliform organisms in the wastewater after disinfection cannot exceed 240 per 100 milliliters, based on a 7 day sample period.

E1.2.3 Water Rights

Water reclamation regulations state that reuse water is not consumptive and remains part of the City's water right to be used for City purposes. Regulations also state that any project involving water reclamation must not have an adverse impact on downstream water rights. At this point it is not clear what impacts might be to downstream water rights by removing the wastewater discharge from the river.

E1.2.4 Anticipated Water Quality

Water quality produced by the treatment facility is expected to meet Class C or Class D reclaimed water requirements. This precludes the use of reclaimed water for landscape irrigation or irrigation of edible crops. Class C and Class D wastewater is suitable for fodder, fiber, and seed crops. It is assumed that alfalfa and winter wheat will be grown on the land application site. Alfalfa would be used for fodder and winter wheat would undergo physical or chemical processing prior to consumption. Other expected effluent parameters are listed below:

Ammonia	less than 1 milligram per liter (mg/L)
Total Nitrogen	20 mg/L
Total Phosphorus	0.5 mg/L

E1.2.5 Required Setback

The land application irrigation system was sized within the following setback constraints. A 100-foot setback is provided around the perimeter of the land application site. One known well was found on the land application site which required a 300 foot setback from the land application area. Relevant setback requirements for City of Spokane reclaimed water facilities are shown in Table E1-1.

TABLE E1-1
Required Setbacks for Reclaimed Water

Condition	Setback Distance (Feet) by Type of Reclaimed Water			
	Class A	Class B	Class C	Class D
Distance between pipeline and potable water supply well	50	100	100	300
Distance between irrigation area and potable water supply well	50	100	100	300
Distance between irrigation area and areas accessible to the public/ irrigation area property line	0	50	50	100
Distance between lined storage pond and potable water supply well	100	100	100	200

E1.2.6 Impoundment Requirements

Impoundments that store more than 10 acre feet (af) of water above the ground surface require a dam safety permit. Embankments that are fifteen feet in height require at least 2 feet of freeboard, and must be designed to withstand a 100-year flood. Impoundments must also be sized to contain a 24-hour, 25-year storm event without spillage.

E1.2.7 Interbasin Transfer

The major portion of the land application acreage is located in the Spokane River basin. However, some of the acreage is within the Crab Creek watershed. Thus, an interbasin water transfer agreement would need to be obtained from Ecology before land application could commence in the Crab Creek watershed.

E1.3 Design Considerations

E1.3.1 Water Quality Degradation

Storage is required in the spring and fall to balance irrigation demand and reclaimed water production rates. Water quality may degrade due to algae growth and potentially plug irrigation equipment. Additionally, oxygen depletion at lower depths may produce anaerobic gases and cause odors. Wind powered pond mixing equipment such as produced by Lake Aid Systems has been included as part of the design concept to provide deep circulation of pond waters thereby aiding the natural aeration process.

E1.3.2 Unused Water

The storage pond was sized to be empty at the end of September so that it would be ready to begin filling in October when there is low irrigation demand but still full water production. This water will not be used for irrigation and must be disposed of back to the river during the winter months. The storage pond is sited at an elevation approximately 700 feet higher than the treatment plant, allowing for gravity flow back to the plant. If re-treatment of the wastewater is necessary, flow can be bled back through the plant allowing algae removal, additional disinfection, and aeration to raise the dissolved oxygen levels.

E1.3.3 Crops

A combination of alfalfa and wheat were selected as the crops due to their relatively high water consumption and ability to utilize nutrients. Alfalfa can consume up to 36 inches of water per year and wheat consumes 24 inches per year. Both alfalfa and wheat consume nitrogen and phosphorus. These crops should be suitable for the selected land application site and are known to be grown in the area. It is assumed that 6/7 of the fields will be planted for alfalfa hay and 1/7 of the fields will be planted for winter wheat. The crops will be rotated on a 7 year cycle, with 6 years of alfalfa, and one year of wheat.

E1.3.4 Nitrogen and Phosphorus Loadings

Assuming 10,258 irrigated acres, an average daily flow rate of 55.9 million gallons per day (mgd), and 214 days of irrigation, the 20 mg/L total nitrogen concentration in the reclaimed water results in an annual loading of 195 lb nitrogen per acre. Using a 0.5 mg/L total phosphorus concentration results in an annual loading of 5 pounds (lb) per acre. The nutrient uptake of the crops is shown in Table E1-2.

TABLE E1-2
Crop Uptake

Crop	Yield	Unit Uptake Rate (lb/yield)	Total Uptake by Crop (lb/acre)
Wheat	100 bu/acre	1.2 lb N/bu/acre	120 lb N/acre
	100 bu/acre	0.22 lb P/bu/acre	22 lb P/acre
Alfalfa Hay	6 tons/acre	41.7 lb N/ton/acre	250 lb N/acre
	6 tons/acre	4.72 lb P/ton/acre	28 lb P/acre

bu = bushels
lb N = pounds of nitrogen
lb P = pounds of phosphorus

Total nitrogen uptake assuming alfalfa is 6/7 of the fields and wheat is 1/7 calculates to 230 lb N/acre which exceeds the loading of 195 pounds of nitrogen per acre (lb N/acre). Total phosphorus uptake assuming the same field split calculates to 27 pounds of phosphorus per acre (lb P/acre), which exceeds the 5 lb P/acre loading.

E1.3.5 Salinity

It is assumed that the wastewater effluent has a total dissolved salt concentration level of approximately 650 mg/L, which is a typical value for municipal effluent. This salinity value

corresponds to an Electrical Conductivity (EC) value of approximately 1.0 deciSiemens per meter (dS/m). According to information published by the U.S. Salinity Laboratory, USDA, alfalfa is moderately sensitive to salinity whereas wheat is tolerant. The threshold at which some impact of the soil salinity is noticed is at 2.0 dS/m for alfalfa and 6.0 dS/m for wheat. The salinity is measured by extracting moisture from the root zone in the form of a saturated paste and testing for EC. Since salts tend to become more concentrated in the soil as the plants use the water and leave the salts behind, it is necessary to use irrigation water that is at least 1.5 times less saline than the crop will tolerate. The EC of the irrigation water should be better than about 1.3 dS/m for alfalfa and about 4.0 dS/m for wheat. Lower yields will result with more saline water. There is one well on-site that could provide dilution water if needed, but it is assumed at this point that no dilution water is needed. The dissolved salt concentration of the well water in not known.

E1.3.6 Growing Season

The growing season is assumed to be from April 1 to October 31. This coincides with the requirement to be out of the river between mid-April to mid-October. Water production exceeds crop consumptive use in the spring and fall and will require storage.

E1.3.7 Washington Irrigation Guide Net Irrigation Requirements

Table E1-3 lists the net irrigation requirements used to size the land application system. Net irrigation requirements include crop consumptive use, precipitation, and leaching rates. The hydraulic flushing rate (leaching rate) is typically 10 to 20 percent excess water beyond the water consumed by the crops.

TABLE E1-3
Net Irrigation Requirements

Crop	April	May	June	July	August	September	October
Alfalfa, inches of water	0	1.72	5.44	8.41	6.72	4.11	0.22
Wheat, inches of water	1.42	4.86	6.79	7.93	0.70	0	0

E1.4 Site Considerations

The distance from the treatment plant to the storage pond is approximately 13 miles. This distance was deemed necessary to find enough open contiguous land, which is advantageous for land application systems. The land application site covers an area that is in both Spokane and Lincoln Counties. Land use in the Reardan/Deep Creek area is mainly agricultural. The railroad and Highway 2 both cross the land application area. Fee simple purchase of the land is recommended.

Runoff at land application sites from the application of reclaimed water is not allowed, and run-on and runoff from precipitation at the site should be minimized. Site drainage requirements are very specific to location and final design requirements. Costs for site drainage have not been included in the estimates. The depth to groundwater in the land application area typically ranges from 150-300 feet. In the Reardan area, there appears to be some shallow groundwater.

The soil structure, chemistry, and hydraulic characteristics must be suitable for the application of reclaimed water. According to USDA Soil Surveys for Lincoln and Spokane Counties, soils in the land application acreage in Spokane County are of the Hesseltine-Cheney-Uhlig soil association which is shallow to moderately deep and gravelly and rocky; or of the Athena-Reardan association which is medium to moderately fine textured soil, well drained and slowly permeable. The Athena and Reardan soils are typically used for grain, peas, alfalfa, and grass. Land application acreage in Lincoln County is the Broadax-Hanning series which is very deep, well-drained soil.

E1.5 Land and Storage Requirements

E1.5.1 Quantity of Water

The average daily flow is assumed to be 45.9 mgd through the mid-point of the project duration. Then, an additional 10 mgd of flow would be added from Spokane County for a total of 55.9 mgd. The land application site and irrigation equipment have been sized to dispose of this flow during the growing season. The peak instantaneous flow is assumed to be 98.3 mgd. The conveyance facilities have been sized to convey this flow to the storage pond at the land application site.

E1.5.2 Land and Storage Sizing

Table E1-4 lists quantity of water applied each month to each crop.

TABLE E1-4
Quantity of Water Applied

Crop		Month							Seasonal Total
		Apr	May	June	July	Aug	Sep	Oct	
Alfalfa (1)	inches	0	1.47	4.66	7.21	5.76	3.52	0.19	22.81
	gal/acre	0	39,914	126,530	195,769	156,398	95,576	5,159	619,346
Wheat (2)	inches	0.20	0.69	0.97	1.13	0.1	0	0	3.09
	gal/acre	5,430	18,735	26,338	30,682	2,715	0	0	83,900
Total	inches	0.20	2.16	5.63	8.34	5.86	3.52	0.19	25.90
	gal/acre	5,430	58,649	152,868	226,451	159,113	95,576	5,159	703,246

(1) 6/7 of net irrigation requirement
(2) 1/7 of net irrigation requirement

gal = gallons

The total annual quantity of water used by crops is 703,246 gallons per acre (gal/acre). Assuming a 70 percent sprinkler efficiency, 1,004,637 gal/acre need to be applied. Total available water is 55.9 mgd X 214 days = 11,963,000,000 gallons. Table E1-5 shows the optimized sizing of the land application acreage and the storage pond. The facilities are optimized keeping in mind the storage pond should be nearly empty at the end of September, as there will be little irrigation in October.

TABLE E1-5
Pond and Land Optimization

Month	Days/ Month	Available Effluent (MG)	Alfalfa Consumption (gal/acre)	Wheat Consumption (gal/ acre)	Total Consumption (MG/ acre)	Applied Water (MG/acre)	Total Applied Water (MG)	Pond Volume End of Month (MG)	Pond Volume End of Month (acre-ft)
Oct.	31	1,733	5,159	0	0.0052	0.0074	76	1,657	5,086
Nov.	30	0	0	0	0	0	0	0	0
Dec.	31	0	0	0	0	0	0	0	0
Jan.	31	0	0	0	0	0	0	0	0
Feb.	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	1,677	0	5,430	0.0054	0.0078	80	1,597	4,903
May	31	1,733	39,914	18,735	0.0586	0.0838	859	2,471	7,583
June	30	1,677	126,530	26,338	0.1529	0.2184	2,240	1,908	5,855
July	31	1,733	195,769	30,682	0.2265	0.3235	3,318	322	989
Aug.	31	1,733	156,398	2,715	0.1591	0.2273	2,332	-277	-849
Sep.	30	1,677	95,576	0	0.0956	0.1365	1,401	0	-1
Total		11,963			0.7032	1.0046	10,306		

Note: No allowance has been made for evaporation or precipitation on pond surface.

The maximum amount of storage required occurs in May at 2,471 million gallons. Land application area required is 10,306 million gallons (MG) water applied divided by 1.0046 MG/acre = 10,258 acres. The pond is 15 feet deep, with 2 feet of freeboard, and approximately 680 acres in size, which includes embankments and access roads. Potential wave action and required freeboard should be revisited in design. The storage pond includes the cost of a synthetic liner. Assuming a 100 foot buffer around the entire site, approximately 200 acres of additional land will be required in addition to the irrigated acreage. To irrigate 10,258 acres of land, approximately 85 center pivots irrigating 120 acres each are required. Due to existing surface features in the Reardan/Deep Creek area, approximately 13,600 total acres are required to allow the installation of the center pivots, storage pond, and buffer zone. Figure E1-1 shows the land application facilities. Costs for owner relocation have been included in the land application costs.

E1.6 Pumping and Conveyance

E1.6.1 Pumping

There will be a 100 mgd pump station located at the treatment plant, sized to convey peak instantaneous flows to an intermediate pump station. The pump station will have five 25 mgd pumps, with two pumps operating at average flow, and four pumps operating at peak flow with one standby. Each pump will be sized for 380 feet of total dynamic head and provided with 2,000 hp motors and variable speed drives. An intermediate pump station of similar size is provided to reduce total head on the system so that more standard working

pressures are encountered and standard materials can be used. Each pump station will have a 1,500 square foot footprint.

E1.6.2 Pipeline Alignment

The conveyance pipeline will be a 72-inch diameter welded steel pipe, coated and lined, and provided with cathodic protection. The pipeline crosses the Spokane River at the treatment plant, then follows an existing pipeline alignment cross-country for nine miles to Highway 2 near the Fairchild Air Force Base. The alignment then follows Highway 2 for four miles past the town of Deep Creek to the storage pond located adjacent to Highway 2. Figure E1-1 shows the proposed alignment. Land costs for a 50-foot wide strip of land along the alignment have been included in the cost estimate for the conveyance pipeline.

E1.7 Irrigation Equipment

Each center pivot will irrigate 120 acres and convey 1,000 gallons per minute (gpm) of flow. Half of the center pivots will run at one time. Therefore, a 42,000 gpm irrigation pump station will be provided at the storage pond to deliver water to the center pivots. Distribution piping of various sizes conveys the water to each pivot. Every 5 days, half of the land application site will be watered. Therefore, the pump station will run continuous, 24 hours per day, 7 days per week in the summer.

E1.8 Costs

E1.8.1 Capital Costs

Capital Costs for the land application system is summarized in Table E1-6. Detailed estimates can be found in Attachment E1.1. All costs are in 2004 dollars.

TABLE E1-6
Land Application Capital Costs

Description	Capital Cost ($million)
Conveyance Pipeline	110.9
Irrigation Distribution Pipe	111.0
WWTP Pump Station	15.1
Intermediate Pump Station	15.1
Irrigation Pump Station	1.5
Storage Pond	89.5
Land Acquisition	61.7
Total ($million)	**$404.7**
Unit Cost (dollars/gallon capacity)	**$7.24**

E1.8.2 Operation and Maintenance

Operation and maintenance costs for the land application system are summarized in Table E1-7. Detailed estimates can be found in Attachment E1.1. Costs are based on 55.9 mgd of flow and April through October operation. Power cost is assumed to be $0.06 per kilowatt-hour (kWh). All costs are in 2004 dollars.

TABLE E1-7
Annual Operation and Maintenance Costs

Facility	Power	Maintenance and Repair	Operator Salary	Annual O&M Cost
Center Pivot Irrigation System	$14,000	$128,000	0 (1)	$142,000
WWTP Pump Station	$960,000	$25,000	$20,000	$1,005,000
Intermediate Pump Station	$960,000	$25,000	$20,000	$1,005,000
Irrigation Pump Station	$384,000	$10,000	$20,000	$414,000
Storage Pond	$6,000	$7,000	$5,000	$18,000
			Total Annual O&M Cost:	**$2,600,000**

(1) No operator salary is required for the center pivot irrigation system since it is assumed that the land will be leased to farmers. It is assumed that leasing income is offset by administration costs.

E1.8.3 Total Annualized Cost and Net Present Value

Assuming a 20-year life cycle and a 5 percent discount rate, the total annualized cost for the proposed land application project is $35.1 million per year, whereas the net present value is $437.1 million. These values are stated in 2004 dollars, and are based on a total capital cost of $404.7 million and an annual O&M cost of $2.6 million.

E1.9 Non-agricultural Reuse

Non-agricultural reuse includes irrigation of green spaces such as golf courses, parks, freeway landscaping, and cemetery landscaping. These uses require Class A or Class B reclaimed water depending on public access to the green spaces. This would require increased treatment from what is currently envisioned for agricultural irrigation. CH2MHILL has surveyed the Spokane area for green spaces for potential reclaimed water use. A listing of cemeteries, colleges, golf courses, and parks showing location, acreage, and distance from the treatment plant can be found in Attachment E1.2. Assuming that a potential reuse site should take at least 1 percent of the flow to be viable, this would require sites that have at least 25 acres of irrigable area. Table E1-8 lists sites in the Spokane area that meet this criterion and includes size, location, and distance from the treatment plant.

TABLE E1-8
Potential Reclaimed Water Reuse Sites

Site	Acreage	Distance from WWTP (miles)
Holy Cross Cemetery	49.75	3.25
Fairmount Memorial Gardens	83.75	0.75
Gonzaga University	104.0	4.0
Spokane Falls Community College	123.0	1.75
Spokane Community College	87.50	5.50
Whitworth College	200.0	4.75
Intercollegiate Center for Nursing	84.25	1.75
Mukogowa-Fort Wright Institute	92.50	1.50
Esmerelda Golf Course	163.72	5.75
Downriver Golf Course	140.50	1.0
Indian Canyon Golf Course	198.98	3.25
The Creek at Qualchan Golf Course	187.07	6.75
Sky Prairie Park	26.25	3.0
Wyakin Park	26.85	1.50
Dwight Merkel Sports Complex	31.72	1.0
Franklin Park	26.81	3.0
Camp Sekani Park	124.98	7.75
Shadle Park	34.23	1.50
Minnehaha Park	39.78	6.0
Audubon Park	28.71	1.0
Upriver Drive Parkway	56.09	5.75
Palisades Park	399.20	2.25
High Bridge Park	44.21	3.0
Indian Canyon Park	155.73	3.25
Liberty Park	30.78	5.25
Finch Arboretum	59.46	3.75
Lincoln Park	58.41	6.25
Manito Park	85.09	5.25
High Drive Park	177.41	5.75
Comstock Park	25.80	5.50
Qualchan Hills Park	27.88	6.5
Hangman Park	179.61	7.25

The acreages cited in Table E1-8 are gross acreages, and not all of the acreage is irrigable. Generally, parks, cemeteries, and golf courses consist of mostly irrigable land. However, before any assumptions can be made about the availability of this land for irrigation, a more detailed assessment of the land use, surrounding neighborhoods, set-back requirements and public acceptance would be required. In addition, there has been no attempt to determine the most cost-effective approach to serving these lands, either through a central reclamation plant or satellite plants. Assuming 50 percent of all acreage is irrigable, we estimate approximately 1,200 acres of potential irrigable lands within a 10 mile radius of the treatment plant capable of disposing about 10 mgd during the peak summer months of July and August (based on an application rate of 120 acres per mgd). Thus, water reuse for local irrigation during the peak summer months appears to have reasonable potential and could result in disposal of wastewater other than to the river in the peak summer months of July and August. This would reduce phosphorus loading directly to the river and result in a net reduction in groundwater consumption. Assuming that treated wastewater contains 0.5 mg/L of phosphorus, reuse would also result in a net reduction in phosphorus loading to the Spokane River of approximately 2,600 pounds during July and August.

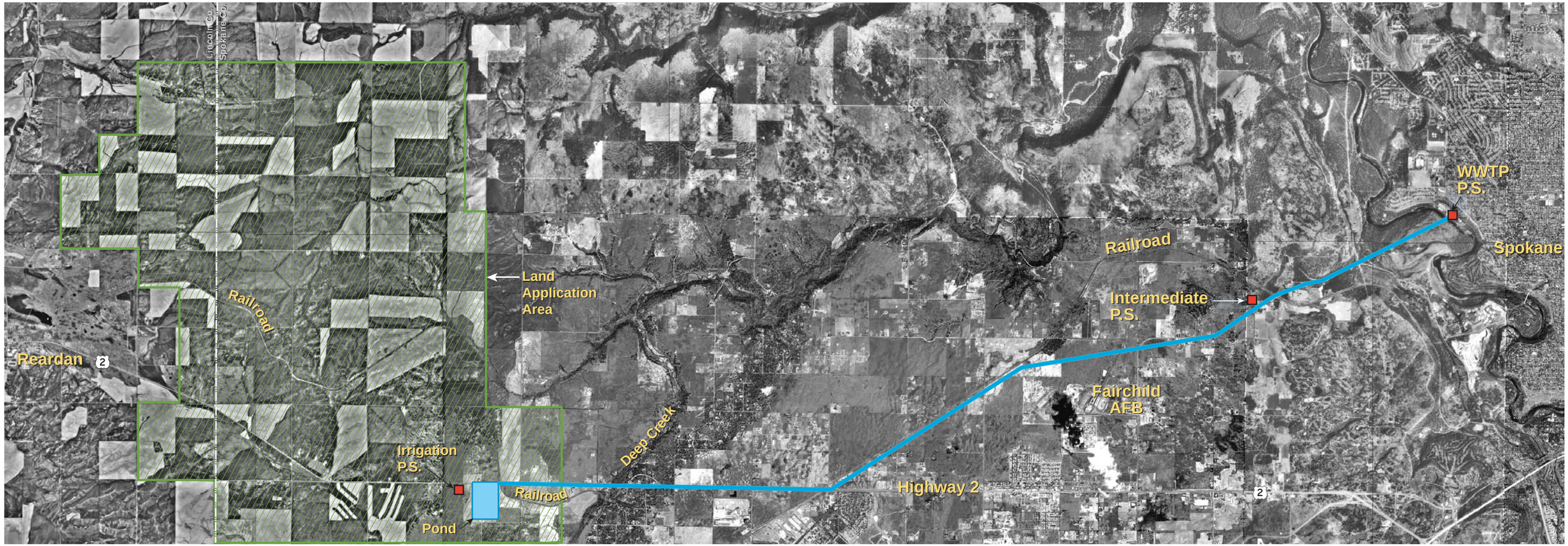
E1.9.1 Cost for Non-agricultural Reuse Conveyance Facilities

In this section, capital and O&M costs are provided for conveyance facilities to be used to provide reuse water for irrigation of an area golf course and park. These costs are calculated as an example of representative costs to convey reclaimed water to an urban irrigation site. We have chosen sites of similar size but of different distances from the wastewater treatment plant. The Downriver Golf Course and Camp Sekani Park were the two locations selected for the cost analysis. For each of these non-agricultural reuse sites, capital items included in the cost analysis were a pump station located at the treatment plant, and a transmission pipeline from the treatment plant to the reuse site. Assuming that the City will be able to locate the pump station on existing City-owned land near the wastewater treatment plant and that the transmission pipe will be aligned along existing City-owned utility right-of-ways, land acquisition costs were not included in the cost analysis. Also excluded from the analysis are costs associated with irrigation application equipment such as sprinkler heads and distribution pipe, since the cost for these items will be borne by the property owner. Table E1-9 contains cost estimates for the selected non-agricultural reuse conveyance facilities. Included in the table are capital costs, O&M costs, net present value, and total annualized costs. All costs are stated in 2004 dollars. For net present value and total annualized costs, a 5 percent discount rate and 20-year life cycle were used in the calculations.

TABLE E1-9
Estimated Costs for Selected Non-agricultural Reuse Conveyance Facilities

Reuse Site	Capital Costs	Annual Operation and Maintenance Costs	Net Present Value[1]	Total Annualized Costs[2]
Downriver Golf Course	$700,000	$24,000	$999,000	$80,000 per year
Camp Sekani Park	$3,516,000	$36,000	$3,965,000	$318,000 per year

[1] Net present value costs are in 2004 dollars, based on a 20-year life cycle discounted at 5 percent per annum.
[2] Total annualized costs are in 2004 dollars, and are calculated over a 20-year period at 5 percent per annum discount rate.



N

Approximate Scale in Miles

0 1 2 3 4

FIGURE E1-1
LAND APPLICATION SITE PLAN
CITY OF SPOKANE
USE ATTAINABILITY ANALYSIS

W102004007BOI

CH2MHILL

Attachment E1.1

Cost Estimates

ATTACHMENT E1.1

Cost Estimates

Cost Estimate Tables

E1.1-1 Summary of Capital Costs

E1.1-2 Annual Operations and Maintenance Costs

E1.1-3 Estimated Capital Costs for Conveyance Pipeline

E1.1-4 Estimated Capital Costs for Irrigation Distribution Pipe

E1.1-5 Estimated Capital Costs for WWTP Pump Station

E1.1-6 Estimated Capital Costs for Intermediate Pump Station

E1.1-7 Estimated Capital Costs for Irrigation Pump Station

E1.1-8 Estimated Capital Costs for Lined Storage Pond

E1.1-9 Estimated Capital Costs for Land Acquisition

E1.1-10 Estimated Capital Costs for Downriver Golf Course

E1.1-11 Estimated Capital Costs for Camp Sekani Park Pump Station & Pipeline

Acronyms and Abbreviations

AC	acres
CY	cubic yards
EA	each
I&C	instrumentation and control
kWh	kilowatt-hour
LF	linear feet
LS	lump sum
Mob	mobilization
O&M	operations and maintenance
SDC	services during construction
SF	square feet

Table E1.1-1

Summary of Land Application Capital Costs

Costs are in Present Dollars (2004)

	Cost
Conveyance Pipeline	$110,861,000
Irrigation Distribution Pipe	$110,975,000
WWTP Pump Station	$15,080,000
Intermediate Pump Station	$15,082,000
Irrigation Pump Station	$1,451,000
Lined Storage Pond	$89,459,000
Land Acquisition	$61,747,000
TOTAL CAPITAL COST:	***$404,655,000***
Cost per mgd =	***$7,239,000***

(Based on 55.9 million gallons per day (mgd) average output)

Table E1.1-2

Annual Operations and Maintenance Costs

Costs are in Present Dollars (2004)

Facility	Power (@ $0.06/kWh)	Maintenance and Repairs	Operator Salary	Annual O&M Cost
Center Pivot Irrigation System	$14,000	$128,000	$0	$142,000
WWTP Pump Station	$960,000	$25,000	$20,000	$1,005,000
Intermediate Pump Station	$960,000	$25,000	$20,000	$1,005,000
Irrigation Pump Station	$384,000	$10,000	$20,000	$414,000
Storage Pond	$6,000	$7,000	$5,000	$18,000
		Total Annual O&M Cost		***$2,584,000***

Note: No operator salary required for irrigation system, since land will be leased to farmers.

Table E1.1-3

Estimated Capital Costs for Conveyance Pipeline

Item	Unit Cost	Unit	Quantity	Extended Total
72" Diameter Steel Pipe	$415	LF	69,300	28,759,500
Total Excavation, Pipe Bed, & Backfill	$235	LF	69,300	16,285,500
Gravel Surface Repair-Road Crossings	$50	CY	550	27,500
Highway Surface Repair	$100	LF	100	10,000
River Crossing	$4,500	LF	580	2,610,000
Pipeline & RR Borings	$4,000	LF	1,000	4,000,000
Land Purchase, 50'-wide strip	$5	LF	69,300	346,500
			SUBTOTAL	$52,039,000
Washington State Sales Tax			8.10%	4,215,000
			SUBTOTAL	$56,254,000
Sitework (incl. in Line Items)			0%	0
			SUBTOTAL	$56,254,000
Mobilization, Bonds and Insurance			5%	2,813,000
			SUBTOTAL	$59,067,000
Contractor Overhead and Profit			10%	5,907,000
			SUBTOTAL	$64,974,000
Miscellaneous Items and Contingencies			30%	19,492,000
			SUBTOTAL	$84,466,000
Construction Contingencies/Change Orders			5%	4,223,000
			SUBTOTAL	$88,689,000
Engineering, Legal and Fiscal			25%	22,172,000
			TOTAL ESTIMATED COST:	**$110,861,000**

Table E1.1-4

Estimated Capital Costs for Irrigation Distribution Pipe

Item	Unit Cost	Unit	Quantity	Extended Total
10" PVC Pipe	$22	LF	39,600	871,200
Excavation & Pipe Bed-10" Pipe	$13	LF	39,600	514,800
12" PVC Pipe	$26	LF	18,500	481,000
Excavation & Pipe Bed-12" Pipe	$16	LF	18,500	296,000
16" PVC Pipe	$35	LF	26,400	924,000
Excavation & Pipe Bed-16" Pipe	$21	LF	26,400	554,400
18" PVC Pipe	$40	LF	31,700	1,268,000
Excavation & Pipe Bed-18" Pipe	$24	LF	31,700	760,800
24" PVC Pipe	$60	LF	75,500	4,530,000
Excavation & Pipe Bed-24" Pipe	$36	LF	75,500	2,718,000
36" PVC Pipe	$90	LF	202,200	18,198,000
Excavation & Pipe Bed-36" Pipe	$54	LF	202,200	10,918,800
54" Diameter Steel Pipe	$335	LF	2,700	904,500
Excavation & Pipe Bed-54" Pipe	$97	LF	2,700	261,900
Gravel Surface Repair-Road Crossi	$50	CY	350	17,500
Highway Surface Repair	$100	LF	200	20,000
Railroad Crossing-18" Pipe	$3,000	LF	250	750,000
Pipeline & Railroad Borings	$2,500	LF	500	1,250,000
Center Pivots-120 acre	$75,000	EA	85	6,375,000
			SUBTOTAL	$51,614,000
Washington State Sales Tax			8.10%	4,181,000
			SUBTOTAL	$55,795,000
Sitework, Roads, etc.			1%	516,000
			SUBTOTAL	$56,311,000
Mobilization, Bonds and Insurance			5%	2,816,000
			SUBTOTAL	$59,127,000
Contractor Overhead and Profit			10%	5,913,000
			SUBTOTAL	$65,040,000
Miscellaneous Items and Contingencies			30%	19,512,000
			SUBTOTAL	$84,552,000
Construction Contingencies/Change Orders			5%	4,228,000
			SUBTOTAL	$88,780,000
Engineering, Legal and Fiscal			25%	22,195,000
			TOTAL ESTIMATED COST:	**$110,975,000**

Table E1.1-5

Estimated Capital Costs for WWTP Pump Station

Item	Cost
Sitework	30,000
Concrete	150,000
Masonry	150,000
Metals	50,000
Equipment (incl. Pumps)	4,000,000
ITEM SUBTOTAL:	$4,380,000
Allowances	
Finishes-2%	87,600
I&C-8%	350,400
Mechanical-25%	1,095,000
Electrical-15%	657,000
ALLOWANCES SUBTOTAL:	$2,190,000
FACILITY COST:	$6,570,000
Additional Facility Costs	
Demolition-3%	197,100
Overall Sitework-5%	328,500
Computer System-1%	65,700
Yard Electrical-10%	657,000
Yard Piping-3%	197,100
ADDITIONAL COSTS SUBTOTAL:	$1,445,000
SUBTOTAL:	$8,015,000
Washington State Sales Tax-8.1%	649,000
SUBTOTAL:	$8,664,000
Contractor Markups	
Overhead-10%	801,500
Profit-5%	400,750
Mob/Bonds/Insurance-5%	400,750
Contingency-30%	2,404,500
CONTRACTOR MARKUP SUBTOTAL:	$4,008,000
TOTAL CONSTRUCTION COST:	$12,672,000
Non-Construction Costs	
Permitting-1%	126,720
Engineering-10%	1,267,200
SDC-5%	633,600
Commissioning & Startup-2%	253,440
Legal/Administrative-1%	126,720
NON-CONST COST SUBTOTAL:	$2,408,000
TOTAL ESTIMATED CAPITAL COST:	**$15,080,000**

Table E1.1-6

Estimated Capital Costs for Intermediate Pump Station

Item	Cost
Sitework	30,000
Concrete	150,000
Masonry	150,000
Metals	50,000
Equipment (incl. Pumps)	4,000,000
ITEM SUBTOTAL:	$4,380,000
Allowances	
Finishes-2%	87,600
I&C-8%	350,400
Mechanical-25%	1,095,000
Electrical-15%	657,000
ALLOWANCES SUBTOTAL:	$2,190,000
FACILITY COST:	$6,570,000
Additional Facility Costs	
Demolition-3%	197,100
Overall Sitework-5%	328,500
Computer System-1%	65,700
Yard Electrical-10%	657,000
Yard Piping-3%	197,100
ADDITIONAL COSTS SUBTOTAL:	$1,445,000
SUBTOTAL:	$8,015,000
Washington State Sales Tax-8.1%	649,000
SUBTOTAL:	$8,664,000
Contractor Markups	
Overhead-10%	801,500
Profit-5%	400,750
Mob/Bonds/Insurance-5%	400,750
Contingency-30%	2,404,500
CONTRACTOR MARKUP SUBTOTAL:	$4,008,000
TOTAL CONSTRUCTION COST:	$12,672,000
Non-Construction Costs	
Permitting-1%	126,720
Engineering-10%	1,267,200
Land Acquision-0.5 acres	2,000
SDC-5%	633,600
Commissioning & Startup-2%	253,440
Legal/Administrative-1%	126,720
NON-CONST COST SUBTOTAL:	$2,410,000
TOTAL ESTIMATED CAPITAL COST:	**$15,082,000**

Table E1.1-7

Estimated Capital Costs for Irrigation Pump Station

Item	Cost
Sitework	7,000
Concrete	66,500
Masonry	103,500
Metals	15,000
Equipment (incl. Pumps)	281,000
ITEM SUBTOTAL:	$473,000
Allowances	
Finishes-2%	9,460
I&C-8%	37,840
Mechanical-25%	118,250
Electrical-8%	37,840
ALLOWANCES SUBTOTAL:	$203,000
FACILITY COST:	$676,000
Additional Facility Costs	
Demolition-3%	20,280
Overall Sitework-5%	33,800
Computer System-1%	6,760
Yard Electrical-2%	13,520
Yard Piping-3%	20,280
ADDITIONAL COST SUBTOTAL:	$95,000
SUBTOTAL:	$771,000
Washington State Sales Tax-8.1%	$62,000
SUBTOTAL:	$833,000
Contractor Markups	
Overhead-10%	77,100
Profit-5%	38,550
Mob/Bonds/Insurance-5%	38,550
Contingency-30%	231,300
CONTRACTOR MARKUP SUBTOTAL:	$386,000
TOTAL CONSTRUCTION COST:	$1,219,000
Non-Construction Costs	
Permitting-1%	12,190
Engineering-10%	121,900
SDC-5%	60,950
Commissioning & Startup-2%	24,380
Legal/Administrative-1%	12,190
NON-CONST COST SUBTOTAL:	$232,000
TOTAL ESTIMATED CAPITAL COST:	**$1,451,000**

Table E1.1-8

Estimated Capital Costs for Lined Storage Pond

Item	Unit Cost	Unit	Quantity	Extended Total
Earthwork	$6	CY	750,000	4,500,000
Geomembrane Liner	$1	SF	26,543,000	26,543,000
Imported Subgrade for Liner	$20	CY	492,000	9,840,000
Inlet/Outlet Structures	$100,000	LS	1	100,000
Aerators	$18,000	EA	20	360,000
Aerator Electrical Ductbank System	$400,000	LS	1	400,000
Aerator Anchor Blocks & Cables	$250,000	LS	1	250,000
			SUBTOTAL	$41,993,000
Washington State Sales Tax			8.10%	3,401,000
			SUBTOTAL	$45,394,000
Sitework (incl. in Line Items)			0%	0
			SUBTOTAL	$45,394,000
Mobilization, Bonds and Insurance			5%	2,270,000
			SUBTOTAL	$47,664,000
Contractor Overhead and Profit			10%	4,766,000
			SUBTOTAL	$52,430,000
Miscellaneous Items and Contingencies			30%	15,729,000
			SUBTOTAL	$68,159,000
Construction Contingencies/Change Orders			5%	3,408,000
			SUBTOTAL	$71,567,000
Engineering, Legal and Fiscal			25%	$17,892,000
			TOTAL ESTIMATED COST:	**$89,459,000**

Table E1.1-9

Estimated Capital Costs for Land Acquisition

Item	Unit Cost	Unit	Quantity	Extended Total
Crop Land for Irrigation	$4,000	AC	13,600	54,400,000
Land for Storage Pond	$4,000	AC	680	2,720,000
			ITEM SUBTOTAL:	$57,120,000
	Washington State Sales Tax		8.10%	4,627,000
			SUBTOTAL:	$4,627,000
			TOTAL ESTIMATED CAPITAL COST:	**$61,747,000**

Table E1.1-10

Estimated Capital Costs for Downriver Golf Course

Item	Cost
Sitework	2,200
Concrete	22,500
Masonry	27,900
Metals	2,000
Equipment (incl. Pumps)	37,100
ITEM SUBTOTAL:	$92,000
Allowances	
Finishes-2%	1,840
I&C-8%	7,360
Mechanical-25%	23,000
Electrical-8%	7,360
ALLOWANCES SUBTOTAL:	$40,000
FACILITY COST:	$132,000
Additional Facility Costs	
Demolition-3%	3,960
Overall Sitework-5%	6,600
Computer System-1%	1,320
Yard Electrical-2%	2,640
Yard Piping-3%	3,960
ADDITIONAL COST SUBTOTAL:	$18,000
SUBTOTAL:	$150,000
Transmission Pipeline	
12" PVC Pipe-5,280 LF @ $26/LF	137,300
Excavation & Pipe Bed-5,280 LF @$16/LF	84,500
TRANSMISSION PIPELINE SUBTOTAL:	$222,000
SUBTOTAL:	$372,000
Washington State Sales Tax-8.1%	$30,000
SUBTOTAL:	$402,000
Contractor Markups	
Overhead-10%	37,200
Profit-5%	18,600
Mob/Bonds/Insurance-5%	18,600
Contingency-30%	111,600
CONTRACTOR MARKUP SUBTOTAL:	$186,000
TOTAL CONSTRUCTION COST:	$588,000
Non-Construction Costs	
Permitting-1%	5,880
Engineering-10%	58,800
SDC-5%	29,400
Commissioning & Startup-2%	11,760
Legal/Administrative-1%	5,880
NON-CONST COST SUBTOTAL:	$112,000
TOTAL ESTIMATED CAPITAL COST:	**$700,000**
Annual O&M Costs	
Power-205,000 kWh @ $0.06/kWh	12,000
Maintenance and Repairs	4,000
Operator Salary	8,000
ANNUAL O&M TOTAL:	**$24,000**

Table E1.1-11

Estimated Capital Costs for Camp Sekani Park Pump Station & Pipeline

Item	Cost
Sitework	2,200
Concrete	22,500
Masonry	27,900
Metals	2,000
Equipment (incl. Pumps)	37,100
ITEM SUBTOTAL:	$92,000
Allowances	
Finishes-2%	1,840
I&C-8%	7,360
Mechanical-25%	23,000
Electrical-8%	7,360
ALLOWANCES SUBTOTAL:	$40,000
FACILITY COST:	$132,000
Additional Facility Costs	
Demolition-3%	3,960
Overall Sitework-5%	6,600
Computer System-1%	1,320
Yard Electrical-2%	2,640
Yard Piping-3%	3,960
ADDITIONAL COST SUBTOTAL:	$18,000
SUBTOTAL:	$150,000
Transmission Pipeline	
12" PVC Pipe-40,900 LF @ $26/LF	1,063,900
Excavation & Pipe Bed-40,900 LF @$16/LF	654,700
TRANSMISSION PIPELINE SUBTOTAL:	$1,719,000
SUBTOTAL:	$1,869,000
Washington State Sales Tax-8.1%	$151,000
SUBTOTAL:	$2,020,000
Contractor Markups	
Overhead-10%	186,900
Profit-5%	93,450
Mob/Bonds/Insurance-5%	93,450
Contingency-30%	560,700
CONTRACTOR MARKUP SUBTOTAL:	$935,000
TOTAL CONSTRUCTION COST:	$2,955,000
Non-Construction Costs	
Permitting-1%	29,550
Engineering-10%	295,500
SDC-5%	147,750
Commissioning & Startup-2%	59,100
Legal/Administrative-1%	29,550
NON-CONST COST SUBTOTAL:	$561,000
TOTAL ESTIMATED CAPITAL COST:	**$3,516,000**
Annual O&M Costs	
Power-410,000 kWh @ $0.06/kWh	24,000
Maintenance and Repairs	4000
Operator Salary	8000
ANNUAL O&M TOTAL:	**$36,000**

Attachment E1.2

Reuse Sites Database

TABLE E1.2-1
Reuse Sites Database

Site Name	Location (Direction from WWTP)	Section, Township, Range	Latitude/Longitude		Distance (Miles from WWTP)	Acreage
Golf Courses						
Esmeralda Golf Course	East	SEC 3, T 25N, R 43E	Latitude: Longitude:	47.693140 -117.351991	5.75	163.72
Downriver Golf Course	South	SEC 2&11, T 25N, R 42E	Latitude: Longitude:	47.684056 -117.467289	1.00	140.50
Indian Canyon Golf Course	South	SEC 22&23, T 25N, R 42E	Latitude: Longitude:	47.650589 -117.472375	3.25	198.98
The Creek At Qualchan Golf Course	Southeast	SEC 5&6, T 24N, R 43E	Latitude: Longitude:	47.608479 -117.412473	6.75	187.07
Cemeteries						
Holy Cross Cemetery	Northeast	SEC 30, T 26N, R 43E	Latitude: Longitude:	47.724087 -117.418819	3.25	49.75
Fairmount Memorial Park	Northwest	SEC 34, T 26N, R 42E	Latitude: Longitude:	47.704904 -117.488676	0.75	83.75
Spokane Memorial Gardens	South	SEC 1, T 24N, R 42E	Latitude: Longitude:	47.598162 -117.441333	7.00	23.25
Landscaping						
Northside Landfill	Northwest	SEC 28, T 26N, R 42E	Latitude: Longitude:	47.728889 -117.498056	2.50	4.00
Parks						
Meadowglen Conservation Area	North	SEC 15, T 26N, R 42E	Latitude: Longitude:	47.757930 -117.493286	4.25	15.96
Meadowglen Park	North	SEC 15, T 26N, R 42E	Latitude: Longitude:	47.756097 -117.493290	4.00	14.30

TABLE E1.2-1
Reuse Sites Database

Site Name	Location (Direction from WWTP)	Section, Township, Range	Latitude/Longitude		Distance (Miles from WWTP)	Acreage
Northpoint Park	Northeast	SEC 20, T 26N, R 43E	Latitude: Longitude:	47.739968 -117.405162	4.50	3.84
Pacific Park	North	SEC 22, T 26N, R 42E	Latitude: Longitude:	47.736570 -117.485975	2.75	4.85
Sky Prairie Park	North	SEC 24, T 26N, R 42E	Latitude: Longitude:	47.734578 -117.446967	3.00	26.25
Friendship Park	Northeast	SEC 29, T 26N, R 43E	Latitude: Longitude:	47.725905 -117.400494	4.00	11.79
Indian Trail Park	North	SEC 26, T 26N, R 42E	Latitude: Longitude:	47.721085 -117.470149	1.75	3.73
Westgate Park	North	SEC 27, T 26N, R 42E	Latitude: Longitude:	47.720757 -117.490938	1.75	5.28
Wyakin Park	North	SEC 27, T 26N, R 42E	Latitude: Longitude:	47.717673 -117.477933	1.50	26.85
Harmon Park	Northeast	SEC 34, T 26N, R 43E	Latitude: Longitude:	47.713095 -117.366430	5.25	10.96
Ruth Park	Northeast	SEC 31, T 26N, R 43E	Latitude: Longitude:	47.712862 -117.415913	3.00	2.01
Nevada Park	East	SEC 32, T 26N, R 43E	Latitude: Longitude:	47.710588 -117.396749	3.75	9.57
Loma Vista Park	Northeast	SEC 36, T 26N, R 42E	Latitude: Longitude:	47.711198 -117.447482	1.75	8.63
Hill, James J. Park	East	SEC 33, T 26N, R 43E	Latitude: Longitude:	47.709064 -117.372691	5.00	2.09
Dwight Merkel Sports Complex	North	SEC 34, T 26N, R 42E	Latitude: Longitude:	47.711016 -117.478270	1.00	31.72

TABLE E1.2-1
Reuse Sites Database

Site Name	Location (Direction from WWTP)	Section, Township, Range	Latitude/Longitude		Distance (Miles from WWTP)	Acreage
Franklin Park	East	SEC 31, T 26N, R 43E	Latitude: Longitude:	47.705907 -117.413391	3.00	26.81
Rochester Heights Park	East	SEC 33, T 26N, R 43E	Latitude: Longitude:	47.706924 -117.381671	4.50	4.29
Franklin Sports Complex	East	SEC 31, T 26N, R 43E	Latitude: Longitude:	47.707329 -117.414545	3.00	15.19
St. Patrick's Park	East	SEC 33, T 26N, R 43E	Latitude: Longitude:	47.703019 -117.369929	5.00	1.85
Camp Sekani Park	East	SEC 1, T 25N, R 43E	Latitude: Longitude:	47.697373 -117.309528	7.75	124.98
Shadle Park	East	SEC 1, T 25N, R 42E	Latitude: Longitude:	47.698974 -117.440366	1.50	34.23
Glass Park	East	SEC 5, T 25N, R 43E	Latitude: Longitude:	47.698793 -117.399180	3.50	3.64
Byrne, Patrick S. Park	East	SEC 5, T 25N, R 43E	Latitude: Longitude:	47.694981 -117.407366	3.25	3.61
Clark, B.A. Park	East	SEC 6, T 25N, R 43E	Latitude: Longitude:	47.694413 -117.412533	3.00	9.61
Wildhorse Park	East	SEC 3, T 25N, R 43E	Latitude: Longitude:	47.692882 -117.362181	5.25	2.82
Webster Park	East	SEC 2, T 25N, R 42E	Latitude: Longitude:	47.694941 -117.466146	0.50	2.38
Hays Park	East	SEC 4, T 25N, R 43E	Latitude: Longitude:	47.691702 -117.381679	4.50	8.85
Upriver Park	East	SEC 2, T 25N, R 43E	Latitude: Longitude:	47.688410 -117.326112	7.00	8.99

TABLE E1.2-1
Reuse Sites Database

Site Name	Location (Direction from WWTP)	Section, Township, Range	Latitude/Longitude		Distance (Miles from WWTP)	Acreage
Minnehaha Park	East	SEC 2&3, T 25N, R 43E	Latitude: Longitude:	47.687821 -117.348094	6.00	39.78
Audubon Park	East	SEC 1&2, T 25N, R 42E	Latitude: Longitude:	47.690059 -117.453821	1.00	28.71
Courtland Park	East	SEC 4, T 25N, R 43E	Latitude: Longitude:	47.689957 -117.374828	4.75	3.28
Upriver Drive Parkway	Southeast	SEC 2,9,10,&11, T 25N, R 43E	Latitude: Longitude:	47.679191 -117.354881	5.75	56.09
Emerson Park	Southeast	SEC 6, T 25N, R 43E	Latitude: Longitude:	47.688366 -117.428898	2.25	2.47
Drumheller Springs Park	Southeast	SEC 1, T 25N, R 42E	Latitude: Longitude:	47.687002 -117.438944	2.00	15.91
Corbin Park	Southeast	SEC 7, T 25N, R 43E	Latitude: Longitude:	47.684895 -117.418629	2.75	12.63
Heath Park	Southeast	SEC 8, T 25N, R 43E	Latitude: Longitude:	47.672537 -117.400489	4.00	5.38
Chief Garry Park	Southeast	SEC 16, T 25N, R 43E	Latitude: Longitude:	47.671297 -117.370996	5.25	11.29
Mission Park	Southeast	SEC 17, T 25N, R 43E	Latitude: Longitude:	47.670583 -117.391068	4.25	20.12
A.M. Cannon Park	Southeast	SEC 12&13, T 25N, R 42E	Latitude: Longitude:	47.671588 -117.441569	2.50	8.25
Palisades Park	South	SEC 15, T 25N, R 42E	Latitude: Longitude:	47.665340 -117.482466	2.25	399.20
North Bank Park	Southeast	SEC 18, T 25N, R 43E	Latitude: Longitude:	47.665665 -117.419259	3.50	1.03

TABLE E1.2-1
Reuse Sites Database

Site Name	Location (Direction from WWTP)	Section, Township, Range	Latitude/Longitude		Distance (Miles from WWTP)	Acreage
Riverfront Park	Southeast	SEC 18, T 25N, R 43E	Latitude: Longitude:	47.662268 -117.420207	3.50	5.19
High Bridge Park	South	SEC 13,14,23,&24, T 25N, R 42E	Latitude: Longitude:	47.654837 -117.453948	3.00	44.21
Herbert M. Hamblen Conservation Area	Southeast	SEC 13, T 25N, R 42E	Latitude: Longitude:	47.660860 -117.437172	3.00	11.63
Glover Field Park	Southeast	SEC 18, T 25N, R 43E	Latitude: Longitude:	47.659537 -117.431675	3.25	4.17
Peaceful Valley Conservation Area	Southeast	SEC 13, T25N, R 42E	Latitude: Longitude:	47.658441 -117.448073	3.00	2.00
Indian Canyon Park	South	SEC 22&23, T 25N, R 42E	Latitude: Longitude:	47.652041 -117.481746	3.25	155.73
Liberty Park	Southeast	SEC 20&21, T 25N, R 43E	Latitude: Longitude:	47.652197 -117.388696	5.25	30.78
Coeur d'Alene Park	Southeast	SEC 24, T 25N, R 42E	Latitude: Longitude:	47.653557 -117.444651	3.25	11.00
Freeway Courts Park	Southeast	SEC 19, T 25N, R 43E	Latitude: Longitude:	47.652722 -117.414165	4.25	0.66
Underhill Park	Southeast	SEC 22, T 25N, R 43E	Latitude: Longitude:	47.648149 -117.367080	6.25	19.83
Cowley Park	Southeast	SEC 19, T 25N, R 43E	Latitude: Longitude:	47.649908 -117.411853	4.50	2.02
Pioneer Park	Southeast	SEC 19, T 25N, R 43E	Latitude: Longitude:	47.648161 -117.420114	4.25	11.76
Whittier Park	South	SEC 23, T 25N, R 42E	Latitude: Longitude:	47.649722 -117.463251	3.25	4.14

TABLE E1.2-1
Reuse Sites Database

Site Name	Location (Direction from WWTP)	Section, Township, Range	Latitude/Longitude		Distance (Miles from WWTP)	Acreage
Grant Park	Southeast	SEC 20, T 25N, R 43E	Latitude: Longitude:	47.646124 -117.392684	5.25	11.70
Cliff Park	Southeast	SEC 19, T 25N, R 43E	Latitude: Longitude:	47.644392 -117.418663	4.50	5.65
Finch Arboretum	South	SEC 23,24,&26, T 25N, R 42E	Latitude: Longitude:	47.642106 -117.464883	3.75	59.46
Polly Judd Park	Southeast	SEC 24, T 25N, R 42E	Latitude: Longitude:	47.643407 -117.439407	4.00	5.61
Latah Creek Park	South	SEC 25, T 25N, R 42E	Latitude: Longitude:	47.639777 -117.441750	4.25	4.78
Lincoln Park	Southeast	SEC 28, T 25N, R 43E	Latitude: Longitude:	47.637559 -117.375227	6.25	58.41
Manito Park	Southeast	SEC 29&30, T 25N, R 43E	Latitude: Longitude:	47.636506 -117.410978	5.25	85.09
Wentel Grant Park	South	SEC 25, T 25N, R 4E	Latitude: Longitude:	47.639162 -117.441520	4.25	3.08
Cannon Hill Park	Southeast	SEC 30, T 25N, R 43E	Latitude: Longitude:	47.637966 -117.422142	4.75	10.88
Grandview Park	South	SEC 26, T 25N, R 42E	Latitude: Longitude:	47.638738 -117.461020	4.00	5.64
High Drive Park	Southeast	SEC 30&31, T 25N, R 43E	Latitude: Longitude:	47.620615 -117.425227	5.75	177.41
Thornton Murphy Park	Southeast	SEC 27, T 25N, R 43E	Latitude: Longitude:	47.630926 -117.365588	6.75	2.94
Sterling Heights Park	South	SEC 26, T 25N, R 42E	Latitude: Longitude:	47.630859 -117.470992	4.50	9.18

TABLE E1.2-1
Reuse Sites Database

Site Name	Location (Direction from WWTP)	Section, Township, Range	Latitude/Longitude		Distance (Miles from WWTP)	Acreage
Comstock Park	Southeast	SEC 31, T 25N, R 43E	Latitude: Longitude:	47.626020 -117.422107	5.50	25.80
Hamblen Park	Southeast	SEC 33, T 25N, R 43E	Latitude: Longitude:	47.619351 -117.380505	7.00	15.53
Ben Burr Park	Southeast	SEC 2, T 24N, R 43E & SEC 35, T 25N, R 43E	Latitude: Longitude:	47.613846 -117.345694	8.25	8.90
Qualchan Hills Park	Southeast	SEC 6, T 24N, R 43E	Latitude: Longitude:	47.611382 -117.423389	6.50	27.88
Southside Sports Complex	Southeast	SEC 4, T 24N, R 43E	Latitude: Longitude:	47.610470 -117.371090	7.75	18.01
Hangman Park	Southeast	SEC 5,6,&8, T 24N, R 43E	Latitude: Longitude:	47.604533 -117.402955	7.25	179.61
Campion Park	Southeast	SEC 8, T 24N, R 43E	Latitude: Longitude:	47.591921 -117.402750	8.00	19.05
Riverside State Park	Northwest	SEC 6,7,17,18,19,20,21,28,29,30,33,34, T 26N, R 42	Latitude: Longitude:	47.737731 -117.531310	3.75	5480.85
Colleges and Universities						
Gonzaga University	Southeast	SEC 17, T 25N, R 43E	Latitude: Longitude:	47.668233 -117.401992	4.00	104.00
Spokane Falls Community College	South	SEC 11, T 25N, R 42E	Latitude: Longitude:	47.675573 -117.462610	1.75	123.00
Spokane Community College	East	SEC 10, T 25N, R 43E	Latitude: Longitude:	47.674720 -117.362635	5.50	87.50
Washington State University Ext.	Southeast	SEC 19, T 25N, R 43E	Latitude: Longitude:	47.656361 -117.420826	3.75	0.34

TABLE E1.2-1
Reuse Sites Database

Site Name	Location (Direction from WWTP)	Section, Township, Range	Latitude/Longitude		Distance (Miles from WWTP)	Acreage
Whitworth College	Northeast	SEC 18, T 26N, R 43E	Latitude: Longitude:	47.752908 -117.417757	4.75	200.00
Phillips Junior College	East	SEC 14, T 25N, R 43E	Latitude: Longitude:	47.667146 -117.325858	7.25	2.25
Eastern Washington University Ext.	Southeast	SEC 19, T 25N, R 43E	Latitude: Longitude:	47.656317 -117.421960	3.75	0.57
Washington State University Coop	Southeast	SEC 14, T 25N, R 43E	Latitude: Longitude:	47.659490 -117.346547	6.50	0.00
Intercollegiate Center for Nursing	South	SEC 11, T 25N, R 42E	Latitude: Longitude:	47.675746 -117.454510	1.75	84.25
Mukogowa-Fort Wright Institute	South	SEC 11, T 25N, R 42E	Latitude: Longitude:	47.676880 -117.473769	1.50	92.50
Washington State University Spokane	Southeast	SEC 17, T 25N, R 43E	Latitude: Longitude:	47.661729 -117.405402	4.00	22.00

Appendix E2

Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent

Technical Memorandum

Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent

Appendix E2 of Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent

PREPARED FOR: The City of Spokane
PREPARED BY: Dave Reynolds / CH2M HILL
Jim Lozier / CH2M HILL
Jason Assouline / CH2M HILL

DATE: November 9, 2004

This technical memorandum (TM) presents a conceptual-level design for the treatment of secondary effluent from the City of Spokane's Riverside Park Water Reclamation Plant for the purpose of reducing total phosphorus in the effluent to less than or equal to 0.01 milligrams per liter (mg / L; 10 µg / L). This is the maximum concentration of phosphorus that the Washington State Department of Ecology is currently proposing as a waste load allocation to the City of Spokane for continued discharge to the Spokane River. A workshop held on August 23, 2004 with wastewater treatment experts from CH2M HILL, HDR Engineering, Esvelt Environmental Engineering and the University of Washington concluded that reverse osmosis could produce the lowest concentrations of phosphorus of any known process and would come closest to Ecology's waste load allocation. The conceptual design is based on the use of reverse osmosis (RO) as the primary treatment process to provide greater than 98 percent phosphorus removal. Fine screening and submerged ultrafiltration (UF), a low-pressure membrane filtration process, is used to "pretreat" the secondary effluent to removal particulates and microorganisms to enable the RO process to operate cost effectively. The liquid waste stream or concentrate from the RO treatment step is disposed of by treatment using mechanical evaporation followed by crystallization. This produces a dry salt that is landfilled and a high quality distillate that can be discharged to the Spokane River.

Order of magnitude cost opinions are also presented herein for these treatment processes for three wastewater effluent peak flow rates: 70.3 million gallons per day (mgd; representing Year 1995) and 98.3 mgd and 75.7 mgd (representing Year 2015 with and without 10 mgd of Spokane County flow). The estimated capital cost of the dual-stage membrane process (UF+RO), together with other necessary unit operations and concentrate treatment, designed for the 2015 diurnal peak of 98.3 mgd, is estimated to be $559 million with an annual O&M cost of $17 million. Annual O&M costs assume operation of the reverse osmosis systems from April 1 to October 31 with average flow of 55.9 mgd. It should be noted that the annual O&M cost includes $4,000,000 for natural gas consumption needed to operate the mechanical evaporation and crystallization treatment of the concentrate flow based on an assumed natural gas cost of $0.50 per therm (1 therm=100,000 British thermal units [BTU]).

Background

Increasingly stringent nutrient effluent standards for surface discharge of treated wastewater streams are requiring greater phosphorus removal from wastewater treatment facilities. The tightening nutrient discharge requirements are the result of widespread environmental impacts of large urban areas. Increased levels of nutrients in rivers, lakes and reservoirs from wastewater discharges can lead to algal blooms, which can have repercussions on both wildlife and humans. Excessive nutrient loading can induce depleted oxygen levels, reduced sunlight penetration, and create a general imbalance in the ecosystem.

Historically, phosphorus removal at the Riverside Park Water Reclamation Plant has been achieved by the use of inorganic coagulants (aluminum salts) to chemically precipitate the soluble portion of the phosphorus as highly insoluble alumino-phosphates. This process has demonstrated that it can reliably produce an effluent total phosphorus (TP) level of less than 0.5 mg/L. To produce an effluent TP of less than or equal to 0.01 mg/L (10 µg/L) as required by Washington State Department of Ecology, given current secondary effluent TP levels of 0.5 mg/L, a process or processes must be capable of providing greater than 98 percent removal of TP from the effluent. The only treatment that has been demonstrated to provide this level of P removal is reverse osmosis (RO), a pressure drive process that uses semipermeable membranes to separate dissolved solids from water.

RO can remove greater than 99 percent of TP, including the soluble fraction (orthophosphate). Therefore, RO was selected as the treatment process to treat the wastewater effluent in order to reliably produce a treated water that can comply with the 10 µg/L TP requirement and be safely discharged to the Spokane River. To be properly and cost effectively processed by RO, the secondary effluent must first be treated to reduce the level of particulates and microorganisms to very low levels. This is necessary because RO membranes are readily fouled by these contaminants. To minimize fouling, the conceptual design described in this technical memorandum assumes that UF is used to “pre-treat” the secondary effluent to produce a low-fouling RO feedwater. Additional unit operations and processes are also required and will be described in subsequent sections of this report.

In addition to the process challenge of adequate removal of TP, this large wastewater treatment plant must operate as a zero liquid discharge facility. This will require the use of both energy and capital intensive treatment of the RO waste concentrate stream using enhanced mechanical evaporation and crystallization technologies to dewater the concentrate stream to a dry salt. These systems entail significant capital costs, O&M costs as well as an imposing physical structure. Nonetheless, mechanical evaporation with a crystallizer can achieve 99.5 percent brine concentration, facilitating simplified solids disposal at a local landfill.

Basis for Conceptual Design

A process schematic for the treatment components comprising the phosphorus removal facility are shown in Attachment E2.1 and include: effluent pumping, chloramination, fine screening, UF, filtrate storage and pumping, and RO. The UF filtrate is dosed with a threshold inhibitor to prevent mineral precipitation and scaling with the RO system. The

following subsections describe the unit operations and processes of the phosphorus removal facility and present conceptual level design criteria.

Effluent Pumping

Depending on the hydraulic regime following secondary clarification at this facility, an effluent pump station would be need to be constructed between the chlorine contact basin and the pre-screening stage leading up to the UF units. The effluent pump station would be designed based on the assumed parameters outlined in Table E2-1. This design incorporates the use of three high capacity (34,000 gallons per minute [gpm]) vertical turbine pumps with the firm pump capacity provided by any two of the three pumps. Dimensions of the pump station would be based on the 3 feet of freeboard, 5 feet static water depth and an operational depth of 12 feet, which would accommodate a 10 minute hydraulic retention time based on the maximum 106.8 mgd.

TABLE E2-1
Effluent pump station characteristics

Design Parameters	Design Values
Pump type	Vertical turbine
Pump type	Cascade
Pump flow	34,000 gpm each
Pump drive	700 hp
Number of pumps	3
Pump TDH	25
Pump station (LxWxH)	193 x 193 x 20 feet
Static water depth	5 feet
Freeboard	3 feet

H = height
L = length
W = width

Chloramination

Secondary effluent, even following disinfection with chlorine, still maintains a high biological activity due the presence of high nutrient levels (organics, nitrogen and phosphorus) as well as bacteria. When the effluent is processed by membrane processes such as UF and RO, the bacteria present in the effluent can quickly colonize and grow on the membrane surface in the presence of these nutrients, which can be concentrated at the membrane surface. The growth of bacterial films, termed biofouling, will quickly compromise the performance of the UF and RO processes, resulting in high operating costs and premature membrane replacement. To prevent biofouling, a low concentration of chloramines (measured as combined chlorine), 2.0 to 3.0 mg/L must be maintained on a continuous basis in the secondary effluent feeding the UF and RO processes. Chloramines,

rather than free chlorine, must be used because the RO membranes are rapidly and irreversibly damaged by free chlorine.

Because the secondary effluent has less than 0.2 mg/L ammonia, chemical storage and feed facilities are required to dose ammonia at a concentration of 0.7 to 1.0 mg/L into the secondary effluent. Assuming a 3:1 ammonia to chlorine ratio, this ammonia dose will produce a combined chlorine residual of 2.1 to 3.0 mg/L. It is assumed that a free chlorine residual of 2.0 to 3.0 mg/L is maintained at the outlet of the chlorine contact tanks so that no additional chlorine feed is necessary.

Assuming the use of liquid ammonia at an initial concentration of 25 percent, a 6400-gallon storage tank will be required. The use of dry, liquid, or anhydrous ammonia gas depends on the utility's preference, the availability of the various forms and the cost. Other factors that would influence the use of different chemical forms of ammonia would include size constraints associated with construction of the storage tank.

Fine Screening

Screening of the chloraminated UF feed water will ensure the removal of any particles larger than 0.5 mm. Pre-screening of the feed water decreases the presence of potentially fouling particles, which would impede the performance of the UF units and potentially damage the hollow fibers. These fine mesh screens are easy to clean and provide a safety barrier protecting the UF units from having to remove particles larger than the original design intent.

Ultrafiltration

Ultrafiltration (UF) uses hollow fibers operating under low pressure or vacuum to remove particulates, including pathogenic and non-pathogenic microorganisms from a feed stream. The hollow fiber membranes can be configured inside pressure vessels with the treated water filtering through the fibers under pressure or can be submerged (or immersed) directly in the feed stream with the treated water pulled through the fibers under vacuum. The pores of UF membranes range from 0.01 to 0.05 um, small enough to physically retain nearly all particles forming turbidity and microorganisms such as viruses and bacteria. As such, UF can reduce bacterial counts to less than detectable levels and turbidity to less than 0.1 NTU producing a feedwater that will have very little particulate fouling potential for the RO membranes.

UF is one of two membrane technologies that are used for particulate removal and RO feedwater pretreatment. The other is microfiltration (MF), which is similar to UF in nearly all respects except for having membrane pores that are slightly larger (0.1 to 0.2 um). For purposes of this memorandum, UF and MF are interchangeable and the selection of UF for purposes of the conceptual design is for convenience only in order to select a specific product to develop design criteria and cost opinions.

For plants with greater than 20 mgd capacity, the submerged MF/UF operating configuration has been shown to be most cost effective and is used for this design. The dominant submerged UF technology is called ZeeWeed and is manufactured by Zenon Environmental, Inc. of Oakville, Ontario, Canada. Specifically, the ZeeWeed 1000 model UF technology has been used for costing purposes. Detailed description of the ZeeWeed process

and the ZeeWeed 1000 product is presented in Attachment E2.2. Functionally equivalent and cost competitive submerged MF/UF products are manufactured by USFilter.

Characteristics and design criteria for ZeeWeed 1000 is presented in Table E2-2. ZeeWeed 1000 operates in a dead-end flow configuration, where the secondary effluent is filtered directly through the membranes. No waste stream is produced and contaminants not capable of passing through the membrane pores are retained at the membrane surface. Periodically, the filtration process is stopped and treated water (filtrate or permeate) is pumped back through the membrane in the opposite direction, thereby displacing the accumulated solids, similar to the backwashing step used with a gravity media filter. Likewise, air is also used on the feed side of the membrane to assisting in dislodging solids from the membrane surface. Less often, the membranes are removed from service and a chemical solution, typically chlorine or acid, is circulated through the membranes to solubilize contaminants that cannot be removed by backwashing and air scour.

For this design, the backwash waste, accounting for 10 percent of the secondary effluent, is flow equalized and pumped back to the WWTP headworks to remove solids. It is assumed that the backwash flow, which has no appreciable BOD load, can be satisfactorily accommodated by the WWTP without a reduction in wastewater treatment capacity or performance.

Because the UF process retains nearly all particulates, it will result in some reduction of total phosphorus in the effluent due to the removal of particulate phosphorus. It is anticipated that this reduction could be as much as 0.05 mg/L TP, however for purposes of this memorandum, no phosphorus removal is assumed. Additionally, a significant fraction of the soluble (orthophosphate) present in the secondary effluent can be removed by UF if the UF feedwater is first dosed with a coagulant such as ferric chloride or alum. Again, no dosing was assumed based on the assumption that all of the required phosphorus removal (from 0.5 mg/L to 10 µg/L) would be achieved by RO. Coagulant dosing to the UF feedwater will increase the solids load at the surface of the UF membranes and result in an increase in UF capital and operating costs. As such, there is no economic incentive to include coagulant dosing to achieve the design goal. In the event that orthophosphate levels in the secondary effluent were appreciably greater than 0.5 mg/L, there may be a need to consider coagulant dosing to ensure that the RO process will reliably produce a 10 µg/L TP concentration in the final discharge.

The UF system consists of the following components: process tanks, membrane cassettes, permeate pumps, backwash tank (for storage of filtrate) and backwash pumps, air blowers and clean in place tankage and pumps for chemically cleaning the membrane, as well as associated piping, valving and instrumentation. The UF equipment, including tankage, is located within a building that is provided with an overhead bridge crane for installation and removal of membrane cassettes and other heavy equipment. Space is also provided within the building for electrical equipment, a control room, maintenance room, and lavatories.

TABLE E2-2
ZeeWeed 1000 System configuration

Design Capacity ADF	70.3 mgd	98.3 mgd*
Number of Trains	11	15
Number of Cassettes Per Train	12	12
Total Number of Cassettes	132	180
Number of Modules per Cassette	81	92
Number of Module Spaces per Cassette	15	12
Spare Space	16%	13%
Module Surface Area	500 ft^2	500 ft^2
Design Flux (Nominal)		
@ ADF	14.5 gfd	14.3 gfd
@ ADF with one train off-line	16.1 gfd	15.7 gfd
Preliminary Membrane Tank Dimensions (L x W x H)	11 tanks each 32.7 ft x 14.1 ft x 12.5 ft	15 tanks each 32.7 ft x 14.1 ft x 12.5 ft

*Scaled from 70.3 and 78.3 mgd vendor designs
ADF = average daily flow
gfd = gallons per square foot per day

Filtrate Storage, Chemical Conditioning, and Pumping

The filtrate storage tank is assumed to be below grade and beneath the building housing the UF and RO systems. In order to provide a 30 minute hydraulic retention time, this tank will need to be 2 mgd or 274,000 cubic feet. Additional pumps will be required to propel the feed water through the RO units at the required pressure needed to drive the system. The design required for the RO facility was made up of twenty-four, 4.1 mgd RO trains. Two additional pumps will serve as backup for the system. A summary of the design criteria for the filtrate storage tank and RO feed pumps is presented in Table E2-3.

TABLE E2-3
RO feed pumps and filtrate facility

RO feed pumps	
Number of pumps	22
Maximum feed pressure (pounds per square inch)	200
Pump capacity (gallons per minute)	2,800
Filtrate storage facility (cubic feet)	218,000

The UF process is not continuous due to the need to backwash the membranes. As such, flow between the UF process and RO process (which is continuous) must be hydraulically balanced. This is achieved by use of a break or balance tank to store the UF filtrate at a sufficient volume to account for flow fluctuations between the two processes. The tank also serves as a wetwell for the RO feed pumps. Prior to the UF filtrate entering the balance tank, it is dosed with a threshold or scale inhibitor to prevent the precipitation of sparingly soluble salts that might be formed during RO treatment as such salts are concentrated. Although the level of sparingly soluble salts, including calcium sulfate, fluoride, phosphate, carbonate, barium sulfate, strontium sulfate, and silica have not been measured in the secondary effluent, it is typical that one or more of these salts will be concentrated to a level that exceeds their solubility. The addition of threshold inhibitor ensures that such concentration does not result in the formation of scale on the RO membranes when solubility is exceeded.

The RO process operates at relatively high pressure, in the range of 150 to 200 pounds per square inch (psi). Vertical turbine pumps, installed directly on the filtrate tank, are used to produce this pressure. The pumps are operated as a pumping center and discharge into a common header that feeds the RO trains. A combination of constant speed and variable speed motors are used to provide the pressure and flow to the RO trains depending upon how many are in operation based on wastewater effluent flow.

Reverse Osmosis

A simplified process schematic is shown in Figure E2-1. Feedwater, in this case ultrafiltered secondary effluent, is pressurized and flows tangentially across the surface of a flat sheet RO membrane contained in a pressure vessel. A portion passes through the membrane to become the treated water or permeate containing less than 10 µg/L of TP as well as very low concentrations of other salts and organics. The remaining feedwater exits the pressure vessel as reject or concentrate, containing the rejected phosphorus, salts and organics as the process waste stream. As such the RO process, unlike UF, produces a continuous waste stream. For the treatment of secondary effluents, the typical amount of permeate produced per unit of feed flow is 85 percent. This is referred to as the feedwater recovery of the RO system. This means that 15 percent of the feed flow is concentrate. The actual recovery of the RO system may be higher (or lower) than the 85 percent assumed in this design depending upon the actual concentrations of sparingly soluble salts in the secondary effluent. Where recovery is higher, the cost of the RO system will increase (more product water is produced requiring more RO trains), however the cost of the concentrate treatment facilities (discussed in a subsequent section) will be reduced. As the cost of concentrate treatment (per gallon) is considerable higher than the cost of RO treatment, maximizing RO feedwater recovery will reduced overall cost of the phosphorus removal process.

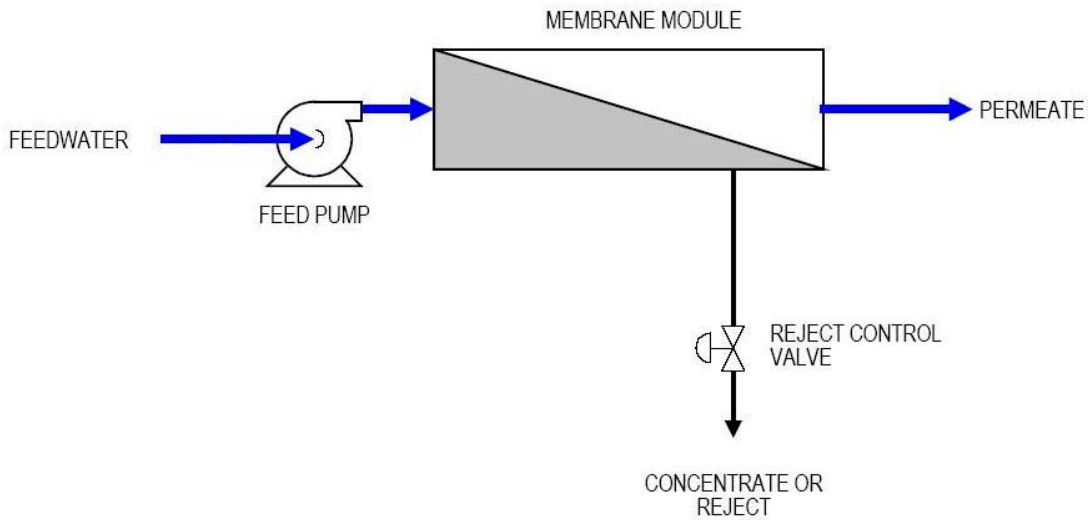


FIGURE E2-1 – SIMPLIFIED FLOW SCHEMATIC FOR PRESSURE-DRIVEN MEMBRANE PROCESS

The RO system consists of RO trains, and chemical cleaning system. The RO trains contain racks of pressure vessels arranged in parallel and series containing the RO membrane elements along with associated piping, valving and instrumentation. The cleaning system consists of a tank for preparation of cleaning solutions, a cleaning pump for transfer and recirculation of cleaning solutions between the tank and the RO trains, a cartridge filter and associated piping, valving and instrumentation. Each RO train contains three stages, as shown in Figure E2-2. This is required to achieve the high (85 percent) feedwater recovery. The RO system is housed in a common building with the UF equipment and a common control room.

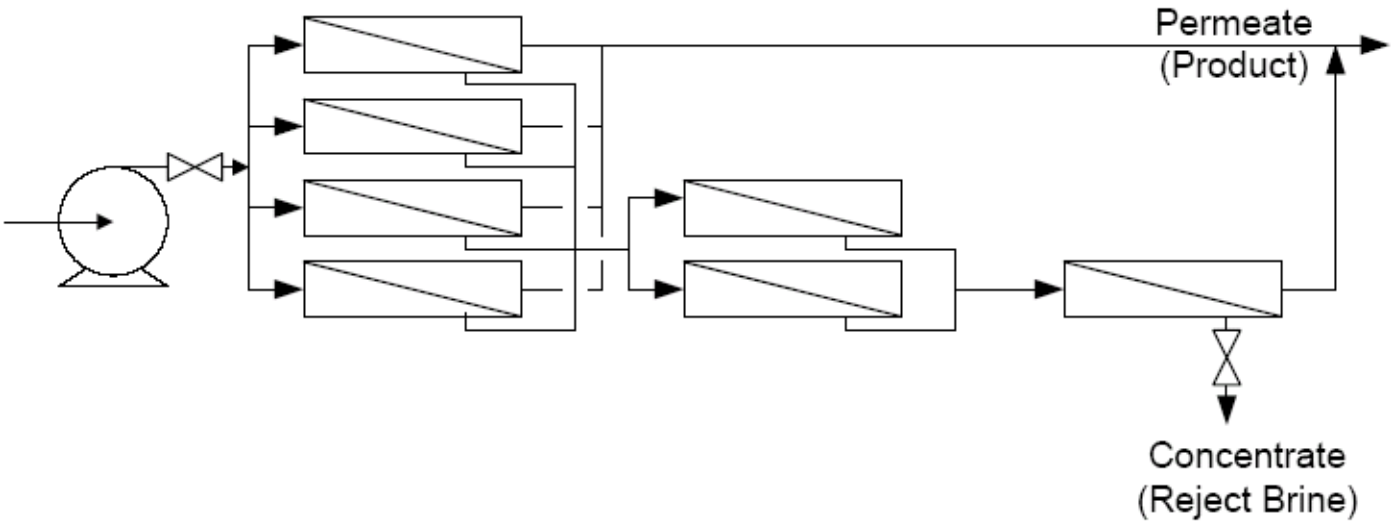


FIGURE E2-2 – REPRESENTATIVE PROCESS SCHEMATIC FOR 3-STAGE RO PROCESS.

RO Modeling Input and Results

Several RO system design and operational criteria require the use of computer software for their determination, including the RO train array (number and staging of pressure vessels and feed pressure). Performance projections were made using the software program ROSA™, a product of Dow Filmtec Corporation. ROSA is one of many software programs available from a variety of RO membrane suppliers and results from ROSA are considered representative of other RO software.

RO performance projections utilized the 3-stage RO array operating at 85 percent feedwater recovery and a membrane flux of 11 gallons per square foot per day (gfd), the latter demonstrated as appropriate by several RO plants operating on secondary effluent. Projections were conducted at two feedwater and membrane fouling conditions to estimate maximum feed pressure and average feed pressure conditions. These conditions are shown in Table E2-4. The resulting feed pressures were used to size and cost RO feed pumps and motors in the capital cost opinions and annual RO system energy usage in the operating and maintenance cost opinions. Table E2-4 delineates the variations in the different cases examined in the modeling program. The minimum temperature (10 ^{O}C), where the viscosity of the water will be the greatest, was selected to determine the maximum feed pressure. This was used to determine the maximum pressure the system will experience allowing for adequate sizing of the pump capacity needed. Pump capacity and pricing at each design flow (70.3 and 98.3 mgd) were analyzed. A TDS feed concentration of 750 mg/L, 0.88 recovery, and a temperature of 15° C comprising the average operational conditions that are expected was calculated for the 2015 design flow conditions only.

TABLE E2-4
Input Parameters for ROSA Model

Parameter	Units	Maximum Feed Pressure Case	Average Feed Pressure Case
Feed Flow	mgd	98.3	98.3
Feed TDS	mg/L	1,000	750
Temperature	^{O} C	10	15
Fouling Factor		0.75	0.88

ROSA membrane modeling program was developed by Dow/Filmtec

Results for the two ROSA™ performance projections are shown below in Table E2-5. The results in Table E2-4 indicate that the TDS of the RO permeate will be very low (less than 20 mg/L) and the RO concentrate TDS will be moderately brackish (5,000 to 7,000 mg/L). RO feed pressures are projected to range from 142 psig on average to a maximum of 187 psig at year 5 of RO membrane life.

Neither ROSA™ or the other membrane suppliers' software programs estimate the rejection of phosphorus. CH2M HILL analyzed phosphorus removals by RO systems treating secondary effluents at other pilot or full-scale plants, including the City of San Diego's Aqua 2000 facility and the Singapore's NEWater plants at Bedok and Kranji. RO systems at these facilities operated at similar membrane flux and slightly lower feedwater recovery (75 to 80 percent). Reported phosphorus rejections were greater than 99 percent at both facilities where RO feedwater total phosphorus concentrations ranged from 2 to 40 mg/L and at

feedwater temperatures of 20 to 30° C. These results provide empirical evidence that the RO treatment of the secondary effluent from the City's WWTP will be 10 µg/L based on an effluent total phosphorus level of 0.5 mg/L.

TABLE E2-5
Results of ROSA™ Performance Projections

Parameter	Units	Maximum Pressure	Average Pressure
Feed Flow	mgd	98.3	98.3
Feed TDS	mg/L	1000	750
Feed Pressure	psig	187.42	142.12
Average Flux	gfd	11.04	11.04
Recovery	%	85	85
Permeate TDS	mg/L	18	18
Concentrate TDS	mg/L	6566	4892

RO Concentrate Treatment

A variety of alternatives are available for treatment and/or disposal of the RO concentrate. These include discharge to a surface water, land application, deep-well injection, evaporation ponds and mechanical evaporation. As a zero liquid discharge facility, acceptable disposal alternatives for use at the City's WWTP are limited to mechanical evaporation followed by spray crystallization.

This process combination entails heating and evaporating the water in the highly saline RO concentrate to generate a dry salt. The salt is then sent to a landfill for final disposal and the distillate produced by the evaporation process is combined with the RO permeate for discharge to the Spokane River. The RO concentrate flow at 2015 peak day wastewater flow, based on an assumed 85 percent recovery, will be roughly 14.7 mgd. This large liquid waste stream will significantly increase the capital and O&M costs associated with the phosphorus removal facilities. Based on initial estimates for the facility layout, the concentration/crystallization process would involve 8-10 concentrators, with a total footprint of 450 feet by 500 feet and a maximum height of 95 feet.

Permit requirements are minimal for operation of mechanical evaporation equipment for RO concentrate disposal. The concentrate handling process does not directly emit any air pollution, however, the on-site power generation from natural gas could warrant the necessity to follow through on some permitting issues. Depending on the zoning regulations and height of the falling film brine concentrator, a variance to allow a structure in excess of the regulated maximum height may be required. State and local agencies should be contacted for other regulations that may apply.

Mechanical Evaporation Process Explanation

The membrane reject stream enters the mechanical evaporation process through a heat exchanger that raises the temperature to the boiling point (see Figure E2-3). Hot feed is combined with the circulating brine slurry in the sump. Calcium sulfate crystals are seeded

into the brine slurry to act as precipitation nuclei for scalants that would otherwise scale the heat transfer surfaces. A falling film of the concentrate flows down through the tubes and back into the sump.

Vapor enters the vapor compressor, which heats it slightly before it flows to the outside of the heat transfer tubes. Mechanical compressors are used in most applications. The mechanical vapor compressor is responsible for about 80 to 90percent of the 70- to 90-kilowatt-hours (kWh) power usage per 1,000 gallons of brine concentrator feed. A thermal (or steam-driven vapor compressor) are alternatives to a mechanical evaporator if waste steam is readily available. For this design, no waste heat was assumed and electrical energy was assumed to drive the mechanical evaporator.

Heat from the compressed vapor is then transferred to the cooler brine falling inside the tubes, causing some of the brine to evaporate. As the compressed vapor releases heat, it condenses as product water. This condensate is highly pure with a TDS content from 5 to 10 mg/L, making it an excellent water source for boiler makeup, cooling makeup, and process use. As with steam transfer and reuse, there may be potential to negotiate the sale of this low-TDS product to others. Moreover, the sale of the distillate may be more economical than blending with plant effluent to reduce TDS and other challenging water quality parameters.

Heat is somewhat recycled within the system as the high-purity distillate is pumped back through the heat exchanger, where it is allowed to release heat to the incoming concentrate stream. Total product water recovery across the brine concentrator is assumed to be between 95 and 99 percent. The distillate is of a very high quality suitable for use as drinking water. For purposes of this design, the distillate is assumed to be combined with the RO permeate and discharged to the Spokane River. From 1 to 5 percent of the brine slurry is blown down from the sump to control the brine density to between 20 and 30 percent (200,000 to 300,000 mg/L).

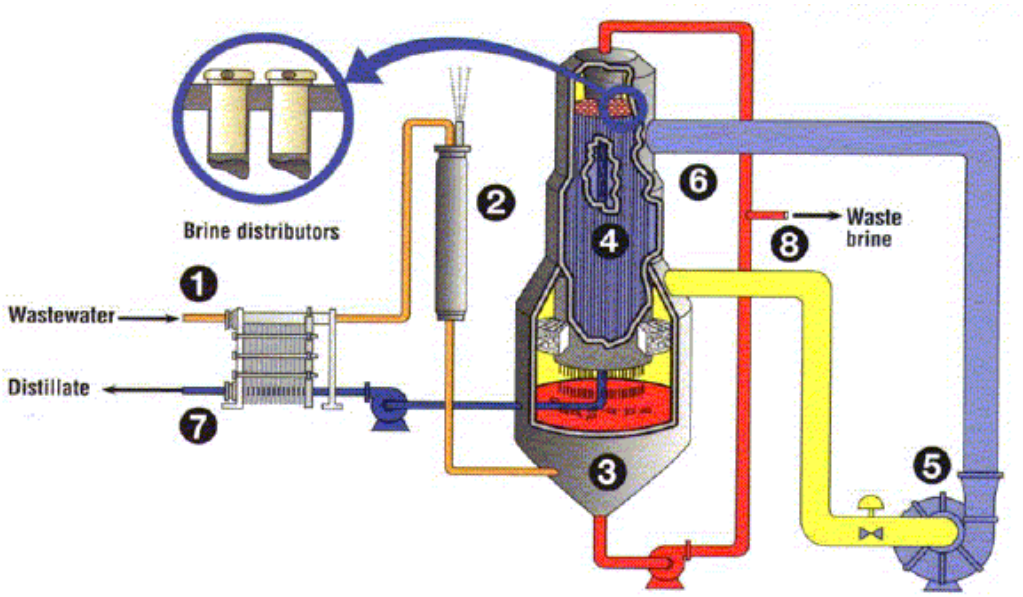


FIGURE E2-3 – SIMPLIFIED MECHANICAL EVAPORATION SCHEMTIC (SUPPLIED BY IONICS, INC-RCC THERMAL PRODUCTS).

Brine Crystallization Process

Blowdown (brine) from the mechanical evaporator is sent to a crystallizer feed tank and then on to the forced-circulation crystallizer (Figure E2-4). The 20 to 30 percent brine is recirculated through a heat exchanger under pressure to prevent boiling and subsequent scale formation in the tubes. The pressurized brine then enters a separator chamber operating at a slightly lower pressure or partial vacuum, resulting in flash evaporation of water and formation of insoluble salt crystals in the brine.

The vapor passes through mist eliminators and enters the vapor compressor, which heats it, as in the evaporation unit. Compressed vapor flows to the outside of the heat transfer tubes heat the recirculated brine flowing inside the tubes. Mechanical compressors are used in most applications. The mechanical vapor compressor is responsible for about 80percent of the 250-kWh power usage per 1,000 gallons in the forced-circulation crystallizer feed.

From 1 to 5 percent of the brine/crystal liquor is wasted in order to separate the insoluble salts. Typically, salt crystals are separated from the liquor with centrifuges or filter presses. The separated salts will be landfilled and the concentrate or filtrate returned to the forced-circulation crystallizer feed tank.

A potential option for decreasing the amount of mechanical equipment involved is to replace the forced-circulation crystallizer with solar evaporation ponds. In this case, the falling film brine concentrator would be used to reduce the volume of the membrane concentrate prior to solar evaporation. The 200,000- to 300,000-mg/L TDS brine from the evaporator is pumped to a solar evaporation pond for additional volume reduction. Effective salt concentration in the evaporation ponds relies predominantly on regional climate characteristics and land availability. Pan evaporation rates in Spokane are insufficient to support the use of solar evaporation rates.

Total product water recovery across the crystallizer is between 95 and 99 percent. For purposes of this design, the condensate is blended with the RO permeate and evaporator distillate and discharged to the Spokane River. In addition to the large size of mechanical evaporation equipment, evaporators and crystallizers are relatively complex to operate and maintain compared to the UF and RO membranes processes used to treat the secondary effluent.

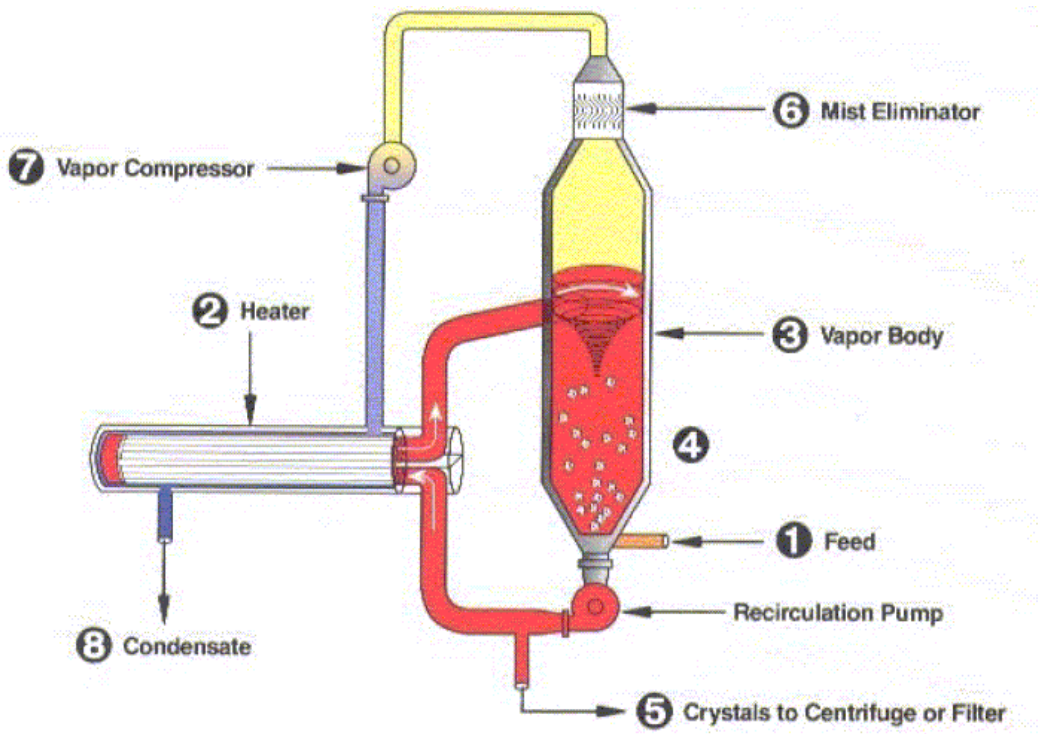


FIGURE E2-4 – SIMPLIFIED BRINE CRYSTALLIZER SCHEMATIC (SUPPLIED BY IONICS, INC-RCC THERMAL PRODUCTS).

Opinions of Cost for Proposed Phosphorus Removal Facility

Opinions of cost for both construction and operation and maintenance (O&M) for the proposed phosphorus removal facility are summarized in Table E2-6. The cost opinions were performed using the CH2M Hill Parametric Cost Estimating System (CPES). CPES cost opinions are order-of-magnitude estimates as defined by the Association of American Cost Engineers and are considered to be accurate to +50/-30 percent of actual costs. CPES cost opinions are developed using discrete cost "modules" for each unit operation or process of the overall treatment train as described above. Inputs are provided for basic design criteria, which together with pre-defined incorporates the plant flows, membrane flux and pressure along with other user defined criteria to estimate project, construction, total capital and O&M costs. The project cost is based on all equipment associated with the process. Construction costs include all the equipment and all the necessary yardpiping, sitework, electrical, and instruments and controls pertinent to the operation of these facilities. A 30 percent contingency is factored into the construction cost. Total project cost figures encompass all estimated costs of the project, including engineering (15 percent), legal/administrative (10 percent), and local taxes (8 percent).

The 70.3 mgd design capacity represents the peak dry weather diurnal 1995 flow with 10-percent added safety factor. The 75.7 mgd design capacity is the peak flow with 10 mgd of average Spokane County flow removed. The 98.3 mgd design capacity is the peak flow with no Spokane County flow removed.

Cost opinions for operations and maintenance (O&M) shown in Table E2-6 include labor necessary to run the membrane and concentrate handling facilities only. Included in the cost opinions are chemical feed systems, UF, filtrate pumping and storage, effluent pumping

station, reverse osmosis, and the concentrate handling facilities. The majority of the O&M cost listed below is derived from the energy consumption and additional labor requirements associated with the operation and maintenance of the mechanical evaporation and crystallization processes. Energy for the concentrate handling operation was assumed to come solely from natural gas purchased by the facility at $0.50 per therm. Natural gas storage tank construction was not included in the estimation.

TABLE E2-6
Cost Opinions for Phosphorus Removal Facility

		1995	2015	2015
		70.3 mgd Design Capacity	**75.7 mgd Design Capacity**	**98.3 mgd Design Capacity**
Chemical feed/storage		$399,000	$430,000	$557,000
Ultrafiltration (UF)		$20,259,000	$21,752,000	$28,000,000
Clearwell		$340,000	$470,000	$582,000
Pump station		$874,000	$920,000	$1,042,000
Reverse osmosis		$59,916,000	$63,672,000	$83,000,000
Brine evaporation/crystallization		$95,000,000	$95,000,000	$95,000,000
Subtotal		$176,788,000	$182,244,000	$208,181,000
Sitework	5%	$8,839,000	$9,112,000	$10,409,000
Yardpiping	10%	$17,679,000	$18,224,000	$20,818,000
Electrical	8%	$14,143,000	$14,580,000	$16,654,000
Instrumentation and controls	5%	$8,839,000	$9,112,000	$10,409,000
Subtotal		$226,288,000	$233,272,000	$266,471,000
Contractor overhead	10%	$22,629,000	$23,327,000	$26,647,000
Contractor profit	5%	$12,446,000	$12,830,000	$14,656,000
Mobilization/bonds/insurance	5%	$13,068,000	$13,471,000	$15,389,000
Contingency	30%	$82,329,000	$84,870,000	$96,949,000
Construction cost		$356,760,000	$367,770,000	$420,112,000
Engineering, legal and administration	25%	$89,190,000	$91,943,000	$105,028,000
Sales tax	8%	$28,541,000	$29,422,000	$33,609,000
Total project cost		**$474,491,000**	**$489,135,000**	**$558,749,000**
Annual O&M cost		**$12,400,000**	**$14,400,000**	**$17,000,000**

Cost estimation performed using CH2M HILL CPES proprietary software.

The cost estimates presented in this study are “order-of-magnitude” estimates, as defined by the American National Standards Institute (ANSI) and the American Association of Cost Engineers (AACE) as “approximate estimates made without detailed engineering data. It is

normally expected that estimates of this type will be accurate within plus 50 percent or minus 30 percent." This range implies that there is a high probability that the final project cost will fall within the range.

A 30 percent contingency has been included in these cost estimates as a provision for unforeseeable, additional costs within the general bounds of the project scope, particularly where previous experience has shown that unforeseeable events that will increase costs are likely to occur. The contingency is used as a means to reduce the risk of possible cost overruns. The contingency in these estimates consists of two components: *Bid Contingency* and *Scope Contingency*. Bid Contingency covers the unknown costs associated with constructing a given project scope, such as adverse weather conditions, strikes by material suppliers, geotechnical unknowns, and unfavorable market conditions for a particular project scope. Scope Contingency covers scope changes that invariably occur during final design and implementation.

The cost estimates have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimates. The final cost for the project will depend on such criteria as actual labor and material costs, competitive market conditions, actual site conditions, final project scope, and other variables. As a result, the final project cost will vary from this estimate. The proximity to actual costs will depend on how close the assumptions of this estimate match final project conditions. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help assure proper project evaluation and adequate funding.

UF/RO Costs

Cost opinions for the RO system and the entire UF/RO process are broken down in Table E2-6, above. Several 3-stage treatment trains, operating in parallel, will be required to treat the maximum 98.3 mgd design capacity of this facility. As described in previous sections, 11 to 15 UF trains would be required while 24 RO trains would be needed. When the direct cost is compared to the construction cost, it is apparent that construction of the membrane facilities contributes significantly to the overall capital cost due to the numerous pipes, valves, and pumps needed. Concrete and other costs result from the construction of the housing facility and the underground filtrate storage facility, all part of the membrane treatment process needed to produce the desired effluent quality.

Annual O&M costs will be particularly driven by the RO process. Pumping requirements to produce the pressure needed to drive RO, when compared with UF, will be significant, despite the fact that low energy membranes were selected. Depending on the configuration of the effluent pumping station, the UF process may feasibly operate by gravity. In addition to electrical expenses, four membrane cleanings will be needed each year and the membranes will need to be replaced every five years. Membrane cleanings will require additional labor as well as chemicals needed for the removal of scale and other fouling agents which accumulate over time on the membrane surface.

Mechanical Evaporation/Crystallization Costs

The primary drawback for implementing mechanical evaporation for membrane concentrate disposal is the relative high expense. Mechanical evaporation equipment is both

capital and operational cost-intensive. Equipment manufacturers have been contacted for capital cost of mechanical evaporation equipment because the materials of construction of the mechanical evaporation equipment are sensitive to membrane concentrate quality. The falling film brine concentrator is more costly than the forced-circulation crystallizer due to the higher concentrator flow.

Operational cost of the mechanical evaporation equipment is almost completely associated with power usage of the large vapor compressors used in the process. Based on cost estimations provided by a concentrate evaporation/crystallization vendor, the capital cost for a facility handling a maximum of 15 mgd of concentrate would be $65,000,000. The installation cost of the 8 to 10 units needed would be roughly $30,000,000 and the annual maintenance cost would be about 1 percent of the total capital cost or $950,000. In this application, energy for the concentrate handling operation was assumed to come solely from natural gas purchased by the facility at $0.50 per therm. This facility would only be operated only from April 1 through October 31 (214 days per year). Therefore, the annual natural gas consumption based on a 46 megawatt (MW) power consumption would be about $4,000,000.

From these figures, mechanical evaporation is extremely sensitive to power costs at a given location. A small increase in power costs can dramatically increase the cost to treat a specified volume of membrane concentrate. The installation of a high recovery RO system, with seawater membranes, could reduce the cost about 30 percent and power consumption by 50 percent, depending on the wastewater flows. Reuse of steam or thermal energy from this facility or other nearby facilities would serve to reduce the massive energy required to operate the steam driven vapor compressor.

Landfill costs are also incurred for ultimate disposal of the municipal waste concentrate. Due to the nature of the feed solution, special permitting may be involved in the disposal of this municipal waste concentrate. Either the sludge must be disposed of in a municipal landfill or an RCRA-approved landfill depending on the makeup of state regulations regarding concentrate disposal. Disposal of salt sludge in an RCRA-approved landfill will increase costs due to the liner and leak detection system requirements.

Summary

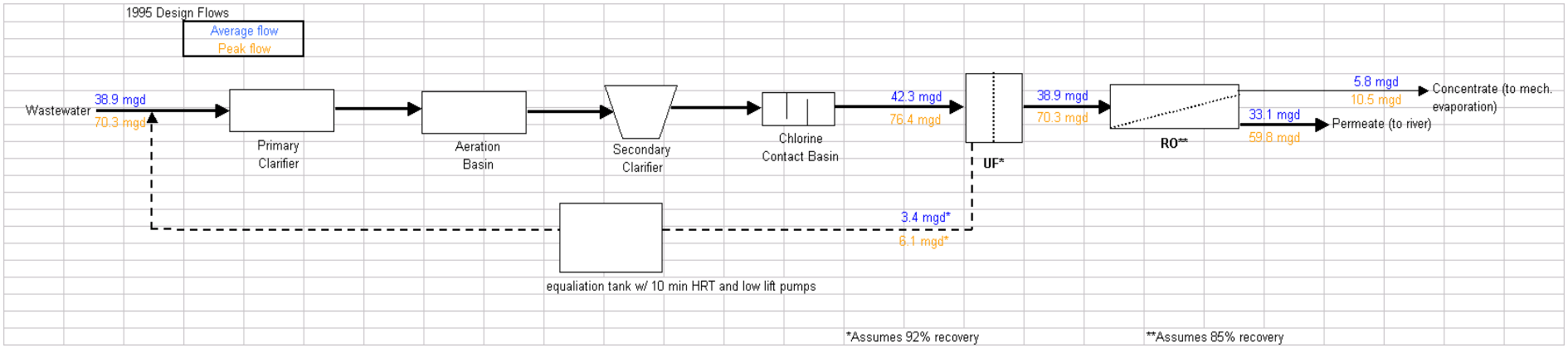
In order to remove phosphorus to 10 µg/L, dual membrane treatment, UF followed by reverse osmosis, is necessary. Further, to provide for zero liquid discharge at the WWTP, the waste concentrate from the RO process must be processed using expensive and energy intensive evaporation and crystallization technologies. The combination of dual membrane for effluent treatment and evaporation/crystallization of the concentrate result in very high capital and operating costs for the overall phosphorus removal facility. To treat the 2015 peak wastewater flow condition, the estimated total capital cost and annual operating and maintenance costs exceed $559 million and $17 million, respectively. These costs do not include the operating costs for landfilling the dry salts produced from the evaporation and crystallization process.

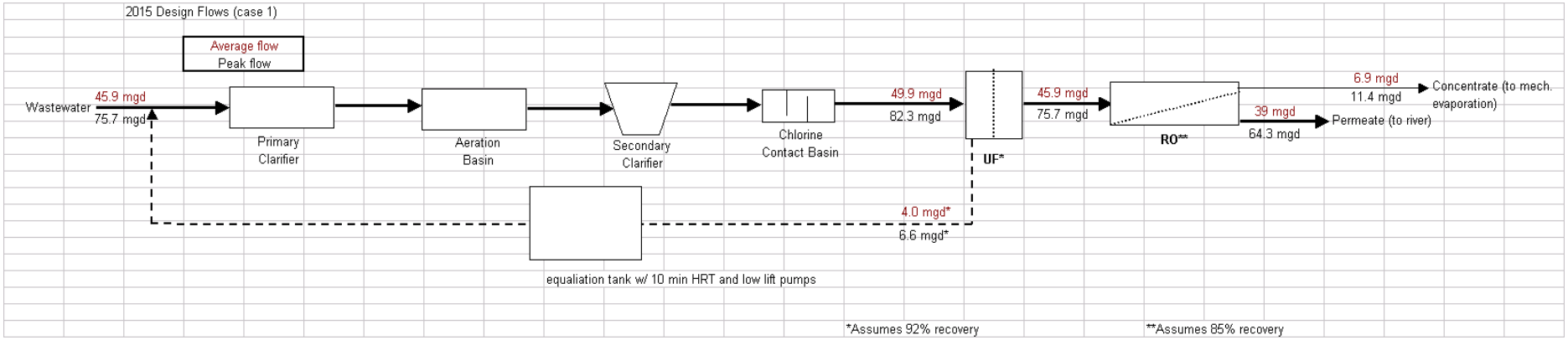
Attachment E2.1

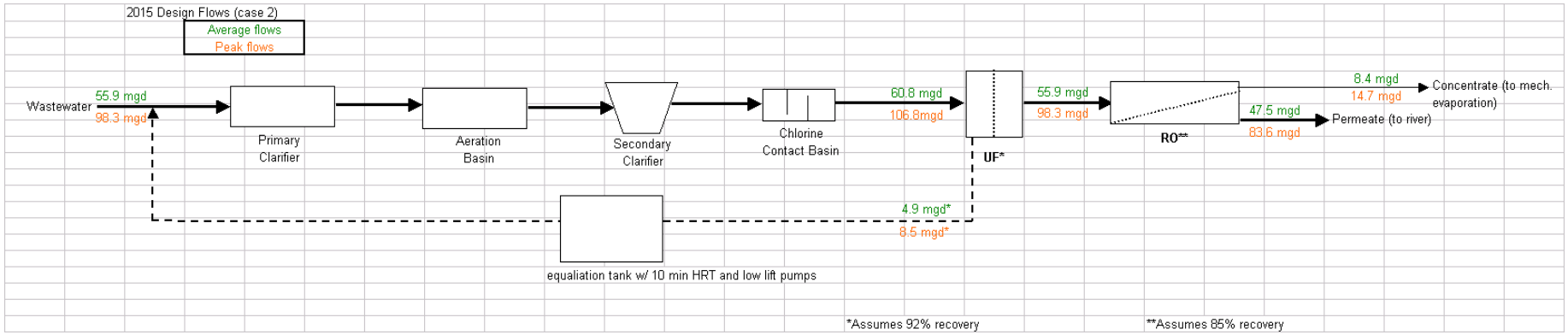
Proposed Process Flow Schematics for Flow Conditions

ATTACHMENT E2.1

Proposed Process Flow Schematics for Flow Conditions






2015 Design Flows (case 2)
Average flows
Peak flows
Wastewater
55.9 mgd
98.3 mgd
Primary Clarifier
Aeration Basin
Secondary Clarifier
Chlorine Contact Basin
60.8 mgd
106.8mgd
UF*
55.9 mgd
98.3 mgd
RO**
8.4 mgd
14.7 mgd
Concentrate (to mech. evaporation)
47.5 mgd
83.6 mgd
Permeate (to river)
4.9 mgd*
8.5 mgd*
equaliation tank w/ 10 min HRT and low lift pumps
*Assumes 92% recovery
**Assumes 85% recovery

Attachment E2.2

Description of Zenon Ultrafiltration Process

ATTACHMENT E2.2

Description of Zenon Ultrafiltration Process

Zenon pioneered the use of immersed, hollow-fiber membranes for water treatment and has over a decade of experience in their design, manufacture and sale to customers worldwide. With more than 100 drinking water and over 220 wastewater installations globally, each new ZeeWeed facility benefits from this experience base.

With a nominal pore size of 0.02 µm, ZeeWeed 1000 ultrafiltration (UF) membranes are designed to remove suspended solids, protozoa, bacteria and viruses through an "Outside-In" flow regime. Specifically targeted to produce RO feed waters containing low amounts of suspended solids, this product can be easily tailored to fit in existing facilities. In addition to configuration and operational flexibility, very little pressure head is needed to drive the operation of these filters (10 feet of water or 4 psi), making gravity fed systems optimal.

ZeeWeed membranes are immersed and can tolerate high levels of solids. This is an advantage in tertiary treatment since the ZeeWeed plant continues to operate well even if the upstream process is upset. The capacity to handle solids also means that there is no need to pre-treat the secondary effluent, thus avoiding additional filtration such as sand filters or cartridge filters often required by other membrane technologies. Nonetheless, the ZeeWeed design inherently incorporates a 0.5 mm pre-screen upstream of the UF units.

In this design, a 92 percent recovery was projected by the Zenon vendors. The ZeeWeed membrane technology process consistently produces high quality water, as long as the membranes are not subjected to stress, pressurization or rapid pressure fluctuations. The small variations in operating pressure occur smoothly over relatively long periods so that at no time is the membrane stressed. By feeding the secondary effluent through the UF membranes, the cleaning, overall maintenance and life of the RO units will be prolonged. In addition, they will be able to obtain superior performance with less risk of scaling and biofouling. Figure E2.2-1 shows a picture of a ZeeWeed 1000.

FIGURE E2.2-1. ZEEWEED 1000 VERSION 3 CASSETTE WITH ONE MEMBRANE MODULE EXTENDED.

Appendix E3

Spokane Phosphorus Removal Costs

APPENDIX E3

Spokane Phosphorus Removal Costs

Spokane Phosporus Removal Costs

Estimate the capital and annual O&M costs to provide tertiary clarification and effluent filtration for phosphorus removal equivalent to the Rock Creek WWTP operated by Clean Water Services.

Capital

2015 costs in October 2004 dollars

Facilities required: secondary effluent pumping, ballasted sedimentation and effluent filtration
Source: Conceptual Design Report for the Phase 1 Liquids Improvements by CH2M HILL July 2001

Secondary effluent pumping and ballasted sedimentation for 2045 (Table 7-1) for 180 MGD			
Secondary effluent pumping		$ 1,470,000	
Ballasted sedimentation		$ 8,940,000	
Total		$ 10,410,000	
Adjust to 2015 flow--100 MGD using 0.7 scale factor			$ 6,899,000
Effluent filtration for 2015 flow (Table 8-3)			$ 33,150,000
Total 2015 construction cost in 2000 dollars			$ 40,049,000
June 2000 Seattle ENR CCI	7,157		
October 2004 Seattle ENR CCI	8,152		
Inflation to October 2004	1.14		
Total 2015 construction cost in 2004 dollars			$ 45,617,000
Engineering, legal and admin.	25%		$ 11,404,000
Total 2015 project cost			**$ 57,021,000**

Annual O&M

Additional costs
- Alum chemical
- Additional chemical sludge
- Operations labor
- Maintenance
- Analytical labor

Assumptions

Alum dosage	60	mg/L	$136	/ton of alum
Additional chemical sludge	18	mg/L	$10	/wet ton of sludge
Operations labor	1	FTE per shift @	$50,000	/FTE
Maintenance	1%	of construction cost per year		
Analytical labor	1	FTE @	$60,000	/year
2005 average dry weather flow	47.4	MGD		
2015 average dry weather flow	55.9	MGD		
Operating period	April 1 to October 31		214	days per year

Spokane Phosporus Removal Costs

Estimate the capital and annual O&M costs to provide tertiary clarification and effluent filtration for phosphorus removal equivalent to the Rock Creek WWTP operated by Clean Water Services.

Annual O&M costs		**2005**		**2015**
Alum chemical	$	345,000	$	407,000
Additional chemical sludge	$	42,000	$	50,000
Operations labor	$	200,000	$	200,000
Maintenance	$	456,000	$	456,000
Analytical labor	$	60,000	$	60,000
Total annual O&M costs	**$**	**1,103,000**	**$**	**1,173,000**

Appendix E4

Spokane County Preliminary Evaluation of Land Application

FINAL DRAFT

Spokane County
PRELIMINARY EVALUATION OF LAND APPLICATION

Prepared for

Spokane County Public Works
Mail Stop PWK 4
1116 West Broadway Avenue
Spokane, WA 99260-0170

September 2004

HDR Engineering. Inc.
Boise, Idaho

Table of Contents

SECTION 1. INTRODUCTION 1-1

SECTION 2. REGULATORY AND DESIGN CONSIDERATIONS 2-1

2.1 Overview of Regulatory Requirements 2-1
2.1.1 Classes of Reclaimed Water 2-1
2.1.2 Allowable Uses of Reclaimed Water 2-2
2.1.3 Setback Distances 2-4
2.2 Anticipated Water Quality Requirements for Land Application Program 2-4
2.3 Quantity of Water 2-5
2.4 Wastewater Loading Considerations 2-5
2.5 General Design Considerations 2-6

SECTION 3. WATER BALANCE, LAND AND STORAGE REQUIREMENTS 3-1

3.1 Water Balance 3-1
3.2 Land Acquisition and Storage Requirements 3-1
3.3 Conveyance Requirements 3-3
3.4 Impact of Shorter Summer Permit Season on Land and Storage Requirements 3-3

SECTION 4. SITE CONSIDERATIONS 4-1

4.1 North Site 4-1
4.2 South Site 4-1

SECTION 5. OPERATIONAL CONSIDERATIONS 5-1

5.1 Crops and Market 5-1
5.2 Irrigation Practices 5-1
5.3 Farm Management 5-1
5.4 Monitoring 5-1

SECTION 6. ECONOMIC EVALUATION 6-1

6.1 Capital Costs 6-1
6.1.1 Conveyance to and from Land Application Site 6-1
6.1.2 Land Application Site Development 6-2
6.1.3 Raw Sewage Conveyance and River Outfall 6-3
6.1.4 Treatment Costs 6-5
6.2 Operation and Maintenance Costs 6-5
6.2.1 Land Application Conveyance and Site Management 6-5
6.2.2 Treatment 6-6

SECTION 7. IMPLEMENTATION CONSIDERATIONS 7-1

7.1 Land Acquisition 7-1
7.2 Reservoir Siting 7-1
7.3 Water Rights 7-1
7.4 Return of Unused Reclaimed Water for River Discharge 7-1

Appendices

Appendix A. Water Balance for Baseline Scenario

Appendix B. Water Balance for Reduced Season

Appendix C. Capital Cost Estimate for North Site Facilities

Appendix D. Capital Cost Estimate for South Site Facilities

Appendix E. Capital Cost Estimate for Treatment

Appendix F. Operating Cost Estimate for Land Application Program

List of Figures

Figure 1 Pond Storage Versus Land Requirements for Alfalfa and Winter Wheat for Reclaimed Water Irrigation....3-2

Figure 2. Water Supply, Demand and Storage (Based On 1500 Acres of Alfalfa and 370 MG Pond)....3-2

Figure 3. Area map showing City of Spokane and potential North and South Land Application Sites....4-2

Figure 4. Northern pipeline alignment....4-3

Figure 5. Southern pipeline alignment....5-4

Figure 6. North Land Application Site....6-3

Figure 7. South Land Application Site....6-4

List of Tables

Table 1. Characteristics of the Four Classes of Reclaimed Water....2-1

Table 2. Allowable Uses of Reclaimed Water and Required Water Quality....2-2

Table 3. Required Setback Distance for Reclaimed Water....2-4

Table 4. General Design Considerations for Land Application Systems....2-6

Table 5. Soil Composition of the North Site....4-5

Table 6. Soil Composition of the South Site....4-6

Table 7. Summary of Estimated Capital Costs for Land Application Program....6-1

Table 8. Cost Estimate Design Basis for Conveyance Facilities....6-2

Table 9. Cost Estimate Design Basis for Site Development....6-2

Table 10. Estimated Capital Cost for Raw Sewage Conveyance (from 2004 Facilities Plan Update)....6-5

Section 1. INTRODUCTION

The Washington Department of Ecology (Ecology) is preparing a dissolved-oxygen Total Maximum Daily Load (TMDL) for the Spokane River. Depending on the final requirements of the TMDL, Spokane County may need to reduce or eliminate the quantity of water discharged to the Spokane River during the summer permit season. Given this situation, the County has elected to conduct a preliminary evaluation of land application as a potential wastewater management option.

In this concept, treated effluent would be sent to a storage reservoir beginning in April of each year. It would then be used to meet seasonal irrigation demands for agricultural crops. Following the irrigation season, effluent would continue to be sent to the reservoir until mid-October, when effluent discharge to the Spokane River could resume. To develop technical and economic requirements, two potential land application areas are evaluated: one to the north of Spokane Valley and one to the south. Accompanying maps illustrate these locations, along with potential pipeline routes from the anticipated treatment plant location. The land application sites are located in areas where sufficient agricultural land is currently available. Site considerations have been developed to a conceptual level, meaning that site locations are based on a review of maps, aerial photographs, and a "windshield" drive-through on public roads. Land owners have not been contacted nor have detailed assessments of site suitability been performed.

The purpose of this technical document is to present preliminary findings regarding the feasibility of reclaimed water for agricultural land application. Preliminary cost estimates and implementation considerations are presented.

This technical report has been organized into the following sections:

- **Section 2.0 – Regulatory and Design Considerations.** Presents Washington regulatory requirements for reclaimed water land application, lists anticipated effluent quality requirements for a program in Spokane County, and presents general design considerations for a land application site.
- **Section 3.0 – Water Balance, Land and Storage Requirements**. Presents supply and demand analysis for land application, along with estimated requirements for land acquisition and reservoir volume.
- **Section 4.0 – Site Considerations.** Describes site requirements and presents screening information for potential areas for land application.
- **Section 5.0 – Operations Considerations.** Describes general operational considerations for application of reclaimed water to agricultural lands.
- **Section 6.0 – Economic Evaluation.** Presents capital and operation and maintenance costs associated with a land application program.
- **Section 7.0 – Implementation Considerations.** Describes key implementation issues for a land application program.

Section 2. REGULATORY AND DESIGN CONSIDERATIONS

2.1 Overview of Regulatory Requirements

Reclaimed water generation and use are governed through reclaimed water permits, which are issued jointly by the Washington State Departments of Health and Ecology. Reuse applications in the State of Washington are addressed in the Water Reclamation and Reuse Standards, established in 1997 under RCW 90.46 (Reclaimed Water). These reuse standards are not rules, but are used as guidance for best management practices and development of reclaimed water permit conditions.

Reuse programs must also be protective of groundwater quality. In this respect, reuse programs must comply with the antidegradation policy set forth in Chapter 173-200 WAC and with the non-degradation policy that serves as the basis for aquifer protection in Spokane County.

2.1.1 Classes of Reclaimed Water

The Water Reclamation and Reuse Standards establish four classes of reclaimed water with respect to both treatment technique and effluent quality (see Table 1).

Table 1. Characteristics of the Four Classes of Reclaimed Water

Class	Characteristics
A	Class A reclaimed water will at all times be oxidized, coagulated, filtered, and disinfected wastewater. State water reclamation and reuse standards call for Class A reclamation water to be filtered to a turbidity level which does not exceed an average operating turbidity of 2 nephelometric units (NTU), determined monthly, and which does not exceed 5 NTU at any time. Filtration can be achieved by passing oxidized wastewater through natural undisturbed soils or through filter media such as sand or anthracite. Class A reclaimed water must be disinfected such that the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last seven days for which analyses have been completed, and such that the number of total coliform organisms does not exceed 23 per 100 milliliters in any sample. Class A reclaimed water is currently the only reclaimed water class for which the Department of Ecology requires coagulation and filtration. Further, the disinfection requirements for Class A reclaimed water are more stringent than for Class C or D reclaimed water (the disinfection requirements for Class B reclaimed water are identical to those for Class A). Class A reclaimed water must be used where the potential for public exposure to reclaimed water is high.
B	Class B reclaimed water will at all times be oxidized and disinfected wastewater. The wastewater will be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last seven days for which analyses have been completed, and the number of total coliform organisms does not exceed 23 per 100 milliliters in any sample.
C	Class C reclaimed water will at all times be oxidized and disinfected wastewater. The wastewater will be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 23 per 100 milliliters, as determined from the bacteriological results of the last seven days for which analyses have been completed, and the number of total coliform organisms does not exceed 240 per 100 milliliters in any sample.
D	Class D reclaimed water will at all times be oxidized and disinfected wastewater. The wastewater will be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 240 per 100 milliliters, as determined from the bacteriological results of the last seven days for which analyses have been completed.

2.1.2 Allowable Uses of Reclaimed Water

The State of Washington Water Reclamation and Reuse Standards allow for many uses of reclaimed water, including irrigation, impoundments, groundwater recharge, commercial uses, and industrial uses. Generally, areas with potentially high human contact require the use of Class A reclaimed water; whereas areas with low likelihood of human contact can utilize Class D reclaimed water. Under no circumstances may reclaimed water be used for food preparation or be incorporated into food or drink for human consumption. Table 2 provides more information regarding types of use and classes of reclaimed water allowed by the Departments of Health and Ecology.

Table 2. Allowable Uses of Reclaimed Water and Required Water Quality

Use	Type of Reclaimed Water Allowed			
	Class A	Class B	Class C	Class D
Irrigation of Nonfood Crops				
▪ Trees and Fodder, Fiber, and Seed Crops	YES	YES	YES	YES
▪ Sod, Ornamental Plants for Commercial Use, and Pasture to Which Milking Cows or Goats Have Access	YES	YES	YES	NO
Irrigation of Food Crops				
▪ Spray Irrigation				
▪ All Food Crops	YES	NO	NO	NO
▪ Food Crops Which Undergo Physical or Chemical Processing ▪ Sufficient to Destroy All Pathogenic Agents	YES	YES	YES	YES
Surface Irrigation				
▪ Food Crops Where There is No Reclaimed Water Contact With Edible Portion of Crop	YES	YES	NO	NO
▪ Root Crops	YES	NO	NO	NO
▪ Orchards and Vineyards	YES	YES	YES	YES
▪ Food Crops Which Undergo Physical or Chemical Processing Sufficient to Destroy All Pathogenic Agents	YES	YES	YES	YES
Landscape Irrigation				
▪ Restricted Access Areas (e.g., Cemeteries and Freeway Landscapes)	YES	YES	YES	NO
▪ Open Access Areas (e.g., Golf Courses, Parks, Playgrounds, School Yards and Residential Landscapes)	YES	NO	NO	NO
Impoundments				
▪ Landscape Impoundments	YES	YES	YES	NO
▪ Restricted Recreational Impoundments	YES	YES	NO	NO
▪ Non-restricted Recreational Impoundments	YES	NO	NO	NO
Fish Hatchery Basins	YES	YES	NO	NO
Decorative Fountains	YES	NO	NO	NO
Flushing of Sanitary Sewers	YES	YES	YES	YES

Use	Type of Reclaimed Water Allowed			
	Class A	Class B	Class C	Class D
Street Cleaning				
▪ Street Sweeping, Brush Dampening	YES	YES	YES	NO
▪ Street Washing, Spray	YES	NO	NO	NO
Washing of Corporation Yards, Lots, and Sidewalks	YES	YES	NO	NO
Dust Control (Dampening Unpaved Roads and Other Surfaces)	YES	YES	YES	NO
Dampening of Soil for Compaction (at Construction Sites, Landfills, etc.)	YES	YES	YES	NO
Water Jetting for Consolidation of Backfill Around Pipelines				
▪ Pipelines for Reclaimed Water, Sewage, Storm Drainage, and Gas, and Conduits for Electricity	YES	YES	YES	NO
Fire Fighting and Protection				
▪ Dumping from Aircraft	YES	YES	YES	NO
▪ Hydrants or Sprinkler Systems in Buildings	YES	NO	NO	NO
Toilet and Urinal Flushing	YES	NO	NO	NO
Ship Ballast	YES	YES	YES	NO
Washing Aggregate and Making Concrete	YES	YES	YES	NO
Industrial Boiler Feed	YES	YES	YES	NO
Industrial Cooling				
▪ Aerosols or Other Mist Not Created	YES	YES	YES	NO
▪ Aerosols or Other Mist Created (e.g., Use in Cooling Towers, Forced Air Evaporation, or Spraying)	YES	NO	NO	NO
Industrial Process				
▪ Without Exposure of Workers	YES	YES	YES	NO
▪ With Exposure of Workers	YES	NO	NO	NO
Wetlands				
▪ All Wetlands	YES	YES	YES	YES
▪ Non-contact Recreational or Educational Use With Restricted Access	YES	YES	YES	NO
▪ Fisheries Use, or Non-contact Recreational or Educational Use with Open (Unrestricted) Access	YES	YES	NO	NO
▪ Potential Human Contact Recreational or Educational Use	YES	NO	NO	NO
Ground Water Recharge	YES	NO	NO	NO
Indirect Potable Reuse	YES	NO	NO	NO
Streamflow Augmentation	YES	NO	NO	NO

2.1.3 Setback Distances

To protect public health and safety, setbacks are required for transport and delivery of reclaimed water. Table 3 lists the required setback distances.

Table 3. Required Setback Distance for Reclaimed Water

Conditions	Setback Distance (Feet) By Type of Reclaimed Water			
	Class A	Class B	Class C	Class D
Minimum Distance between any reclaimed water pipeline and potable water supply well.	50	100	100	300
Where reclaimed water is used for spray or surface irrigation, minimum distance between the area subject to irrigation, and any potable water supply well.	50	100	100	300
Where reclaimed water is used for spray irrigation, minimum distance between the area subject to irrigation and areas accessible to the public and the use area property line.	0	50	50	100
Where reclaimed water is used for an impoundment that is not lined or sealed to prevent measurable seepage, minimum distance between the perimeter of the impoundment and any potable water supply well.	500	500	500	n/a
Where reclaimed water is used for an impoundment that is lined or sealed to prevent measurable seepage, minimum distance between the perimeter of the impoundment and any potable water supply well.	100	100	100	n/a
Where reclaimed water is used for a storage pond that is not lined or sealed to prevent measurable seepage, minimum distance between the perimeter of the pond and any potable water supply well.	500	500	500	1,000
Where reclaimed water is used for a storage pond that is lined or sealed to prevent measurable seepage, minimum distance between the perimeter of the pond and any potable water supply well.	100	100	100	200

2.2 Anticipated Water Quality Requirements for Land Application Program

As discussed later in this report, alfalfa and winter wheat are the anticipated crops to be grown in the land application program. With these crops, and the assumption that the County could acquire sufficient land to meet all setback requirements, the Reclaimed Water Standards would allow use of Class C or D water for the land application program. Other considerations; however, would likely result in the need for a higher quality effluent. These include:

- **Potential for Water Quality Degradation During Reclaimed Water Storage.** To balance irrigation demand and reclaimed water production rates, large volumes of water must be stored in reservoirs during the spring and fall (see discussion in Section 3). Unless the organic and nutrient concentrations in the water are reduced, water quality degradation may occur, either through algae and zooplankton growth, or through hydrogen sulfide generation in the anoxic zones of a stratified reservoir. The resulting water quality changes may impact the suitability of the water for irrigation due to odor or plugging of irrigation equipment. Also, keeping the reservoirs aesthetically pleasing to neighbors is an important public relations issue.
- **River Discharge of Unused Reclaimed Water.** In this analysis, it has been assumed that excess reclaimed water stored during the fall (following the irrigation season) may be discharged to the

Spokane River during the winter permit season, when stream flows and assimilative capacity are high. Water quality analyses indicate that an effluent quality meeting secondary effluent will probably be sufficient for discharge during this period; however, there is a possibility that some reduction in phosphorus or ammonia-nitrogen would be required during the winter. A further consideration is that some "re-treatment" of the water stored in the reservoirs may be necessary prior to discharge to the river. Depending on the water quality issues, this may involve supplemental disinfection, aeration to increase the effluent dissolved oxygen concentration, and/or filtration to remove algae generated in the reservoir.

- **Limitations on Reuse Flexibility.** If the County produced only Class C or D reclaimed water, this would preclude development of other reuse opportunities that require Class A water, such as urban irrigation (golf courses, green spaces, etc.).
- **Preliminary Regulatory Reaction to Land Application Concept.** During preliminary discussions of the land application concept with Spokane County, Ecology staff have indicated that use of Class C or D water would not be favorably received by the Department.

Based on these considerations, it seems likely that a Class A water would be required for a major land application program in Spokane County. To address all water quality concerns, it also may be necessary to provide nitrification and/or partial phosphorus removal.

2.3 Quantity of Water

This preliminary analysis is based on an average effluent flow rate of 10 million gallons per day (mgd). In the baseline scenario, effluent would be conveyed to the land application site from April 15 to October 15, for a total of 1,835 million gallons (MG). Based on a water balance considering irrigation water requirements for alfalfa, daily reclaimed water generation, and storage capacity, 1,480 MG of reclaimed water would be land applied. The remaining effluent would either evaporate during pond storage or be conveyed back to the plant for wintertime discharge to the river.

A second scenario was developed to determine the sensitivity of facility requirements and cost to the period of year in which effluent discharge to the river must be eliminated. In this case, effluent would be conveyed to the land application site from June 1 to October 15 for a total of 1,375 MG. Approximately 1,290 MG would be land applied.

2.4 Wastewater Loading Considerations

For agricultural irrigation, the parameters of key importance are the loading rates for nitrogen, phosphorus and salt.

At the wastewater treatment plant, the influent total nitrogen concentration is projected to be 39 to 40 mg/L (personnel communication Bruce Willey, May 5, 2004). For estimating nitrogen loadings to the land application site, it has been assumed that the reclaimed water would be produced without use of a nitrification treatment process (a conservative assumption). In this scenario, nitrogen removal across the plant would be limited to 8 to 10 mg/L (biological growth requirements), resulting in an effluent total nitrogen concentration of about 30 to 32 mg/L. A total nitrogen concentration of 32 mg/L would result in an annual nitrogen loading rate of 262 lbs/acre for a 1,500 acre site and 197 lbs/acre for a 2,000 acre site[1]. This is in the higher range for land application of reclaimed water (without luxury consumption), but still within the agronomic range. Approximately 75 percent of the reclaimed water nitrogen would be in the ammonium form. Depending upon the pH of the reclaimed water, some of this nitrogen can be expected to volatilize during storage and irrigation. Ammonium is a desirable form of nitrogen for land application in that ammonium is a cation that will adsorb to soils and is only susceptible to leaching when it converts to nitrate.

[1] Preliminary estimates of land requirements vary from 1,500 to 2,000 acres (see later discussion in Section 3).

The influent total phosphorus concentration is about 7 mg/L. Unless, chemical precipitation or enhanced biological phosphorus removal is practiced, about 1 to 2 mg/L of phosphorus would be removed in the treatment system through biological growth (personnel communication Bruce Willey, May 10, 2004). A phosphorus concentration of 5 mg/L in the effluent would result in an annual loading of 41 lbs/acre for a 1500 acre site and 31 lbs/acre for a 2000 acres site. These loadings are within the acceptable agronomic rates for most agricultural crops, including alfalfa.

Assuming a potable water TDS of 350 mg/L and an increase of 300 mg/L in the wastewater treatment system, the effluent TDS is expected to be approximately 650 mg/L. A TDS concentration of 650 mg/L results in an annual salt loading of 5,323 and 3,990 lbs/acre for 1500 and 2000 acre sites, respectively. Generally, there is sufficient precipitation in the Spokane area to minimize salt buildup. However, potential TDS impacts to groundwater will need to be addressed in the permit. It is assumed that there will be no fresh water available at the identified potential land application areas.

2.5 General Design Considerations

The Washington State Department of Ecology has prepared *Guidelines for Preparation of Engineering Reports for Industrial Wastewater Land Application Systems*, May 1993. This document identifies the information required in a Detailed Engineering Report, as well as general design considerations for application of reclaimed water. This information is summarized in Table 4.

Table 4. General Design Considerations for Land Application Systems

Climate
The ability to distribute water and the evaporation rate are affected by air temperature. Soil temperature and moisture affect plant growth and nutrient uptake. A 10-year recurrence interval is recommended for water budget calculations.
Topography
Runoff at the application site from the application of reclaimed water is not allowed. Run-on and runoff from precipitation at the site should be minimized.
Soils
The application of the reclaimed water must be suitable for soil structure, texture chemistry and hydraulic characteristics.
Crops
Crop selection should consider the ability of the crop to utilize available nutrients under actual site conditions and should be suitable for soil and climate conditions. Periodic harvesting may be needed for nutrient removal. Cover crops should be established with water that does not inhibit crop growth. Reclaimed water should only be applied to established crops. Livestock grazing is not recommended on the land application site.
Wetlands
Any wetlands on the land application site should be delineated. Further, the wetlands should be classified as a category 1, 2, 3, or 4, wetland according to the *Washington State Wetlands Rating System; Western Washington*, October 1991, Washington State Department of Ecology Publication #91-57.
Wetland Categories 1 or 2 are not appropriate for use, and a minimum 50 foot buffer is required between the land application site and category 1 or 2 wetland boundaries. If a Category 3 or 4 wetland is used, the application shall not: 1) result in nutrient loading disruptive to plant communities or wetland function, 2) negatively alter hydroperiodicity, or 3) reduce flow storage.
Land Use
Land use on and adjacent to the site, as well as planning and zoning considerations and restrictions should be evaluated. Agricultural or silvicultural lands are preferable for land application.
Land Ownership/Agreements
Fee simple purchase of the land application site is recommended. Leases or easements can be considered if the duration of the lease/easement is 5 years or more. Leases/easements should provide for a minimum of two years notification prior to termination.

Treatment Prior to Application
Treatment prior to reuse is necessary to improve operational efficiency, protect the treatment potential of the application site, protect wetland functions and values, and protect water quality.
Impoundments
Impoundments may be necessary when land application is precluded by climatic conditions, crop harvesting, or other conditions.
Impoundments should be lines with an engineered synthetic liner. Surface impoundments where embankments are less than 15 feet in height require a minimum two foot freeboard. Impoundments with embankments exceeding 15 feet in height require a 3.5 foot minimum freeboard. Embankments should be designed to withstand a 100 year flood. A dam safety permit is needed if the storage capacity of the impoundment is greater than 10 acre-feet.
Monitoring
A monitoring program is required at the following locations: 1) wastewater treatment facility, 2) land application site, soil, and 3) land application site, groundwater. Monitoring may be required in the vadose zone and crop or at other locations if warranted by unique characteristics of the reclaimed water or land application site.
System Operations
Considerations for drift of reclaimed water onto public roadways or adjacent residential areas during high winds, considerations for odors, and other site-specific issues should be addressed.
Emergency Plans
An emergency response plan including notification procedures and alternative methods of operation is required.
Detailed Engineering Report
A Detailed Engineering Report will likely be required. The report must include the following:
▪ Project Summary. The project summary includes the facility design criteria and describes the land application system. Potential environmental impacts and impacts to ground water are covered in the Project Summary. ▪ Site Considerations Details regarding the land application site are discussed in this section, including site boundaries, surface waters, surface and subsurface drainage systems, wells, current and past land use, existing vegetation, potential of expansion, and buffer zones. Also included in the site considerations section are the method and route of delivery of wastewater to the site and treatment prior to application. ▪ Site Geology The surface and underlying geology of the site are identified. Boring logs and boring location map are included. Regional geology, including fault, fracture, and structural trends are identified. ▪ Wastewater Analysis Analyses of wastewater with considerations of seasonal variations are included in this section. Analyses for new facilities may be based on similar facilities using similar processes. ▪ Solids Handling Solids handling, treatment, reuse/recycling and disposal procedures are described. ▪ Soils Characterization Physical and chemical characteristics of soils on the land application site are discussed. The soils report should be prepared by a soil scientist. ▪ Hydrogeologic Characterization A hydrogeologic report providing detailed information about aquifers underlying the site is prepared. The Department of Ecology may require a hydrogeologic model of potential impacts to groundwater. ▪ Design Considerations Nutrient, hydraulic, and organic loadings are evaluated. Other limiting constituents, such as BOD, salts, or total dissolved solids are discussed. Design limiting parameters are defined. ▪ Irrigation and Crop Management Plan. An irrigation management is developed with consideration of the following: 1) efficiency and uniformity of application, 2) soil water holding capacity, 3) frequency and timing of irrigation, 4) infiltration and leaching rates, and 5) consumptive use of the crops.
The crop management plan is developed by a soil scientist and defines design parameters including:
Method(s) of establishing a crop;
Cropping patterns;
Nutrient uptake;
Salt tolerance threshold;
Cultivation and harvesting requirements;
Fertilizer, herbicide, and pesticide applications;

Crop management;
Expected crop yield;
Supplemental irrigation water requirements for the crop;
Expected irrigation return intervals for supplemental and wastewater applications for crop water consumption, and
Recommended rest cycles for wastewater application where organic or hydraulic loading is a concern.
The irrigation and crop management plan should protect groundwater and include warm and cold weather management practices.
In the Design Engineering Report, the following should be avoided through design and/or management:
▪ The application of wastewater over all or portions of the site in quantities that:
significantly reduce or destroy the long-term infiltration rate of the soil;
cause long-term anaerobic conditions in the soil;
cause prolonged ponding of wastewater for periods long enough to produce objectionable odors or provide sustenance for insects or vectors from the ponded water; or
that would cause unacceptable leaching losses of constituents of concern beyond the treatment zone or in excess of the approved design.
▪ The application of wastewater to bare soil:
at rates that destroy the short-term infiltration capability of the soil;
for durations sufficient to cause objectionable odors from ponding; or
for durations to cause site runoff.
Local Regulations
Land application sites not zoned industrial may require conditional use permits from local or county planning departments. Conditional use permit review requires a State Environmental Policy Act (SEPA) review.

Section 3. WATER BALANCE, LAND AND STORAGE REQUIREMENTS

This section provides an analysis of water supply and demand for a land application program in Spokane County. Based on this analysis, estimated requirements are presented for land acquisition, storage reservoirs and conveyance facilities.

3.1 Water Balance

The following constraints were placed on the development of a water balance:

- 10 mgd of reclaimed water would be conveyed from the Spokane County Regional Treatment Plant (SCRTP) to the land application site between April 15 and October 15.
- Water stored following the growing season, but before the end of the summer permit season, could be conveyed back to the treatment plant for discharge to the river.
- Crops are limited to alfalfa and winter wheat, and could be planted in any combination.
- Full crop irrigation requirements would be met, rather than using a deficient irrigation practice.
- Irrigation water requirements take into account crop planting, harvesting and maintenance requirements as well as the anticipated efficiency of the irrigation system.

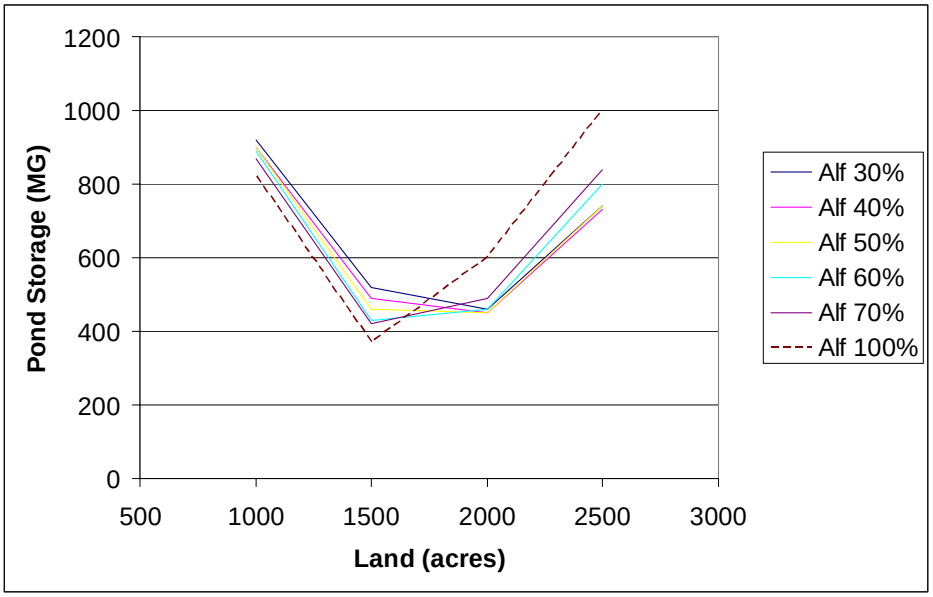
The irrigation water requirement for a crop changes throughout the growing season, with the highest demand being in July /August for alfalfa and May / June for winter wheat. Given a constant 10 mgd of reclaimed water, the water balance shows an oversupply of reclaimed water in the early part of the season (requiring storage of this excess water), not enough reclaimed water during the mid-summer months (requiring that the stored water be utilized), and too much reclaimed water in the later growing season months (requiring storage of excess water). Thus, storage of wastewater is needed in the spring and fall, and some of this stored water would be utilized in the mid-growing season. To balance the supply and demand, a lined storage pond is required.

In the baseline scenario (reclaimed water generation from April 15 to October 15), the total volume of conveyed water is estimated to be 1,835 MG. The estimated volume to be land applied is 1,480 MG. The remaining water would be either be lost through evaporation during pond storage (approximately 58 MG) or conveyed back to the treatment plant after the summer permit season (approximately 330 MG). An example water balance for the baseline scenario is presented in Appendix A.

3.2 Land Acquisition and Storage Requirements

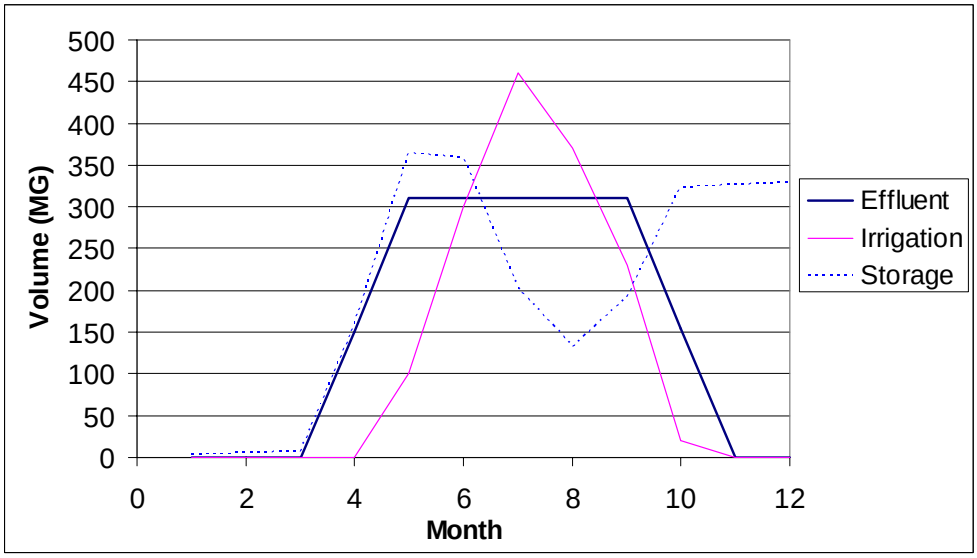
Figure 1 presents a graph illustrating the relationship between pond storage volumes and land required for irrigation using different ratios of alfalfa and winter wheat grown on this land. Based on this analysis, the optimal design would involve growing 100 percent alfalfa. This scenario would require approximately 1,500 acres of irrigated land and a 370 MG storage facility. For costing purposes, 2,400 acres and a 400 MG pond have been assumed. The 2,400 acre estimate allows for setbacks, location of the storage pond and maintenance facilities, and variation of the acreages devoted to alfalfa and winter wheat.

Figure 1. Pond Storage Versus Land Requirements for Alfalfa and Winter Wheat for Reclaimed Water Irrigation



Storage of reclaimed water is necessary during the early part of the growing season, during harvesting, and in the late growing season. Figure 2 presents an example water balance for crop demand, reclaimed water supply, and storage. It has been assumed that a lined storage pond will be required to protect groundwater quality.

Figure 2. Water Supply, Demand and Storage (Based On 1500 Acres of Alfalfa and 370 MG Pond)



3.3 Conveyance Requirements

Conveyance Facilities will be required to 1) send reclaimed water from the SCRTP to the land application site and 2) return unused reclaimed water to the SCRTP for polishing and river discharge.

At the SCRTP, an effluent pumping station will be required, along with an effluent storage tank to equalize diurnal variations in flow. The pumping station, along with the force main to the land application site, would be sized to handle the projected maximum-day flow of 14 mgd.

As described earlier, the water balance is based on the assumption that stored water remaining at the end of the growing season would be pumped back to the SCRTP for discharge into the Spokane River. For a return period of November through February, this equates to approximately 3 mgd of return water. To convey this water, the force main to the site would be operated in a reverse direction. Depending on the elevation of the storage pond relative to the SCRTP site, conveyance of the return flow may require construction of a 3 mgd pump station adjacent to the pond.

3.4 Impact of Shorter Summer Permit Season on Land and Storage Requirements

A second scenario was developed to determine the sensitivity of facility requirements to the period of year in which effluent discharge to the river must be eliminated. In this case, effluent would be conveyed to the land application site from June 1 to October 15.

The water balance, shown in Appendix B indicates that the irrigated land requirements for 100% alfalfa operation would be 1300 acres, and the required storage volume would be approximately 226 MG.

Based on recent discussions with Ecology, it appears likely that the summer permit season would start closer to April 15 than June 1. Therefore, this alternative was not developed further.

Section 4. SITE CONSIDERATIONS

Based on the estimated land requirements for the land application program, two general areas (sites) have been identified as being potentially suitable. These sites, the North and South Sites, are described below and shown in Figure 3.

4.1 North Site

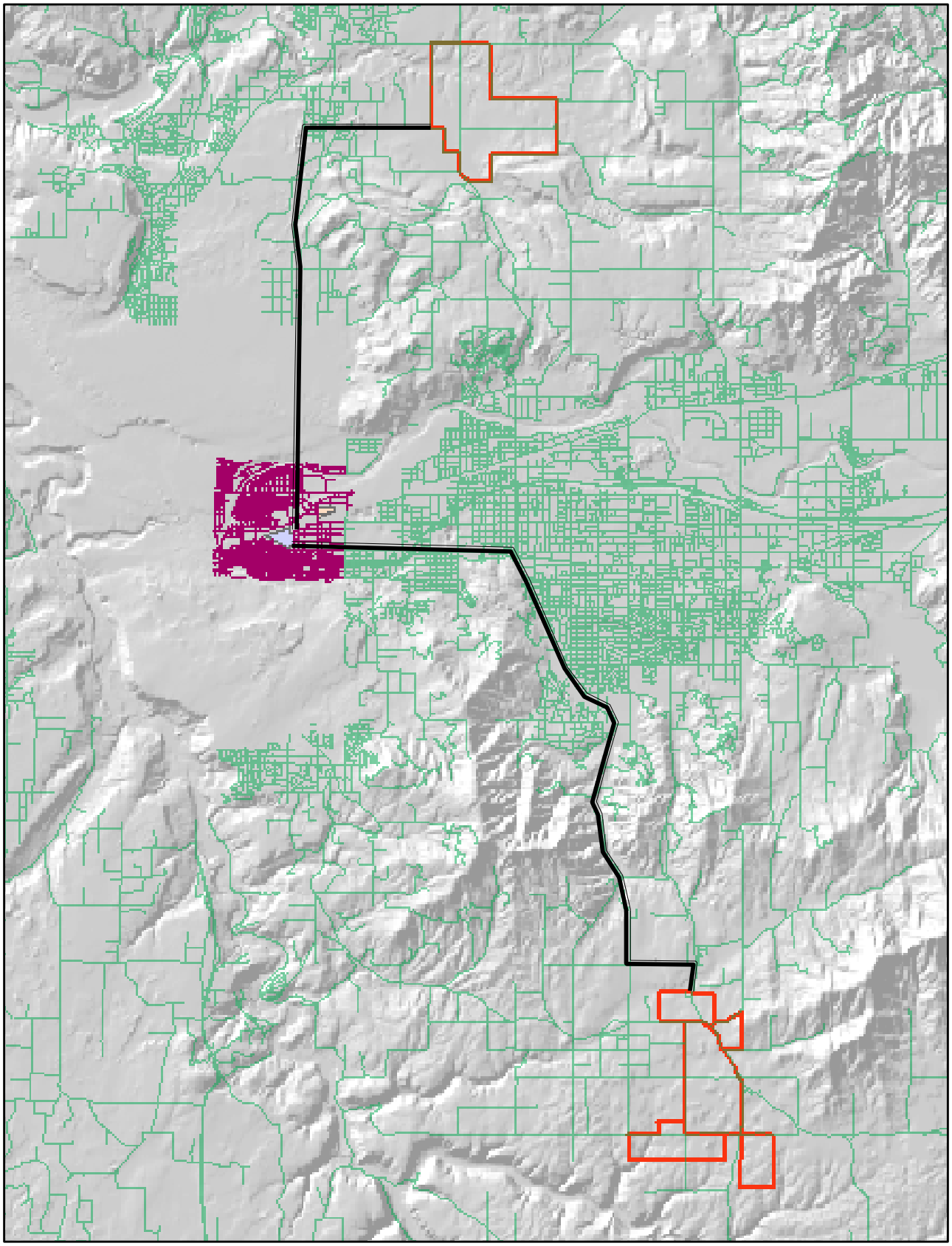
- The North Site is 9.6 pipeline miles from the proposed location of the SCRTP. The land application area is approximately 60 feet lower in elevation than the treatment plant. The conveyance pipeline to and from the site would cross over the hills to the north of the Spokane River at an elevation of approximately 2,033 and fall to approximately 1,900 feet. This pipeline route follows north along the railroad right-of-way alignment, and then turns east to its termination at the holding pond location. A plan and profile of the pipeline route is shown in Figure 4.
- Preliminary evaluation of the North Site indicates that site soils are suitable for agricultural production (Table 5). It may be difficult to find a contiguous 2,400 acres in this area. The area is rapidly being developed, and neighbors will likely be in close proximity to the land application site and pond. A number of areas were identified that would be suitable for pivot irrigation systems.
- Based on well logs located on or near the North Site, depth to groundwater ranges from 30-120 feet below ground surface (bgs). The site is outside of the Spokane-Rathdrum Prairie Aquifer recharge area.

4.2 South Site

- South Site is 13.6 pipeline miles from the SCRTP. The land application area is approximately 670 feet higher than the treatment plant. A plan and profile of the pipeline route is shown in Figure 5.
- Preliminary evaluation indicates soils are suitable for agricultural production but that slopes may restrict application (Table 6). Runoff control measures will be required. There is more agricultural land and less development near the South Site. Finding a contiguous 2,400 acres of land may be difficult in this area. Also, due to the topography of the area, it is anticipated that big gun and wheel line sprinkler systems may be more favorable over pivot systems.
- Based on well logs located on or near the South Site, depth to groundwater ranges from 15-125 feet below ground surface (bgs). The site is outside of the Spokane-Rathdrum Prairie Aquifer recharge area.

For design purposes, it has been assumed that there is no irrigation water available at either site.

Figure 3. Area map showing City of Spokane and potential North and South Land Application Sites.

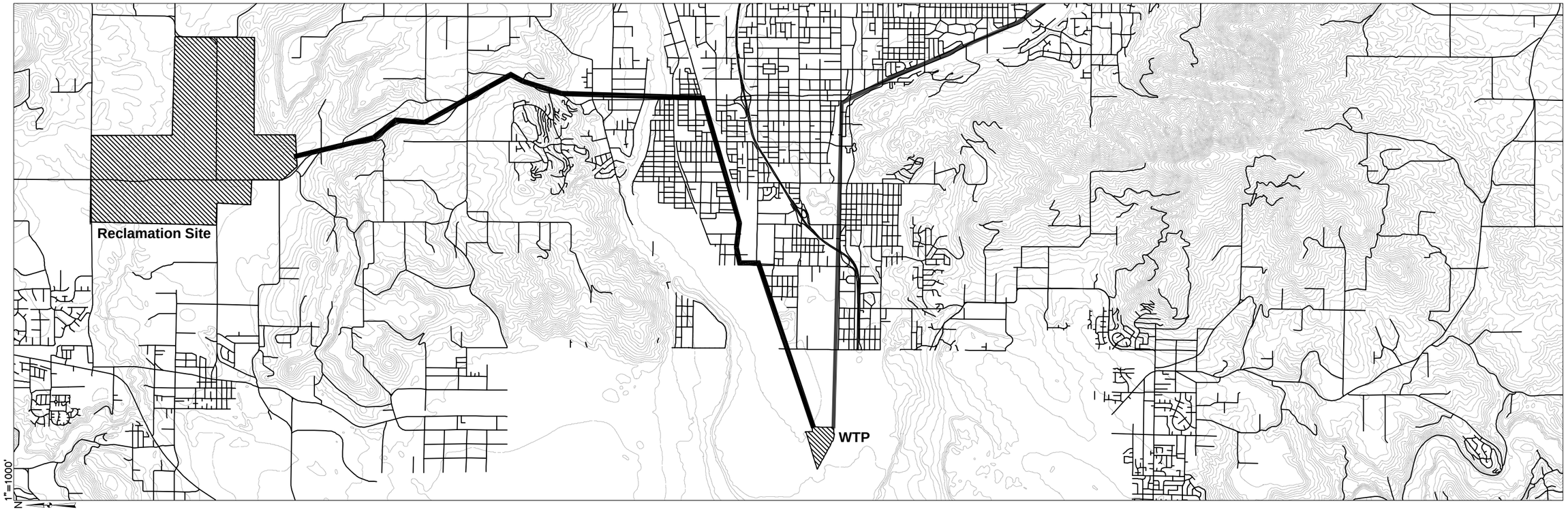


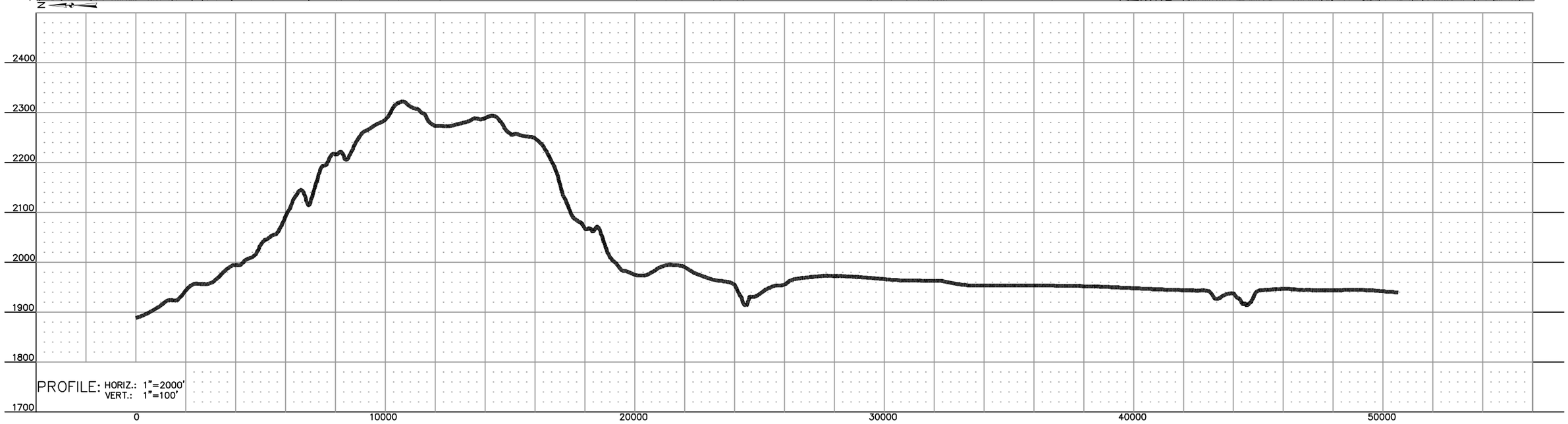
N
W E
S

0 0.5 1 2 3 4 5 Miles

ONE COMPANY | *Many Solutions*™ HDR

Date: May 11, 2004





Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
	MODIFIED BY ADDENDA – AS BID	4/7/04				

HDR Engineering, Inc.

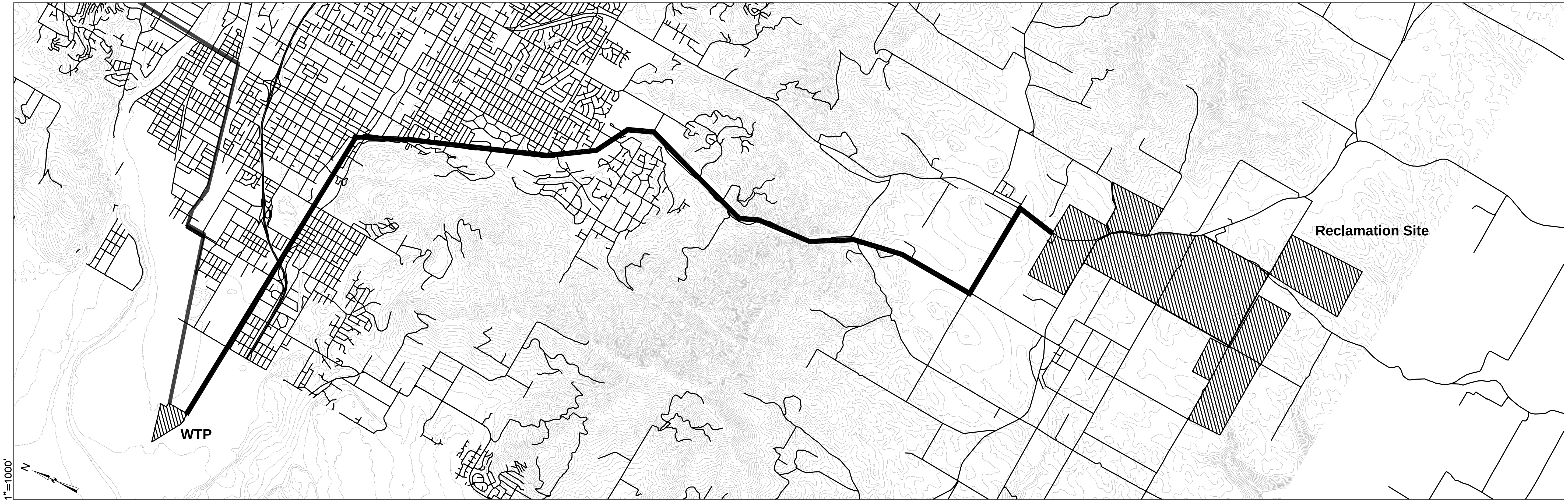
BAR LENGTH ON ORIGINAL DRAWING EQUALS ONE INCH. ADJUST SCALE ACCORDINGLY.

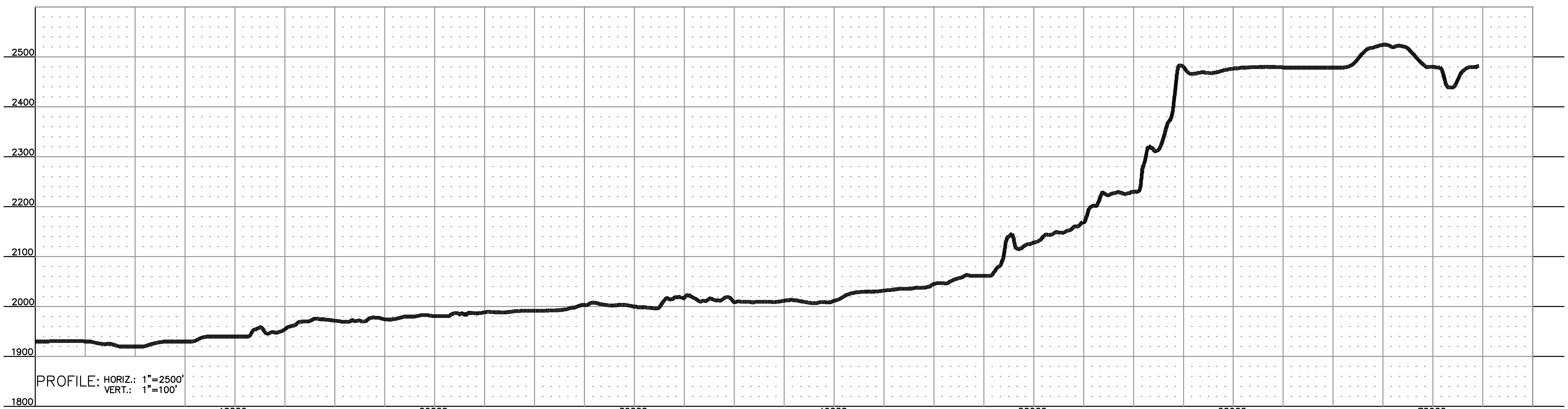
Project Manager
Designed
Designed
Checked
Drawn

Spokane County
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXX

Figure 4 Reclaimed Water Pipeline Alignment
Northern Alignment

Date	City Project No.	HDR Project No.	Index No.	Sheet No.
CIP #'s		File Name		of





Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
	MODIFIED BY ADDENDA – AS BID	4/7/04				

HDR

HDR Engineering, Inc.

BAR LENGTH ON ORIGINAL DRAWING EQUALS ONE INCH. ADJUST SCALE ACCORDINGLY.

Project Manager

Designed

Designed

Checked

Drawn

Spokane County

Reclamation Water Pipeline Alignment
Southern Alignment

Date | City Project No. | HDR Project No. | Index No. | Sheet No.

CIP #'s | File Name | of

Table 5. Soil Composition of the North Site

Name	Description
Bernhill Silt Loam, 20-30% slopes (BaC)	This very deep, well drained soil is on moderately steep uplands. It formed in glacial till mixed with loess and volcanic ash in the upper part. Typically the surface layer is silt loam 16 inches thick. The subsoil is loam 13 inches thick over heavy loam 16 inches thick. The substratum is loam to a depth of 60 inches. Elevations are 1,800 to 2,800 feet. The average annual precipitation is 18 to 23 inches. The frost-free season is 105 to 125 days.
Bernhill Silt Loam, moderately shallow, 0-20% slopes (BbB)	This moderately deep, well drained soil is on nearly level to moderately steep uplands. It formed in glacial till mixed with loess and volcanic ash in the upper part. Typically the surface layer is silt loam 6 inches thick. The subsoil is gravelly loam 10 inches thick. The substratum is gravelly loam 12 inches thick over bedrock. Depth to bedrock ranges from 20 to 40 inches. Elevations are 1,800 to 2,800 feet. The average annual precipitation is 18 to 23 inches. The frost-free season is 105 to 125 days.
Bernhill gravelly silt loam, 0-20% slopes (BeB)	This very deep, well drained soil is on nearly level to moderately steep uplands. It formed in glacial till mixed with loess and volcanic ash in the upper part. Typically the surface layer is gravelly silt loam 16 inches thick. The subsoil is gravelly loam 29 inches thick. The substratum is gravelly loam to a depth of 60 inches. Elevations are 1,800 to 2,800 feet. The average annual precipitation is 18 to 23 inches. The frost-free season is 105 to 125 days.
Bernhill very rocky complex, 0-30% slopes (BkC)	This map unit consists of about 50 percent Bernhill silt loam, 40 percent Rock outcrop, and 10 percent other soils. It is on nearly level to moderately steep uplands. The Bernhill soil is very deep and well drained. It formed in glacial till mixed with loess and volcanic ash in the upper part. Typically, the surface is covered with a thin mat of needles, leaves, and twigs. The surface layer is silt loam about 16 inches thick. The subsoil is loam to a depth of about 29 inches. The substratum is loam to a depth of 60 inches or more. Elevations are 1,800 to 2,800 feet. The average annual precipitation is 18 to 23 inches. The frost-free season is 105 to 125 days.
Cedonia silt loam, 5-20% slopes (CeB)	This very deep, well drained soil is on gently sloping to moderately steep terraces. It formed in calcareous glacial lake sediments with a component of loess and volcanic ash. Typically the surface layer is silt loam 12 inches thick. The subsoil is silt loam 21 inches thick. The substratum is calcareous silt loam to a depth of 60 inches. Elevations are 1,750 to 1,900 feet. The average annual precipitation is 18 to 21 inches. The frost-free season is about 135 days.
Cedonia silt loam, 20-30% slopes, severely eroded (CeC3)	This very deep, well drained soil is on moderately steep dissected terraces along drainageways. It formed in calcareous glacial lake sediments with a component of loess and volcanic ash. Typically the surface layer is silt loam 6 inches thick. The subsoil is silt loam 21inches thick. The substratum is calcareous silt loam to a depth of 60 inches. Elevations are 1,750 to 1,900 feet. The average annual precipitation is 18 to 21 inches. The frost-free season is about 135 days.
Hardesty silt loam, 0-5% slopes (HhA)	This very deep, moderately well drained soil is in depressions and on nearly level areas along drainageways. It formed in volcanic ash alluvium. Typically the surface layer is silt loam 11 inches thick. The substratum is mottled silt loam 21 inches thick over mottled very fine sandy loam to a depth of 60 inches. Depth to a seasonal high water table is 3.5 to 4 feet from December to April. Elevations are 1,800 to 2,500 feet. The average annual precipitation is 18 to 25 inches. The frost-free season is about 110 days.

Name	Description
Peone silt loam, 0-5% slopes (PeA)	This very deep, poorly drained soil is on nearly level to gently sloping flood plains. It formed in alluvium with a high content of volcanic ash. Typically the surface layer is silt loam 6 inches thick. The subsoil is mottled silt loam 5 inches thick. The substratum is mottled silt loam and very fine sandy loam 31 inches thick over mottled loamy coarse sand to a depth of 60 inches or more. Depth to a seasonal high water table is 0.5 to 1.5 feet from February through May. This soil is subject to frequent flooding during late winter and spring. Elevations are 2,000 to 2,500 feet. The average annual precipitation is about 21 inches. The frost-free season is about 90 days.
Peone silt loam, drained, 0-5% slopes (PoA)	This very deep, somewhat poorly drained soil is on nearly level to gently sloping flood plains. Drainage has been improved by artificial means or by natural stream cutting. It formed in alluvium with a high content of volcanic ash. Typically the surface layer is silt loam 6 inches thick. The subsoil is mottled silt loam 5 inches thick. The substratum is mottled silt loam and very fine sandy loam 31 inches thick over mottled loamy coarse sand to a depth of 60 inches or more. Depth to a seasonal high water table is 2 to 3 feet from February through May. This soil is subject to occasional flooding during late winter and spring. Elevations are 2,000 to 2,500 feet. The average annual precipitation is about 21 inches. The frost-free season is about 90 days.
Snow silt loam, 0-5% slopes (SnA)	This very deep, well drained soil is on nearly level to gently sloping terraces and footslopes. It formed in a mixture of loess, volcanic ash and alluvium washed from surrounding uplands. Typically the surface layer is silt loam 21 inches thick. The subsoil is silt loam 15 inches thick. The substratum is silt loam to a depth of 60 inches or more. Elevations are 2,000 to 2,700 feet. The average annual precipitation is 19 to 22 inches. The frost-free season is 110 to 140 days.
Snow silt loam, 5-30% slopes (SnC)	This very deep, well drained soil is on gently sloping to moderately steep terraces and footslopes. It formed in a mixture of loess, volcanic ash and alluvium washed from surrounding uplands. Typically the surface layer is silt loam 21 inches thick. The subsoil is silt loam 15 inches thick. The substratum is silt loam to a depth of 60 inches or more. Elevations are 2,000 to 2,700 feet. The average annual precipitation is 19 to 22 inches. The frost-free season is 110 to 140 days.
Uhlig silt loam, 5-20% slopes (UhB)	This very deep, well drained soil is on gently sloping to moderately steep uplands. It formed in glacial till and outwash mixed with loess and volcanic ash in the upper part. Typically the surface layer is silt loam 10 inches thick over loam 8 inches thick. The subsoil is loam 24 inches thick. The substratum is very fine sandy loam to a depth of 60 inches or more. Elevations are 2,000 to 2,500 feet. The average annual precipitation is 15 to 21 inches. The frost-free season is about 140 days.

Table 6. Soil Composition of the South Site

Name	Description
Bernhill silt loam, 30-55% slopes (BaD)	This very deep, well drained soil is on steep to very steep uplands. It formed in glacial till mixed with loess and volcanic ash in the upper part. Typically the surface layer is silt loam 16 inches thick. The subsoil is loam 13 inches thick over heavy loam 16 inches thick. The substratum is loam to a depth of 60 inches or more. Elevations are 1,800 to 2,800 feet. The average annual precipitation is 18 to 23 inches. The frost-free season is 105 to 125 days.
Caldwell silt loam (Ca)	This very deep, somewhat poorly drained soil is on nearly level bottomlands along streams. Slopes are 0 to 3 percent. It formed in silty alluvium with a component of volcanic ash. Typically the surface layer is silt loam 38 inches thick. The underlying material is silty clay loam to a depth of 60 inches or more. Depth to a seasonal high water table is 2 to 5 feet. This soil is subject to occasional flooding in late winter and spring. Elevations are 2,400 to 2,800 feet. The average annual precipitation is 18 to 22 inches.

Name	Description
Dearyton silt loam, 5-20% slopes (DaB)	This very deep, moderately well drained soil is on gently sloping to moderately steep uplands. It formed in a mantle of loess and volcanic ash over glacial till or material weathered from granitic rock. Typically the surface layer is silt loam 7 inches thick. The subsurface layer is loam 18 inches thick. The upper subsoil is light clay 13 inches thick over clay loam 8 inches thick. The lower subsoil is gravelly clay loam to a depth of 60 inches. Depth to a seasonal perched water table is 1.5 to 2.5 feet from February to April. Elevations are 2,000 to 3,000 feet. The average annual precipitation is about 23 inches. The frost-free season is about 135 days.
Glenrose silt loam, 5-20% slopes (GpB)	This very deep, well drained soil is on gently sloping to moderately steep uplands. It formed in glacial till mixed with loess and volcanic ash in the upper part. Typically the surface layer is silt loam 13 inches thick. The upper subsoil is silt loam 11 inches thick. The lower subsoil is loam to a depth of 60 inches. Elevations are 2,400 to 2,800 feet. The average annual precipitation is about 21 inches. The frost-free season is about 135 days.
Hesseltine silt loam, moderately deep, 0-8% slopes (HoB)	This very deep, well drained soil is on nearly level to gently sloping outwash plains on the channeled scablands. It formed in glacial outwash mixed with loess and volcanic ash in the upper part. Typically the surface layer is silt loam 9 inches thick. The subsoil is silt loam 15 inches thick. The substratum is very gravelly coarse sandy loam 19 inches thick over extremely gravelly coarse sand to a depth of 60 inches. Depth to very gravelly material ranges from 20 to 36 inches. Elevations are 2,100 to 2,500 feet. The average annual precipitation is 17 to 20 inches. The frost-free season is about 125 days.
Hesseltine stony silt loam, 0-20% slopes (HsB)	This very deep, well drained soil is on nearly level to moderately steep outwash plains on the channeled scablands. It formed in glacial outwash mixed with loess and volcanic ash in the upper part. Typically the surface layer is stony silt loam 6 inches thick. The subsoil is gravelly silt loam 11 inches thick. The substratum is very gravelly coarse sandy loam 19 inches thick over extremely gravelly coarse sand to a depth of 60 inches. Depth to very gravelly material ranges from 12 to 20 inches. Elevations are 2,100 to 2,500 feet. The average annual precipitation is 17 to 20 inches. The frost-free season is about 125 days.
Larkin silt loam, 0-5% slopes, eroded (LnA2)	This very deep, well drained soil is on nearly level to gently sloping uplands. It formed in loess containing some volcanic ash. Typically the surface layer is silt loam 13 inches thick. The subsoil is silt loam 43 inches thick. The substratum is silt loam to a depth of 60 inches. Elevations are 2,400 to 3,000 feet. The average annual precipitation is 22 to 25 inches. The frost-free season is 100 to 130 days.
Larkin silt loam, 5-20% slopes, eroded (LnB2)	This very deep, well drained soil is on gently sloping to moderately steep uplands. It formed in loess containing some volcanic ash. Typically the surface layer is silt loam 13 inches thick. The subsoil is silt loam 43 inches thick. The substratum is silt loam to a depth of 60 inches. Elevations are 2,400 to 3,000 feet. The average annual precipitation is 22 to 25 inches. The frost-free season is 100 to 130 days.

Section 5. OPERATIONAL CONSIDERATIONS

5.1 Crops and Market

Based on discussions with local farmers and the National Resource Conservation Service (NRCS), alfalfa and winter grain (wheat or barley) appear to be the most favorable crops for a land application system in terms of marketability for the Spokane area, irrigation water demand, and reclaimed water restriction of crop uses. A five-year rotation of alfalfa with winter wheat is assumed.

5.2 Irrigation Practices

It is assumed that the fields would be leased to farmers who would be responsible for growing crops that require irrigation. The farmers would contract with the County and would pay a set fee for use of the land, irrigation equipment, and reclaimed water.

5.3 Farm Management

It is assumed that the County would own the land-application sites and irrigation equipment. Contract farmers would be responsible for marketing of crops and the County would be responsible for monitoring activities to meet land application permit requirements. No livestock grazing would be allowed.

5.4 Monitoring

As part of the reclaimed water permit, Spokane County would be required to monitor the land application system. Monitoring activities would likely include:

Soil Monitoring – generally in the spring and fall, from depth 0 to 3 feet below ground surface. Parameters include soil nutrients (nitrogen, phosphorus), soluble salts, and pH. Analysis of metals is generally not required.

Groundwater Monitoring – the need for monitoring wells is site specific; however, installation and monitoring of groundwater is assumed for costing purposes. In addition to monitoring wells, sampling of nearby potable wells may be required. Monitoring parameters for land application sites include nitrate, total dissolved solids, pH, total or fecal coliform, and sodium.

Reclaimed Water Monitoring – monitoring of reclaimed water will be required at a minimum of once per month to assess water quality and calculate loading rates. Important parameters include nitrate, ammonium, total Kjeldahl nitrogen, pH, total phosphorus, sulfate, chloride, sodium, total dissolved solids, and non-volatile dissolved solids. In addition to water quality, the quantity of reclaimed water quantity sent to each field must be metered.

Crop Tissue Monitoring – Crop yields and tissue analysis are generally included in a land application permit. Tissue analysis includes ash, total nitrogen, nitrate, and phosphate.

As part of the monitoring activities, an annual monitoring report is required.

Section 6. ECONOMIC EVALUATION

This section provides preliminary cost estimates for the estimated conveyance, storage and land application systems. It also presents estimated costs for raw sewage conveyance, treatment and river discharge (winter permit season) at the SCRTP.

The estimates presented in this section are planning level estimates made without detailed engineering or site specific data. For consistency, all cost estimates are presented in uninflated 2004 dollars and are based on a conventional design-bid-build implementation method.

6.1 Capital Costs

Estimated capital costs for the North and South land application sites are summarized in Table 7. More detailed estimates for the two land application sites are presented in Appendices C and D, and estimated costs for wastewater treatment are presented in Appendix E.

Table 7. Summary of Estimated Capital Costs for Land Application Program (Based on 10 mgd Average Flow Rate)

Program Elements	Uninflated Capital Cost, $ millions	
	North Site	South Site
Wastewater Treatment	$73.0	$73.0
Return Flow Retreatment	$5.5	$5.5
Outfall to River	$5.1	$5.1
Reclaimed Water Pumping Station / Reservoir	$2.3	$2.3
Intermediate Reclaimed Water Pumping Station	$0.0	$1.5
Reclaimed Water Pipeline	$23.0	$42.0
Return Water Pumping Station	$0.8	$0.0
Storage Reservoir	$23.5	$23.5
Irrigation Pumping Station	$1.5	$1.5
Land Application Site Development	$6.6	$6.6
Land Acquisition - Treatment Plant	$3.5	$3.5
Land Acquisition - Land Application Site	$9.6	$4.8
Land Acquisition - Pumping Stations	$0.4	$0.5
Total	**$172.8**	**$187.8**

The following discussion describes key assumptions and facility requirements used in developing the capital cost estimates.

6.1.1 Conveyance to and from Land Application Site

Pipeline routes for each land application site were selected based upon the following criteria:

- Follow existing public or railroad right-of-ways
- Minimize elevation gain

Initial routing was determined based on field reconnaissance conducted with Spokane County personnel. The north site route was later revised to reduce the amount of elevation gain between the treatment plant and application site. The south site route was not revised. Existing property rights, site conditions, and conditional use considerations have not evaluated for these pipeline routes.

Key assumptions used in developing conveyance costs are listed in Table 8.

Table 8. Cost Estimate Design Basis for Conveyance Facilities

1	High pressure effluent pumping station at SCRTP with firm capacity of 14 mgd
2	On-site reservoir at SCRTP to equalize diurnal flows
3	Assume 5 feet per second water velocity in delivery pipeline
4	SCRTP site elevation is 1970'.
5	South Site Reservoir Elevation is 2540'+30'=2570'
6	North Site Reservoir Elevation is 1880'+30'=1910'
7	South Site Lift = 2570'-1970'= 600'.
8	North Site Lift = 1910'-1970'= -60'.
9	Assume 20' for minor losses in piping
10	Use of an intermediate pump station along the route to the South Site (firm capacity of 14 mgd)
11	Use of return flow pumping station at the North Site (firm capacity of 4 mgd)
12	Return flow from South Site may be conveyed to SCRTP by gravity

Estimated pipeline requirements are listed below:

- North site requires 50,000 feet of 30-inch pipe
- South site requires 72,500 feet of 30-inch pipe, with significant portions requiring high pressure rating

6.1.2 Land Application Site Development

At both sites, a 400 MG storage pond is needed. Estimated construction requirements include approximately one million cubic yards of excavation and 3.8 million square feet of HDPE liner.

The on-site irrigation pump station must deliver 15 mgd of reclaimed water from the pond to the irrigation system.

For conceptual purposes, it has been assumed that the irrigation system at the North site would be comprised of 16 center pivots (125 acres each) and several wheel lines. Figure 6 illustrates the concept level pipeline and the center pivots.

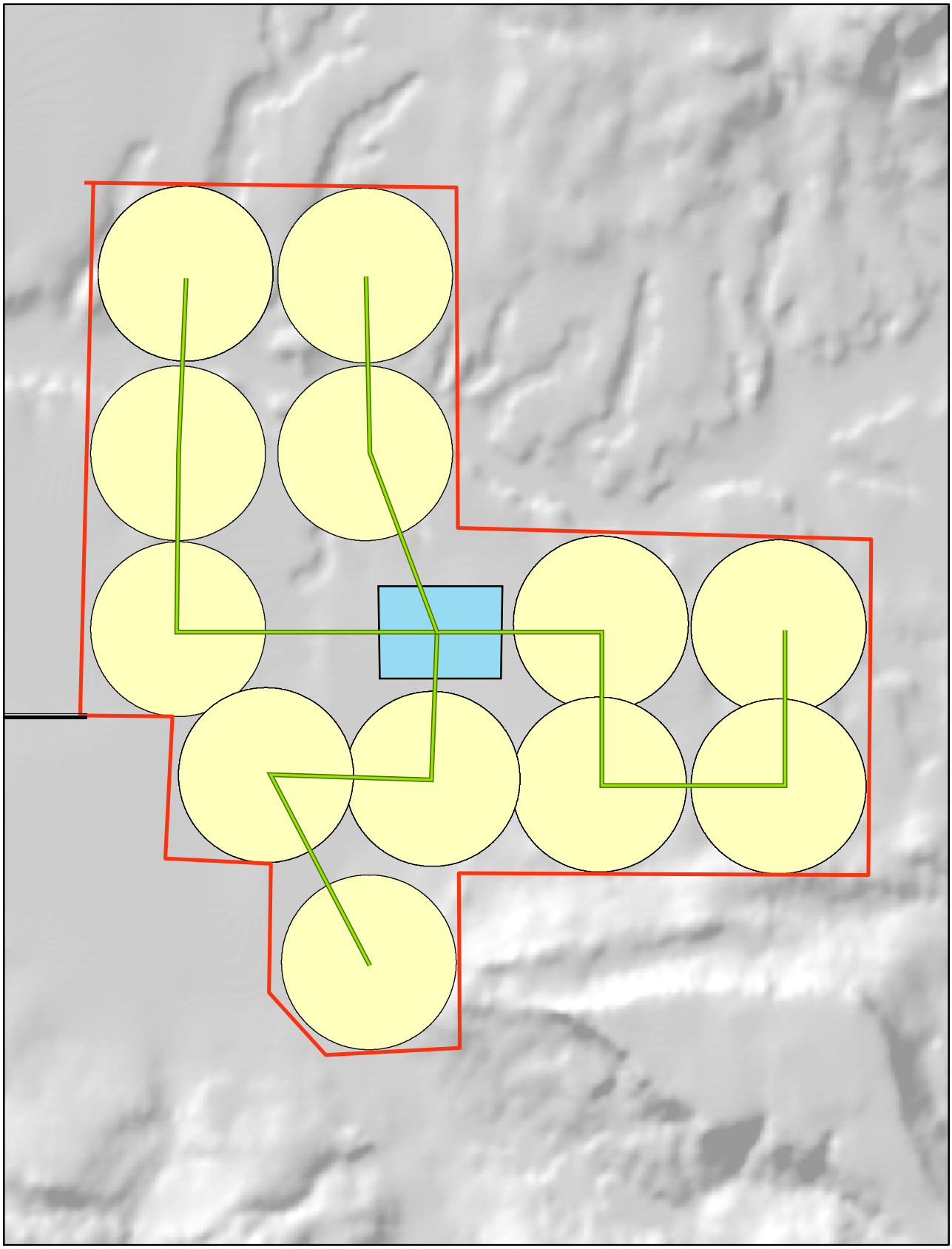
Compared to the North Site, it is likely that a land application system at the South Site would use fewer pivots and more wheel lines, hand sets, and/or big guns due to the steep terrain. For cost estimating purposes, 16 center pivots (125 acres each) were assumed (see Figure 7). On a per acre basis, the cost for wheel lines and pivots are similar.

Key assumptions used in developing site development costs are listed in Table 9.

Table 9. Cost Estimate Design Basis for Site Development

1	Wastewater loading rate limits are based on irrigation demand and not nutrient loadings
2	No fresh water (irrigation water) is available to the site.
3	There is sufficient precipitation in the Spokane area to minimize salt buildup on soils.
4	Gasketed PVC pipe is acceptable.
5	One 15 mgd pump station at the reservoir at the irrigation site.
6	Site work costs based upon RS Means cost estimating publication.

Figure 6. North Land Application Site



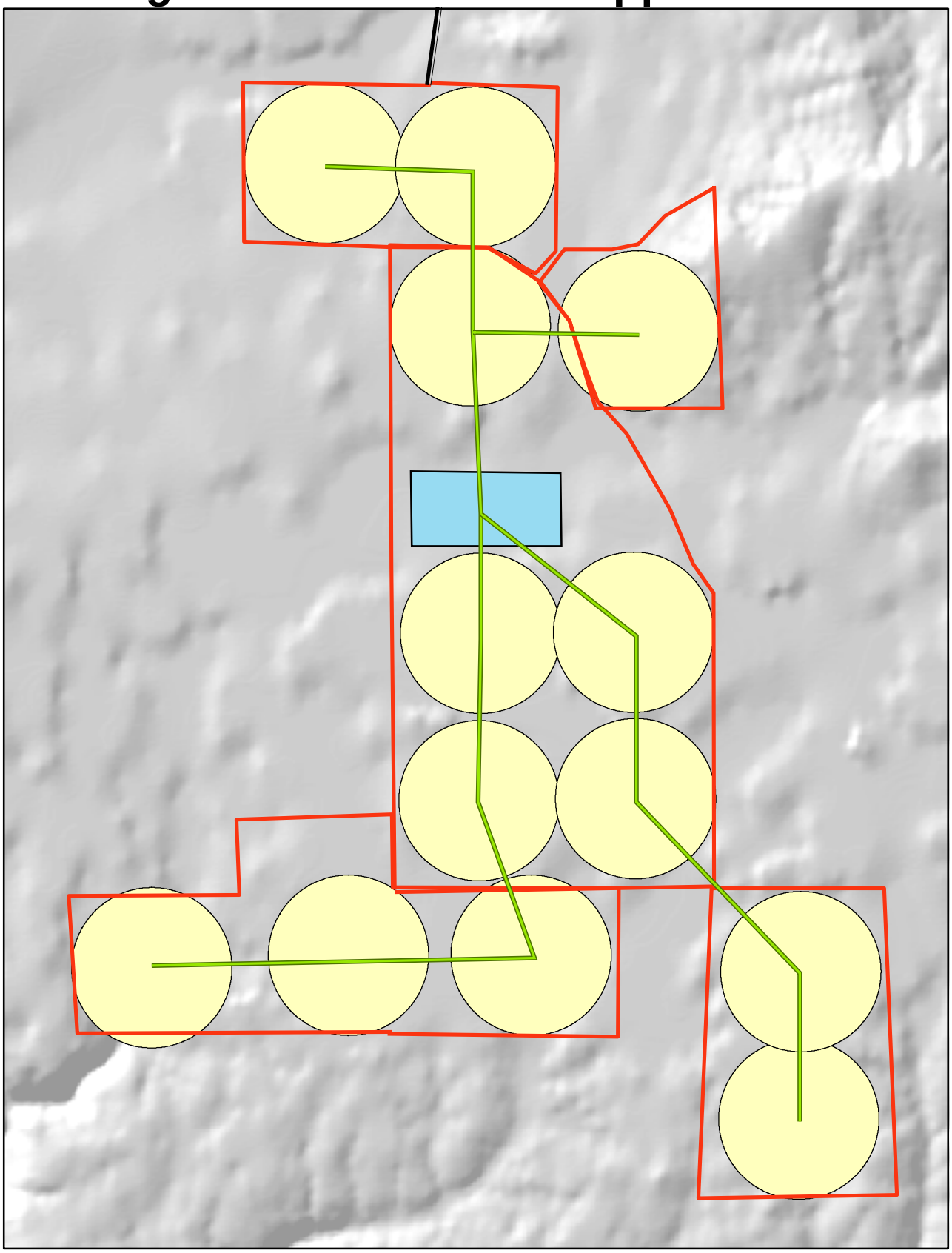
N
W E
S

0 0.5 1 Miles

ONE COMPANY | *Many Solutions*™ HDR

Date: May 11, 2004

Figure 7. South Land Application Site



N
W E
S

0 0.5 1 Miles

ONE COMPANY | *Many Solutions*™ HDR

Date: May 11, 2004

6.1.3 Raw Sewage Conveyance and River Outfall

It has been assumed that the cost for raw sewage conveyance include the components shown in Table 10.

Table 10. Estimated Capital Cost for Raw Sewage Conveyance (from 2004 Facilities Plan Update)

Project Component	Uninflated Capital Cost, $ millions
NVI Pumping Station	7.1
NVI Force Main	1.8
SVI Pumping Station	4.8
SVI Force Main	4.3
Total	**18.0**

Estimated outfall costs are based on locating the SCRTP at the Stockyards site and discharging to the Spokane River at the Front Avenue location. Cost estimates developed in the 2004 Facilities Plan Update have used in this analysis.

6.1.4 Treatment Costs

Facility requirements for treatment must consider both production of reclaimed water for the land application program and treatment of return flow from the storage pond.

For the land application program, it has been assumed that a nitrified, Class A water quality must be produced. Although the Washington State Reuse rules allow use of Class C or D water quality for land application, it appears unlikely that this practice would be acceptable in Spokane County (see discussion in Section 2). Enhanced phosphorus removal may be required, but has not been assumed in this preliminary analysis.

For cost estimating purposes, the anticipated treatment system would consist of nitrifying activated sludge followed by conventional effluent filtration and disinfection using hypochlorite. During the winter, dechlorination would be practiced for all water discharged to the river. Biosolids handling would consist of thickening, anaerobic digestion, dewatering and haul to dedicated land application sites following 40 CFR 503 regulations. Biosolids would be land applied at locations separate from the reclaimed water site. Costs are based on an annual average flow rate of 10 mgd.

"Re-treatment" facilities would probably be needed to polish the stored reclaimed water prior to discharge to the Spokane River. The following re-treatment facilities have been assumed for this 3 mgd flow rate: conventional filtration, post aeration, and chlorination/dechlorination. The re-treatment capacity for filtration, post aeration and chlorination/dechlorination must be in excess of that needed to treat wintertime flows to the plant.

6.2 Operation and Maintenance Costs

6.2.1 Land Application Conveyance and Site Management

The following items were considered in evaluating annual operation and maintenance (O&M) costs:

- A large expenditure is pumping costs. Pumping to the land application, irrigation pumping, and return flow pumping were considered.
- Labor considerations included operation of effluent, irrigation and return flow pumping facilities, irrigation system maintenance, and pond inspection/maintenance.

- Monitoring and reporting as part of the land application permit
- Equipment repair and replacement costs
- Cash revenue from contractors for managing crops

O&M annual costs are presented in Tables 11 and 12 for the North and South sites, respectively. For the North Site, the estimated annual O&M is $259,000 compared to the South site of $570,000. The higher O&M costs for the South Site are primarily attributed to the pumping costs.

6.2.2 Treatment

The estimated operating cost to produce a Class A, nitrified effluent is approximately $900 per MG if the plant is operated at full capacity. The operating cost to retreat the return flow is approximately $150 per MG of return flow.

Section 7. IMPLEMENTATION CONSIDERATIONS

Implementation of a major land application program in Spokane County requires successfully addressing a wide range of implementation issues. These include challenges associated with land acquisition, siting a reservoir, water rights and NPDES permit requirements.

7.1 Land Acquisition

Acquiring 2,400 acres of agricultural property for a wastewater management program will be a daunting challenge for the County. There likely will be significant public opposition to a government entity acquiring this much prime agricultural land to solve an urban issue. If large tracts of contiguous property can not be acquired, the cost and complexity of the land application program will increase.

7.2 Reservoir Siting

Depending on the water depth (20 to 30 feet), the storage pond would occupy 40 to 60 acres. Siting a facility of this nature has historically been difficult due to localized public opposition. Key public concerns will likely include odor, visual aesthetics, potential for groundwater contamination and impacts on property value.

7.3 Water Rights

The proposed land application program would remove flow from the river during the critical low-flow period, affecting water supplies to downstream users. It also would convey the flow out of the Spokane River watershed. At this time, it is not known whether this action would be subject to water rights challenges. Such challenges, if successful, could derail the land application concept.

While there is sufficient reclaimed water to meet crop irrigation demands, it is desirable to have a fresh water irrigation source available at the land application site. Municipal wastewater has slightly elevated salt concentrations (TDS is typically in the 600 to 800 mg/L range). Furthermore, the reclaimed water may have high sodium or chloride levels, depending upon the treatment process and influent characteristics. A fresh water source provides the site manager the ability to restore reclaimed fields that may develop saline or sodic conditions, or establish some crops that may be sensitive to foliage damage from high sodium or chloride levels. The County will likely be required to purchase water rights to drill a new well or purchase land with existing water rights

7.4 Return of Unused Reclaimed Water for River Discharge

The proposed water management concept is based on the assumption that unused reclaimed water could be returned to the SCRTP during the winter for discharge to the Spokane River. This would increase the wintertime effluent flow rate by 3 mgd. It is not certain whether Ecology would permit this management practice, or what effluent quality requirements would be imposed. If the practice is not permitted, the required reservoir volume would roughly double, and additional land would be required to use the excess water.

APPENDIX A

WATER BALANCE FOR BASELINE SCENARIO

Appendix A
Spokane County Waste Water Reuse Estimates
Full Irrigation - Alfalfa only
10/1/2004

Month	Influent	Precip	Precip	Evap	Evap	Net Irrigation	Gross Irrigation	Irrigation	Vol Change	Vol in Ponds	Pond Depth
	Gal/mo	(in/mo)	(gal/mo)	(in/mo)	(gal/mo)	(in/mo)	(in/mo)	(gal/mo)		0	0
Jan		2.47	4,100,000	0.4	700,000	0.00	0.00	0	3,400,000		
										3,400,000	0
Feb	0	1.61	2,700,000	0.3	500,000	0.00	0.00	0	2,200,000		
										5,600,000	0
March	0	1.36	2,300,000	0.5	900,000	0.00	0.00	0	1,400,000		
										7,000,000	0
Apr	150,000,000	1.08	1,800,000	1.1	1,800,000	0.00	0.00	0	150,000,000		
										157,000,000	8
May	310,000,000	1.38	2,300,000	3.2	5,300,000	1.72	2.29	100,000,000	207,000,000		
										364,000,000	19
June	300,000,000	1.23	2,100,000	4.2	6,900,000	5.44	7.25	300,000,000	-4,800,000		
										359,200,000	18
Jul	310,000,000	0.50	900,000	4.9	8,000,000	8.41	11.21	460,000,000	-157,100,000		
										202,100,000	10
Aug	310,000,000	0.74	1,300,000	6.7	11,000,000	6.72	8.96	370,000,000	-69,700,000		
										132,400,000	7
Sep	300,000,000	0.71	1,200,000	6.3	10,300,000	4.11	5.48	230,000,000	60,900,000		
										193,300,000	10
Oct	155,000,000	1.08	1,800,000	3.9	6,400,000	0.22	0.29	20,000,000	130,400,000		
										323,700,000	17
Nov		2.06	3,400,000	2.1	3,500,000	0.00	0.00	0	-100,000		
										323,600,000	17
Dec		2.49	4,100,000	1.4	2,300,000	0.00	0.00	0	1,800,000		
										325,400,000	17
	1,835,000,000	**16.7**	**28,000,000**	**35.0**	**57,600,000**	**26.6**	**35.5**	**1,480,000,000**			

Assumptions

Pond Area (acres)	60
Irrigated Area (Acres)	1500
Irrigation Efficiency	75%

APPENDIX B

WATER BALANCE FOR REDUCED SEASON

Appendix B
Spokane County Waste Water Reuse Estimates
short season alfalfa - 2016 acres of Alfalfa

Month	Influent	Precip	Precip	Evap	Evap	Net Irrigation	Gross Irrigation	Irrigation	Vol Change	Vol in Ponds	Pond Depth
	Gal/mo	(in/mo)	(gal/mo)	(in/mo)	(gal/mo)	(in/mo)	(in/mo)	(gal/mo)		170,000,000	9
Jan		2.47	4,100,000	0.4	700,000	0.00	0.00	0	3,400,000		
										173,400,000	9
Feb	0	1.61	2,700,000	0.3	500,000	0.00	0.00	0	2,200,000		
										175,600,000	9
March	0	1.36	2,300,000	0.5	900,000	0.00	0.00	0	1,400,000		
										177,000,000	9
Apr	0	1.08	1,800,000	1.1	1,800,000	0.00	0.00	0	0		
										177,000,000	9
May	0	1.38	2,300,000	3.2	5,300,000	1.72	2.29	90,000,000	-93,000,000		
										84,000,000	4
June	300,000,000	1.23	2,100,000	4.2	6,900,000	5.44	7.25	260,000,000	35,200,000		
										119,200,000	6
Jul	310,000,000	0.50	900,000	4.9	8,000,000	8.41	11.21	400,000,000	-97,100,000		
										22,100,000	1
Aug	310,000,000	0.74	1,300,000	6.7	11,000,000	6.72	8.96	320,000,000	-19,700,000		
										2,400,000	0
Sep	300,000,000	0.71	1,200,000	6.3	10,300,000	4.11	5.48	200,000,000	90,900,000		
										93,300,000	5
Oct	155,000,000	1.08	1,800,000	3.9	6,400,000	0.22	0.29	20,000,000	130,400,000		
										223,700,000	11
Nov		2.06	3,400,000	2.1	3,500,000	0.00	0.00	0	-100,000		
										223,600,000	11
Dec		2.49	4,100,000	1.4	2,300,000	0.00	0.00	0	1,800,000		
										225,400,000	12
	1,375,000,000	**16.7**	**28,000,000**	**35.0**	**57,600,000**	**26.6**	**35.5**	**1,290,000,000**			

Assumptions

Pond Area (acres)	60
Irrigated Area (Acres)	1300
Irrigation Efficiency	75%

APPENDIX C

CAPITAL COST ESTIMATE FOR NORTH SITE FACILITIES

Appendix C - Estimated Capital Costs for North Land Application Site

High Pressure Pump Station at SCRTP	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
400,000 Gallon Reservoir	$400,000	LS	1	$400,000
Structure/building	$200,000	LS	1	$200,000
Pumps & Motors	$60,000	EA	4	$240,000
Station Valving & Piping	$100,000	LS	1	$100,000
Electrical	$100,000	LS	1	$100,000
Instrumentation	$50,000	LS	1	$50,000
		Subtotal		$1,150,000
		Sitework	10%	$ 115,000
		Subtotal		*$ 1,265,000*
		Mobilization Bonds and Insurance	5%	$ 63,000
		Contractor's Overhead and Profit	10%	$ 127,000
		Subtotal		*$ 1,340,000*
		Miscellaneous Items and Contingencies	20%	$ 268,000
		Subtotal		*$ 1,608,000*
		Washington State Salse Tax	8.1%	$ 130,000
		Subtotal		*$ 1,738,000*
		Construction Contingency (Change Orders)	5%	$ 87,000
		Subtotal		*$ 1,825,000*
		Engineering, Legal and Fiscal	25%	$ 456,000
		Total Estimated Cost		**$ 2,281,000**

Conveyance Pipeline	Unit Cost	Unit	Quantity	Extended Total
30-PVC, DR18	$140.00	LF	50,000	$7,000,000
Total Excavation and Pipe Bed	$70.00	LF	50,000	$3,500,000
Misc. Valving	$5,000.00	LS	1	$5,000
Telemetry System	$10,000.00	LS	12	$120,000
Discharge Structure	$25,000	LS	1	$25,000
Gravel Surface Repair- 5 Gravel Intersections	$50.00	CY	100	$5,000
Roadway Surface Repair- 12 xings @ 60ft & 6000ft in road	$33.00	LF	6,720	$221,760
River Crossing	$500,000.00	LS	1	$500,000
Highway/Railroad borings	$900.00	LF	400	$360,000
		Subtotal		$11,736,760
		Sitework (included in line items)	0%	$ -
		Subtotal		*$ 11,736,760*
		Mobilization Bonds and Insurance	5%	$ 587,000
		Contractor's Overhead and Profit	10%	$ 1,174,000
		Subtotal		*$ 13,497,760*
		Miscellaneous Items and Contingencies	20%	$ 2,700,000
		Subtotal		*$ 16,198,000*
		Washington State Salse Tax	8.1%	$ 1,312,000
		Subtotal		*$ 17,510,000*
		Construction Contingency (Change Orders)	5%	$ 876,000
		Subtotal		*$ 18,386,000*
		Engineering, Legal and Fiscal	25%	$ 4,597,000
		Total Estimated Cost		**$ 22,983,000**

Return Flow Pump Station	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$30,000	LS	1	$30,000
Building/Intake	$150,000	LS	1	$150,000
Pumps&Motors	$40,000	EA	3	$120,000
Station Valving & Piping	$50,000	LS	1	$50,000
Electrical	$50,000	LS	1	$50,000
Instrumentation	$25,000	LS	1	$25,000
		Subtotal		$425,000
		Sitework	10%	$ 42,500
		Subtotal		*$ 467,500*
		Mobilization Bonds and Insurance	5%	$ 23,000
		Contractor's Overhead and Profit	10%	$ 47,000
		Subtotal		*$ 495,000*
		Miscellaneous Items and Contingencies	20%	$ 99,000
		Subtotal		*$ 594,000*
		Washington State Salse Tax	8.1%	$ 48,000
		Subtotal		*$ 642,000*
		Construction Contingency (Change Orders)	5%	$ 32,000
		Subtotal		*$ 674,000*
		Engineering, Legal and Fiscal	25%	$ 169,000
		Total Estimated Cost		**$ 843,000**

Irrigation Pump Station	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
Building/Intake	$200,000	LS	1	$200,000
Pumps&Motors	$60,000	EA	4	$240,000
Station Valving & Piping	$100,000	LS	1	$100,000
Electrical	$100,000	LS	1	$100,000
Instrumentation	$50,000	LS	1	$50,000
		Subtotal		$750,000
		Sitework	10%	$ 75,000
		Subtotal		*$ 825,000*
		Mobilization Bonds and Insurance	5%	$ 41,000
		Contractor's Overhead and Profit	10%	$ 83,000
		Subtotal		*$ 874,000*
		Miscellaneous Items and Contingencies	20%	$ 175,000
		Subtotal		*$ 1,049,000*
		Washington State Salse Tax	8.1%	$ 85,000
		Subtotal		*$ 1,134,000*
		Construction Contingency (Change Orders)	5%	$ 57,000
		Subtotal		*$ 1,191,000*
		Engineering, Legal and Fiscal	25%	$ 298,000
		Total Estimated Cost		**$ 1,489,000**

Land Application Site	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
Fencing	$5.00	LF	40,000	$200,000
Electrical	$4.00	LF	75,000	$300,000
Maintenance Building	$1.00	LS	100,000	$100,000
Piping from Storage Pond - 10"	$30.00	LF	7,560	$226,800
Piping from Storage Pond - 15"	$40.00	LF	15,630	$625,200
Piping from Storage Pond - 18"	$50.00	LF	13,590	$679,500
Center Pivots (125 acres each)	$50,000	EA	16	$800,000
Rehabilitation - Pipe Trenches	$2.00	LF	36,780	$73,560
Roads	$33.00	LF	10,000	$330,000
		Subtotal		$3,395,060
		Sitework (included in line items)	0%	$ -
		Subtotal		*$ 3,395,060*
		Mobilization Bonds and Insurance	5%	$ 170,000
		Contractor's Overhead and Profit	10%	$ 340,000
		Subtotal		*$ 3,905,060*
		Miscellaneous Items and Contingencies	20%	$ 781,000
		Subtotal		*$ 4,686,000*
		Washington State Salse Tax	8.1%	$ 380,000
		Subtotal		*$ 5,066,000*
		Construction Contingency (Change Orders)	5%	$ 253,000
		Subtotal		*$ 5,319,000*
		Engineering, Legal and Fiscal	25%	$ 1,330,000
		Total Estimated Cost		**$ 6,649,000**

Lined Storage Facility	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
Earthwork	$6.00	CY	1,300,000	$7,800,000
Imported Subgrade	$22.00	CY	50,000	$1,100,000
Geomembrane Liner	$1.00	SF	3,000,000	$3,000,000
Inlet/Outlet Structures & By-Pass	$50,000	LS	1	$50,000
		Subtotal		$12,010,000
		Sitework (included in line items)	0%	$ -
		Subtotal		*$ 12,010,000*
		Mobilization Bonds and Insurance	5%	$ 601,000
		Contractor's Overhead and Profit	10%	$ 1,201,000
		Subtotal		*$ 13,812,000*
		Miscellaneous Items and Contingencies	20%	$ 2,762,000
		Subtotal		*$ 16,574,000*
		Washington State Salse Tax	8.1%	$ 1,342,000
		Subtotal		*$ 17,916,000*
		Construction Contingency (Change Orders)	5%	$ 896,000
		Subtotal		*$ 18,812,000*
		Engineering, Legal and Fiscal	25%	$ 4,703,000
		Total Estimated Cost		**$ 23,515,000**

Land Acquisition	Unit Cost	Unit	Quantity	Extended Total
Land Application Site	$4,000	acre	2,400	$9,600,000
Pump Station at SCRTP	$100,000	LS	1	$100,000
Total				**$9,700,000**

APPENDIX D

CAPITAL COST ESTIMATE FOR SOUTH SITE FACILITIES

Appendix D - Estimated Capital Costs for South Land Application Site

High Pressure Pump Station at SCRTP	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
400,000 Gallon Reservoir	$400,000	LS	1	$400,000
Structure/building	$200,000	LS	1	$200,000
Pumps & Motors	$60,000	EA	4	$240,000
Station Valving & Piping	$100,000	LS	1	$100,000
Electrical	$100,000	LS	1	$100,000
Instrumentation	$50,000	LS	1	$50,000
		Subtotal		$1,150,000
		Sitework	10%	$ 115,000
		Subtotal		*$ 1,265,000*
		Mobilization Bonds and Insurance	5%	$ 63,000
		Contractor's Overhead and Profit	10%	$ 127,000
		Subtotal		*$ 1,340,000*
		Miscellaneous Items and Contingencies	20%	$ 268,000
		Subtotal		*$ 1,608,000*
		Washington State Salse Tax	8.1%	$ 130,000
		Subtotal		*$ 1,738,000*
		Construction Contingency (Change Orders)	5%	$ 87,000
		Subtotal		*$ 1,825,000*
		Engineering, Legal and Fiscal	25%	$ 456,000
		Total Estimated Cost		**$ 2,281,000**

Conveyance Pipeline	Unit Cost	Unit	Quantity	Extended Total
30-PVC, DR18	$140.00	LF	25,000	$3,500,000
30-Ductile Iron, Pressure 350 psi	$250.00	LF	47,520	$11,880,000
Total Excavation and Pipe Bed	$70.00	LF	72,520	$5,076,400
Misc. Valving	$5,000.00	LS	1	$5,000
Telemetry System	$10,000.00	LS	13	$130,000
Discharge Structure	$25,000	LS	1	$25,000
Gravel Surface Repair- 5 Gravel Intersections	$50.00	CY	100	$5,000
Roadway Surface Repair- 12 xings @ 60ft & 6000ft in road	$33.00	LF	960	$31,680
Highway/Railroad borings	$900.00	LF	900	$810,000
		Subtotal		$21,463,080
		Sitework (included in line items)	0%	$ -
		Subtotal		*$ 21,463,080*
		Mobilization Bonds and Insurance	5%	$ 1,073,000
		Contractor's Overhead and Profit	10%	$ 2,146,000
		Subtotal		*$ 24,682,080*
		Miscellaneous Items and Contingencies	20%	$ 4,936,000
		Subtotal		*$ 29,618,000*
		Washington State Salse Tax	8.1%	$ 2,399,000
		Subtotal		*$ 32,017,000*
		Construction Contingency (Change Orders)	5%	$ 1,601,000
		Subtotal		*$ 33,618,000*
		Engineering, Legal and Fiscal	25%	$ 8,405,000
		Total Estimated Cost		**$ 42,023,000**

Intermediate Pump Station	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
Structure/building	$200,000	LS	1	$200,000
Pumps & Motors	$60,000	EA	4	$240,000
Station Valving & Piping	$100,000	LS	1	$100,000
Electrical	$100,000	LS	1	$100,000
Instrumentation	$50,000	LS	1	$50,000
		Subtotal		$750,000
		Sitework	10%	$ 75,000
		Subtotal		*$ 825,000*
		Mobilization Bonds and Insurance	5%	$ 41,000
		Contractor's Overhead and Profit	10%	$ 83,000
		Subtotal		*$ 874,000*
		Miscellaneous Items and Contingencies	20%	$ 175,000
		Subtotal		*$ 1,049,000*
		Washington State Salse Tax	8.1%	$ 85,000
		Subtotal		*$ 1,134,000*
		Construction Contingency (Change Orders)	5%	$ 57,000
		Subtotal		*$ 1,191,000*
		Engineering, Legal and Fiscal	25%	$ 298,000
		Total Estimated Cost		**$ 1,489,000**

Irrigation Pump Station	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
Building/Intake	$200,000	LS	1	$200,000
Pumps&Motors	$60,000	EA	4	$240,000
Station Valving & Piping	$100,000	LS	1	$100,000
Electrical	$100,000	LS	1	$100,000
Instrumentation	$50,000	LS	1	$50,000
		Subtotal		$750,000
		Sitework	10%	$ 75,000
		Subtotal		*$ 825,000*
		Mobilization Bonds and Insurance	5%	$ 41,000
		Contractor's Overhead and Profit	10%	$ 83,000
		Subtotal		*$ 874,000*
		Miscellaneous Items and Contingencies	20%	$ 175,000
		Subtotal		*$ 1,049,000*
		Washington State Salse Tax	8.1%	$ 85,000
		Subtotal		*$ 1,134,000*
		Construction Contingency (Change Orders)	5%	$ 57,000
		Subtotal		*$ 1,191,000*
		Engineering, Legal and Fiscal	25%	$ 298,000
		Total Estimated Cost		**$ 1,489,000**

Land Application Site	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
Fencing	$5.00	LF	40,000	$200,000
Electrical	$4.00	LF	75,000	$300,000
Maintenance Building	$100,000.00	LS	1	$100,000
Piping from Storage Pond - 10"	$30.00	LF	7,560	$226,800
Piping from Storage Pond - 15"	$40.00	LF	15,630	$625,200
Piping from Storage Pond - 18"	$50.00	LF	13,590	$679,500
Center Pivots (125 acres each)	$50,000	EA	16	$800,000
Rehabilitation - Pipe Trenches	$2.00	LF	36,780	$73,560
Roads	$33.00	LF	10,000	$330,000
		Subtotal		$3,395,060
		Sitework (included in line items)	0%	$ -
		Subtotal		*$ 3,395,060*
		Mobilization Bonds and Insurance	5%	$ 170,000
		Contractor's Overhead and Profit	10%	$ 340,000
		Subtotal		*$ 3,905,060*
		Miscellaneous Items and Contingencies	20%	$ 781,000
		Subtotal		*$ 4,686,000*
		Washington State Salse Tax	8.1%	$ 380,000
		Subtotal		*$ 5,066,000*
		Construction Contingency (Change Orders)	5%	$ 253,000
		Subtotal		*$ 5,319,000*
		Engineering, Legal and Fiscal	25%	$ 1,330,000
		Total Estimated Cost		**$ 6,649,000**

Lined Storage Facility	Unit Cost	Unit	Quantity	Extended Total
Mobilization	$60,000	LS	1	$60,000
Earthwork	$6.00	CY	1,300,000	$7,800,000
Imported Subgrade	$22.00	CY	50,000	$1,100,000
Geomembrane Liner	$1.00	SF	3,000,000	$3,000,000
Inlet/Outlet Structures & By-Pass	$50,000	LS	1	$50,000
		Subtotal		$12,010,000
		Sitework (included in line items)	0%	$ -
		Subtotal		*$ 12,010,000*
		Mobilization Bonds and Insurance	5%	$ 601,000
		Contractor's Overhead and Profit	10%	$ 1,201,000
		Subtotal		*$ 13,812,000*
		Miscellaneous Items and Contingencies	20%	$ 2,762,000
		Subtotal		*$ 16,574,000*
		Washington State Salse Tax	8.1%	$ 1,342,000
		Subtotal		*$ 17,916,000*
		Construction Contingency (Change Orders)	5%	$ 896,000
		Subtotal		*$ 18,812,000*
		Engineering, Legal and Fiscal	25%	$ 4,703,000
		Total Estimated Cost		**$ 23,515,000**

Land Acquisition	Unit Cost	Unit	Quantity	Extended Total
Land Application Site	$2,000	acre	2,400	$4,800,000
Intermediate Pump Station	$1	LS	50,000	$50,000
Pump Station at SCRTP	$100,000	LS	1	$100,000
Total				**$4,950,000**

APPENDIX E

CAPITAL COST ESTIMATE FOR TREATMENT FACILITIES

Capital Costs for Class A Treatment with Nitrification

Costs are based on 2003 and 2004 FPA estimates for 2-phase 12 mgd plant.
Unit cost per gallon treated based on sum of both phases devided by 12 mgd.
Costs presented in 2004 dollars.

	Stockyards		
	Phase 1 (8 mgd)	Phase 2 (4 mgd)	
Description	**Total ($ millions)**	**Total ($ millions)**	**Comments**
Influent Junction and MLSS Split Boxes	0.15	-	Costs developed during 2004 FPA
Septage Handling	0.33	-	Costs developed during 2004 FPA
Preliminary Treatment	1.66	-	Costs developed during 2004 FPA
Primary Treatment	2.18	0.80	Costs developed during 2004 FPA
Aearation Basins	3.90	1.82	Costs from 2003 FPA plus covers, inflated to 2004 dollars
Blower Building	1.37		Costs from 2003 FPA, inflated to 2004 dollars
Secondary Clarifiers	3.33	1.18	Costs from 2003 FPA plus covers, inflated to 2004 dollars
RAS/WAS Pumping	2.42	0.63	Costs from 2003 FPA, inflated to 2004 dollars
Filtration System	4.84	2.47	Costs from 2003 FPA, inflated to 2004 dollars
Post Aeration	0.19	-	Costs developed during 2004 FPA
Chlorination/Dechlorination	1.52	0.54	Costs developed during 2004 FPA, adjusted to flow rate
Chemical Feed and Storage	0.59	0.04	Costs developed during 2004 FPA
WAS Thickening	0.59	0.32	Costs developed during 2004 FPA
Anaerobic Digestion	4.12	1.07	Costs developed during 2004 FPA
Solids Dewatering	3.18	-	Costs developed during 2004 FPA
Odor Control	1.07	0.12	Costs developed during 2004 FPA
Administration	1.32	-	Costs developed during 2004 FPA
Support Facilities/Site Work	4.36	0.59	Costs developed during 2004 FPA
Subtotal A	***37.12***	***9.57***	
Mobilization Bonds and Insurance (5% of A)	1.86	0.48	
Contractor's Overhead and Profit (10% of A)	3.71	0.96	
Subtotal B	***42.69***	***11.00***	
Miscellaneous Items and Contingencies (15% of B)	6.40	1.65	
Subtotal C	***49.09***	***12.65***	
Washington State Sales Tax (8.1% of C)	3.98	1.03	
Subtotal D	***53.07***	***13.68***	
Construction Contingency (Change Orders) (5% of D	2.65	0.68	
Subtotal E	***55.72***	***14.36***	
Engineering, Legal and Fiscal (25% of E)	13.93	3.59	
Total	**69.66**	**17.95**	
Total Cost (Phases 1 and 2)		**87.61**	

Cost per gallon (average day flow) **$ 7.30**

Capital Costs for Return Flow Treatment

Costs presented in 2004 dollars.

Description	3 mgd Total ($ millions)
Junction Box	0.15
Filtration	1.81
Post Aeration	0.05
Chlorination/Dechlorination	0.57
Chemical Feed and Storage	0.10
Support Facilities/Site Work	0.27
Subtotal A	***2.95***
Mobilization Bonds and Insurance (5% of A)	0.15
Contractor's Overhead and Profit (10% of A)	0.29
Subtotal B	***3.39***
Miscellaneous Items and Contingencies (15% of B)	0.51
Subtotal C	***3.90***
Washington State Sales Tax (8.1% of C)	0.32
Subtotal D	***4.21***
Construction Contingency (Change Orders) (5% of D)	0.21
Subtotal E	***4.42***
Engineering, Legal and Fiscal (25% of E)	1.11
Total	**5.53**

APPENDIX F

OPERATING COST ESTIMATES FOR LAND APPLICATION PROGRAM

Appendix F-1
Operating Costs for Land Application System
North Site

Item	Description	Unit Cost Source	Unit Cost	Quantity	Cost	Cost Assumptions	Comments
Power							
	Discharge Pumping	Facility Plan	$0.065/kW-hr	1,980,000 kW-hr/yr	$ 128,700	TDH=220 ft, Q=6945gpm	All pumps run 24hr/day, for half the year with pump and motor efficency = 80%
	Irrigation Pumping	Facility Plan	$0.065/kW-hr	1,846,000 kW-hr/yr	$ 119,990	TDH=250 ft, Q=5710 gpm	
	Return Flow Pumping	Facility Plan	$0.065/kW-hr	382,600 kW-hr/yr	$ 24,869	TDH=220 ft, Q=4100 gpm	
Power Subtotal	***Includes Tax and Demand Charges***			**4,208,600 kW-hr/yr**	**$ 273,559**		

Labor (Operations and Maintenance)

	Discharge Pumping	Facility Plan	$32.63/hr	312 hr	$ 10,181	6 hours/week	Added labor to Operation Cost to discharge to river 6 hours per week for 1/2 year
	Irrigation System	Facility Plan	$32.63/hr	744 hr	$ 24,277	13 hours/week, plus 40 hours each at startup & shutdown	Assume renter responsible for day to day maintenance
	Lagoon Inspection/ Maintenance	Facility Plan	$32.63/hr	104 hr	$ 3,394	2 hours/week	Year Round
	Return Flow Pumping	Facility Plan	$32.63/hr	156 hr	$ 5,090	6 hours/week	Operations = 6*52 weeks/year*1/2 year
O&M Labor Subtotal				**0.6 FTEs**	**$ 42,941**		

Annual Reporting

	Annual Reporting and GW Monitoring	*Experience with similarly sized waste water reuse monitoring and reporting*	LS	$80,000	$ 80,000	Estimate based on Operator collected data/samples and annual report writing	
Subtotal					**$ 80,000**		

Materials

	Discharge Pumping	5% of equipment	$ 200,000	5%	$ 10,000	Estimate	
	Irrigation System	6% of equipment	$ 589,000	6%	$ 35,340	Estimate	annual cost to repair/replace hoses, nozzles, drives ect.
	Lagoon Maintenance	0.2% of equipment	$ 8,500,000	0.20%	$ 17,000	Estimate	annual cost to repair liner
Materials Subtotal					**$ 62,340**		
				Annual O & M Costs	**$ 458,840**		

Cash Rent Revenue

	Cash Rent		$100.00/acre	2,000	$ 200,000		
Subtotal					**$ 200,000**		

Total Annual O & M Costs **$258,840**

Appendix F-2
Operating Cost for Land Application System
South Site

Item	Description	Unit Cost Source	Unit Cost	Quantity	Cost	Cost Assumptions	Comments
Power							
	Discharge Pumping	Facility Plan	$0.065/kW-hr	7,185,312 kW-hr/yr	$ 467,045	TDH=800 ft, Q=6945gpm	pump and motor eff = 80%
	Irrigation Pumping	Facility Plan	$0.065/kW-hr	1,846,000 kW-hr/yr	$ 119,990	TDH=250 ft, Q=5710 gpm, pumps run 24 hrs/day, 183 days/year	pump and motor eff = 80%
	Return Flow Pumping			0 kW-hr/yr	$ -		Gravity Flow
Power Subtotal	***Includes Tax and Demand Charges***			**9,031,312 kW-hr/yr**	**$ 587,035**		
Labor (Operations and Maintenance)							
	Discharge Pumping	Facility Plan	$32.63/hr	312 hr	$ 10,181	6 hours/week	Added labor to Operation Cost to discharge to river
	Irrigation System	Facility Plan	$32.63/hr	744 hr	$ 24,277	13 hours/week, plus 40 hours each at startup & shutdown	Assume renter responsible for day to day maintenance
	Lagoon Inspection/ Maintenance	Facility Plan	$32.63/hr	156 hr	$ 5,090	6 hours/week	Operations = 6*52 weeks/year*1/2 year
	Return Flow Pumping		$32.63/hr		$ -		Gravity Flow
O&M Labor Subtotal				**0.6 FTEs**	**$ 39,548**		
Annual Reporting							
	Annual Reporting and GW Monitoring	*Experience with similarly sized waste water reuse monitoring and reporting*	LS	$80,000	$ 80,000	Estimate based on Operator collected data/samples and annual report writing	
Subtotal					**$ 80,000**		
Materials							
	Discharge Pumping	5% of equipment	$ 200,000	5%	$ 10,000	Estimate	
	Irrigation System	6% of equipment	$ 589,000	6%	$ 35,340	Estimate	annual cost to repair/replace hoses, nozzles, drives ect.
	Lagoon Maintenance	0.2% of equipment	$ 8,500,000	0.20%	$ 17,000	Estimate	annual cost to repair liner
Materials Subtotal					**$ 62,340**		
				Annual O & M Costs	**$ 768,923**		
Cash Rent Revenue							
	Cash Rent		$100.00/acre	2,000	$ 200,000		
Subtotal					**$ 200,000**		

Total Annual O & M Costs **$568,923**

Appendix F

Advanced Wastewater Treatment Technology Evaluation Workshop (August 24, 2004)

Advanced Wastewater Treatment Technology Evaluation Workshop

PREPARED FOR: City of Spokane and Spokane County

PREPARED BY: Jim Correll, CH2M HILL

COPIES:
Dale Arnold/City of Spokane
Bruce Rawls/Spokane County
Neil Kersten/Spokane Valley
Lee Mellish/Liberty Lake Sewer and Water District
Rick Fink/Inland Empire Paper
Pat Blau/Kaiser Aluminum
Terry Werner/Post Falls
Sid Fredrickson/City of Coeur d'Alene
Kent Helmer/Hayden Regional Sewer Board

DATE: September 27, 2004

F. Executive Summary

Background

The Washington State Department of Ecology (Ecology) has proposed that all Spokane River wastewater dischargers upgrade their respective treatment processes to achieve an instantaneous maximum total phosphorus effluent concentration of 50 µg/l. Ecology also has proposed that the phosphorus limit for future flow increases be reduced to a not-to-exceed concentration of 10 µg/l. Lastly, Ecology has stated that technologies currently exist that can consistently meet these proposed limits.

In response Spokane County and the City of Spokane jointly sponsored a one-day workshop on August 23, 2004, to evaluate advanced wastewater treatment technologies. The main objective of this workshop was to identify all proven and emerging technologies and to estimate what ranges of effluent phosphorus concentrations could be consistently and reliably achieved utilizing those technologies.

Participants

The workshop was facilitated by Mike Doleac/CH2M HILL and conducted by four nationally noted wastewater treatment process experts including:

- Dr. David Stensel, Wastewater Treatment Professor, University of Washington
- Dr. Glen Daigger, Chief Technology Officer, CH2M HILL
- Dr. J.B. Neethling, Director of Wastewater Treatment Technology, HDR
- Dr. Larry Esvelt, Esvelt Environmental Engineering

Other participants in the workshop included:

- Jerry Anderson/Regional Ecology
- Kathy Cupps/HQ Ecology
- Dave Reynolds/CH2M HILL
- Dave Clark/HDR
- Jim Kimball/JUB
- Terry Dokken/Operations Management Inc.
- Carlo Spani/Clean Water Services
- Mark Esvelt/EEE
- Bruce Rawls/Spokane County
- Lars Hendron/City of Spokane

Evaluation Criteria and Process

Washington State requires that all wastewater treatment facilities meet "AKART." AKART stands for All Known, Available and Reasonable methods of prevention, control and Treatment of wastewater. Determination of AKART entails a comprehensive engineering and economic assessment that would be beyond the scope of this workshop. Nevertheless, AKART was considered to provide an initial basis for evaluating alternative technologies. Since AKART must be a "proven" technology, a key focus of this workshop was to determine which technologies are sufficiently "proven" to be considered potentially compliant with AKART.

The workshop participants agreed that instantaneous maximum effluent phosphorus concentration limits were not reasonable criteria upon which to evaluate alternative technologies. The variability of both influent quality and rates of flow, coupled with the complexities of the processes used to treat the wastewater, result in too much short-term variation in effluent constituent concentrations. The ability to meet a 30-day median phosphorus concentration of 50 µg/l was, therefore, used as an initial screen to reduce the array of technologies being evaluated.

An international evaluation of membrane bioreactors, conducted by the Rockefeller Foundation in 2003 in Bellagio, Italy, was used as the basis for selecting evaluation criteria and a scoring system that could assess the "readiness" of a technology to be implemented. "Readiness" was based on the fundamental premise that, when technical risks are sufficiently well characterized, they can be managed. Then the technology is ready for widespread application.

The workshop participants established several additional basic ground rules to apply to the identification and evaluation of technologies:

- All conclusions were to be by consensus.
- The evaluation would consider only technologies appropriate for discharge to surface water.
- The inability to achieve a 30-day median total phosphorus concentration of 50 µg/l would be considered a fatal flaw.

Alternative Technologies

A total of 21 technologies, capable of achieving extremely low effluent phosphorus concentrations, were identified by the workshop participants. These technologies included various combinations of direct filtration, dual sand filtration, tertiary filtration, granular media filtration, micro-filtration, enhanced biological phosphorus removal, reverse osmosis, ultrafiltration, ion exchange, distillation, wetland polishing, evaporation, and post secondary lime treatment.

Ten treatment technologies survived the initial screening. These technologies were then scored for "Technical Readiness," using the criteria previously discussed. The technologies that scored highest were:

- Tertiary Clarification and Granular Media Filtration with Aluminum salt(s) (e.g. Alum)
- Post Secondary Micro Filtration with Aluminum salt(s) (e.g. Alum)
- Micro Filtration with Reverse Osmosis and Aluminum salt(s) (e.g. Alum)
- Membrane Bioreactor with Enhanced Biological Phosphorus Removal and chemical injection (e.g. aluminum salt(s), Alum)
- Post Secondary Lime Treatment

Phosphorus Discharge Results

Microfiltration coupled with Reverse Osmosis was determined to be the only known technology capable of meeting a proposed maximum instantaneous total phosphorus discharge limit of 50 μg/l. The workshop participants agreed that there is no known or emerging treatment process capable of meeting a maximum instantaneous phosphorus discharge limit of 10 μg/l. Several of the treatment processes were found capable of delivering 50 μg/l or less as a median effluent phosphorus concentration.

F.1. Background and Purpose

For the past two years, the Washington State Department of Ecology (Ecology) has been conducting a Dissolved Oxygen Total Maximum Daily Loading (DO TMDL) evaluation of the Spokane River. As a potential outcome of the DO TMDL process, Ecology has proposed that all municipalities and industries, currently discharging treated wastewater to the river, immediately upgrade their respective treatment technologies to achieve a maximum total phosphorus effluent concentration of 0.05 mg/l (50 μg/l). The agency also has proposed that all future increases in treated wastewater discharge to the river be limited to a maximum phosphorus concentration of 0.01 mg/l (10 μg/l).

In response to these proposed requirements, the City of Spokane and Spokane County sponsored an Advanced Wastewater Treatment Technology Evaluation Workshop. The purpose of this workshop was to identify all proven and emerging wastewater treatment technologies and to estimate what ranges of effluent phosphorus concentrations could be consistently and reliably achieved utilizing those technologies. While the workshop was not intended to be a comprehensive AKART (All Known, Available, and Reasonable methods of prevention, control and Treatment of wastewater) evaluation, it was intended to identify some of the key criteria that could be used to further define AKART at a future date.

F.2. Workshop Participants

The workshop was facilitated by Mike Doleac, a professional value engineer employed by CH2M HILL. Four nationally noted wastewater treatment process experts conducted the technical discussion, including:

- Dr. David Stensel, Wastewater Treatment Professor, University of Washington
- Dr. Glen Daigger, Chief Technology Officer, CH2M HILL
- Dr. J.B. Neethling, Director of Wastewater Treatment Technology, HDR
- Dr. Larry Esvelt, Esvelt Environmental Engineering

Other participants in the workshop included:

- Jerry Anderson/Regional Ecology
- Kathy Cupps/HQ Ecology
- Dave Reynolds/CH2M HILL
- Dave Clark/HDR
- Jim Kimball/JUB
- Terry Dokken/Operations Management Inc.
- Carlo Spani/Clean Water Services
- Mark Esvelt/EEE
- Bruce Rawls/Spokane County
- Lars Hendron/City of Spokane

F.3. Evaluation Criteria

F.3.1. AKART Considerations

Ecology has established the level of treatment technology that is required for all water reclamation facilities throughout the State of Washington. This technology is called AKART, which stands for "All Known, Available and Reasonable methods of prevention, control and Treatment." There is no precise definition of what AKART actually entails. It is not defined in either the Revised Code of Washington (RCW) or the Washington Administrative Code (WAC).

AKART must include only "proven" technologies that can reliably and consistently achieve the desired treatment objectives at a "reasonable" cost. "Proven" also means that the technology has been demonstrated to reliably and consistently perform at some appropriate scale. A discharger cannot be required to develop and implement an unproven technology. At a minimum, AKART requires secondary treatment plus disinfection as well as compliance with the water quality standards of the receiving stream.

The definition of "reasonable" in AKART is very difficult to establish. It implies that the costs for implementation and operation of the technology must meet some acceptable economic threshold. However, no requirement addresses the relationship between costs for facilities versus the benefits derived.

The federal government corollary to AKART is Best Available Technology (BAT). The federal government has attempted to deal with the "reasonableness" of BAT by requiring that, if BAT cannot achieve the desired water quality standards, then a Use Attainability Analysis (UAA) must be performed. The UAA must confirm the existing and attainable

beneficial uses of the stream and the corresponding water quality standards required to protect those uses. If the cost to achieve the required water quality standards using BAT is determined to create a severe social and economic hardship, then the discharger can petition for a lesser degree of treatment technology.

In a similar fashion, Washington State has partially addressed the economic impact concern by making municipalities eligible for grant funds if the projected capital, operations, and maintenance costs resulting from implementation of AKART would create an "economic hardship" for the discharger. Economic hardship at the state level occurs when costs resulting from implementation of AKART exceed 1.5 percent of the median family income.

Because the definition, interpretation, and application of AKART are so imprecise, AKART has necessarily been defined on a case-by-case basis through the use of comprehensive engineering and economic analyses. Clearly, such a rigorous evaluation was well beyond the scope of this workshop. Nevertheless, consideration of AKART provided a good starting point for identifying all known available technologies and for determining the criteria upon which those technologies could be evaluated.

F.3.2. Evaluation Criteria

Key Issues

Numerous issues were considered and discussed during the course of the workshop. A main goal of the discussion was to minimize subjectivity and apply the technical knowledge and experience of the participants to establish and apply appropriate evaluation criteria. Some of the key issues that influenced the evaluation process included:

- The need to consider only treatment technologies that will discharge to the river.

  This was based on the fundamental premise that the proposed total phosphorus discharge limits are intended to protect the water quality in the river. Only if those limits cannot be met will land application and reuse alternatives become necessary. Then, the main issue would become economic and subject to further analysis beyond the scope of this workshop.

- The need to focus on what total phosphorus removals can and cannot be consistently achieved, based on known scientific principles, coupled with demonstrated experience.

- The basis upon which a technology can be determined to be "proven."

- The basis upon which to assess the reliability of a technology to achieve a particular degree of performance.

- The rationale for setting phosphorus discharge limits that are scientifically and technically achievable.

The rates of flow and constituent concentrations of municipal wastewater influents vary over a wide range, diurnally and seasonally. Wastewater treatment process technologies are complex and are not quickly adaptable to significant influent variations. As a consequence, treated effluent total phosphorus concentrations also vary over a considerable range. Effluent data from the Rock Creek and Durham tertiary treatment facilities in Oregon clearly demonstrate this variability (Attachment 1).

Further, the natural biological systems in receiving streams respond slowly to short term changes in phosphorus loading. Recognition of these facts is the reason that the vast majority of Washington State water quality regulatory agencies have adopted seasonal or monthly median discharge limits; to do otherwise is simply inconsistent with the processes occurring in the natural environment. The proposal to set instantaneous maximum phosphorus discharge limits contradicts this fundamental scientific premise and, in the opinion of the workshop participants, is inappropriate.

Technical Readiness

The Rockefeller Foundation sponsored a two-week long technical assessment of membrane bioreactor (mbr) technology in April 2003, in Bellagio, Italy. This assessment was conducted by fourteen of the world's foremost wastewater process technology experts. The purpose of the assessment was to determine the "technical readiness" of membrane technology to be implemented in both developed and developing countries.

Dr. Glen Daigger, who participated in that 2003 assessment, presented a summary of the conclusions as they related to establishing appropriate wastewater technology evaluation criteria (Attachment 2).

The definition of "technical readiness" that emerged during the Rockefeller assessment was based on a fundamental concept, i.e., when the technical risks associated with a new technology are sufficiently well characterized that they can be managed with confidence, then the technology is ready for widespread application. Under these circumstances the technology can be implemented and will perform in a repeatable, predictable fashion. If the risks are not yet sufficiently well characterized, then further modeling and testing are necessary before the technology can be deemed "technically ready."

Five criteria were selected upon which to evaluate the alternative wastewater treatment technologies:

1. **Scientific Principles**—The degree of understanding of the scientific principles upon which the technology is based.
2. **Engineering Principles**—The degree of understanding of the engineering principles required to successfully implement the technology, including process and facility design criteria, required facilities, and operations and maintenance requirements.
3. **Construction Resources**—The ability of owners to obtain the resources needed to successfully construct the required facilities.
4. **O&M Resources**—The ability of owners to obtain the resources to successfully operate and maintain the process.
5. **Level of Development**—The level of proven demonstration of the technology.

Each of the criteria was weighted, based on the workshop participants' assessment of the relative importance of the criteria. Within each criterion, a set of utility scales was established. These utility scales enabled the workshop participants to apply a score from 0 to 10 points for each criterion to each technology.

The workshop participants agreed that this approach would provide a fair and objective basis for the treatment technologies evaluation. It was acknowledged that a technology could be deemed technically ready and it still might not be "reasonable" when considered as part of an AKART assessment because other non-technical factors also would need to be considered.

F.4. Technology Evaluation

F.4.1. Evaluation Process

The evaluation process consisted of five steps:

1. Identification of all known and emerging technologies
2. Initial screening to remove obviously less acceptable or inappropriate technologies
3. Final scoring and ranking of the remaining technologies
4. Assessment of phosphorus removal capability of each technology
5. Approximation of relative costs

Virtually every known and emerging advanced wastewater treatment technology and combination of technologies were identified and discussed by the workshop participants. Following identification of technologies, any technology deemed incapable of meeting an average phosphorus discharge of 50 μg/l was eliminated from further consideration. Also, several were screened out because they were clearly inferior to other similar technologies on the list.

The remaining group of technologies was scored, using the system described above. Each scoring criterion was applied uniformly across the technologies to ensure consistent interpretation and assessment. After the scoring was completed, the technologies were compared on the basis of their respective abilities to achieve total phosphorus effluent concentrations of not-to-exceed 50 μg/l, not-to-exceed 10 μg/l, median 50 μg/l, and average 50 μg/l. Lastly, the relative capital and O&M costs of the technologies were approximated.

F.4.2. Technologies Considered

A total of 21 alternative treatment technologies were identified by the workshop participants (see the table in Attachment 3 for a list of those technologies and brief descriptions).

F.4.3. Initial Screening

The table provided in Attachment 3 summarizes the results of the screening exercise. Further discussion of the technologies eliminated is provided below.

It was recognized that tertiary treatment might lower phosphorus concentrations too low for subsequent enhanced biological phosphorus removal to function. This could be a fatal flaw for technology numbers 3, 19, and 20. Professor Stensel noted, however, that if filtration was staged it could maintain sufficient phosphorus to seed the biological process. Thus, technology numbers 3, 19, and 20 remained in the evaluation.

Evaporation (technology number 18) was eliminated because it would not result in a discharge back to the river.

Membrane filtration followed by reverse osmosis (technology number 6) might pose an insurmountable brine disposal problem. Dr. Daigger presented a way to handle the sidestream with microfiltration that may overcome the problem. Therefore, technology number 6 was retained in the evaluation.

Established scientific evidence, especially that of Jenkins and Hermanowicz of the University of California at Berkeley, indicates that the solubility of aluminum phosphate is measurably lower than that of ferric phosphate. These results were verified by pilot testing at the Rock Creek AWTP. Thus, the conventional wisdom is that chemical phosphorus removal systems using aluminum (Al^{+3}) salts are capable of producing lower effluent TP concentrations than those using ferric (Fe^{+3}) salts. Consequently, all of the technologies that utilized Fe^{+3} were eliminated in favor of technologies that use Al^{+3}, which is generally considered superior for removal of phosphorous. This decision eliminated technology numbers 2, 5, 9, and 12 from further consideration.

More recent data developed by the Washington Area Sewage Authority (WASA) in Washington DC suggests that the solubility of ferric phosphate may be lower than indicated by the work of Jenkins and Hermanowicz. These results are preliminary and still are still being evaluated. Even if they are verified they will have only modest impacts on this technology evaluation because: aluminum and ferric salts represent reasonably equivalent treatment options in most instances; aluminum salts are generally less expensive than iron salts in the Pacific Northwest; and because most systems can be configured to use either.

Ion exchange (technology number 15) was eliminated because reverse osmosis (technology number 6) is just as effective and the RO process is far better known and understood.

Distillation (technology number 16) was eliminated because it is less effective for phosphorus removal than reverse osmosis (technology number 6).

Ultrafiltration (technology number 7) was eliminated because it is not a phosphorus removal technology.

Direct filtration with Fe^{+3} for polishing (technology number 8) was eliminated because it is not capable of consistently achieving an effluent phosphorus concentration of less than 200 μg/l, almost an order of magnitude higher than the objective. Scientific knowledge is still emerging as evidenced by recent testing at DCWASA.

Contact clarifier/granular media filtration with Al^{+3} (technology number 14) was eliminated because it is a subset of tertiary clarification with granular media filtration with Al^{+3} for polishing (technology number 1).

F.4.4. Final Evaluations, Scoring and Ranking

Following the initial screening, ten technologies were carried forward for final evaluation, scoring, and ranking. The following are brief evaluation comments, excerpted from the workshop discussion:

Technology #1 **Tertiary clarification and granular media filtration w/ Al^{+3} for polishing**—This technology is currently in operation at the Rock Creek treatment plant in Hillsboro, Oregon. The science is still evolving, but much full-scale data is now available upon which to predict performance.

Technology #3 **Membrane bioreactor (MBR) with enhanced biological phosphorus removal and chemicals**—This is an emerging technology and the engineering principles are only partially established. Some question exists regarding how far the MBR process can be "pushed" without damaging its effectiveness for biological treatment. Biological treatment capabilities must be maintain in an MBR, and biological systems require a minimum residual ortho-phosphate concentration so that the residual ortho-phosphate concentration is not limiting to biological growth. This minimum ortho-phosphate concentration is likely to be higher than the solubility of the metal salts used for chemical phosphate removal and, consequently, it is likely to increase the achievable effluent total phosphate in comparison to straight chemical phosphorus removal systems. Membrane replacement is the principal equipment replacement issue. This issue can significantly affect the costs for this option.

Technology #4 **Post secondary microfiltration with Al^{+3} for polishing**—Scientific and engineering principles are well known. Construction methods and materials are conventional. Operations are less challenging than MBR. A number are in full operations, but not for phosphorus removal.

Technology #6 **Microfiltration with reverse osmosis**—Scientific and engineering principles are well understood. RO suppliers are well established. This has never been used full scale for phosphorus removal. Orange County, California is building an 80-mgd plant and is going to aquifer recharge.

Technology #10 **Direct filtration using iron coated media and Al^{+3} for polishing (Bluewater technology)**—During pilot testing, Coeur d'Alene, Idaho intermittently achieved about 40 µg/l. A pilot program was conducted at Moscow, Idaho that achieved TP concentrations of less than 100 µg/l. Occasional "upsets" caused effluent TP to approximately equal the influent concentration during an extended trial (28 days). Trials with Al^{+3} resulted in approximately equivalent performance. A larger scale plant is under construction at Hayden, Idaho for further studies. The scientific principles are not as well known as for MBR and Enhanced Biological Phosphorus Removal (EBPR). No full scale facilities are in operation.

Technology #11 **Dual sand filtration with Al^{+3} for polishing (Micromedia Filtration)**—Information was requested from Micromedia prior to the workshop, but nothing was received (refer to Attachment 5, email information request). Dr. Esvelt received a compact disc from the vendor that contained some general descriptive information and performance data from small pilot systems installed in New York State and in Georgia. The New York data emphasized removal of cysts and is therefore of relatively little value in the current application. The Georgia study indicated reduction of TP to an average concentration of less than 20 µg/l from an EBPR effluent with concentrations less than 1.0 mg/l. The technology is proprietary, so instrumentation and control (I&C) and software are limited to a single source supplier. Scientific and engineering data and design criteria are available for similar small-scale facilities, but only to a limited extent as described by the current purveyor of the technology.

Technology #13 **Dual sand filtration using Al^{+3} to treat primary effluent (Micromedia Filtration)**—One or more small residential systems allegedly are in operation. Information published from one pilot system indicated TP reduction to 400 µg/l, although the study was performed to determine heavy metals reduction. Same comments as for technology number 11. Also, this process is technically incapable of achieving soluble BOD, NO_3, and ammonia removal.

Technology #17 **Wetland polishing and discharge with or without Al^{+3}**—Algae-based science is just emerging in Florida. Local climate does not support direct technology transfer from Florida. No applicable engineering design criteria exist. This technology has extensive operational challenges. The Cheney effluent polishing wetland does not appear to reduce P from the EBPR effluent to limits proposed for evaluation here.

Technology #19 **Membrane bioreactor with enhanced biological phosphorus removal and chemicals followed by microfiltration with chemicals**—Similar performance to MF plus RO is expected. Some proprietary technology restricts design options and flexibility.

Technology #21 **Post lime treatment**—This is technically well known and understood. Lake Tahoe tertiary plant is longest running example. It has no unusual construction requirements. The treatment is very difficult to operate and maintain. Lime is difficult to handle and store. This technology is no longer considered to be a preferred industry standard.

The following table presents the "technical readiness" scores assigned by the workshop participants to the technologies for each of the evaluation criteria.

Alternative Technology	Scientific Principles	Engrg Principles	Constr Resources	O&M Resources	Level of Development
1. Tertiary Clarif + Gran. Filtr w/ Alum	7	10	10	8	7
3. MBR with EBPR + Chem	6	6	9	6	4
4. Post-Sec Micro + Alum	10	9	10	7	5
6. MF/RO w/ Alum	10	8	10	7	6
10. Direct Filtration w/ Iron-Coated Media	5	2	6	5	3
11. Dual Sand Filtr w/ Alum	6	6	10	8	5
13. Dual Sand Filtr for PE	0	3	10	4	0
17. Wetlands w/ Alum	2	0	4	6	0
19. MBR/EBPR/Chem + Microfiltration	10	9	9	6	3
21. Post Lime	10	10	10	7	8

After applying the weighting for each of the criteria, the final "technical readiness" scoring and ranking of the technologies were as follows:

Alternative Technology	Total Score
21. Post Lime Treatment	900
1. Tertiary Clarif + Gran. Filtr w/ Alum	825
4. Post-Sec Micro + Alum	815
6. MF/RO w/ Alum	810
19. MBR/EBPR/Chem + Microfiltration	745
11. Dual Sand Filtr w/ Alum	660
3. MBR with EBPR + Chem	590
10. Direct Filtration w/ Iron-Coated Media	395
13. Dual Sand Filtr for PE	255
17. Wetlands w/ Alum	210

F.4.5. Phosphorus Removal Assessment

Ecology is proposing to establish an instantaneous maximum permitable effluent phosphorus concentration of 50 µg/l applied to all current discharges, and a 10 µg/l maximum limit applied to all future flow increases. It is very unusual for states to impose phosphorus discharge limits below 200 µg/l and, even in those cases, the limits are typically based on either seasonal averages or 30-day medians of data samples, not on instantaneous not-to-exceed values. Samples are typically 24-hour composites, so each data point represents the average discharge concentration for a 24-hour period.

There are a number of reasons why medians, means, or averages are normally used to establish phosphorus discharge limits (and limits for other constituents where treatment

performance as well as sampling and testing procedures cause variations in reported effluent values). The influent flow rates to municipal wastewater treatment plants routinely vary by over a 100 percent during the course of a day and significantly between wet and dry weather. The concentration of phosphorus contained in the influent also can vary dramatically. Treatment technologies employed to reduce phosphorus concentrations are chemically, mechanically, and biologically complex and they cannot respond quickly to significant changes in influent loading. Consequently, the concentrations of phosphorus contained in the treated effluent normally fluctuate widely as well.

Both the Rock Creek and Durham tertiary treatment facilities have discharge permits limiting median phosphorus effluent concentrations to a maximum of 100 μg/l. The data shows that the short term phosphorus effluent concentrations range from as little as 10 μg/l to in excess of 200 μg/l, but the monthly median is approximately 60 μg/l, well within the permit limits. (Attachment 1).

The motivation for reducing phosphorus in treated effluent is to reduce the mass of nutrients that feed algae in the receiving stream. This, in turn, reduces the oxygen depletion imposed by bacteria consuming the dying algae. Clearly, there is a biological correlation between mass loading of phosphorus and oxygen depletion, but this relationship is by no means instantaneous. It takes place over an extended period of time. Phosphorus discharge permit limits, set on a median, mean, or average basis over some reasonable duration, take into account these complex variables while controlling the mass loading to the receiving stream, thereby protecting the quality of the water.

Based on the variability of phosphorus concentrations generated by all advanced wastewater treatment technologies, the workshop participants concluded that meeting an instantaneous maximum limit was an inappropriate objective. Nevertheless, the potential performance capabilities of each of the alternative technologies were compared against the proposed not-to-exceed standards of 50 μg/l and 10 μg/l. These technologies also were evaluated on the basis of meeting 50 μg/l median and average effluent phosphorus concentrations. The results of that evaluation are summarized in the table below.

Alternative Technology	Meets 50 μg/L Not to Exceed?	Meets 10 μg/L Not to Exceed?	Meets 50 μg/L on a Median Basis?	Meets 50 μg/L on an Average Basis?
1. Tertiary Clarif + Gran. Filtr w/ Alum	No	No	Probably	No
3. MBR with EBPR + Chem	No	No	Maybe	Maybe
4. Post-Sec Micro + Alum	Probably	No	Yes	Yes
6. MF/RO w/ Alum	Yes	Maybe	Yes	Yes
10. Direct Filtration w/ Iron-Coated Media	No	No	No	No
11. Dual Sand Filtr w/ Alum	No	No	Probably	No
13. Dual Sand Filtr for PE	No	No	No	No
17. Wetlands w/ Alum	Unknown	No	Unknown	Unknown
19. MBR/EBPR/Chem + Microfiltration	Probably	No	Yes	Yes
21. Post Lime	No	No	Yes	Maybe

The only "technically ready" treatment technology in existence today that can meet a maximum instantaneous 50 µg/l effluent phosphorus concentration limit is microfiltration followed by reverse osmosis with alum. No technology exists that can meet a maximum instantaneous effluent phosphorus concentration limit of 10 µg/l. Based on statistical data analyses, several of the technologies are capable of achieving median 50 µg/l effluent phosphorus concentrations.

F.4.6. Relative Cost Comparisons

As a tacit acknowledgement that technical readiness is independent of cost, all of the technology evaluations were performed without regard to cost. The final step in the evaluation process was to perform a very approximate relative cost comparison of the alternative technologies. The following table summarizes the results of that assessment.

Alternative Technology	Relative Capital Cost	Relative O&M Cost
1. Tertiary Clarif + Gran. Filtr w/ Alum	100%	100%
3. MBR with EBPR + Chem	150% to 200%	100% to 150%
4. Post-Sec Micro + Alum	150% to 200%	100% to 150%
6. MF/RO w/ Alum	500%to 1000%	200% to 300%
10. Direct Filtration w/ Iron-Coated Media	unknown	unknown
11. Dual Sand Filtr w/ Alum	150% to 200%	100% to 150%
13. Dual Sand Filtr for PE	unknown	unknown
17. Wetlands w/ Alum	1000%+	50% to 100%
19. MBR/EBPR/Chem + Microfiltration	200% to 300%	150% to 200%
21. Post Lime	200% to 300%	150% to 200%

F.5. Key Conclusions

- Determination of AKART entails a comprehensive engineering and economic assessment that is beyond the scope of this workshop.
- Instantaneous maximum effluent phosphorus concentration limits are inappropriate criteria upon which to evaluate alternative technologies.
- When technical risks are sufficiently well characterized that they can be managed, then the technology is ready for widespread application.
- The "technical readiness" of virtually every known and emerging advanced wastewater treatment technology and combination of technologies was evaluated.
- Microfiltration, coupled with Reverse Osmosis, is the only known "technically ready" technology capable of meeting a proposed maximum instantaneous total phosphorus discharge limit of 50 µg/l.
- There is no known or emerging "technically ready" treatment process capable of meeting a maximum instantaneous phosphorus discharge limit of 10 µg/l.
- Several "technically ready" treatment processes were found capable of delivering a median effluent phosphorus concentration of 50 µg/l or less.

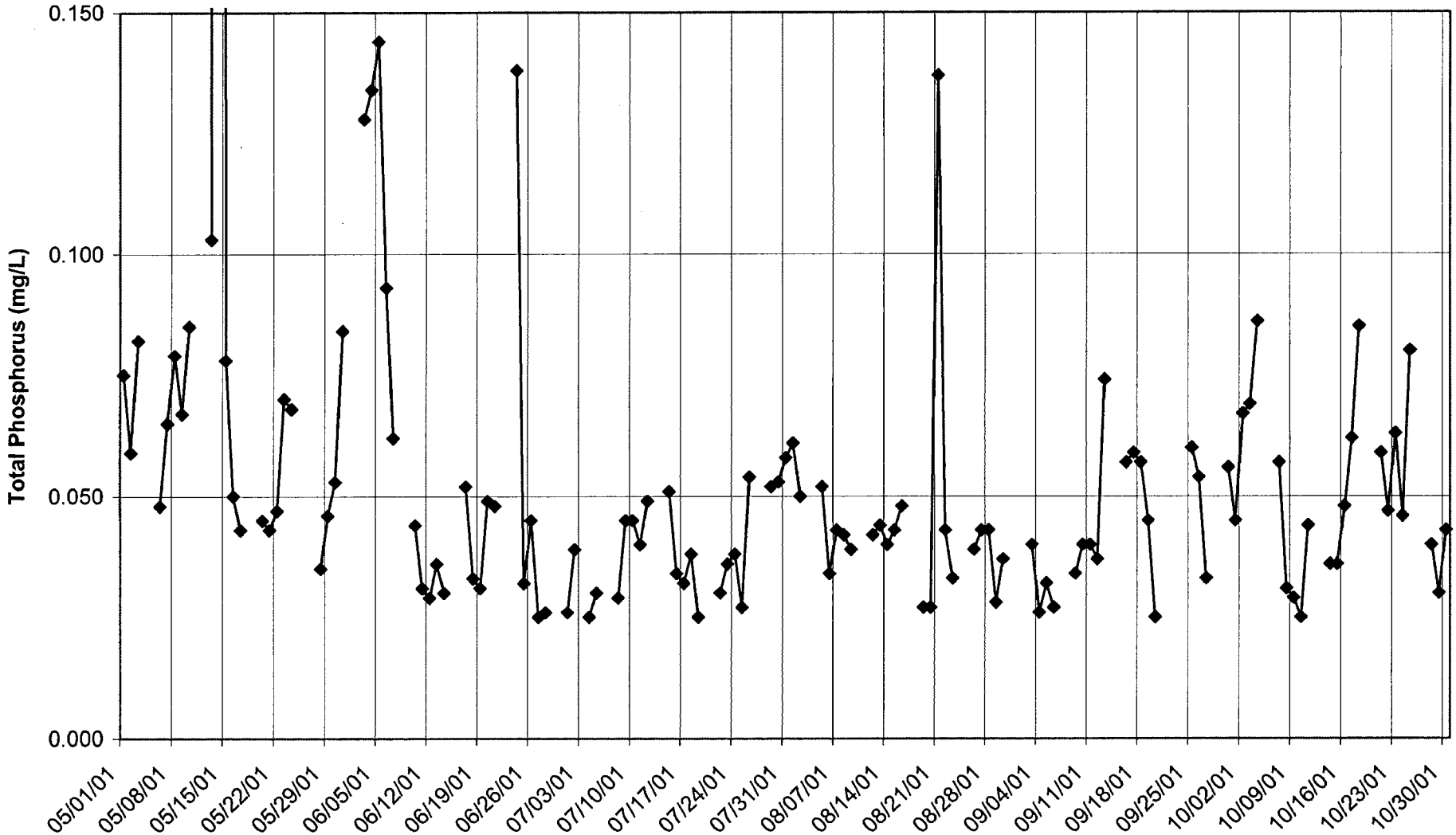
ATTACHMENT F.1

Effluent Phosphorus Data, Rock Creek and Durham Tertiary Wastewater Treatment Facilities

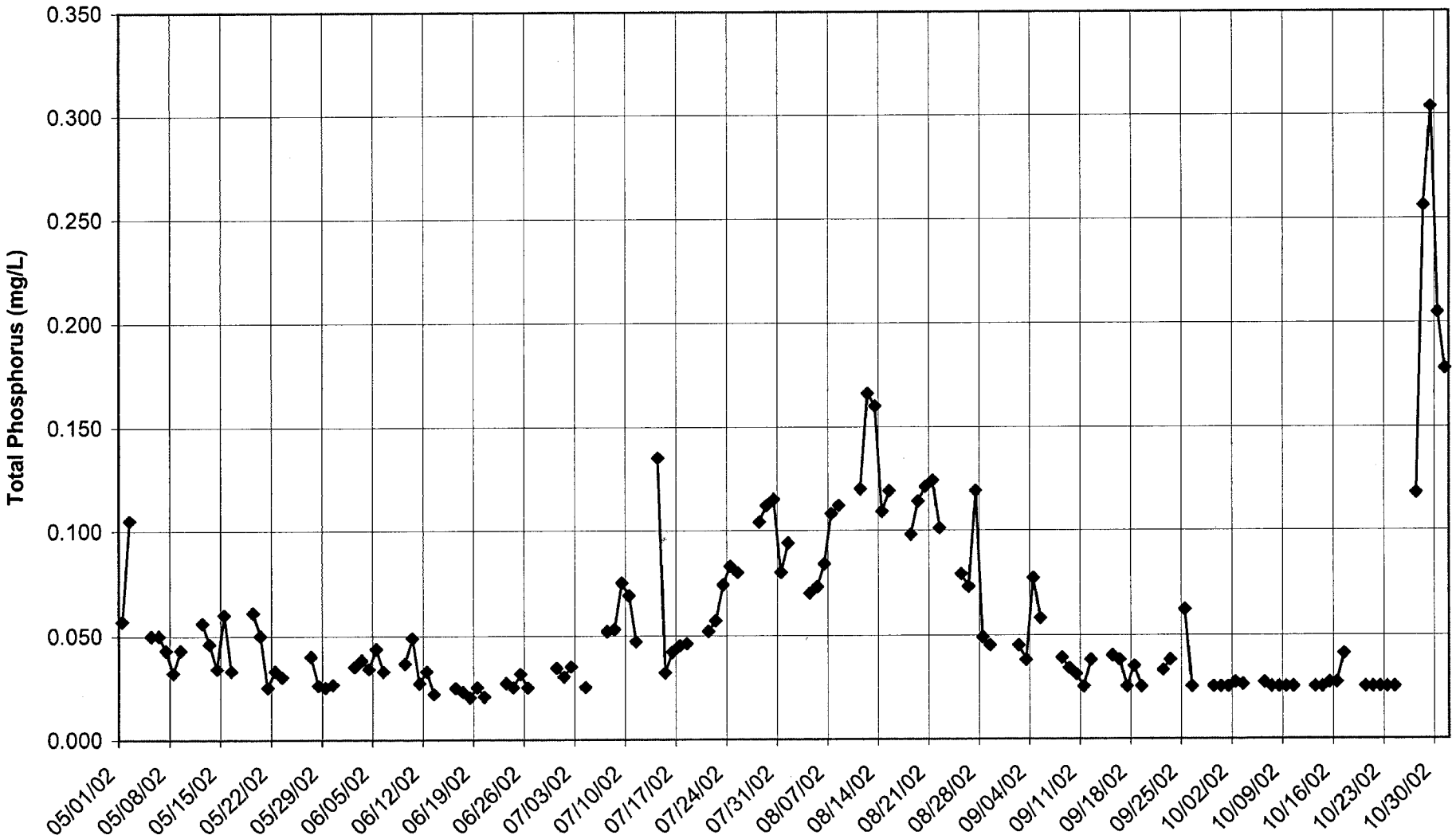
Rock Creek Final Effluent Total Phosphorus Summary

Year	Log Normal Mean (mg/L)	Log Normal Variance (mg/L)	Log Normal Coefficient of Variation	Maximum Day 95th Percentile (mg/L)	Maximum Day 99th Percentile (mg/L)	Observed Maximum (mg/L)	Effluent TP Samples per Month	Monthly Average Limit 99th Percentile (mg/L)	Seasonal Limit 99th Percentile (Assume May 1 to November 1--180 days)
2000	0.082	0.001470	0.469	0.154	0.209	0.219	30	0.098	0.089
2001	0.054	0.000855	0.541	0.109	0.154	1.530	30	0.066	0.059
2002	0.057	0.001517	0.686	0.130	0.198	0.304	30	0.074	0.064
2003	0.048	0.000395	0.416	0.085	0.112	0.114	30	0.056	0.051

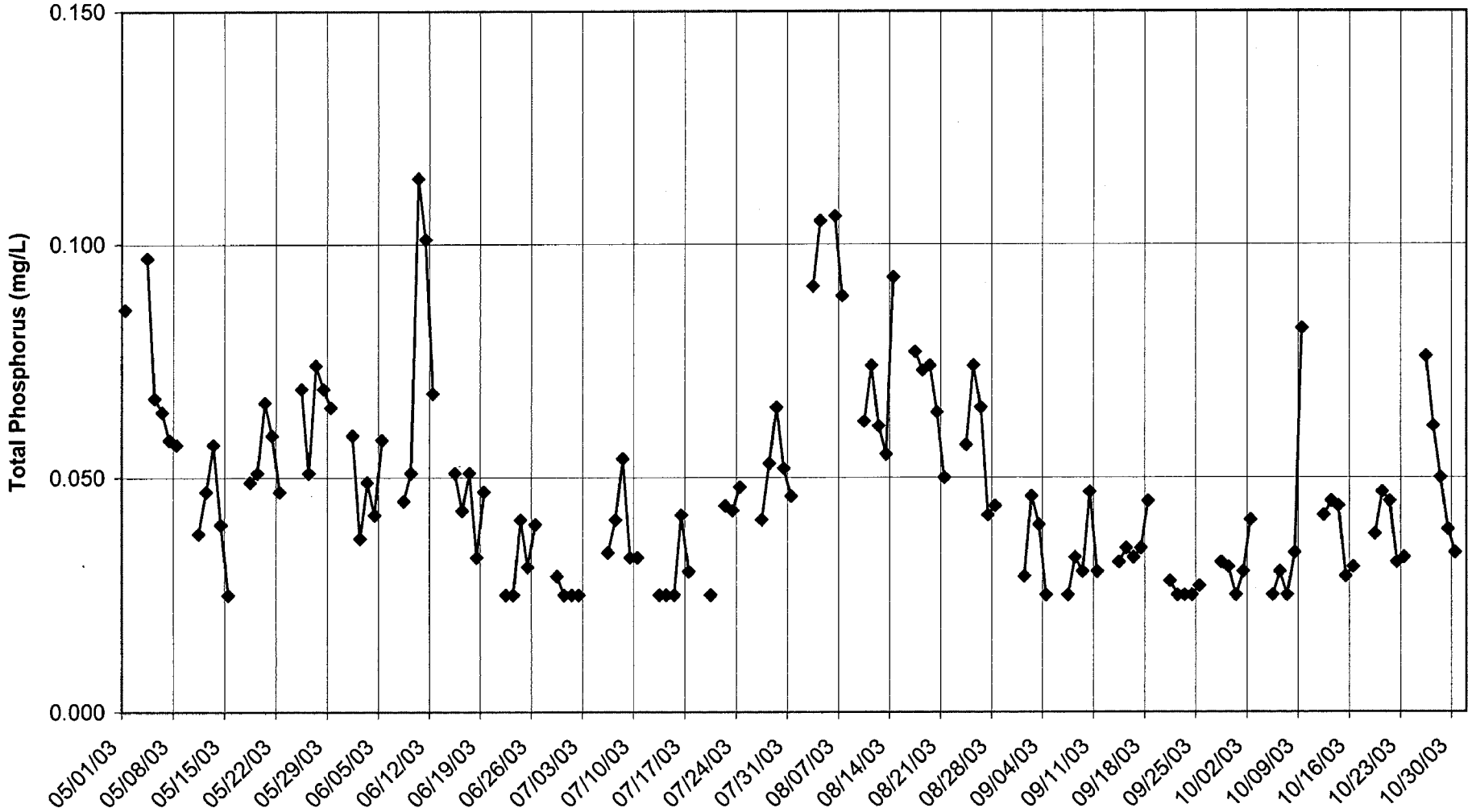
Rock Creek Effluent Total Phosphorus 2001



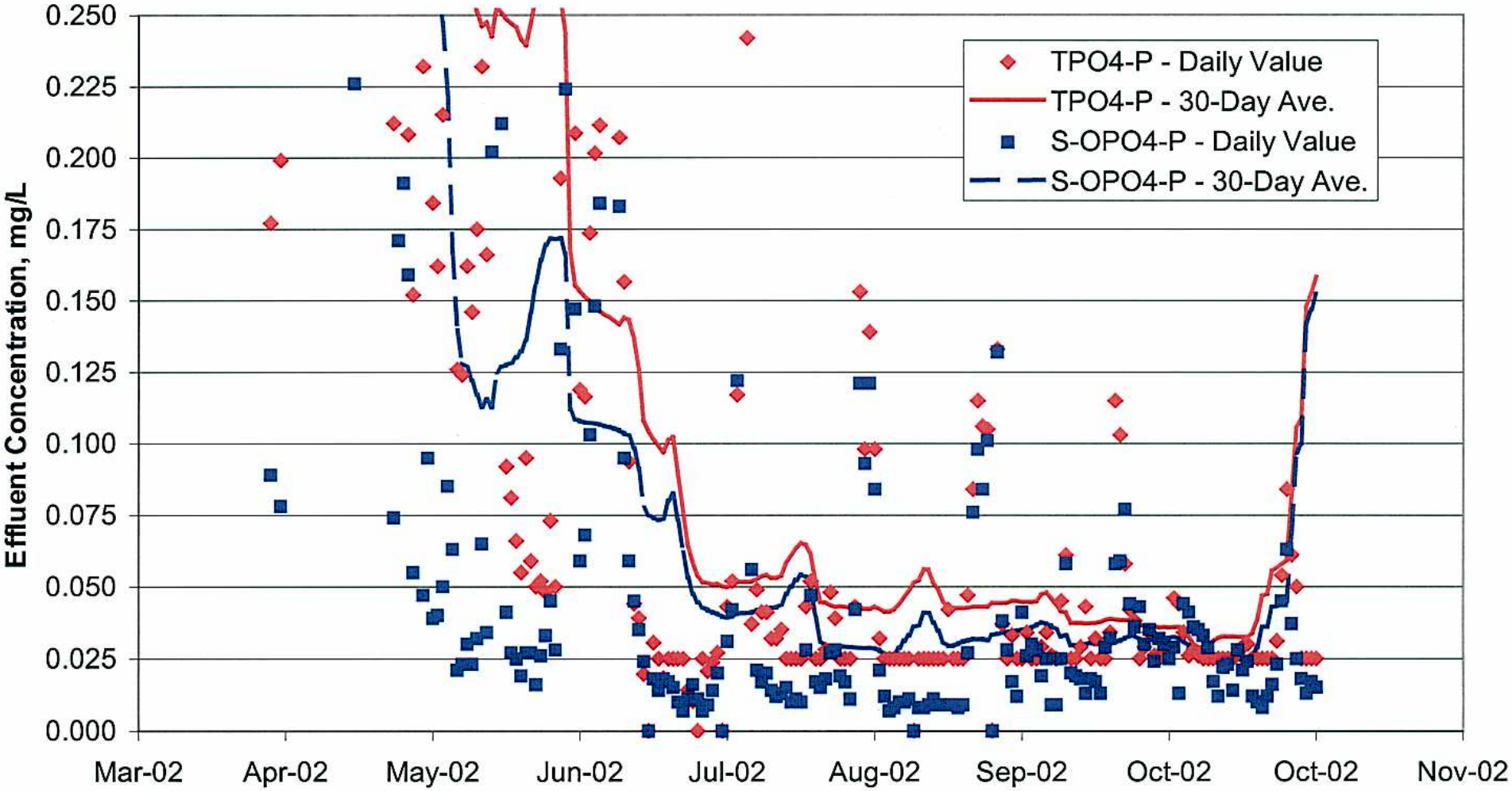
Rock Creek Effluent Total Phosphorus 2002



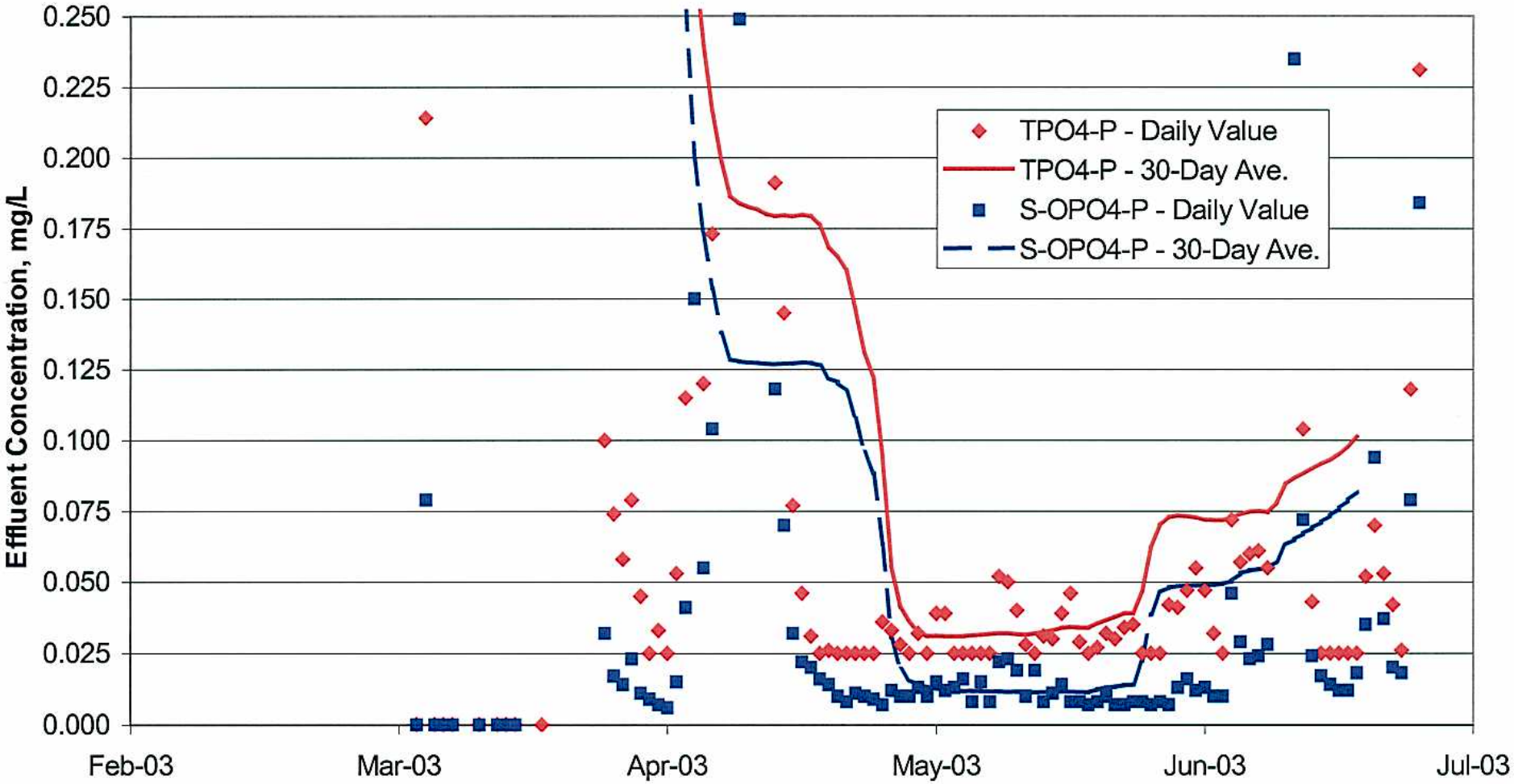
Rock Creek Effluent Total Phosphorus 2003



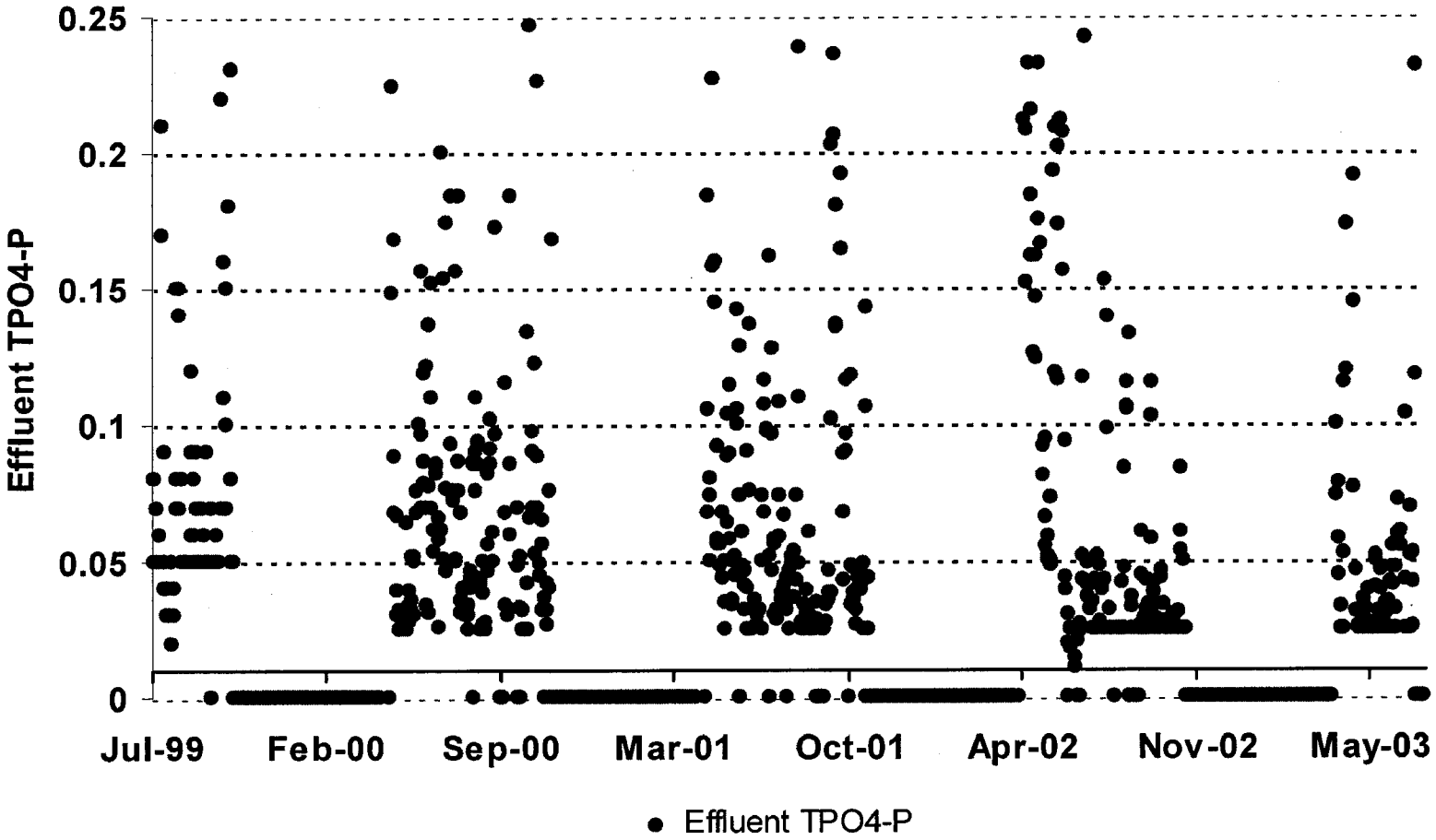
Durham – 2002 Data (scale < 0.25 mg/L)



Durham – 2003 Data (scale < 0.25 mg/L)



Durham Trend 1999-2003



ATTACHMENT F.2

Readiness of Membrane Bioreactors for Widespread Application

READINESS OF MEMBRANE BIOREACTORS FOR WIDESPREAD APPLICATION

Glen T. Daigger[1], Bruce E. Rittmann[2], Samer Adham[3], Gianni Andreottola[4]

[1] CH2M HILL, 9191 South Jamaica Street, Englewood, CO 80112 USA, gdaigger@ch2m.com
[2] Northwestern University, 2145 Sheridan Road, Evanston, IL 60208-3109 USA, b-rittmann@northwestern.edu
[3] Montgomery Watson Harza, 301 North Lake Av. Suite 600, Pasadena, CA 91101 USA, Samer.S.Adham@mwhglobal.com
[4] Dept. of Civil and Environmental Engineering, University of Trento Italy, gianni.andreottola@ing.unitn.it

INTRODUCTION

Membrane Bioreactors (MBRs) are an emerging wastewater treatment technology that combines the suspended growth biomass utilized in the traditional activated sludge process with a membrane system (rather than gravity sedimentation) for biomass retention and effluent clarification (Daigger, *et al.*, 2001; Adham, *et al.*, 2001; Gunder, 2001; van der Roost, *et al.* , 2002; and Stephenson, *et al.*, 2000). Figure 1 illustrates the components of an MBR and contrasts them to a traditional activated sludge process.

MBRs offer several significant advantages:

- Because the membrane separator completely retains particulate matter, the effluent is very low in total suspended solids (TSS), turbidity, suspended BOD (biochemical oxygen demand), and most pathogens.
- The membrane also completely retains biomass, which makes retention of slow-growing microorganisms with low yields more reliable.
- Reliable biomass retention makes it possible to operate with high mixed-liquor suspended solids (MLSS) concentrations. MLSS concentrations of 10 to 20 g/L can be and routinely are accumulated in MBRs, while 3 g/L is typical for traditional activated sludge (Rittmann and McCarty, 2001; Grady *et al.*, 1999). High MLSS allows moderately sized bioreactors, despite relatively long solids retention times (SRTs).
- Modestly sized bioreactors, along with no external clarifiers or filters, give MBRs small overall plant footprints.
- When combined with MBR reliability, modern process-control equipment, such as programmable logic controllers, allows most operation to be automated.
- Because membranes can be added in modules, designing new plants or retrofitting existing wastewater treatment facilities is especially versatile.

The result of all the advantages should be a compact treatment system that can produce a very high quality effluent and can be operated remotely or with minimal attention. The compact nature of MBRs makes them attractive for applications in crowded urban areas. The high quality of the effluent creates opportunities for reuse of the treated effluent rather than discharge to surface waters. The potential for remote operation makes them especially suitable for decentralized treatment. Thus,

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

MBRs offer significant potential to contribute to more sustainable approaches to urban water management. But, is MBR technology ready for widespread use in crowded urban areas, for reuse, and with decentralized operation?

On the one hand, MBR technology has been used for a variety of specialty treatment applications for nearly 20 years (Stephenson, *et al.*, 2000). The more recent introduction of immersed membranes has reduced costs (capital and operating) relative to the use of external membranes and increased the range of applications for which MBRs can be cost competitive (Daigger, *et al.* 2001). On the other hand, many practitioners are not familiar with MBR technology and, consequently, are hesitant to use it. They worry about cost, reliability, and operating problems. Is MBR technology ready to convince the doubters?

The authors were part of the Rockefeller Foundation-sponsored Team Residency entitled "Exploration of the Potential of Membrane Technology for Sustainable Decentralized Sanitation," held at the Bellagio (Italy) Study and Conference Center in April 2003. The goal of the Team Residency was to evaluate critically the status of membrane processes – with special emphasis on MBRs – for making water sanitation more sustainable and decentralized. The Team consisted of 14 experts on different aspects of membrane technology and its application in all setting. The Acknowledgement lists all members of the team, and an overall summary of the Team's findings and its "Bellagio Statement" are in DiGiano, *et al.*, (2004).

Here, we report on one of the major topics of the Team Residency: the readiness of MBR technology for widespread application in the the developed and developing worlds. The opportunities for MBR technology differ between developed and developing countries, and the technical and social settings also differ in important ways.

Our focus is on technical readiness, rather than "societal" readiness. We consider a technology to be technically ready for application when the technical risks are sufficiently well characterized so that they can be managed. Societal readiness is a broader topic and refers to the acceptability of the technology by the affected public, essentially a social science issue.

One societal factor that we cannot overlook is the technology-adoption cycle. Which is a well-characterized process that can be described by an "S curve," as illustrated in Figure 2 (Rogers, 1995; [illegible] technology becomes more acceptable to a wider range of users. Eventually, growth in use of the new technology slows and asymptotically approaches market saturation.

Also shown in Figure 2 are the types of adopters in the various stages of the adoption process. The initial set of adopters, referred to as innovators, generally represent 2 to 5 percent of the total user population. They are motivated by interest in the technology and play a crucial role in the technology development cycle, as they often fund technology development. However, they do not motivate others to adopt the technology, since they often are not viewed as "responsible" users of new technology. Early adopters, who catalyze adoption by being opinion leaders, represent about 10 percent of the total users. They are recognized leaders who adopt the technology to create competitive advantage and are watched closely by others within the particular user segment. Their adoption of the technology "catalyzes" further adoption, as their successful use of the technology, and the advantage that it crates for them, motivates others to rapidly adopt it. The majority of the users (the early and late majority), representing about two-thirds of the total user base, come next. Early and late majority adopters are characterized by their risk aversion and relative readiness to adopt new ideas. Finally come the "laggards," who adopt new technology only when it becomes necessary. The technology no longer provides a competitive advantage, but it is an expectation, or something necessary to compete with other members of the user community.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

TECHNICAL READINESS CRITERIA

The criteria for technical readiness include fundamental engineering and science factors, but, since facilities must be built and operated in the real world, commercial factors also are important. Engineering is scientifically based, but empirical evidence and experience are also needed to confirm the expectations developed based on scientific principals. Thus, we consider that a technology is ready for widespread application when the following criteria are met:

1. The engineering principals are understood well enough to allow systems to be implemented successfully in a range of settings.
2. Reliable equipment and technological support are commercially available in sufficient quantities to meet existing and developing demand.
3. Significant applications experiences verify successful performance and identify the factors most critical for successful design and operation.

We use these three criteria to assess the readiness of MBR technology for widespread application in urban water management systems. The first two criteria – the engineering principals and equipment/technical support – tend to be most important in the early stages of the adoption process and, consequently, are addressed by the innovators and early adopters. Initial applications experience is accumulated during this phase as well, but the majority of the applications experience is gained during the early majority phase. Thus, development of technical readiness is tied to the social process of technology adoption, and technology readiness is at least partially assessed by the stage of adoption.

READINESS ASSESSMENT FOR THE DEVELOPED WORLD

MBR technology is applied in the developed world mainly to achieve one of four goals: advanced removal of BOD and nutrients from wastewater before its discharge to a surface water, production of high-purity water as a pre-treatment to reverse osmosis (RO), advanced control of micro-pollutants, and recycling of grey water. Table 1 summarizes our analysis of these four applications in terms of the three readiness criteria. Only the first application has moved past the early adopters phase, but the good experience in that area suggests that technical roadblocks should not stop advancement for any of the applications. We evaluate each criterion based largely on the experience with advanced wastewater treatment.

Criterion 1 – MBR Engineering Principals

Given the similarities of the traditional activated sludge and the MBR processes (recall Fig. 1), one might hypothesize that much of our extensive knowledge about the traditional activated sludge process can be applied directly to the MBR process. Indeed, experience demonstrates that this is the case, as indicated by the following observations based on a series of recent studies (Fernandez, *et al.*, 2000; Fleischer, *et al.*, 2001; Merlo, *et al.*, 2000; Gunder, 2001; van der Roost, *et al.*, 2002; and Stephenson, *et al.*, 2000; Urbain et al., 1999):

1. MBR MLSS develop as aggregates, just as in the many variants of the activated sludge process. Both have a wide range of aggregate types, and aggregate structure is not a distinction between MBR and activated sludge.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

2. The stoichiometry and kinetics of the MBR process appear to be consistent with those for the traditional activated sludge process. Thus, established process design procedures and models used with the activated sludge process also can be used successfully with the MBR process.

3. The growth rates of microorganisms growing in MBR systems are within the same ranges as those growing in traditional activated sludge. For example, the SRT required to achieve nitrification in MBR processes is the same as required in traditional activated sludge.

4. Process configurations similar or identical to those used in traditional activated sludge produce similar performance results when applied to the MBR process.

5. The same equipment used in the activated sludge process for oxygen transfer, mixing, and pumping can be used successfully for an MBR process.

Criterion 2 – MBR Equipment and Support

Membrane modules for MBRs are widely available from at least four manufacturers (Zenon, U.S. Filter, Kubota, and Mitsubishi-Rayon), with others developing relevant products. Figures 3 and 4 illustrate the type of immersed-membrane equipment used in MBR facilities. The equipment shown is from Zenon and, while the specific details for other manufacturers differ, illustrates the principal components of typical systems. Figure 3 illustrates an individual immersed membrane module showing vertically oriented hollow fiber membrane strands potted into horizontally oriented collectors (on left). Individual modules are "ganged" together into cassettes to facilitate collection of effluent from individual membrane modules. The lower portion of the cassette (in this design) also provides aeration to transport accumulating biomass away from the membranes themselves for subsequent return to the main bioreactor.

Figure 4 illustrates how a membrane cassette (as illustrated in Figure 3) is inserted into a process tank large enougth to require several cassettes. Effluent (permeate) usually is withdrawn by pumps (located adjacent), and the required piping is shown. Air manifolds providing air to the membranes for fouling control are also shown. Permeate pumps, blowers, and chemical cleaning equipment are located adjacent.

Membranes require periodic cleaning to control biological and chemical fouling. Cleaning methods are well developed and defined for those membrane products typically used in MBRs. Thus, the necessary facilities are known and are routinely provided with these facilities.

One important point is that membrane equipment and related facilities are essentially the same for MBRs and drinking-water applications. Lower hydraulic application rates (flow rate per membrane surface area – called overflow rate for gravity sedimentation units, but referred to as flux in the membrane industry) are required with MBRs than for typical water treatment applications. Several relatively large immersed-membrane installations demonstrate the capability of the industry to successfully implement large, as well as small, submerged membrane installations (Daigger, *et al.*, 2003; AWWA, 1996).

Considering immersed-membrane equipment for MBRs, the total installed capacity is relatively small at this time. A large number of installations exist, but most are small. If membranes were produced only for MBRs, the low installed-MBR capacity would mean that the production capacity could constrain growing application. Fortunately, this is not the case, because immersed membranes are used in a variety of water-treatment applications, including potable water treatment. As a consequence, the total membrane production capacity far exceeds the current demand for membrane equipment for MBR applications. Thus, the already widespread and growing use of membrane technology for a variety of applications, including water treatment, enables widespread application of MBRs.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

The costs for membrane equipment have been declining in absolute terms (and even more in relative terms) for more than a decade. Today, the cost of membrane equipment (micro- and ultra-filtration) is less than one tenth the cost of membrane equipment in the early 1990s (Kumar, *et al.*, 2004). This has occurred due to the development of improved materials, greater knowledge and understanding of how to cost-effectively configure membrane facilities, reduced production costs resulting from greater economies of scale and improved approaches to production, and increased competition due to the entry of new manufacturers into the marketplace. The declining costs, in turn, have allowed membrane use in a wider variety of applications, which has increased demand for membrane equipment. The result is a "virtuous cycle" in which declining costs increase use that funds innovation and increased production, both of which result in further cost reductions. MBR technology is a beneficiary of this virtuous cycle, as the corresponding improvements in membrane technology and reduced cost make MBRs more effective and cost competitive relative to competing technologies.

Criterion 3 – MBR Applications

Although the number of MBR applications worldwide is not precisely defined, they number in the thousands. A database of MBR installations assembled by the Water Environment Research Foundation (Daigger, *et al.*, 2002) lists over 1,000 installations in Asia, Europe, and North America. Most of these installations are small. MBRs have been applied to a wide range of wastewaters, including municipal and a variety of industrial wastewaters. Based on this application experience, we conclude that:

1. MBRs can be used to treat a variety of wastewaters – probably the same range of wastewater types to which the traditional activated sludge process is applied.

2. MBRs have been used up to now primarily for the treatment of relatively small wastewater flows.

The second is likely to be overthrown. A 40,000-m^3/day MBR facility was started up recently in Northern Italy (Cote, et. al. 2004), a 32,000 m^3/day facility recently started up in Northern Michigan, USA (Crawford and Lewis, 2004), and several installations of this size or larger are currently in various stages of implementation. Furthermore, facilities with capacities ranging from 30,000 to 150,000 m^3/day are being implemented for a variety of applications (Daigger, *et al.*, 2003; Fleischer, *et al.*, 2002; Fleischer, *et al.*, 2001). Evaluations have been completed of the potential to use MBR technology for facilities ranging in capacity from 300,000 to 800,000 m^3/day. And they indicated that MBR technology could be implemented successfully at this scale. Thus, MBR technology is currently being scaled up from facilities with a capacity of a few hundred m^3/day to facilities with capacities of several thousand's of m^3/day and even to several 100s of thousands of m^3/day in capacity.

As MBR technology is installed in larger facilities, the method of implementing MBRs is changing. Due to their small size in the past, MBRs often were installed as complete treatment units provided by the MBR manufacturer. In the common vernacular, they were sold as "package plants." The small size of many existing units and the objective to minimize operator attention often led to conservative designs that included very long SRTs of 30 to 50 days and high MLSS concentrations on the order of 10 to 20 g/L, even up to 30 g/L. This led to the assumption, by many, that these conservative operating parameters are necessary for successful MBRs.

Subsequent research and experience has demonstrated, however, that process designs based on specific process objectives, but lower MLSS concentrations (generally under 10 g/L) can be used and that they are more cost-effective for larger installations. In a WERF-funded study, researchers evaluated MBR performance with a variable MLSS concentration ranging from 2 up to 20 g/L and found no adverse impacts on effluent quality (Adham and Trussell, 2001). At the same time, the

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

design of MBRs has progressed through several "generations" and is now entering the fourth generation that emphasizes economy of scale that is achieved when membrane manufacturers function solely as equipment suppliers, rather than the providers of complete treatment systems (Daigger, *et al.*, 2003; Crawford, *et al.*, 2000; Crawford, *et al.*, 2002). These concepts are incorporated into the larger facilities currently being implemented.

Because MBRs produce high quality effluents, they have been applied for water reuse. In fact, some versions of the MBR process were specifically developed to allow small-scale non-potable water reuse. More recently, the potential for MBRs to function in larger facilities producing effluents of sufficient quality to be applied to indirect potable reuse has been demonstrated (Fernandez, *et al.* 2000; Fleischer, *et al.*, 2001; Fleischer, *et al.*, 2002). Thus, not only can MBRs be used for treatment prior to discharge to surface water, they can also be integral elements of water reclamation and reuse systems

Needed Future Advancements

Although MBRs are ready for widespread application and are being implemented at an increasing rate, technical issues still exist and demand future advancements.

1. **Membrane Life.** The recent use of lower MLSS concentrations has allowed higher water fluxes – a factor that has improved the cost-effectiveness of MBRs and helped accelerate demand. However, the life of the membranes operated with higher fluxes is not known and will not be until sufficient time has passed.

2. **Preliminary Treatment Technology.** Experience indicates that membrane capacity and life can be optimized by appropriate preliminary treatment, which especially includes removing fibrous material such as hair. Screens with an opening of 2 mm or less are currently being implemented. The quantity and noxious nature of the materials removed by such fine screens pose problems for most operations. The proper balance between better screening to prolong membrane life versus the on-going difficulties that the screenings create is not currently established.

3. **MLSS Concentration Trade-offs.** Although high MLSS concentration allows a smaller bioreactor. the trade-offs are greater membrane surface area and increased costs of oxygen transfer. While these effects are understood qualitatively, research is needed to quantify them.

4. **Treatment Effectiveness.** The ability of MBRs to remove micro-pollutants and/or to be used to extract useful products (such as nutrients) from sewage are evolving issues. These are areas where the fundamental scientific and engineering knowledge is incomplete. However, research is on going in these areas, and relevant developments are expected in the near future.

Summary for the Developed World

In summary, the engineering principals required to successfully implement MBRs are available, to a large extent because MBRs are a combination of the bioreactors used with the activated sludge process and submerged membranes used for potable water treatment. The capacity to produce and support MBR equipment also is adequate to meet the expanding demand, since the increased demand for MBR technology can be "piggy backed" on the general expansion of the membrane industry that is currently on-going. MBRs have been used successfully for a wide range of wastewaters, but the applications have been of small size. Larger installations are currently in various stages of implementation, and some reuse applications are in progress. While several future advancements are needed, MBRs generally meet the three criteria for technical readiness for the developed world.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

READINESS ASSESSMENT FOR THE DEVELOPING WORLD

Developing countries may have the most to gain from MBR technology (DiGiano, *et al.,* 2004), because the benefits of MBRs address pressing needs for improved sanitation there. In particular, small footprints, flexible designs, and automation make them ideal for use in rapidly growing urban areas, where large-scale public-works projects are too expensive and too slowly completed. MBRs offer the potential for decentralized systems that make water management more sustainable, particularly in mega-cities in the developing countries.

Countering the potential benefits of MBRs are the special challenges to introducing MBRs in developing countries, Most of these challenges stem from the lack of local resources: financial capital, manufacturing capability, technical support, and trained human resources.

We identified three applications that are most relevant for the developing countries.

- The first is treatment of the full sewage flow in urban areas. The problem here is that urban areas in developing countries do not have sewage-collection systems, and rapid expansion in mega-cities makes it impossible for the large-scale infrastructure (e.g., sewers and large treatment plants) to keep pace. Thus, full treatment requires localized treatment, or decentralization (DiGiano *et al.,* 2004).

- The second is extraction of useful resources from sewage. The main resources, in addition to clean water, are nutrients (N and P, mainly) and energy (in the BOD). In the developing world, human wastes contain a significant resource stream, but the resource value must be captured without polluting the environment or creating public-health risks.

- The third is treating polluted environmental waters, such as highly polluted river water. Today, environmental waters in many developing countries are so highly polluted that they need a form of "wastewater treatment" before they are used for human activities or to prevent serious problems in the environment (e.g., odors, loss of fish habitat, and severe eutrophication).

We analyzed these three applications specific to developing countries. Table 2 shows the results of these analyses in terms of the three readiness criteria. MBRs also offer unique advantages and challenges relative to alternative technologies, and their readiness for application in developing countries is presented in Table 3. The analysis reveals the following:

- The engineering principals are in place for two of the three applications. The exception is extraction of useful products from sewage (except for water), where principals are not in place for extracting nutrients and energy. These engineering principals also support the unique MBR advantages of small footprint and automated operation.

- Equipment availability is an issue for all applications and for the unique advantages of small footprint and automated operation. It is possible for the equipment to be imported from a developed country, but cost may be a roadblock. Technical support must be provided, whether the equipment is manufactured locally or imported, and this may be the biggest constraint in developing countries.

- MBR applications are occurring in developing countries and can provide the applications experience necessary for expanded use. This is occurring in more "traditional" applications, such as conventional sewage treatment, and it is reasonable that this will expand to other applications.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

- Human resources to operate MBRs also constrain their use developing countries. Because this is a general issue for a range of new technologies, general advances in human-workforce education could allow faster implementation of membrane technology.

SUMMARY AND CONCLUSIONS

MBRs are ready for widespread application in the developed world, especially where high quality effluent is needed. The required engineering principals are understood well enough to allow MBRs to meet most technical demands. The necessary equipment is commercially available, and capacity is increasing for crucial components, such as the membrane modules. Although historic MBR applications have been restricted to relatively small applications (on the order of a few hundred m^3/day), on-going implementation of much larger facilities is providing application experience to allow MBRs to be used at almost any scale. Important questions still exist with regard to the optimizing MBRs, including membrane life, requirements for preliminary treatment, and the trade-offs with MLSS concentration. Further research and experience with new full-scale facilities will help to address these issues

MBRs have been implemented almost exclusively in the developed countries, but the potential may be greatest for their use in developing countries, where they can advance sustainable sanitation through their ability to be part of decentralized and flexible water management approaches. Widespread use of MBR technology in developing countries will demand attention to equipment availability and trained human resources.

ACKNOWLEGEMENTS

In addition to the four authors, members of the Residency Team included Francis A. DiGiano, chair of the Bellagio Team Residency and professor in Environmental Sciences and Engineering at the University of North Carolina (Chapel Hill); Chris Buckley, professor in the Pollution Control Group

Civil Engineering Department at the Darmstadt University of Technology (Germany); A G (Tony) Fane, professor and director of the UNESCO Centre for Membrane Science and Technology (Chemical Engineering) at the University of New South Wales (Sydney, Australia) & Temasek Professor at Nanyang Technological University (Singapore); Noah Galil, professor in Civil Engineering at the Technion-Israel Institute of Technology (Haifa, Israel); Joseph G. Jacangelo, Ph.D., vice president in the Lovettsville, Virg. office of Montgomery Watson Harza (Broomfield, Colo.) and adjunct associate professor in the Bloomberg School of Public Health at The Johns Hopkins University (Baltimore, Md.); Alfieri Pollice, research environmental engineer at the CNR-IRSA Water Research Institute (Bari, Italy); Tom Stephenson, professor of Water Sciences, School of Water Sciences at Cranfield University (United Kingdom); and Zaini Ujang, professor and director, Institute of Environmental & Water Resource Management at Universiti Teknologi Malaysia (Johor Bahru, Malaysia). Alberto Rozzi (deceased), professor in Hydraulic, Environmental and Survey Engineering at the Milan Politechnical University (Italy), was instrumental in organizing the team residency. The authors gratefully acknowledge the contributions of these colleagues to the work reported in this paper. The authors also express thanks to the Rockefeller Foundation for their support of the Residency Team.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

REFERENCES

Adham, S.; P. Gagliardo; L. Boulos; J. Oppenheimer; and R.R. Trussell, **2001**. "Feasibility of the Membrane Bioreactor Process for Water Relcamation," *Wat. Sci. Tech.*, **43(10)**, 203-209.

Adham, S.; R.S. Trussell, **2001.** *Membrane Bioreactors: Feasibility and Use in Water Reclamation. San Diego, CA. Final Report,* Water Environment Research Foundation, Alexandria, VA.

American Water Works Association Research Foundation, **1996.** *Water Treatment Membrane Processes*, McGraw-Hill, New York.

Crawford, G.; D. Thompson; J. Lozier; G. Daigger; E. Fleischer, **2000.** "Membrane Bioreactors – A Designer's Perspective," Proceedings of the Water Environment Federation 73rd Annual Conference & Exposition on Water Quality and Wastewater Treatment, Anaheim, CA, CD-ROM, October 14-18, 2000.

Crawford, G.; E. Fleischer; J. Lozier; and G. Daigger, **2002.** "The Evolution of Membrane Bioreactor System Designs for Wastewater Treatment," Presented at the IWA and Ben-Gurion University of the Negev International Conference on Membrane Technology for Wastewater Reclamation and Reuse, Tel-Aviv, Israel, September, 2002.

Crawford, G.; R. Lewis **2004.** "Exceeding expectations," *Civil Eng.*, 74 (1), 62-66.

Cote, P.; L. Luca; S. Rondi; I. Meraviglia, **2004.** "Brescia Large-Scale Membrane Bioreactor: Case-Study," Membrane Academia Industry Network Conference. Cranfield, UK.

Daigger, G. T.; G. V. Crawford; J. C. Lozier, **2003.** "Membrane Bioreactor Practices and Applications in North America," Leading Edge Conference Series – Global Conference on Leading Edge Water and Wastewater Treatment Technologies, Noordwijk/Amsterdam, The Netherlands, 26-28 May 2003

Daigger, G. T.; G. Crawford; A. Fernandez; J. C. Lozier; E. Fleischer, **2001.** "WERF Project: Feasibility of Membrane Technology for Biological Wastewater Treatment – Identification of Issues and MBR Technology Assessment Tool," *Proceedings of the Water Environment Federation 74th Annual Conference & Exposition,* Atlanta, GA, CD-ROM, October 13-17, 2001.

Daigger, G. T.; et al. **2002.** *Membrane Bioreactors for Wastewater Treatment.* Water Environment Research Foundation (WERF) website, Products / Interactive Tools / Membrane Tool, www.werf.org/products/membranetool/home. (WERF Subscriber password required).

DiGiano, F.A.; G. Andreottola; S. Adham; C. Buckley; P. Cornel; G. T. Daigger; A. G. Fane; N. Galil; J. Jacangelo; A. Pollice; B. E. Rittmann; A. Rozzi; T. Stephenson; and Z. Ujang. **2004.** "Safe Water for Everyone: Experts Suggest That Membrane Bioreactors May be a Key to Global Water Sustainability," *Wat. Envir. Tech.* pp. 31-35, June 2004.

Fernandez, A.; J. Lozier; G. Daigger. **2000.** "Investigating Membrane Bioreactor Operation for Domestic Wastewater Treatment: A Case Study," *Proceedings of the Water Environment Federation 73rd Annual Conference & Exposition on Water Quality and Wastewater Treatment,* Anaheim, CA, CD-ROM, October 14-18, 2000.

Fleischer, E. J.; T. A. Broderick; G. T. Daigger; A. D. Fonseca; R. D. Holbrook, **2002.** "Membrane Bioreactor Pilot Facility Achieves Level-of-Technology Effluent Limits" *Proceedings of the Water Environment Federation 75th Annual Conference & Exposition*, Chicago, IL, CD-ROM, Sept 28 – Oct 2, 2002.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

Fleishcer, E. J.; T. A. Broderick; G. T. Daigger; J. C. Lozier; A. M. Wollmann; A. D. Fonseca. **2001.** "Evaluating the Next Generation of Water Reclamation Processes," *Proceedings of the Water Environment Federation 74th Annual Conference & Exposition,* Atlanta, GA, CD-ROM, October 13-17, 2001.

Grady, C. P. L., Jr.; G. T. Daigger. **1999.** H. C. Lim, *Biological Wastewater Treatment*, Second Edition, Marcel Dekker, New York, NY, 1999.

Gunder, B. **2001.** *The Membrane-Coupled Activated Sludge Process in Municipal Wastewater Treatment*, Technomic Publishing Co, Lancaster, PA.

Kumar, M.; S. Adham; W. Pearce. **2004.** "Development of a Cost Model for Brackish and Reclaimed Membrane Desalination Costs," Paper Presented at the Annual AWWA Conference, Orlando, FL, 2004.

Merlo, R.; S. Adham; P. Gagliardo; S. Trussell; R. Trussell, **2000.** "Application of the MBR Technology for Water Reclamation," *Proceedings of the Water Environment Federation 73rd Annual Conference & Exposition on Water Quality and Wastewater Treatment,* Anaheim, CA, CD-ROM, October 14-18, 2000.

Moore, G. A. **1991.** *Crossing the Chasm: marketing and Selling High-Tech Products to Mainstream Customers*, Revised Edition, Harper Business, NY.

Rittmann, B. E.; P. L. McCarty. **2001.** *Environmental Biotechnology: Principles and Applications.* McGraw-Hill Book Co., New York.

Rogers, E. M. **1995.** *Diffusion of Innovations*, Fourth Edition, The Free Press, NY.

Stephenson, T.; S. Judd; B. Jefferson; K. Brindle. **2000.** *Membrane Bioreactors for Wastewater Treatment*, IWA Publishing, London.

Urbain, V.; B. Mobarry; V. de Silva; D.A. Stahl; B.E. Rittmann; J. Manem. **1999.** Integration of performance, molecular biology and modeling to describe the activated sludge process. *Water. Sci. Technol.*, **37** (3), 223-231.

[illegible] *Municipal Wastewater Treatment*, IWA Publishing, London.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

Table 1. Analysis of Developed-Country Applications

Criteria	Advanced Removal of BOD and Nutrients for Discharge	Pre-treatment to Produce High Purity Water with RO	Controlling Micro-Pollutants	Recycling Grey Water
Engineering Principals	Engineering principals well developed and demonstrated.	Engineering principals well developed and demonstrated.	Mechanisms and effectiveness of MBRs to remove micro-pollutants evolving rapidly.	Engineering principals well developed and demonstrated.
Equipment Availability	Equipment widely available, along with associated technical support.	Equipment widely available, along with associated technical support.	Equipment widely available, along with associated technical support.	Equipment widely available, along with associated technical support.
Applications Experience	Being used by innovators and early adopters. Progression to early majority either occurring or will begin soon.	Pilot scale demonstrations complete. Progression to early adopters likely to occur soon.	Benefits becoming recognized by leading practitioners.	Coupled with source separation at the household level. Initial demonstrations of source separation just occurring.
Summary Assessment	Transition from early adopters to early majority beginning. Adoption progressing in normal fashion.	Implementation of this application appears straight-forward and likely to occur.	Implementation of this application appears straight-forward and likely to occur.	MBR technology for this option well developed. Adoption depends on adoption of source separation at the household level.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

Table 2. Analysis of Unique Developing Country Applications

Criteria	Treating Full Sewage Flows	Extracting Useful Resources From Sewage	Treating Highly Polluted Environmental Waters
Engineering Principals	Engineering principals well developed and demonstrated as discussed in connections with overall readiness assessment.	Engineering principals well developed and understood for effluent. Engineering principals developing for extraction of other useful products (such as nutrients and energy).	Engineering principals well developed and demonstrated as discussed in connections with overall readiness assessment.
Equipment Availability	Equipment can be manufactured locally or imported. Sufficient local support not available.	Equipment can be manufactured locally or imported. Sufficient local support not available	Equipment can be manufactured locally or imported. Sufficient local support not available
Applications Experience	Being used by innovators and early adopters in developing countries.	Being used for water extraction by innovators and early adopters in developing countries. Essentially no use to extract other products.	No applications experience.
Summary Assessment	Development of local technical support and further demonstrations needed for widespread application.	Development of local technical support and further demonstrations needed for widespread application for irrigation water. Further technical developments needed for	Development of local technical support needed for widespread application. Technology demonstrations needed to develop local experience.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

Table 3. Analysis of Capturing Unique Advantages of MBRs for Developing Countries

Criteria	Small Footprint	Automated Operation	Development of Training Resources
Engineering Principals	Systematic benefits through smaller bioreactor, elimination of clarifiers and filters. Opportunity for further optimization through refinement of process parameters (MLSS, SRT, aeration).	Equipment well developed and widely available. Further work on sensors needed, along with the development of process control strategies.	Engineering professionals generally present and being educated in developing countries. However, "technician" and other professionals not being recruited and educated.
Equipment Availability	Equipment can be manufactured locally or imported. Sufficient local support not available.	Equipment can be manufactured locally or imported. Sufficient local support not available.	General lack of institutions for the recruitment and education of technical professionals.
Applications Experience	Being used by innovators and early adopters in developing countries.	Hardware generally available in developing countries, but technical support not.	Methods for developing technical professionals in developing countries not demonstrated.
Summary Assessment	Development of local technical support needed for widespread application.	Development of local technical support needed for widespread application.	When considered in connection with need for local technical support, may be critical barrier for widespread application of MBRs in developing countries.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

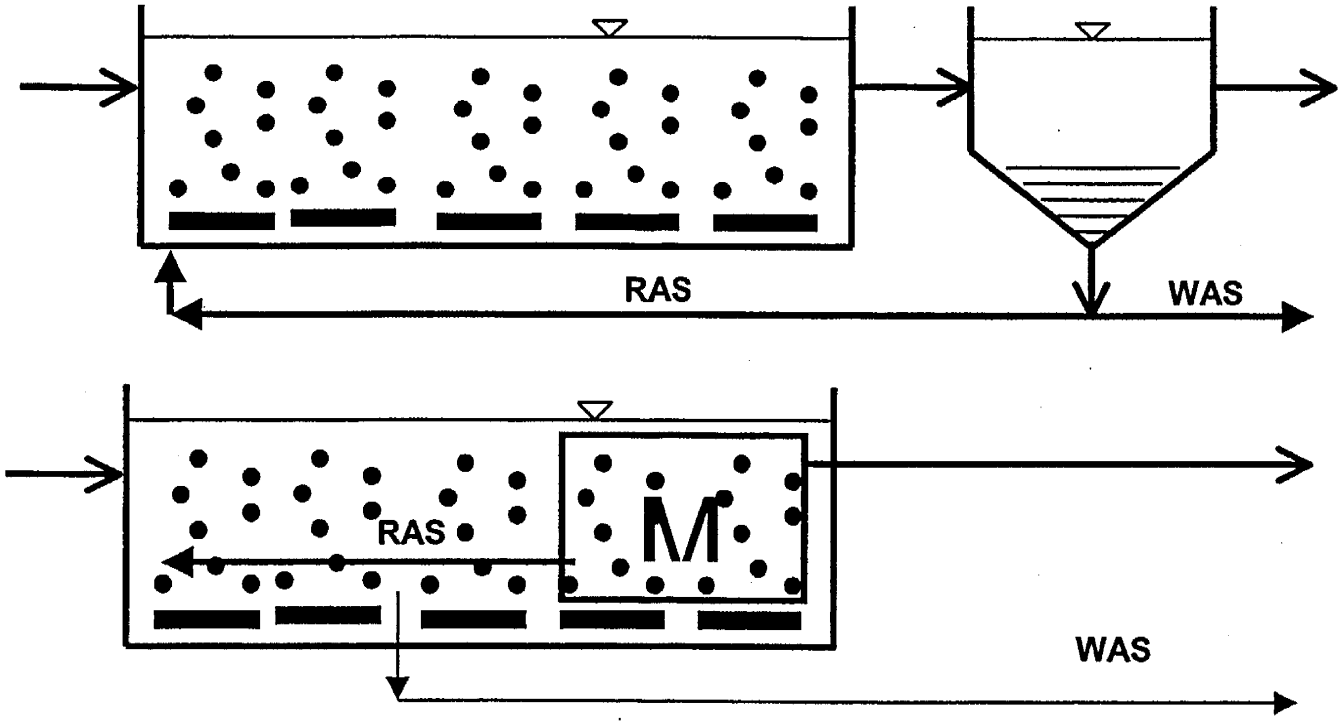


Figure 1. Traditional activated sludge (top) compared to the MBR version of activated sludge using immersed membranes for solids separation. Both systems have the same components, although details differ when membranes replace the settling tank. RAS = return activated sludge. WAS = waste activated sludge. M = membrane separator immersed in the mixed liquor.

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

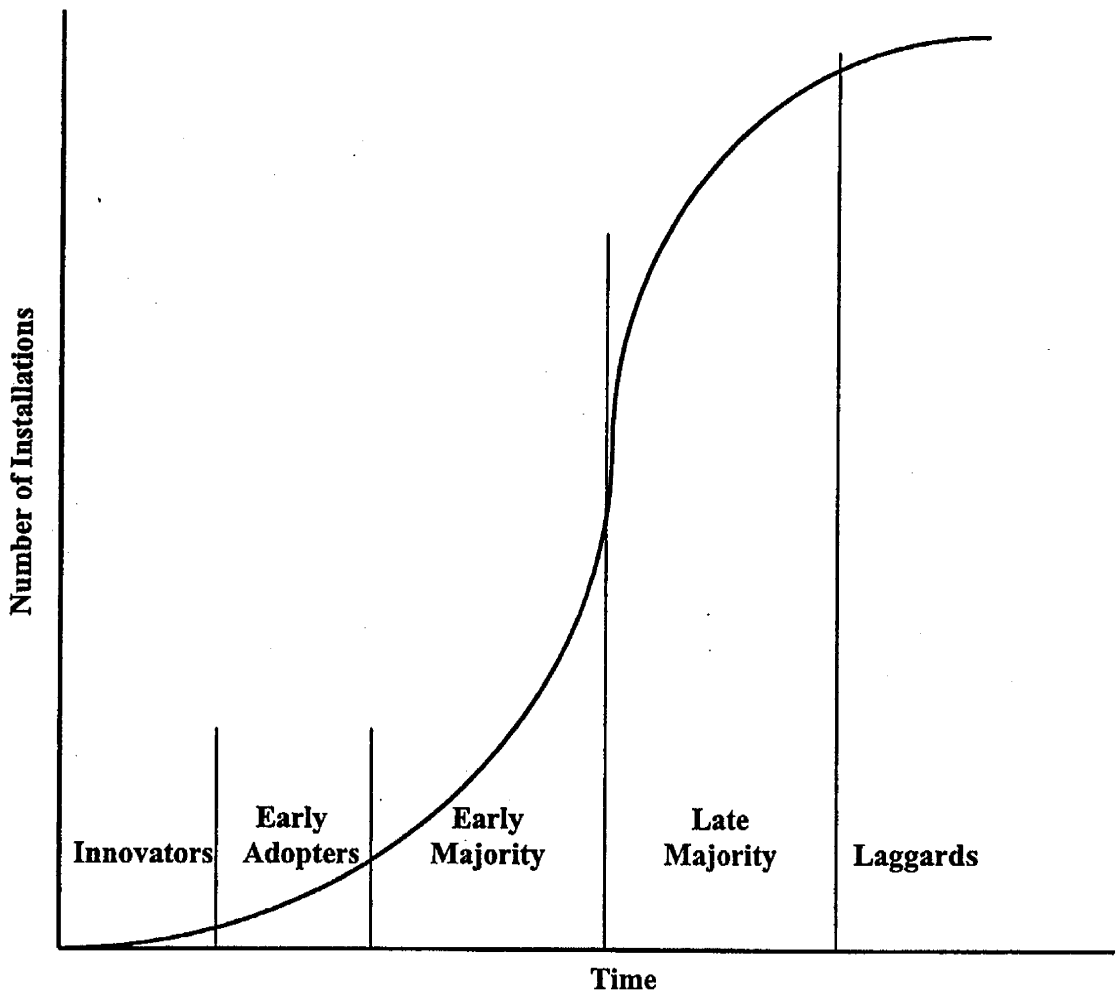


Figure 2. Typical "S Curve" for adoption of a new technology

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

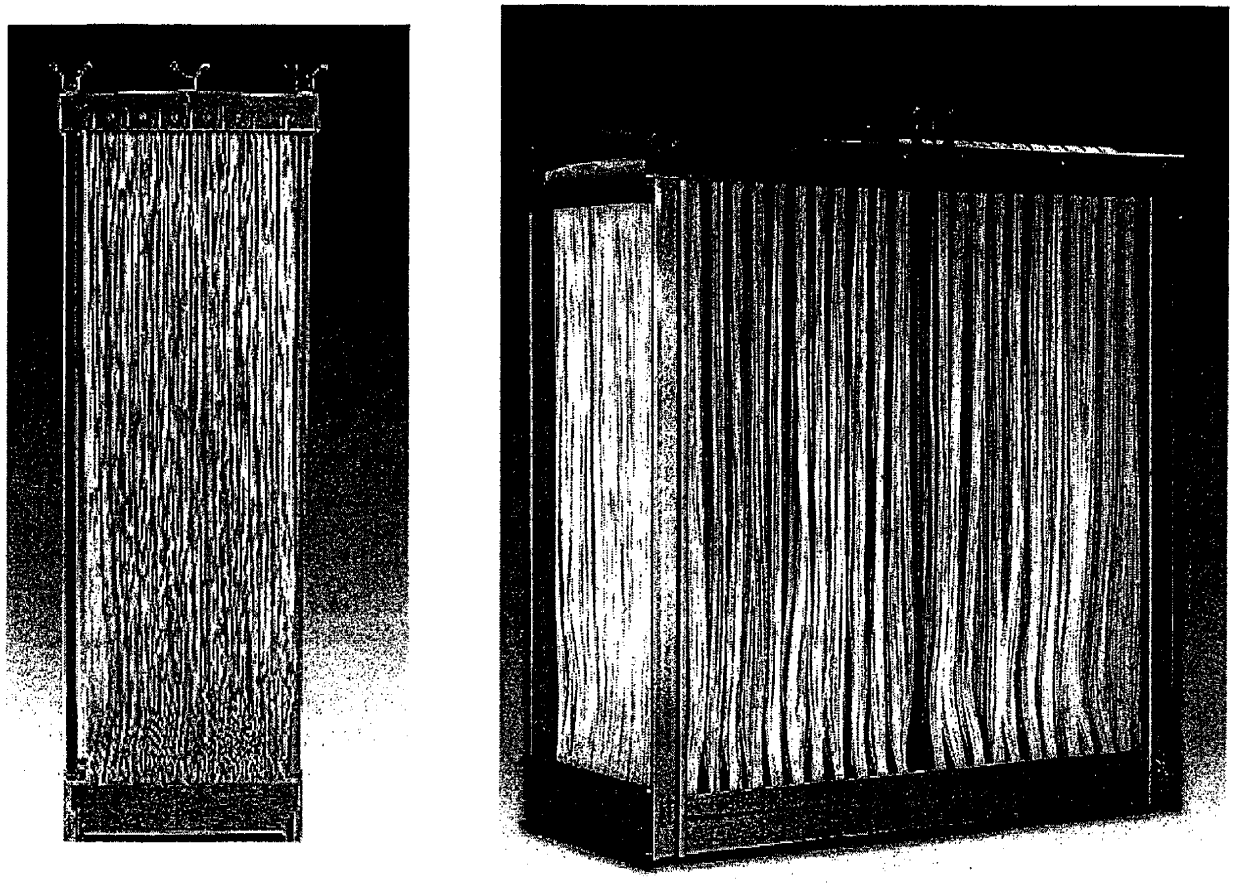


Figure 3. Example of an immersed-membrane module (courtesy of Zenon).

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

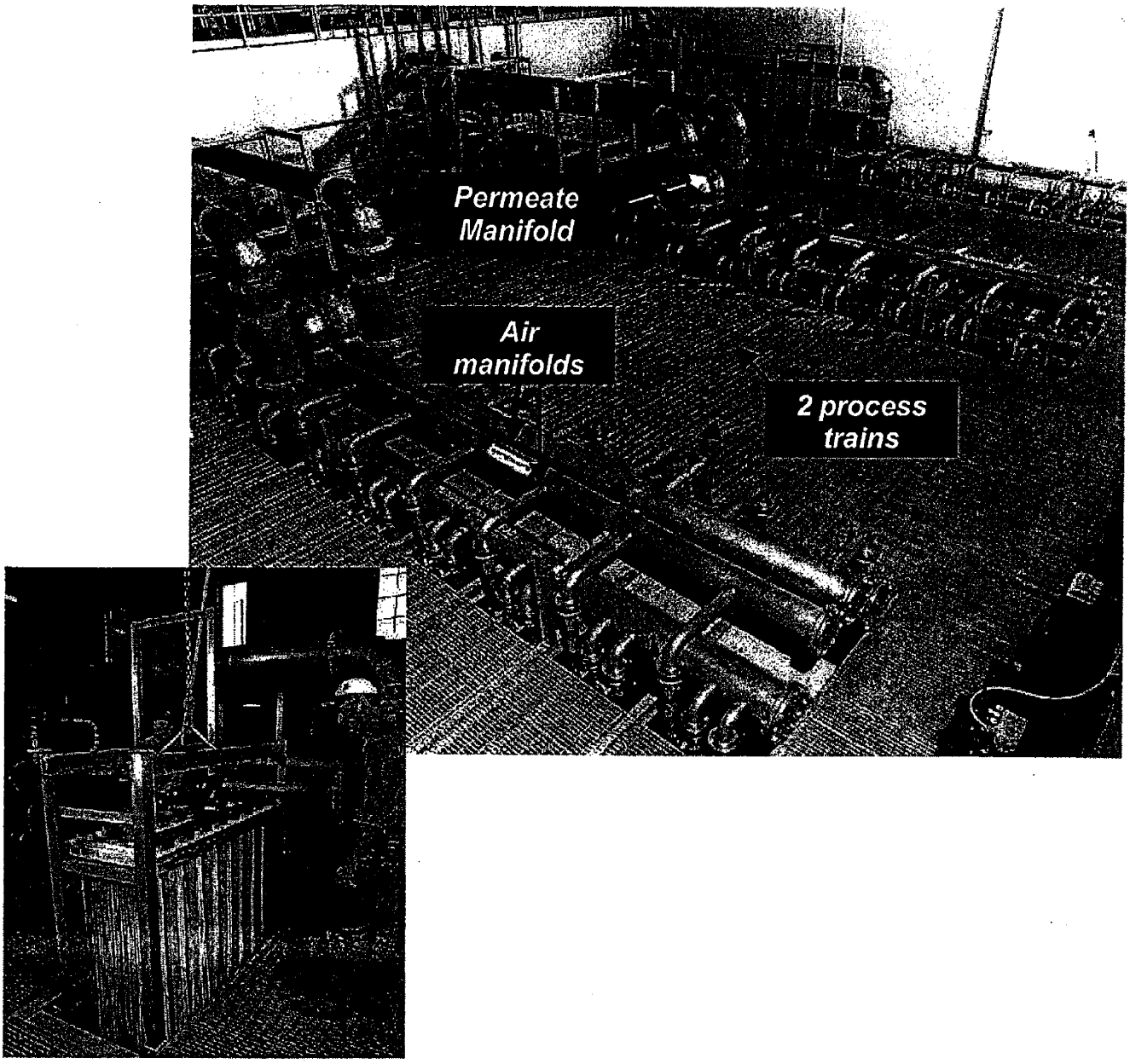


Figure 4. Membrane cassette manifolds assembled to provide complete immersed-membrane system (courtesy of Zenon).

Copyright 2004 by Bellagio International Residency Team.
Reproduction in whole or in part without written consent is prohibited.

ATTACHMENT F.3

Summary and Disposition of Phosphorus Removal Technologies Identified

ATTACHMENT 3
Summary and Disposition of Phosphorus Removal Technologies Identified

Number	Title	Description	Disposition
1	Tertiary Clarification and Granular Media Filtration with Al^{+3} for Polishing	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). An aluminum salt (such as alum or poly aluminum chloride –PAC) and polymer are added and then treated in tertiary clarifiers (to removed settleable solids) and granular media filters.	Retained for further evaluation.
2	Tertiary Clarification and Granular Media Filtration with Fe^{+3} for Polishing	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). A ferric iron salt (such as ferric chloride) is added and then treated in tertiary clarifiers (to removed settleable solids) and granular media filters.	Eliminated – inferior to option 1.
3	Membrane Bioreactor with Enhanced Biological Phosphorus Removal and Chemicals	Biological and chemical treatment of influent wastewater is provided in a membrane bioreactor incorporating anaerobic zones to allow biological phosphorus removal to occur and chemical addition at a location to minimize adverse impacts on the biological processes within the bioreactor and to produce the lowest possible effluent total phosphorus.	Retained for further evaluation.
4	Post Secondary Microfiltration with Al^{+3} for Polishing.	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). An aluminum salt (such as alum or poly aluminum chloride –PAC) and polymer are added and then treated in a membrane treatment system using microfiltration (or ultrafiltrate) membranes..	Retained for further evaluation
5	Post Secondary Microfiltration with Fe^{+3} for Polishing.	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). A ferric iron salt (such as ferric chloride) is added and then treated in a membrane treatment system using microfiltration (or ultrafiltrate) membranes..	Eliminated - inferior to option 4
6	Reverse Osmosis Preceded by Membrane Filtration	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). An aluminum salt (such as alum or poly aluminum chloride –PAC) and polymer are added and then treated in a membrane treatment system using microfiltration (or ultrafiltrate) membranes.. Effluent from the membrane filtration process is further treated by reverse osmosis.	Retained for further evaluation
7	Nanofiltration	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). An aluminum salt (such as alum or poly aluminum chloride –PAC) and polymer are added and then treated in a membrane treatment system using microfiltration (or ultrafiltrate) membranes.. Effluent from the membrane filtration process is further treated by nanofiltration.	Eliminated – not a known phosphorus removal technology

ATTACHMENT 3
Summary and Disposition of Phosphorus Removal Technologies Identified

Number	Title	Description	Disposition
8	Direct Filtration with Fe^{+3} for Polishing	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). A ferric iron salt (such as ferric chloride) is added and then treated in granular media filters.	Eliminated – not capable of reliably reducing TP to less than 200 μg/L
9	Direct Filtration with Al^{+3} for Polishing	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). An aluminum salt (such as alum or poly aluminum chloride –PAC) and polymer are added and then treated in granular media filters.	Eliminated – not capable of reliably reducing TP to less than 200 μg/L
10	Direct Filtration Using Iron-Coated Media with Al^{+3} or Fe^{+3} for Polishing	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). An aluminum salt (such as alum or poly aluminum chloride –PAC) or a ferric iron salt (such as ferric chloride) and polymer are added and then treated in a granular media filter using iron-coated media..	Retained for further evaluation
11	Dual Sand (Media Filtration with Al^{+3} for Polishing	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). An aluminum salt (such as alum or poly aluminum chloride –PAC) and polymer are added and then treated in two granular media filtration systems in series.	Retained for further evaluation
12	Dual Sand (Media Filtration with Fe^{+3} for Polishing	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). A ferric iron salt (such as ferric chloride) and polymer are added and then treated in two granular media filtration systems in series.	Eliminated – inferior to option 11
13	Treat Primary Effluent with Dual Sand Filtration Using Al^{+3} or Fe^{+3}.	Either aluminum salt (such as alum or poly aluminum chloride –PAC) or iron salt (such as ferric chloride) and polymer is added to primary effluent an treated in two granular media filtration systems in series.	Retained for further evaluation
14	Contact Clarifier and Granular Media Filtration with Al^{+3} for polishing.	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). An aluminum salt (such as alum or poly aluminum chloride –PAC) and polymer are added and then treated in a contact clarifier (to removed settleable solids) and granular media filters.	Eliminated – subset of option 1

ATTACHMENT 3
Summary and Disposition of Phosphorus Removal Technologies Identified

Number	Title	Description	Disposition
15	Ion Exchange	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). This influent stream is treated by ion exchange to remove phosphorus.	Eliminated – inferior to option 6
16	Distillation	Biologically treated effluent is treated in a thermal distillation similar to that used for the production of potable water from sea water.	Eliminated – not cost-effective in comparison to option 6
17	Wetland for Polishing and Discharge, with our without Al^{+3}.	Influent consists of the effluent from a biological treatment system (secondary treatment minimum) also incorporating phosphorus removal to lower phosphorus concentration to approximately 0.5 mg/L (500 μg/L). This influent would be treated in a wetlands systems specifically configured to maximize phosphorus removal, such as some of the systems in development to treat stormwater in Southern Florida before it is discharged to the Everglades.	Retained for further evaluation
18	Evaporation	Treated effluent would be evaporated by any of several means, including thermal/mechanical and solar.	Eliminated – would not maintain a river discharge
19	Membrane Bioreactor with Enhanced Biological Phosphorus Removal and Chemicals Followed by Microfiltration with Chemicals	Biological and chemical treatment of influent wastewater is provided in a membrane bioreactor incorporating anaerobic zones to allow biological phosphorus removal to occur and chemical addition. Metal salt (probably aluminum salt) added to membrane bioreactor effluent and subsequently treated in a microfiltration (or ultrafiltration) membrane process.	Retained for further evaluation
20	Membrane Bioreactor with Enhanced Biological Phosphorus Removal and Chemicals Followed by Reverse Osmosis	Biological and chemical treatment of influent wastewater is provided in a membrane bioreactor incorporating anaerobic zones to allow biological phosphorus removal to occur and chemical addition. Membrane bioreactor effluent treated by reverse osmosis.	Eliminated – similar to option 6
21	Post Lime Treatment	Biologically treated effluent is treated by high lime treatment with recarbonation, followed by granular media filtration	Retained for further evaluation

ATTACHMENT F.4

Email Information Request

Correll, Jim/SPK

From: Correll, Jim/SPK
Sent: Monday, August 16, 2004 12:28 PM
To: 'info@micromediafiltration.com'
Cc: Arnold, Dale; Bruce Rawls (brawls@spokanecounty.org); Doleac, Mike/SEA; Reynolds, Dave/SEA; Spencer, John F./SEA
Subject: Advanced Wastewater Technology Evaluation

To Whom it May Concern:

The Washington State Department of Ecology has proposed that all of the wastewater dischargers in the Spokane River basin immediately upgrade their respective treatment technologies to achieve a maximum total phosphorous effluent discharge concentration of .05 mg/l. Ecology has also proposed that all future treated wastewater flow increases be limited to a maximum TP concentration of .01 mg/l. There is some question among the dischargers as to the ability of current wastewater treatment technologies to consistently, reliably and cost effectively achieve the proposed phosphorous limits.

Spokane County and the City of Spokane are jointly sponsoring a one-day workshop on August 23rd to evaluate advanced wastewater treatment technologies. The main objective of this workshop will be to identify both proven and emerging technologies and to estimate what ranges of effluent phosphorous concentrations can be consistently and reliably achieved utilizing those technologies. The workshop will be facilitated by Mike Doleac/CH2M HILL and conducted by several nationally noted wastewater treatment process experts: Dr. David Stensel, University of Washington, Dr. Glen Daigger of CH2M HILL, Dr. J.B. Neethling of HDR, and Dr. Larry Esvelt of Esvelt Environmental Engineering. Other wastewater treatment process specialists will include: Dave Reynolds/CH2M HILL, Bruce Willey/HDR, Jim Kimball/JUB, Dick Finger/King County Metro, Lars Hendron/City of Spokane, and Richard Koch/Ecology.

The purpose of this email is to request the following information from your company so that your treatment technology can be included in the upcoming evaluation:

- A brief description of the technology and process train(s).
- List of installations currently in full operation, including a reference name and phone number for each of the referenced installations.
- The duration, in years, of continuous operation for each referenced installation.
- The capital cost for implementation of each referenced installation.
- The average annual cost of operations and maintenance for each referenced installation.
- The average and peak influent flow rates for each referenced installation.
- The maximum, median, average, and minimum influent and effluent concentrations of total phosphorous, suspended solids, and CBOD corresponding with the flow rates for each of the referenced installations.

Because of the short time available before the workshop, please email your information to mdoleac@ch2m.com. When the workshop has been completed, a white paper will be prepared that summarizes the conclusions and recommendations of the participants. A copy of that document will be provided to you.

Thank you,

Jim Correll, PE
CH2M HILL
Vice President and Spokane Area Manager
9 S. Washington Suite 400
Spokane, Washington 99201
509/747-2000
jcorrell@ch2m.com

"*Quality, Service, Integrity & Value*"

Appendix G

Resumes of Spokane River UAA Project Team

APPENDIX G

Resumes of Spokane River UAA Project Team

This appendix includes the following resumes:

- Daniel D. Ayers, P.E.
- Douglas Bradley
- James S. Correll, P.E.
- David W. Dilks, Ph.D.
- Sherrill Doran, P.G.
- Thomas V. Dupuis, P.E.
- Lynn Foster
- Joseph S. Helfand
- Michael W. Mischuk
- James Ollerenshaw
- Kurt Playstead
- David T. Reynolds, P.E.
- John F. Spencer
- Greg White

Daniel D. Ayers, P.E.

Office Location: Boise, Idaho

Education: Masters of Technology, Hazardous Materials and Waste Management
B.S., Civil Engineering

Registrations: Professional Engineer: Idaho and Arizona

Related Experience:

- ✓ Extensive experience in municipal wastewater treatment design and construction management including the Annacis Island and Lulu Island Wastewater Treatment Plants
- ✓ Involved in two 48-inch-diameter sewer rehabilitation projects using the Insituform technology
- ✓ Industrial experience in the energetics, military, pulp and paper, meat, beverage, non-hazardous liquid waste, mining and power industries
- ✓ Significant acid mine drainage remediation experience with the Pinal Creek Groundwater Treatment project
- ✓ RAM-w, VSAT, and SEMS trained

Mr. Ayers has 20 years of experience in municipal and industrial water and wastewater treatment plant, planning, design and construction management, municipal and industrial infrastructure planning, design and construction management, program management, and pipeline rehabilitation design and construction management.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Responsible for the development of land application option for wastewater disposal. The task included sizing conveyance and irrigation equipment, finding a suitable disposal site, and providing order-of-magnitude cost estimates.

Wastewater Facilities Master Plan, City of Lewiston, Idaho. This facility plan will update the 1995 Wastewater Facilities Master Plan. The facility plan will address liquid and biosolids wastestream treatment process upgrades, liquid disposal options including reuse, solids disposal options including composting, industrial pretreatment issues, and collection system planning. Mr. Ayers is currently serving as solids handling task leader on this planning effort, which will include the evaluation, selection, and development of the definition of solids handling treatment facilities and biosolids disposal options.

Sunnyside WWTP Final Design, Sunnyside, Washington. Involved in the facility planning and final design of the 7-mgd facility.

Boise Biosolids Pipeline Study, Boise, Idaho. Study in progress to determine a repair strategy for a fiberglass sludge pipeline.

Idaho Falls Risk Management Plan Update, Idaho Falls, Idaho. Updated the City's chlorine gas risk management plan for the wastewater treatment plant.

Okuma WWTP Facilities Plan, Okuma, Japan. Provided senior review of the facility plan for the Okuma WWTP.

Meridian NPDES Permit Application, Meridian, Idaho. Assisting the City in obtaining an NPDES permit for their wastewater treatment plant.

WWTP Facilities Plan Review, Lewistown, Montana. Provided third-party review of Peccia Engineering Wastewater Facility Plan for the City of Lewistown.

Project Experience Prior to CH2M HILL

Wastewater Master Plan, Mesa, Arizona. Responsible for sewer master plan that reviewed existing facilities, analyzed future plans, and prepared cost estimates of future facilities. The Mesa master plan focused on the use of satellite water reclamation plants to meet wastewater treatment needs and water reuse goals, rather than on

regional treatment plants. Wastewater reuse focused on both direct and indirect reuse of effluent through turf irrigation and aquifer storage and recharge.

Irrigation Water Supply System, Las Sendas Development, Mesa, Arizona. Designed a 500-gpm irrigation system, including an 8-inch Polyvinyl Chloride (PVC) pressure pipeline and two pump stations. Water was pumped from the CAP canal to a decorative lake.

Arizona Army National Guard Reuse System, Flagstaff, Arizona. Responsible for the design of a wastewater reuse system consisting of a pump station and spray irrigation.

Pinal Creek Group Remedial Water Pipeline, Globe, Arizona. Responsible for design and office construction support of a 9-mile, 18-inch-diameter remedial water pipeline. Project included a well field, two booster stations, surge analysis, and design of large diameter HDPE and lined ductile iron piping.

Priest Drive Outfall Rehabilitation, Tempe, Arizona. Involved in design and construction services of in-situ rehabilitation of 48-inch-diameter sewer. Rehabilitation occurred using Insituform technology in the Salt River bottom.

Priest Drive Trunk Sewer Rehabilitation, Tempe, Arizona. Responsible for the rehabilitation of 1,100 lf of 48-inch-diameter sewer. Rehabilitation occurred in a heavily traveled street using Insituform technology.

Southern Avenue Interceptor (SAI), Mesa, Arizona. Inspected construction of a 2-mile section of 54-inch reinforced concrete sewer interceptor through heavily urbanized areas of Tempe and Mesa.

Meridian Vulnerability Assessment, Meridian, Idaho. Responsible for conducting a water system vulnerability assessment.

Tatum Ranch Water Reclamation Plant, Phoenix, Arizona. Prepared a facility plan including an infiltration/inflow study, reviewing effluent requirements, describing present and future conditions, developing and evaluating treatment alternatives, and recommending the preferred alternative.

Squaw Peak Water Treatment Plant, Phoenix, Arizona. Responsible for the design of new chemical storage and feed equipment, and chlorine CT improvements at the 140-mgd facility.

Meridian Safety Manual, Meridian, Idaho. Responsible for producing a safety procedures manual for the City's Public Works Department.

Lander Street Wastewater Treatment Plant Influent Headworks and Odor Control Study, Boise, Idaho. Responsible for the study and selection of new fine screens and odor control facilities.

West Boise Wastewater Treatment Plant Effluent Filtration and Phosphorus Removal Study, Boise, Idaho. Responsible for the study of effluent filtration technologies to remove phosphorus from secondary effluent, and a potential rerating of the treatment plant.

Coeur d'Alene Wastewater Treatment Plant, Coeur d'Alene, Idaho. Assistant project manager responsible for design of new headworks, odor control facilities, and assistance in project management.

West Boise Wastewater Treatment Plant Effluent Filtration and Phosphorus Removal Study, Boise, Idaho. Project manager responsible for the study of effluent filtration technologies to remove phosphorus from secondary effluent, and a potential rerating of the treatment plant.

Kyrene Water Reclamation Facility, Tempe, Arizona. Project engineer responsible for the design of the 3-mgd facility. Project included influent pump station, screening, equalization, activated sludge aeration with denitrification capability, clarification, flocculation, filtration, ultraviolet disinfection, and odor control.

Annacis Island Treatment Plant, Vancouver, British Columbia, Canada. Project engineer responsible for the design of a $50 million secondary treatment expansion. Design included trickling filters, a pump station, and biofilter odor control facilities. This project was part of a larger $700 million wastewater treatment project.

Lulu Island Wastewater Treatment Plant, Vancouver, British Columbia, Canada. Project engineer responsible for design of a $50 million plant expansion including trickling filters, trickling filter pump station, biofilter odor control, and sludge and scum screening facilities.

El Paso Northwest Wastewater Treatment Plant, El Paso, Texas. Project engineer responsible for design of tertiary filters, ultraviolet disinfection, sludge storage facilities, belt press sludge dewatering, and lime sludge stabilization for a 35-mgd facility.

Los Abrigados Wastewater Treatment Plant, Sedona, Arizona. Project engineer involved in the final design of the wastewater

treatment plant. Responsibilities included adding denitrification capabilities to the plant.

Nogales Wastewater Treatment Plant, Nogales, Arizona. Project engineer involved in preparing the facility plan study for expanding the facility. The project included an infiltration/inflow study, reviewing effluent requirements, describing present and future conditions, developing and evaluating treatment alternatives, and recommending the preferred alternative.

Tolleson Interim Dechlorination Facility, Tolleson, Arizona. Project engineer responsible for design of sodium bisulfite chemical delivery system to dechlorinate treatment plant effluent. Equipment included batch mixing and metering pump feed system.

Westpoint Wastewater Treatment Plant, Seattle, Washington. Project engineer responsible for the design of screenings handling facilities.

Douglas Bradley

Office Location: Boise, Idaho

Education: M.S., Biology (Aquatic Ecology), Ft. Hayes State University
B.S., Environmental Biology, Fort Lewis College

Registrations: N/A

Related Experience:

- ✓ Experienced in the design and implementation of fish and habitat surveys in major rivers within Idaho, Colorado, and Kansas
- ✓ Designed and implemented stream restoration projects that include channel and bank reconstruction and riparian vegetation planning
- ✓ A strong NEPA and NFMA background that includes fisheries and aquatic habitat analyses on watershed analyses, vegetation management, fuels reduction, wildfire and grazing projects that have varied in size and complexity

Mr. Bradley has more than 7 years of experience as a fisheries biologist and aquatic resource specialist responsible for fish and habitat surveys. His work on numerous environmental impact statements and environmental assessments has required strong NEPA and NFMA expertise.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Fisheries technical lead. Examining the potential for meeting the dissolved oxygen (DO) standards for the reservoir, as developed by Washington Ecology. Focus is placed on the ability to meet the standards during summer stratification. Analysis for this project is conducted on the existing and proposed conditions at the fisheries, macroinvertebrates, and aquatic habitat levels. The goal of the project is to develop appropriate standards for DO within Lake Spokane.

Jordanelle Hydroelectric Project, Utah. Fisheries Biologist. Examined the effects of upgrading a dam to a hydroelectric facility on fisheries resources. The analysis evaluated the condition of the reservoir as well as that downstream of the dam. The impacts of potential water quality modifications were examined against the condition of the cold water fishery.

Lost River-Lemhi Grazing EIS, Salmon-Challis National Forest, Idaho. Fisheries technical lead. Evaluating aquatic habitat effects of renewing grazing allotments within the Little Lost and Big Lost River Subbasins. The focus of the project is on the impact of past and future grazing practices on salmonid habitats.

Morgan/Eddy Grazing EIS, Salmon-Challis National Forest, Idaho. Fisheries technical lead. Evaluating aquatic habitat effects of renewing grazing allotments within the upper-main Salmon River drainages. Focus is placed on the impact of historic and future grazing practices on anadromous and inland native fishes.

South Fork Salmon River Subbasin Noxious Weed Management EIS, Idaho. Fisheries technical lead. Evaluating the aquatic habitat effects of managing noxious weeds on Forest lands within the subbasin of South Fork of the Salmon River. Analysis focuses on the potential effects of chemical contaminants to salmonids.

Blackfeet Reservation Water Quality Analysis, Montana. Fisheries technical lead. Examining and comparing the aquatic chemistry conditions and the fisheries resources on 12 lakes across the Blackfeet Nation. Particular focus is placed on the relative conditions of six water chemistry parameters as they relate to the existing condition of the coldwater fisheries.

City of Boise, NPDES Permit Reapplication, Idaho. Fisheries Biologist. Conducted condition factor analysis and statistical support

of fish robustness to include in the NPDES reapplication. Applied Fulton Condition Factor analysis to fisheries data and ANOVA and t-test statistics to attempt to detect differences in fish conditions across the sites and above and below water treatment facilities.

Mica Creek and Mica Bay Impact Assessment, Idaho. Aquatic Biologist. Conducted ecological index analysis of project area streams in northern Idaho. Followed the State of Idaho-Ecological Assessment Framework protocol in conducting fish, macroinvertebrate, and habitat index analyses. Evaluated habitat indices and summarized results of effects that resulted from the highway reconstruction project. Completed a descriptive assessment of the aquatic environment for submission within the final impact assessment report package.

Experience Prior to CH2M HILL

Mill Creek Watershed Analysis, Boise National Forest, Idaho. Fisheries Biologist and Team Lead. Developed and implemented a watershed analysis on 37,000 acres in a drainage in southwestern Idaho. Served as team leader in directing the interdisciplinary team on the methodology and direction of the analysis process. Also served as the fisheries and aquatic biologist on the project by accumulating historic and recent data and examining aquatic and riparian conditions.

Six Shooter Vegetation Management Environmental Impact Statement (EIS), Boise National Forest, Idaho. Fisheries Biologist. Analyzed impacts of the existing road systems, past management impacts and proposed project on the Boise National Forest. The project analysis included impacts to bull trout, redband rainbow trout, whitefish, and sculpin.

Peace Creek Recreation Project Environmental Assessment (EA), Boise National Forest, Idaho. Fisheries Biologist. Technical lead on a recreation project designed to manage and restore the impacts from dispersed recreation within a destination recreation watershed. The project included aquatic analysis and the design and implementation of stream restoration projects. The aquatic analysis examine bull trout, rainbow trout, brook trout and spotted frogs. Implemented numerous restoration projects (e.g. channel and bank reconstruction, ford closures, bridge placements, culvert replacements, campground design and construction and riparian planting).

Danskin Prescribed Fire Environmental Assessment (EA), Boise National Forest, Idaho. Fisheries Biologist. Aquatic analysis included impacts to bull trout, rainbow trout, whitefish and sculpin, as well as examining impacts to riparian habitats. Conducted extensive in-stream monitoring pre- and post-implementation to determine effects to riparian and stream habitats.

Research Weir Removal Project, Boise National Forest, Idaho. Fisheries Biologist and Supervisor. Team lead and fisheries biologist on a project that resulted in the removal of numerous in-stream structures within a high elevation watershed. Coordinated and implemented this multi-agency effort and served as the supervisor to the operators during implementation of the removal of the structures and directed the restoration of the numerous sites.

Deadwood River Bull Trout Research Project, Boise National Forest, Bureau of Reclamation Snake River Office, Idaho. Fisheries Biologist. Coordinated and participated in the design and implementation of a multi-agency agreement that examines the impacts of dam operations on federally listed bull trout. The project included the management of numerous field personnel in remote locations that collected fisheries and aquatic habitat data.

Emmett Ranger District, Boise National Forest, Idaho. District Program Biologist. Responsible for resource planning, development and implementation of the aquatic resource program at the district level. Developed and managed budgets for the fisheries program, equipment, projects and the administration of permanent and seasonal employees. Designed and implemented aquatic monitoring, surveys and research projects. Managed full-time employees and field crews of up to 7 people. Collected and analyzed data on fishes and fish habitat. Coordinated the development of interagency agreements and successfully competed for grant monies.

Western Kansas Aquatic Resource Inventory Project, Kansas. Fisheries Technician. Worked as a team member on a 3-year project that inventoried rivers and streams at 35 sites across western Kansas. Collected and identified stream fishes and macroinvertebrates, as well as collected and analyzed 11 water quality parameters. Information was compiled into a report and submitted to the Kansas Department of Wildlife and Parks.

James S. Correll, P.E.

Office Location: Spokane, Washington

Education: M.S., Civil Engineering
B.S., Civil Engineering

Registrations: Professional Engineer: Idaho and Washington

Related Experience:

- ✓ American Society of Civil Engineers, Engineer of the Year, 2004
- ✓ Area Office Manager and resident of Spokane area since 1979
- ✓ Program Manager for the Spokane Wastewater Treatment Plant expansion
- ✓ Recognized community leader with involvement in multiple civic organizations

Mr. Correll is a vice president and Spokane area manager for CH2M HILL, responsible for managing current projects as well as providing technical assistance and review. As manager of CH2M HILL's Spokane office, he is responsible for ensuring that all services provided from the Spokane office meet or exceed client expectations. Mr. Correll has 35 years of experience with CH2M HILL; his project experience spans a broad spectrum of technical disciplines and includes planning, design and construction of sanitary sewerage collection, treatment and disposal facilities; stormwater management systems; water supply, storage and distribution systems; transportation systems; solid waste landfill closures; and hazardous waste remediation.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. In 2001 the Washington Department of Ecology initiated a dissolved oxygen TMDL process for the Spokane River. Mr. Correll recognized that the TMDL was being developed, based on water quality standards that could likely not be achieved in the river. Consequently, he helped to form a coalition of all of the wastewater dischargers in order to prepare a Use Attainability Analysis. As the principal-in-charge, Mr. Correll has continued to participate in all facets of the Use Attainability Analysis. This has resulted in a proposal to Ecology to establish new DO standards for the Spokane River, upgrade all treatment facilities to meet AKART requirements, and implement a basin-wide plan to reduce non-point source contaminants.

Spokane Advanced Wastewater Treatment Plant. Currently managing the 10-year capital improvement program for upgrading and expanding the City of Spokane's 44-mgd advanced wastewater treatment plant. The program involves identifying and prioritizing all necessary process improvements, preparing designs, managing construction, and commissioning the facilities. Upon completion, the treatment plant will meet the projected needs of the City through at least the year 2015.

Lincoln Street Bridge, Spokane, Washington. Led all phases of planning and design of the $36-million Lincoln Street Bridge project in Spokane, Washington. The City of Spokane ultimately decided against constructing the Lincoln Street Bridge; however, the City still intends on implementing the park improvements and the 275-foot-long pedestrian/utility bridge that were also included in the original project.

North Landfill Remediation, Spokane, Washington. Administered all of the environmental engineering activities associated with Spokane's 345-acre North Landfill. Work on this Superfund site included extensive hydrogeologic studies, remedial investigations, feasibility studies, gas management plans, operations plans, conceptual closure planning, final design of remedial facilities and construction management. Through implementation of numerous innovative design and construction features, the final North Landfill

remediation cost less than half of the amount estimated during closure planning. As a result, the project was selected for the prestigious national Award of Merit by the American Society of Civil Engineers (ASCE).

Legal Testimony. Assisted several clients with expert legal testimony. For example, at the North Landfill, he was an expert witness supporting the City of Spokane's claims for insurance compensation to pay for a portion of the $24-million cleanup. His assistance lead to a $13-million settlement in favor of the City.

Water System Improvements. Conducted comprehensive water system plans, including computerized network analyses, for numerous communities throughout the Pacific Northwest. Notably, Mr. Correll developed Deer Park's first comprehensive water plan in the mid-1980s and he has continued to provide senior water system consultation since then. He has also managed numerous water system design projects including the design of steel and concrete storage reservoirs ranging in size from 65,000 to 3,000,000 gallons; design of wells ranging in capacity from 20 gpm to 4,000 gpm; design of supply and booster pump stations (both constant and variable-speed); and design of complete distribution piping networks and transmission mains.

Storm and Sanitary Sewer Systems. Completed numerous comprehensive storm/sanitary sewer studies, including complete computerized modeling of existing and proposed systems. He has also managed the design of storm /sanitary sewerage improvements ranging from interceptor sewers through complete collection, treatment, and disposal systems.

David W. Dilks, Ph.D.

Office Location:	Spokane, Washington
Education:	Ph.D./Environmental Health Sciences MPH/Water Quality BSNR/Aquatic Biology/Biostatistics
Registrations:	Scientific Reviewer: American Society of Civil Engineering, Great Lakes Research Consortium

Related Experience:

- ✓ Directed and lectured at water quality and watershed modeling training workshops for more than 1,000 State and EPA staff
- ✓ Co-authored three national technical guidance manuals on water quality modeling and assessment
- ✓ Responsible for the development of the EPA-supported water quality models SMPTOX3, SMP, and DYNTOX
- ✓ Served as a member of EPA's SWAT team, a group of experts providing nationwide support in the development of watershed-based Total Maximum Daily Loads (TMDLs)
- ✓ Served as co-Principal Investigator for two Water Environment Research Foundation (WERF) research projects evaluating and designing improvements to the TMDL development process

Dr. Dilks is responsible for the assessment of water quality issues, primarily through the development and/or application of mathematical models. A Vice President at Limno-Tech, Dr. Dilks has directed modeling studies on more than 250 water bodies and watersheds nationwide. This work has included watershed simulation models, hydrodynamic models, and water quality models for conventional and toxic pollutants. He has also directed the development or review of more than 200 Total Maximum Daily Loads (TMDLs).

Dr. Dilks has provided extensive support and training to EPA Region X on the issues of water quality modeling and TMDL development. He developed and applied an environmental fate and transport model for Region X to support the conclusions of the Columbia River Dioxin TMDL in response to a legal challenge of the TMDL. He was subsequently contracted by Region X to extend the application of that model to the Upper and Lower Columbia, Snake and Willamette River Basins. Dr. Dilks was also contracted by Region X to develop a "demonstration TMDL" that could be used as a template for TMDL development throughout the Region. In addition, Dr. Dilks has provided numerous training workshops for Region X staff on the subjects of water quality modeling, mixing zone assessment, and TMDL development.

Dr. Dilks has served as a technical reviewer for EPA guidance documents, professional journals, and research proposals. He also serves as an Adjunct Assistant Professor at the University of Michigan College of Engineering and School of Public Health, where he has taught graduate-level water quality modeling courses. Dr. Dilks has authored more than 40 scientific papers and given approximately 100 presentations at national scientific conferences, including more than a dozen invited presentations. He has also provided expert testimony in several cases related to water quality modeling.

Project Experience

Water Quality Modeling of Columbia Slough, Oregon. Developed and applied water quality model to determine the impact of airport deicing loads on dissolved oxygen concentrations in the Columbia Slough in Portland, Oregon.

Development of TMDLs for Nine Watersheds in Illinois. Directing the compilation of information to support watershed characterization for nine watersheds in central and southern Illinois. Subsequent

project phases will involve modeling recommendations, an assessment of data adequacy to support the modeling and development of a methodology for TMDL development. This work will conclude with public meetings in each of the project watersheds, to share and solicit feedback on the TMDL implementation plan.

Development of a Model Sediment TMDL Protocol. Directing development of a technical protocol for the development of sediment-related TMDLs, with particular focus on controlling the impacts of construction stormwater sources.

Water Quality Modeling Analysis and TMDL Review, Spokane River, Washington. Directing application of near-field and far-field water quality models to evaluate attainment potential for metals, ammonia, CBOD and temperature as part of planning for a proposed municipal wastewater discharge to the Spokane River. Providing technical review of CE-QUAL-W2 modeling of Spokane River and Long Lake in support of TMDL development efforts.

Development and Testing of a Watershed Protocol for Implementing Wet Weather Controls in Northern Kentucky. Directing the development of a protocol for assessing wet weather water quality impacts on streams located in three counties in Northern Kentucky. The protocol is currently being tested on Banklick Creek, which has known wet weather impacts. The final report will present the protocol and a summary of the application of the protocol.

Assessing the Feasibility of Effective Watershed Management in Northern Kentucky through the NPDES Permitting Process. Directed development of a conceptual model for a watershed-based permitting approach for Sanitation District No. 1 of Northern Kentucky that will provide integrated management of storm water, combined sewer overflows, and wastewater treatment plant discharges. Project activities included assessing the feasibility of future implementation of the conceptual model.

Watershed and Water Quality Modeling to Support a Watershed Assessment for Newton County, Georgia. Directing development of a modified version of the Generalized Watershed Loading Functions (GWLF) model to simulate daily flow, phosphorus, sediment and fecal coliform bacteria. The outputs from this model will be used to simulate the impact of future development and BMP implementation on in-stream water quality. The results of the modeling will be used as the basis for the watershed protection and implementation plan.

Platte Lake, Michigan Watershed Modeling Study. Directed development of monitoring and modeling recommendations. Directed development and calibration of the BASINS watershed model for the Big Platte Lake watershed to estimate flows, sediment loads and phosphorus loads at multiple locations throughout the watershed. Continuing work on this project will involve model calibration using event data and scenario model runs.

Monte Carlo Modeling of Mixing Zone Impacts in the Sacramento River. Directed Monte Carlo analysis using the DYNTOX model and the results of a three-dimensional hydrodynamic model to predict water quality impacts in the Sacramento River.

Water Quality Modeling in Support of Discharge Feasibility Analysis for Manistee Lake, Michigan. Directed modeling analysis of proposed industrial wastewater discharge to the Manistee Lake. Project involved assessment of nutrient impacts to lake under various discharge location alternatives and phosphorus loading scenarios.

Development of Computer Tool to Calculate Sediment Erosion from Development. Directed development of an assessment tool to calculate sediment erosion from new development. The tool contains an interactive user-friendly interface that developers and planners can use to calculate sediment erosion from a site, based on the site plan, soil properties and the application of various combinations of best management practices. The resulting sediment load from the site will calculated by the tool and compared to a sediment load criterion that is expected to be protective of aquatic life in the nearby receiving water bodies.

Assessment of TMDL Results for Buxahatchee Creek, Alabama under Various Levels of Model Complexity. Conducted TMDL modeling of the Buxahatchee Creek using the Alabama DEM SWQM model and the QUAL2K model. The models were applied at four levels of complexity, ranging from simple Streeter-Phelps kinetics to full simulation of phytoplankton and periphyton, to determine how effluent limitations varied in response to uncertainty in each level model of model application.

Evaluation and Design of an Improved TMDL Process. Served as project manager of a 3-year study for the Water Environment Research Foundation designed to evaluate the existing TMDL development process and develop and test improved approaches.

Method Development for Addressing Narrative Criteria in TMDLs. Directed review and assessment of existing approaches to

incorporate narrative criteria into TMDL process for the Water Environment Research Foundation. Developed a series of guiding principles to improving the upon existing methods, with a focus on determining impairment, defining causes of impairment, and selecting TMDL endpoints.

Water Quality Modeling and Assessment in Support of the Southerly District CSO Phase II Facilities Plan. Providing technical direction for the development and execution of the monitoring plans (both biological and conventional pollutants) for the CSOs and receiving waters, which include several small creeks and culverted systems, the Cuyahoga River, and Lake Erie. Directing development of the receiving water modeling work plans.

U.S. EPA BASINS Training. Instructor for course sponsored by U.S. EPA Office of Science and Technology, conducted at the University of Texas, Austin, Texas. Lectured on water quality modeling and TMDL development using EPA's BASINS software.

Assessment of Wet Weather Water Quality Impacts on the Ohio River. Directing development of a water quality model of the Ohio River in the vicinity of Louisville, Kentucky. Providing technical oversight for the development of a river monitoring program to assess the impacts of wet weather pollutant loading.

Easterly District CSO Phase II Facilities Plan. Provided technical direction for the development and execution of the monitoring plans (both biological and conventional pollutants) for the CSOs and receiving waters, which include several small creeks and culverted systems, the Cuyahoga River, and Lake Erie. Directed development of the receiving water modeling work plans.

Development of TMDL Work Plans for Massachusetts. Directed the development of work plans for conducting 13 types of TMDLs for the Massachusetts DEP. The 13 types of TMDLs include bacteria (lake, river, coastal); chlorine (river, coastal); phosphorus (lake, river); nitrogen (coastal); un-ionized ammonia (river, coastal); and low DO/organic enrichment (lake, river, coastal). The purpose of these work plans is to summarize the steps involved in conducting each TMDL and the associated cost for each, assuming a low, medium, and high level of complexity.

Pumpkinvine Creek, Georgia Watershed Modeling and Assessment. Directed the development of a linked watershed and water quality model for the Pumpkinvine Creek watershed. Model development involved watershed characterization; water quality, flow and climatic data analysis; and calculation of point source loads. This model simulates flow as well as phosphorus, nitrogen, and sediment loads. The model was calibrated using data collected during 2000-2001, and was applied for future conditions to simulate the impact that future development, increased point source loads, and Best Management Practices will have on receiving water quality.

Sherrill Doran, P.G.

Office Location: Boise, Idaho

Education: M.S., Water Resources Engineering
B.S., Geological Sciences
B.A., Business

Registrations: Professional Geologist

Related Experience:

- ✓ Develops NPDES permitting negotiation strategies, variance requests, and site-specific criteria for point source discharges and stormwater releases
- ✓ Analyzes TMDL requirements, including load and wasteload allocations and implementation strategies
- ✓ Evaluates geomorphic and hydrologic elements of stream restoration, channel improvements

Ms. Doran is a professional geologist with more than a decade of consulting experience evaluating water quality and water resources in the Pacific Northwest. She has contributed to a variety of UAA and site-specific criteria projects by evaluating the physical, chemical, and biological components of a water body in order to evaluate the existing and attainable beneficial uses. This work has provided the basis for use refinement and the development of criteria that protect the appropriate uses. In addition, Ms. Doran managed the water effect ratio project that resulted in site-specific criteria for metals in the lower Boise River and was integrally involved in extensive federal and state agency negotiations that led to the success of this project. She brings extensive experience in evaluating the transport and fate of chemicals that have been released to surface water and groundwater resources, particularly to support NPDES permitting negotiation strategies and variance requests for point source discharges and stormwater releases.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Providing technical support for a use-attainability analysis that will provide the scientific and technical basis for, and appropriate designation of, beneficial uses of the Spokane River from the Lake Coeur d' Alene Outlet to Long Lake Dam. The designated beneficial uses of the river form the fundamental basis for the TMDL. Tasks include data compilation, review, and analysis; identification of critical data gaps; development of the biological basis for site-specific criteria; and evaluation of use attainment and TMDL targets in other comparable systems.

TMDL, Snake River-Hells Canyon, Idaho. Provided technical analysis to support the TMDL for the Snake River-Hells Canyon. Evaluated potential refinement of uses for Brownlee Reservoir and the mainstem Snake River upstream of Brownlee in order to establish a sound regulatory and scientific basis for defensible water quality targets for the TMDL. Idaho Water Users Association members, Boise City and other municipalities in the watershed, Idaho Power Company, the Bureau of Reclamation, water users in Oregon, and several industries sponsored this use refinement project.

Water Effect Ratio Study, City of Boise, Idaho. Managed a Water Effect Ratio (WER) study for the Boise River to establish site-specific aquatic life criteria for copper and lead. Bioassay testing for two facilities include three separate sampling events, and several species (including a water flea (*Ceriodaphnia dubia*), a scud (*Hyallela azteca*), and a fish (*fathead minnow*). Coordinated closely with IDEQ, USEPA staff, and bioassay laboratory in development of study protocols, interpretation of study results, and analysis supporting revised criteria.

Sherrill Doran, P.G.

Technical Support, Lower Boise River, Idaho. Provided technical support to IDEQ and the watershed advisory group to evaluate and refine designated uses for the following lower Boise River tributaries: Indian Creek, Mason Creek, and Sand Hollow Creek. Evaluated whether the designated uses for the tributaries were appropriate, and these use evaluations have resulted in proposed changes in designated uses for each of these creeks and development of applicable site-specific criteria for temperature, pH, and dissolved oxygen. These use changes are also reflected in the TMDL targets being established for these tributaries for sediment and nutrients.

TMDL Implementation Plan, Lower Boise River, Idaho. Developed the TMDL Implementation Plan for the Lower Boise River. This plan is being prepared to provide a framework for the local stakeholders who are ultimately responsible for ensuring that beneficial uses in the Lower Boise River are achieved. The plan includes a description of controls for point and non-point sources of bacteria and sediments. Input from three major stakeholder groups (point sources, urban and suburban stormwater sources, and agricultural non-point sources) was incorporated to determine how the goals of the TMDL can best be achieved using limited resources. The plan also contains information on watershed monitoring, effluent trading within the watershed, and an implementation funding plan.

Pollution Prevention Strategy, Boise, Idaho. Developed a pollution prevention (P2) strategy for a large municipality that evaluated any activity (including the use of materials, processes, or practices) that reduces or eliminates the creation of pollutants or wastes at the source. To build on existing P2 efforts, authored a strategy document that documents existing efforts, identifies and prioritizes potential P2 targets (for example, mercury, dioxin, pesticides, temperature), and identifies potential P2 strategies for each target. A plan for developing a P2 program for each of the targets identified was created so that the client has a blueprint for moving forward with a comprehensive P2 strategy. Each of the target-specific plans presents a brief background on the sources of each target, a recommended course of action, a list of the various regulatory agencies that may need to be involved, and a list of potentially affected entities.

DNA Bacteria Source Summary Report, Lower Boise River, Idaho. Prepared summary report for DNA bacteria source tracking study designed to help differentiate potential sources of fecal coliform colonies (for example, human sources, pet sources, wildlife sources such as avian and elk, and agricultural sources such as cattle and pigs). Local stakeholders, including IDEQ and the Ada County Highway District conducted sampling and testing over a year-long period. Ultimately the results of the study will be used to decide how to best allocate existing resources to reduce bacteria loads to the system.

Technical Analysis for Surface Water Data, Bunker Hill, Idaho. Provided analysis for a technical memorandum summarizing surface water data collected to support the Pilot Phase of the Hillsides Surface Water Monitoring Program. Data include precipitation, air temperature, turbidity, total suspended solids (TSS), and flow. The analysis concluded that the flow-weighted average turbidity is more representative of an event-based sediment load rather than an hourly average turbidity, which is calculated over a much shorter time-period without the incorporation of flow into the calculation. Subsequent memorandums have concluded that the database is enriched over time, the effect of revegetation on runoff volumes will become clearer.

Technical Analysis for Temperature Variance, Snake River, Lewiston, Idaho. Provided technical analysis for development of a variance application for temperature for an NPDES-permitted process wastewater discharge to the Snake River, Idaho. Historical pre-impoundment and more recent post-impoundment data were reviewed to determine appropriate upstream temperature values to use for discharge permit calculations. Reviewed recent literature to provide context for regional water quality standards prior to the development of the Region 10 temperature guidance prepared by EPA.

Technical Analysis, Draft TMDL, Tualatin, Oregon. Provided technical analysis to support client comments on a draft TMDL for phosphorus and nuisance phytoplankton growth. The analysis showed that chlorophyll *a* levels exceeded the state criteria even when phosphorus conditions were maintained at naturally-occurring levels. This issue related directly to the goal of the TMDL (to restore beneficial uses) because no data indicated that the designated beneficial uses were impaired. In addition to the chlorophyll *a* issues, the analysis also showed that more current pH data precluded the use of a phosphorus TMDL to protect pH levels.

Thomas V. Dupuis, P.E.

Office Location: Boise, Idaho
Education: M.S., Environmental Engineering
B.S.C.E., Civil/Environmental Engineering
Registrations: Professional Engineer
Related Experience:

- ✓ Extensive experience in the TMDL program, including work for watershed stakeholder groups, affected permittees, and state water quality agencies
- ✓ Evaluation, design, and implementation of trading options for muncipalities
- ✓ Water quality modeling, TMDL review, and NPDES permit development
- ✓ National expert in stormwater quality regulations
- ✓ Extensive CSO and SSO experience

Mr. Dupuis has 27 years of experience in environmental engineering, with expertise in water quality monitoring and assessment, total maximum daily loads (TMDLs), use attainability analyses (UAAs), National Pollutant Discharge Elimination System (NPDES) permitting assistance, hydroelectric licensing, stormwater management, CSO and SSO evaluations, hydrologic analysis, water resources management, computer modeling, and National Environmental Policy Act (NEPA) assessments. He gained his knowledge of water programs while working for a private environmental research firm, for state water quality and water resources agencies in North Carolina, and for CH2M HILL providing technical and regulatory assistance services to private industry, government agencies, and municipalities.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Overall technical lead for a UAA that will determine what the existing and attainable uses of the river and reservoir are, and to define DO criteria that would be protective of those uses. This was necessary because it appeared that the currently designated uses were not appropriate, and hence the associated DO criteria also needed to be refined. Although the UAA is still underway, it is hoped that refinement of the uses and criteria will lead to development of a DO TMDL that will be focused on attainable conditions and a more rational outcome than forcing dischargers out of the river at extreme costs.

Lower Boise River Water Quality Plan, Idaho. Strategy team leader, senior technical reviewer, and is currently facilitator for the Lower Boise River Water Quality Plan (the watershed advisory group) as it grapples with the TMDL process, and has been a key participant in that watershed effort since 1992. He also participated in the Lower Boise River Effluent Trading Demonstration Project. He assisted in the development of the bacteria TMDL for the river, and was a senior reviewer of a bacteria DNA source tracking study funded in part by a 319 grant. He also directed a UAA study for several tributaries of the lower Boise River. These UAAs led to State adoption of modified aquatic life use designations and associated water quality criteria for temperature and dissolved oxygen.

Snake River Hells Canyon TMDL, Idaho and Oregon. Managed the Snake River Use Refinement Study for consortium of stakeholders in Idaho and Oregon affected by the Snake River-Hells Canyon TMDL. A preliminary evaluation suggested that the designated uses for two reaches of the river warranted additional assessment and probable use refinement. Stakeholders involved believed that a parallel effort to evaluate potential refinement of

uses was necessary to establish a sound basis for water quality targets for the TMDL. Alternative designations were recommended (seasonal cold water/cool water biota) and site-specific criteria for temperature were developed. The study also included review of scientific literature on the effects of algae blooms on fishery and recreation uses and development of a process to identify TMDL targets for chlorophyll.

UAA and NPDES Permit Negotiations, Federal Paper Board Company, North Carolina. Provided technical support to assist Federal Paper Board Company's (now International Paper) Riegelwood, North Carolina, mill in negotiating NPDES permit requirements for BOD and toxic pollutants discharged to the lower Cape Fear River. This project has included water quality modeling, detailed biological surveys of the impact of Federal's discharge, and development of a technical basis for site-specific water quality standards. This project resulted in the North Carolina Division of Environmental Management (DEM) relaxing effluent limitations for BOD during the summer and winter discharge periods and provided technical justification for a variance from the definition of the "summer" period to exclude the months of April and May. This effort resulted in a cost savings to Federal in the range of $25 to $50 million.

Tualatin Subbasin TMDL, Oregon. On behalf of Clean Water Services (formerly Unified Sewerage Agency) (OR), he led a major review of the Draft Tualatin Subbasin TMDL document and development of comments for submittal to the Oregon DEQ. He reviewed the modeling and underlying assumptions for setting wasteload and load allocations for point and nonpoint sources. Modeling reviews were conducted for temperature (Heat Source), dissolved oxygen (QUAL2E), and bacteria and phosphorus (GIS-based models). Mr. Dupuis was responsible for compiling detailed review of the models and development of technical comments. He reviewed CE-QUAL-W2 modeling of Tualatin River in relation to oxygen-demanding constituents and the dissolved oxygen TMDL. Recently completed work on a watershed permitting and water quality trading program, developed technical approaches for temperature and oxygen-demand trading.

Johnson Creek and Fairview Creek TMDLs, Oregon. On behalf of the City of Gresham, Oregon, he is currently reviewing models and TMDLs being developed by the State of Oregon for Johnson and Fairview Creeks for temperature, bacteria, and toxics.

Columbia River Basin TMDL, Multiple Pacific Northwest States. Reviewed EPA Region 10 dioxin TMDL for pulp and paper mills in Columbia River Basin, and developed alternative TMDL spreadsheet model; provided follow-up expert testimony for permit appeals.

Salt Creek, East Branch, and West Branch TMDLs, Illinois. Under CH2M HILL's contract to Illinois EPA, he is currently providing senior review of TMDL assessment, modeling, allocations, and implementation plans for three watersheds in Northeastern Illinois (Salt Creek, East Branch and West Branch of the DuPage River). Models being used include QUAL2E and BASINS/HSPF.

Net Environmental Gain Offsets for Water Resources Diversions in the Great Lakes, Michigan. Technical lead for water quality, permitting issues, and trading model issues. Building a nexus between changes in water uses (e.g., proposed withdrawals) and their resulting environmental impacts by developing a credit system, based on indicators of ecological services, that can be used to quantify and compare positive and negative impacts of the proposed uses, and set benchmarks for mitigation.

U.S. Navy NPDES Permitting, Hampton Roads, Virginia. Senior Technical Reviewer and Task Leader for a major regional water quality study to address NPDES permitting issues for the Navy's five bases and more than 300 permitted outfalls, including mixing zone modeling and field dye dispersion studies, development of site specific criteria for copper, and development of chemical translators for three metals.

Montgomery Water Works and Sanitary Sewer Board, Alabama. Provided senior technical and regulatory direction for a detailed basinwide study of the water quality effects of discharges for wet-weather overflows from the City of Montgomery's sanitary sewer system to Catoma Creek.

TMDL Senior Review, Various Projects and Locations. Directed or provided senior review for TMDL, water quality, and effluent toxicity projects in more than 25 states and two territories. These projects focused on the development of compliance strategies and NPDES permit negotiations and included field studies, mixing zone and water quality modeling, and anti-degradation/anti-backsliding evaluations.

Clean Water Services Watershed Permit and Trading Program, Oregon. Leading technical analyses associated with a national model for development of watershed permitting for four wastewater treatment facilities and municipal separate storm

sewer systems. Conducted review of TMDL assumptions, developing technical basis for trading ratios, and estimating impacts of flow augmentation water quality.

PLOAD Modeling, Stormwater Best Management Practices Effectiveness Reviews, Oregon Association of Clean Water Agencies (ACWA), Oregon. CH2M HILL is currently working on establishing a common basis for assessing and documenting BMP effectiveness for ACWA. These benchmarks will be used by Oregon MS4 NPDES permittees in fulfilling the evaluation and reporting requirements of the new and renewed NPDES Phase I stormwater permits. Mr. Dupuis is leading the task for application of the GIS-based PLOAD model to allow ACWA members to readily develop effective programs and establish defensible benchmarks for compliance.

Research Study for the National Academy of Sciences, National Cooperative Highway Research Program (NCHRP) Relating to Bridge Runoff Impacts. As Principal Investigator, Mr. Dupuis developed a *Practitioner's Handbook* being used by highway agencies throughout the country to evaluate and mitigate effects of bridge runoff, including watershed approaches, BMPs, and effluent trading.

Highway Stormwater Runoff Nationwide Study, Federal Highway Administration (FHWA). Principal investigator of a comprehensive nationwide study of the effects of highway storm water runoff on receiving waters. He planned and coordinated field monitoring and developed impact assessment methodologies; biological, sediment, and water column effects were quantified. He developed several guidelines manuals being used by FHWA and highway agencies for planning and conducting field studies and writing environmental assessments of storm water runoff effects.

Phase I NPDES Stormwater Projects, Six Municipalities in the Hampton Roads, Virginia. Senior consultant for a project related to compliance with Phase I NPDES stormwater regulations. The project included development of innovative performance and compliance indicators for SWP3s.

CSO Experience. Mr. Dupuis has had substantial involvement over his career on CSO projects for Milwaukee, Racine and Kenosha, WI; Northeast Ohio Regional Sewerage District, OH; Boston Area Metropolitan Water Reclamation District, MA; Bangor, ME; Omaha, NE; and Atlanta, GA. This work has included CSO system modeling, water quality standards evaluations, and permit compliance.

Selected Presentations

Consider a Use Attainability Analysis. Presented at Oregon Association of Clean Water Agencies Workshop on Compliance Strategies for Oregon's Temperature Standard. Portland, OR. May 17, 2004.

With Bill Kreutzberger. Wet Weather Discharges: Use Of Time-Variable Toxicity Testing In A Decision-Solution Framework. Presented at WEFTEC 2003, Los Angeles, CA. October 2003.

What are We Trying to Protect?: Beneficial Use Changes in Agricultural Watersheds. Presented at Annual Agriculture and Water Quality Conference, Yakima, WA. November 20, 2002.

Lynn Foster

Office Location: Boise, Idaho

Education: M.S., Fisheries, University of Wyoming
B.S., Biology, Ohio State University

Registrations: N/A

Related Experience:

- ✓ More than 30 years of experience as a consulting biologists specializing in aquatic biology
- ✓ Investigated major river systems, including the Columbia, Snake, Salmon, and Mississippi
- ✓ Served as the team leader, senior reviewer, fisheries biologist, and surface water quality specialist for EIS assessments
- ✓ Served as the EIS/HCP task leader for Plum Creek's Native Fish Habitat Conservation Plan
- ✓ Served as the team leader, senior reviewer, fisheries biologist, and surface water quality specialist for EIS assessments

Mr. Foster specializes in fisheries and aquatic biology and has more than 25 years of experience as a consulting biologist. His past responsibilities include designing and managing programs for industry and government agencies directed at describing existing environmental conditions, assessing potential project impacts, and recommending appropriate mitigation measures. Mr. Foster has participated in studies on major river systems of the United States and has worked extensively with the fisheries of the western and northwestern United States. He is a member of the American Fisheries Society

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Serving as senior reviewer for aquatic biology investigations being conducted as a part of this use attainability analysis (UAA). The UAA is examining the potential for meeting the dissolved oxygen (DO) standards for the reservoir as developed by Washington Ecology. Focus is placed on the ability to meet the standards during summer stratification. Analysis for this project is being conducted on the existing and proposed conditions at the fishery, macroinvertebrate, and aquatic habitat levels. The goal of the project is to develop appropriate standards for DO within Lake Spokane.

Plum Creek's EIS and Native Fish Habitat Conservation Plan (NFHCP), Montana. Served as task leader and fisheries Biologist on the preparation of the combined Environmental Impact Statement and Habitat Conservation Plan for Plum Creek, the U.S. Fish and Wildlife Service (FWS), and the National Marine Fisheries Service (NMFS). Plum Creek's NFHCP covers 1.6 million acres of their lands in Montana, Idaho, and Washington and 17 species of federally listed or unlisted native salmonids under an Incidental Take Permit. Prescriptions have been developed by Plum Creek and negotiated with the FWS and NMFS for eight categories of conservation commitments that are designed to benefit native salmonids such as bull trout, steelhead, westslope cutthroat trout, redband trout, chinook salmon, and others either listed under the Endangered Species Act or having sensitive status.

Interior Columbia Basin Ecosystem Management Project (ICBEMP), Boise Cascade Corporation. Served as fisheries biologist, on behalf of Boise Cascade Corporation, on the complex, multi-state project conducted by the U.S. Forest Service and Bureau of Land Management. His responsibilities included evaluating the adequacy of analyses prepared by the project team on the effects of various land management strategies on the viability of anadromous and resident salmonid fish species; potential management effects on riparian habitat buffer zones ranging from a preservation, no-management philosophy to an active adaptive management

philosophy; and subsequent effects on instream habitat and related fisheries population and life history dynamics. Fish populations evaluated ranged from watersheds in central Oregon eastward to western Montana and from watersheds in northern Idaho southward to northern Utah and Nevada.

Simpson Timber Company EIS and Aquatic Habitat Conservation Plan (AHCP). Served as senior reviewer and fisheries task leader on the EIS prepared for the FWS, NMFS, and Simpson Timber for the proposed AHCP in northern California for chinook salmon, coho salmon, steelhead, coastal cutthroat trout, and two species of herptiles.

EISs, Uinta Basin, Utah, Central Utah Water Development/ Environmental Enhancement Project. Served as the EIS team leader and senior reviewer on two large multi-discipline EISs and an EA prepared for water resource development/ environmental enhancement projects in the Uinta Basin, Utah, as part of the Central Utah Project. The project areas extend from the high-elevation Uinta Mountains to lowland sagebrush areas and encompass federal, state, Ute Tribe, and private lands. Proposed actions and alternatives evaluated were designed to satisfy various landholder needs from a water distribution/efficiency perspective while simultaneously benefiting fish and wildlife as well as recreational needs in the Basin. The Upalco Unit and Uintah Unit Replacement Projects are sponsored by the Central Utah Water Conservancy District with the Department of the Interior as a joint lead agency.

Fisheries enhancement and mitigation opportunities Mr. Foster helped develop for the Central Utah Project include trout stocking and management programs for large storage reservoirs and for the rivers downstream; year-round minimum instream flows for trout fisheries in rivers downstream of the storage reservoirs; and instream and riparian habitat improvements in river reaches with regulated flows below the storage reservoirs. Reservoir evaluations included the establishment and testing of conservation pool criteria to ensure over-winter trout survival, as well as the assessment of reservoir eutrophication potential and possible effects on trout based on dissolved oxygen, water temperature, and nutrient/sediment loading levels. The project also included assessment of four endangered and three candidate fish species.

Noxious Weed EIS, U.S. Forest Service, Idaho. Serving as Environmental Impact Statement (EIS) Task Leader in the development of a Noxious Weed EIS for the approximately 3-million-acre Salmon-Challis National Forest. The forest is located in eastern Idaho in Region 4 of the U.S. Forest Service's management area. CH2M HILL is working with the Forest Service to identify and formulate noxious weed management/treatment options as a basis for EIS alternatives; describe the affected environment for biological, physical, human and socioeconomic, and cultural resources occurring on the Forest; and assess the potential impacts of weed management alternatives, including the evaluation of direct, indirect, cumulative, connected, combined, and similar action effects. In addition, CH2M HILL is working with the Forest Service to identify appropriate mitigation measures and modify treatment alternatives to minimize the potential for significant unavoidable adverse impacts. CH2M HILL support also includes participation in public meetings.

Interior Columbia Basin Ecosystem Management Project (ICBEMP), Boise Cascade Corporation. Served as fisheries biologist, on behalf of Boise Cascade Corporation, on the complex, multi-state project conducted by the U.S. Forest Service and Bureau of Land Management. His responsibilities included evaluating the adequacy of analyses prepared by the project team on the effects of various land management strategies on the viability of anadromous and resident salmonid fish species; potential management effects on riparian habitat buffer zones ranging from a preservation, no-management philosophy to an active adaptive management philosophy; and subsequent effects on instream habitat and related fisheries population and life history dynamics. Fish populations evaluated ranged from watersheds in central Oregon eastward to western Montana and from watersheds in northern Idaho southward to northern Utah and Nevada.

Simpson Timber Company Aquatic Habitat Conservation Plan (AHCP). Serving as senior reviewer and fisheries task leader on the EIS being prepared for the FWS, NMFS, and Simpson Timber for the proposed AHCP in northern California for chinook salmon, coho salmon, steelhead, coastal cutthroat trout, and two species of herptiles.

EISs, Uinta Basin, Utah, Central Utah Project. Served as the EIS team leader and senior reviewer on two large multi-discipline EISs prepared for water resource development/environmental enhancement projects in the Uinta Basin, Utah, as part of the Central Utah Project. The project areas extend from the high-elevation Uinta Mountains to lowland sagebrush areas and encompass federal, state, Ute Tribe, and private lands. Proposed actions and alternatives evaluated were designed to satisfy various landholder needs from a water distribution/efficiency perspective while simultaneously

benefiting fish and wildlife as well as recreational needs in the Basin. The Upalco Unit and Uintah Unit Replacement Projects are sponsored by the Central Utah Water Conservancy District with the Department of the Interior as a joint lead agency.

Fisheries enhancement and mitigation opportunities Mr. Foster helped develop for the Central Utah Project include trout stocking and management programs for large storage reservoirs and for the rivers downstream; year-round minimum instream flows for trout fisheries in rivers downstream of the storage reservoirs; and instream and riparian habitat improvements in river reaches with regulated flows below the storage reservoirs. Reservoir evaluations included the establishment and testing of conservation pool criteria to ensure over-winter trout survival, as well as the assessment of reservoir eutrophication potential and possible effects on trout based on dissolved oxygen, water temperature, and nutrient/sediment loading levels. The project also included assessment of four endangered and three candidate fish species.

Environmental Monitoring. Project manager and fisheries biologist for studies at nuclear and conventional power plant sites in Oregon, Washington, New York, Louisiana, and British Columbia. Major river systems he has investigated include the Columbia, Snake, Klamath, Mississippi, Hudson, and Thompson.

Hydroelectric Projects on the Snake River in Idaho and Columbia River in Oregon. Project manager and fisheries biologist for studies. Conducted instream flow studies to determine the feasibility of hydroelectric projects on streams in Oregon and Washington and was program manager of instream flow studies conducted on Tribal lands in Montana. He is certified to design and conduct instream flow studies using the U.S. Fish and Wildlife Service's instream flow incremental methodology.

Lake Rehabilitation Studies in Oregon and Stream Rehabilitation Studies in Washington. Project manager and fisheries biologist assisting in designing rehabilitation studies for a Washington lake. Mr. Foster studied river rehabilitation effects on salmon, steelhead, and resident trout spawning/rearing success in Idaho. Watershed analysis and riparian habitat management strategies have been a part of these and other projects.

Environmental Reports. As a fisheries biologist, Mr. Foster has conducted field studies and prepared environmental reports for proposed precious metals mines in Idaho and Montana; rock quarry and coal mine sites in Oregon and Washington; hydroelectric sites in Oregon, Washington, California, Colorado, Utah, and Idaho; downstream fish passage facilities in the Northwest; and a fisheries resource plan for the Klamath River, California. Many of these reports were prepared as environmental assessments, environmental impacts statements, or feasibility studies preliminary to the preparation of an environmental assessment or an environmental impact statement, according to National Environmental Policy Act (NEPA) requirements.

Biological Assessment Experience. Has served as project and technical leader on numerous environmental studies prepared as part of ESA consultation and NEPA compliance, and has authored or co-authored various programmatic and site-specific BAs. Serving as EIS task leader and fisheries biologist in the development of a Noxious Weed EIS and Programmatic BA for the approximately 3-million-acre Salmon-Challis National Forest. The BA assesses Snake River chinook salmon, Snake River sockeye salmon, Snake River steelhead, and bull trout, as well as a number of federally listed terrestrial species. Also served as task leader and fisheries biologist on the preparation of the combined EIS and Native Fish Habitat Conservation Plan (NFHCP) for Plum Creek, the FWS, and NMFS. The NFHCP covers 1.6 million acres of Plum Creek lands in Montana, Idaho, and Washington and 17 species of federally listed or unlisted native salmonids. Programmatic assessments were conducted for anadromous and resident native salmonids such as spring/summer and fall chinook salmon, bull trout, steelhead, westslope cutthroat trout, redband trout, and others either listed under the ESA or having sensitive status. Provided assistance to the FWS and NMFS in the assessment of the 17 fish species and in the preparation of the Biological Opinion (BO) for the project.

Examples of other BAs and environmental studies Mr. Foster has participated in that addressed ESA fish and invertebrate species and designated or proposed critical habitat include Use Attainability Analyses and studies of proposed hydroelectric projects on the Snake River by Idaho Power Company, BAs for the US 95 Idaho Sand Creek and Lake Creek/Fighting Creek Projects, a BA for the Milltown Reservoir Sediments and Dam Removal Project on the Clark Fork River in Montana, combined programmatic EAs/BAs for the Bureau of Reclamation's Minidoka and Black Canyon Resource Management Plans, the Lucky Peak Reservoir water renewal contracts BA, the Wilderness Ranch (Mores Creek) BA, and the Blackbird Mine, Idaho BA.

Joseph S. Helfand

Office Location: Ann Arbor, Michigan

Education: M.S., Environmental Health Sciences
B.S., Chemical Engineering

Registrations: N/A

Related Experience:

- ✓ Modeled water quality for conventional or toxic pollutants in more than 30 rivers and 10 lakes and bays
- ✓ Modeled contaminated sediments at seven different sites
- ✓ Completed approximately 10 waste load allocation projects and modeled contaminated soil and groundwater for risk assessments and litigation support at three different land sites
- ✓ Performed various types of statistical analyses of environmental data and statistical methodology development at dozens of different sites
- ✓ Responsible for computer program and/or modeling technology development in more than 20 different projects

Mr. Helfand's expertise is in environmental engineering and project management for modeling and computer simulation of streams, lakes, estuaries, sediments, groundwater, and collection systems for conventional and toxic pollutants. As an environmental engineer with Limno-Tech, Inc. (LTI), he has handled a wide variety of projects that have often advanced the state-of-the-art in model development and application, and in the analysis and display of water quality data. He has been a principal contributor in the development of computer programs for various types of water quality modeling, including several developed for the U.S. Environmental Protection Agency. He has extensive experience in the statistical analysis of water quality data, often involving support of legal cases.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Fisheries technical lead. Examining the potential for meeting the dissolved oxygen (DO) standards for the reservoir, as developed by Washington Ecology. Focus is placed on the ability to meet the standards during summer stratification. Analysis for this project is conducted on the existing and proposed conditions at the fisheries, macroinvertebrates, and aquatic habitat levels. The goal of the project is to develop appropriate standards for DO within Lake Spokane. Conducted several series of scenarios for the Spokane River and Long Lake using the calibrated CE-QUAL-W2 model of the river in Washington in conjunction with a separate CE-QUAL-W2 application for the river in Idaho to provide upstream boundary conditions. Made hydraulic and loading modifications to the model, developed post-processing programs, and compiled comparisons of model results versus criteria.

Remedial Investigation, Feasibility Study, and Remedial Action for Chlorinated Solvent Impacts at Fayette, Ohio. Conducted statistical analyses, including trend analyses, for vinyl chloride in drinking water wells.

Litigation Support for Gwinnett County North Treatment Plant Permit. Performed dam outflow modeling and characterization for a lake in Georgia using the U.S. Army Corps of Engineers CE-QUAL-W2 hydrodynamic and eutrophication model.

2003 Report to Congress Assessing Technologies, Costs and Impacts and Environmental Benefits of CSO and SSO Control Programs. Conducted a series of statistical analyses to estimate national rates of SSO frequencies and their severity. Conducted statistical analyses to estimate distributions of receiving water

properties for the waters of the United States for modeling SSO water quality impacts.

TMDL Development for Phosphorus Loading in the Lower Catawba River Watershed. Performed statistical assessments of model calibration.

Wet Weather Impacts, Ohio River, West Virginia. Set up HEC-2 model of Ohio River.

Water Quality Model of E. coli Bacteria for the St. Joseph and Elkhart Rivers for the Cities of Elkhart, Mishawaka, and South Bend, Indiana. Assembled model inputs.

Environmental Permitting and Compliance Support to the Detroit Metropolitan Wayne County Airport. Performed statistical analyses to support prediction of upper control limits for BOD from laboratory analysis of COD, based upon time-stratified data sets.

Trends in Total PCB Concentrations in Surficial Sediment Deposits of a Wisconsin Lake. Performed statistical analyses to identify and quantify historical time trends of concentration of PCBs in defined depth ranges of multiple sediment deposits in a lake in Wisconsin.

NPDES Permit Evaluation for a Municipality in Northwest Ohio. Performed correlation analyses for river flows against lake seiches.

Analysis of Reservoir Water Quality Impacts. Used the U.S. Army Corps of Engineers CE-QUAL-W2 hydrodynamic model to investigate issues related to potential stratification of a reservoir in Kentucky planned to undergo expansion.

Analysis of NPDES Phosphorus Discharge Limits for a Facility in South Carolina. Identified areas in the watershed that are potential candidates for implementation of BMPs in connection with effluent trading of nonpoint source loads for point source loads.

Development of TMDLs for the Rock Creek Watershed Group within the District of Columbia. Created unified database of sparse sampling data for a large number of parameters in waters and sediments at several stations. Developed a series of cross-tabulational data analyses for answering questions of data adequacy and characteristics.

Renewal of an NPDES Permit for the Baltimore-Washington International Airport. Performed regression analyses to allow prediction of a desired variable, BOD_5, from a surrogate measure, COD. Established by covariance analysis that predictions were unaffected by season or choice of outfall being measured.

Development of a Stream Reaeration Coefficient and Modeling to Support a Dry Weather TMDL for Buxahatchee Creek, Alabama. Developed, applied and calibrated QUAL2K water quality model for Buxahatchee Creek for a range of complexity scenarios to support uncertainty analysis of dry weather TMDLs with respect to data availability.

Review of Chesapeake Bay Criteria and Water Quality Modeling, Potomac Estuary near Washington, D.C. Performed a preliminary evaluation of a watershed model model/data comparison for the Potomac River Fall Line.

Development of a Long-Term Control Plan for Combined Sewer Overflows in the City of Toledo, Ohio. Supported development of a Long-Term Control Plan through collection system hydraulic modeling with the SWMM model, water quality modeling with the WASP model, and statistical modeling of seasonal patterns of flow and seiche activity. Performed extensive analyses of SCADA databases in support of development of calibration metrics for SWMM modeling. Conducted multiple regression analysis and combined Monte Carlo/multiple regression analysis to develop upstream boundary condition time series of water quality parameters for water quality modeling with the WASP model.

Development of a Report to Congress on the Implementation and Enforcement of the National CSO Control Policy. Developed and implemented statistical methodologies to estimate national levels of Combined Sewer Overflow (CSO) event counts and volumes from limited data.

Louisville Area Wet Weather Demonstration Study. Modeling flow through a dam system.

Water Quality Support for the Wastewater Facilities Plan for Spokane County, Washington. Assisted Spokane County, Washington, with finding a site for a new wastewater treatment plant. Coordinated with regulatory agencies such as the Washington State Department of Ecology, and ran scenarios of water quality impacts on the Spokane River for the proposed plant and another major discharger, using models QUAL2E and CE-QUAL-W2. Ran additional scenarios with the CE-QUAL-W2 model for changes in proposed treatment plant location and effluent.

Fox River and Green Bay, Wisconsin PCB Fate and Transport Model Evaluation. Conducted and reviewed statistical analyses of

time trends of PCB concentrations in fish and sediments of the Fox River.

Spokane River Water Quality Management Plan: Supporting Studies and Analyses, Phase II. Managed the recalibration of eutrophication models CE-QUAL-W2 (U.S. Army Corps of Engineers) and QUAL2E (U.S. Environmental Protection Agency) to the Idaho reaches of the Spokane River. Phase II tasks included assessment of additional monitoring data, recalibration of Phase I models incorporating the new data, and scenario evaluation.

Completion of Kanawha River, Pocatalico River and Armour Creek Dioxin TMDL. Managed data collection, modeling, and source allocations for 2nd phase Total Maximum Daily Load (TMDL) development.

Assessment of Wet Weather Water Quality Impacts on the Ohio River. Linked hydrodynamic and water quality models of the Ohio River.

Modeling Support Services for the Truckee River - Phase III. Incorporated enhanced benthic algal processes into the Hydrologic Simulation Program – Fortran (HSPF) water quality model, with supporting model documentation. Developed and implemented a series of statistical measures to compare and contrast HSPF model results with results from another model in a calibration period, and to compare and contrast HSPF model results with observed data for several parameters.

Development and Implementation of a Deicing Runoff Control System for the T.F. Green Airport in Providence, Rhode Island. Led the development of a water quality model of dissolved oxygen depletion by stormwater containing deicing fluid.

Michael W. Mischuk

Office Location: Milwaukee, Wisconsin

Education: M.A., Biology
B.A., Biology

Registrations: Health and Safety Training for Superfund and RCRA Remediation Site Personnel

Related Experience:

- ✓ More than 28 years of experience evaluating both natural and anthropogenic disturbances to freshwater ecosystems
- ✓ Expertise is in algal, macroinvertebrate, and fish systematics, and biomonitoring of aquatic ecosystems

Mr. Mischuk is a senior freshwater ecologist primarily engaged in water resource management issues and the assessment of biological integrity of freshwater ecosystems. He is responsible for budgets, conducting field studies, and analyzing data and reporting on instream bioassessments as part of site characterizations and regulatory compliance issues. Mr. Mischuk has conducted ecological risk assessments as part of CERCLA hazardous waste sites and RCRA corrective actions and conducted ecological investigations and acted as a senior reviewer of ecological risk assessments for USEPA and as part of military base closures.

Project Experience

Lower Des Plaines River Use Attainability Analysis. Assisted in formulating the macroinvertebrate portion of the assessment. Discussion of macroinvertebrate indexes in relation to Illinois general use criteria and assessment of the current aquatic life use using MBI and ICI indexes.

Cedar Resources, Inc. and Union Gold, Inc., Colorado. Conducted an EA of Wayne's Creek which receives treated mine water from the inactive Platoro Mine. The assessment determined if Wayne's Creek could support a Class 1 - Coldwater Aquatic Life use classification, or whether a lesser classification or no classification was more appropriate. Results of this assessment resulted in regulatory relief for the Platoro Mine.

Minnesota Department of Natural Resources, Minnesota. Served as Field Operations Coordinator and Principal Investigator for a study to characterize periphyton populations in rivers and streams near a proposed copper/nickel mine. Obtained technical information to develop public policy and regulation for a new mineral industry in Minnesota.

Integrated Paper Services, Inc., Wisconsin. Investigated and evaluated the effects of effluent discharges on receiving stream water quality.

NPDES Permit Assistance, City of Boise, Idaho. Provided senior review for biomonitoring conducted by USGS.

Bioassessment of Ship Creek, Elmendorf AFB, Alaska. Performed bioassessment of associated ponds and streams as part of screening level ecological risk assessment. Developed work plans and field sampling plans. Characterized biological components of Ship Creek, which received accidental releases of petroleum hydrocarbons, principally JP-4 and diesel fuel.

Ecologist, Milwaukee Metropolitan Sewage District, Wisconsin. Developed update of current conditions of aquatic biota in watersheds within the sewage district's area.

Ecologist, ALCOA Aluminum, New York. Developed a scope of work to conduct bioconcentration studies as required by the New York State Department of Environmental Concentration for ALCOA's Massena (NY) Operations. The studies were used to monitor the bioconcentration of PCBs in biota exposed to plant effluents from outfalls 001 and 004.

Bio-Assessor, Federal Paper Board Company, North Carolina. Assisted in collecting macroinvertebrate and fish in the Cape Fear, Black, and Northeast Cape Fear Rivers, using rapid bio-assessment techniques. Information developed and evaluated during this year-long survey was used in a use attainability study to obtain regulatory relief from the North Carolina Department of Environmental Management.

Bio-Assessor, Champion Paper, Minnesota. Conducted a bio-assessment of Pigeon River as part of a Consent Order to

determine the effects of the company's effluent discharge on the biota of the river and whether Pigeon River was being maintained at its regulatory use attainment.

Bio-Assessor, Simpson Paper, Anderson, California. Conducted a long-term biomonitoring study in the Sacramento River to determine the effects of the effluent discharge on the biota below the discharge point. The study area is in a primary King salmon spawning area and as such is under extreme scrutiny by the California Department of Environmental protection and the general public.

Ecological Assessment, Central Utah Water Conservation District, Roosevelt, Utah. Delineated aquatic communities as part of an EA of several streams (Unita River, Lake Fork River, Whiterocks River, and Yellowstone River). EA was part of an EIS to create five new reservoirs to increase water resources within their water distribution system.

Ecological Assessment, Cedar Resources, Inc. & Union Gold, Inc., Platoro, Colorado. Conducted an EA of Wayne's Creek, which receives treated mine water from the inactive Platoro Mine. The objective of the assessment was to determine if Wayne's Creek could support a Class 1—Coldwater Aquatic Life use classification or whether a lesser classification or no classification was more appropriate. Results of this assessment resulted in regulatory relief for the Platoro Mine.

NPDES Permit Assistance, City of Boise, Idaho. Acted as senior review for biomonitoring conducted by USGS for the City of Boise.

Task Lead, Initial Phase Stormwater/Watershed Assessment Program, Henrico County, Virginia. Mr. Mischuk served as task lead for biological assessments within the selected watersheds in Henrico County. His responsibilities included selection of appropriate assessment sites, leader for biological assessment efforts, and evaluation of resulting data.

Senior Biologist, Integrated Paper Services, Inc., Appleton, Wisconsin. Responsibilities included the design and implementation of research to investigate and evaluate the effects of effluent discharges on receiving stream water quality.

Associate Scientist, The Institute of Paper Chemistry. Spent 12 years conducting investigations to assess effects of pulp and paper wastewater discharges on freshwater ecosystems. Work included instream bioassessments with macroinvertebrates and algae as indicators of biological integrity. He also used bioassays to perform compliance monitoring for NPDES permits and conducting eutrophication assessments using algal bioassays and nutrient loading modeling. Several of these investigations were of the Lower Fox River, Wisconsin. Developed an instream assessment technique that uses filter-feeding caddisfly larvae to determine dioxin and furan levels. The technique was used as a quick response method for evaluation of in-plant remediation effectiveness.

Aquatic Biologist, Minnesota Department of Natural Resources. Served as field operations coordinator and principal investigator for the design and implementation of a study to characterize periphyton populations in rivers and streams proximate to a proposed copper/nickel mine. The work included obtaining technical information for development of public policy and regulation for a new mineral industry in Minnesota.

Water Quality Evaluation, Prince William County, Virginia. Conducted an initial evaluation of water quality in Neabsco Creek, Hooes Run, Powells Creek, Catherpin Run, Little Bull Run, Beaver Dam Branch, Broad Run, Crooked Creek, Slate Run, and Quantico Creek using benthic macroinvertebrate community structure and indicators. This study was part of a county wide watershed management plan.

Chattahoochee Biological Survey, City of Atlanta, Georgia. Objectives of this project were to: 1) determine if the State-designated use for fish and aquatic life was being attained in the study area, 2) provide background information about water quality in the Chattahoochee River at biological sampling locations, 3) provide background information about chemical contaminants in edible fish tissue, and 4) satisfy requirements of a Consent Order by providing information about the quality and health of the Chattahoochee River.

Bioassessment of Ship Creek and Associated Ponds and Streams, Elmendorf Air Force Base, Alaska. Conducted this bioassessment as part of screening level ecological risk assessment. Developed Work Plans and Field Sampling Plans. Conducted field investigation to characterize biological components of Ship Creek which received accidental releases of petroleum hydrocarbons, principally JP-4 and diesel fuel.

Field Investigations/Ecological Risk Assessment, Lackland Air Force Base. Conducted these activities for OT-12 and CF-27 sites as part of base closure actions.

James Ollerenshaw

Office Location: Portland, Oregon

Education: M.A., Organic Chemistry
B.Sc., Chemistry

Registrations: N/A

Related Experience:

- ✓ Currently serving on Oregon DEQ committee providing advice on UAA guidance
- ✓ Experience in federal and state water quality regulations, water quality criteria and water quality-based permitting, and water quality survey planning and data analysis
- ✓ Experienced in NPDES municipal stormwater permit application and negotiation and municipal stormwater management plan preparation

Mr. Ollerenshaw has more than 25 years of experience working on water quality issues, including federal and state water quality regulations, water quality criteria, water quality-based permitting, and water quality survey planning and data analysis. Before joining CH2M HILL, Mr. Ollerenshaw was the technical services manager for the Public Works Department for the City of Eugene, Oregon, where he gained considerable experience in National Pollutant Discharge Elimination System (NPDES) wastewater and storm water permitting. Through years of experience, Mr. Ollerenshaw has developed a broad understanding of water quality issues. He has performed numerous reviews of proposed state and federal legislation pertaining to water quality, and has participated in the development of Oregon's water quality standards.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology.

UAA Guidance, Oregon Association of Clean Water Agencies. Currently representing the Oregon Association of Clean Water Agencies on the Oregon Department of Environmental Quality's advisory committee charged with assisting the Department in its development of UAA guidance. Extensive experience in the development and revision of water quality standards, including membership in Oregon DEQ's Policy advisory Committee for triennial Review of water quality standards.

Clean Water Services Watershed-Based Permitting Project. Managed this multi-year project that will result in a documentable process and regulatory framework that will demonstrate the feasibility of transitioning from a conventional NPDES permit approach to a watershed-based NPDES permit. A water quality trading program is also being developed, which will include inter treatment plant trading for oxygen demanding substances, and a watershed trading program for temperature.

NPDES Stormwater Permitting Program Development, Oregon. Worked with DEQ to help the state plan for and implement both the Phase I and the Phase II stormwater permitting programs. For Phase I, was a key participant in a group of Oregon Association of Clean Water Agencies (ACWA) members who worked with DEQ permitting staff to develop the language of the Phase I NPDES permits. For the Phase II program, was a member of DEQ's "Stormwater Think Tank" working on the development of the Phase II program, including the structure and language of the Phase II general permit. Chaired an ACWA subcommittee that worked on issues regarding the renewal of the Phase I permits, and the group helped DEQ develop a revised version of the general conditions for the NPDES stormwater permits.

Experience Prior to CH2M HILL

NPDES Wastewater Permit Negotiation, City of Eugene, Oregon. As technical services manager for the City of Eugene, responsible for negotiating the NPDES permit for the regional Eugene/Springfield wastewater treatment plant in 1992 and 2002. Included developing technical information and strategic planning for the regional wastewater treatment plant, and preparation of reports, recommendations, and negotiating NPDES permit conditions.

NPDES Stormwater Permit Development and Negotiation, City of Eugene, Oregon. Key staff member involved in the selection of best management practices for inclusion in the City of Eugene's stormwater management plan required for the City's Phase I NPDES stormwater permit application. Author of water quality chapter of the City's Comprehensive Stormwater Management Plan. Participated in negotiation of Eugene's Phase I permit with Oregon DEQ. This permit negotiation was critical, because it was the first Phase I permit issued in Oregon, and the second issued nationwide. Worked with DEQ staff to develop the City's Memorandum of Agreement with DEQ, which enabled the City to take over administration of the DEQ NPDES permitting program for industrial stormwater discharges.

NPDES Stormwater Permit Implementation and Management, Oregon. While at the City of Eugene, was responsible for ensuring compliance with the City's NPDES municipal stormwater permit, and for the annual report. Managed a review of the City's stormwater management plan in 2000 as part of the application for permit renewal. This review resulted in a revised management plan, including both new and modified BMPs.

Stormwater Pollution Prevention Development for Municipal Operations, Oregon. Served as Chair of the City of Eugene's Environmental Review Team. Following a comprehensive review performed by a consultant on the potential environmental impacts of the City's activities, this team was responsible for developing and implementing appropriate changes to priority activities to reduce the potential negative environmental impact. In many cases this was a stormwater quality impact, and numerous changes to City procedures have been implemented as a result of this review, including activities such a vehicle washing, stormwater channel maintenance, parking lot maintenance, etc.

Water Quality Pollution Prevention, Eugene Industrial Pretreatment Program, Oregon. Managed the City of Eugene's industrial pretreatment program, which controls discharges from commercial businesses into the sanitary sewer system. This program received a national excellence award from the Environmental Protection Agency. Also managed the City of Eugene's program for industrial stormwater regulation and enforcement.

Wastewater Discharge Permits, Two Large Industrial Dischargers, Eugene, Oregon. Oversaw development and negotiation for the permits issued by the City of Eugene to control pollutants in wastewater discharge. The location of these high-tech industries in Eugene was the focus of considerable public opposition. Managed the technical issues in the permits, the interactions with the industry representatives, communication with the city council, and the public participation process.

Development and Implementation of an Environmental Management System (EMS) in the Wastewater Division, City of Eugene, Oregon. Managed the division's development and implementation of an environmental management system for the wastewater facilities. The EMS was registered as conformant with ISO 14001 standard in October 2001. This was the first public agency in Oregon to achieve ISO 14001 certification.

American Water Works Association Research Foundation. As principal investigator, conducted research and developed a model EMS for drinking water utilities.

Kurt Playstead

Office Location: Bellevue, Washington
Education: B.S. (cum laude), Economics. MBA
Registrations: N/A
Related Experience:

- ✓ Experience conducting water and sewer utility rate analysis, including cost-of-service rate modeling
- ✓ Analyses also include projecting sources and uses of funds, developing revenue requirements, and calculating required rates
- ✓ Economic modeling technical lead for U.S. Air Force utilities privatization projects in Massachusetts, North Carolina, Arkansas, Michigan, Tennessee, and Alaska

Mr. Playstead is an economist with the Water Group in CH2M HILL's Bellevue, Washington, office. He performs research and data analysis for water, energy, and transportation projects in the Northwest region. He has developed water and sewer utility rates, including cost-of-service rate modeling, cost-of-service analyses, incorporation of revenue requirements, water use characteristics, and separate classifications for residential and retail customers. Mr. Playstead's economic research in the Northwest includes literature reviews, collecting and analyzing statistical data, and comparative analysis.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Economist currently conducting an economic impact assessment in conjunction with the UAA for the Spokane River. The impact assessment will examine whether the different alternatives analyzed in the UAA would result in substantial economic impacts to the communities involved in the study. The economic impact analysis utilized EPA guidelines to assess the potential impact.

Water and Sewer Systems Financial Analysis, City of Bend, Oregon. Economist responsible for conducting financial analysis for water and sewer systems for the city. The financial analysis included projecting sources and uses of funds and estimating impacts to existing rates of implementing a proposed capital improvement plan.

Water and Sewer Systems Financial Analysis, City of The Dalles, Oregon. Economist responsible for conducting financial analysis for water and sewer systems for the city. The financial analysis included projecting sources and uses of funds and estimating impacts to existing rates of implementing a proposed capital improvement plan.

Stormwater Rate Analysis, City of Newcastle, Washington. Economist and project team member that completed a stormwater rate analysis study that estimated the impact to current stormwater rates of implementing a proposed capital improvement project (CIP). Tasks included updating the financial analysis model and developing different rate scenarios.

Service Rate Studies, Jordan Valley Water Conservancy District, Utah. Economist involved in costs-of-service rate studies and updates for water, sewer, and solid waste. The study contained system revenue requirements, water use characteristics, and recommended water rates.

Service Rate Studies, City of Tigard, Oregon. Economist involved in costs-of-service rate studies and updates for water, sewer, and solid waste. Performed financial modeling for cost-of-service rate studies.

Financial Analysis, City of Port Angeles and Grays Harbor County, District No. 7, Washington. Economist responsible for completing the financial analysis section of water system updates. The analysis was conducted to estimate the impact to existing rates of

implementing a proposed CIP. Tasks included construction of an Excel-based economic model, projection of sources and uses of funds, and documentation of the results.

Water Rates Analysis, City of Port Angeles, Washington. Economist responsible for conducting an analysis to determine the impact on the city's water rates if the city purchased a local utility district (LUD). The analysis included developing values of the LUD's water system, calculating the net present value of the LUD's future earnings, and estimating impacts to the city's water rates of purchasing the LUD.

Rate Analysis, City of Millersburg, Oregon. Economist responsible for performing a rate analysis for the City of Millersburg to determine the impacts on rates of the city building its own supply and treatment system. The analysis compared different financing scenarios to the alternative of purchasing services from the City of Albany. The study developed a cost per equivalent dwelling unit for the different alternatives to determine cost-effectiveness.

Start-up Propane Gas Utility Economic Assessment, Southeast Alaska. Economist and part of a team that conducted an economic assessment of a start-up propane gas utility. Tasks included building and maintaining an economic model, conducting research, and documenting results.

U.S. Air Force Utilities Privatization, Feasibility Analysis Report for Projects in Texas, Massachusetts, North Carolina, Arkansas, Tennessee, Michigan, and Alaska. Economic model technical lead. Performed economic analysis for USAF Utilities Privatization, Feasibility Analysis Report for projects in Texas, Massachusetts, North Carolina, Arkansas, Tennessee, Michigan, and Alaska. Conducted the economic modeling for the Life Cycle Cost Comparisons which compared the operating cash flows of the Air Force to a private operator.

Economic Research for Water, Energy, and Transportation Projects, Washington State Department of Transportation (WSDOT), Northwest Region (Washington, Alaska, Oregon). Economic researcher for water, energy, and transportation projects in the Northwest region, which included literature reviews, collecting and analyzing statistical data, and comparative analysis for WSDOT projects. Involved in collecting and analyzing data for the preliminary report for the State of Alaska Energy Plan. Performed economic research for the Northwest Power Planning Council's *Multi-Species Framework Process* to assess the socio-economic impacts of the salmon recovery program in the Columbia Basin.

State Route 509 South Airport Access Environmental Impact Statements and Environmental Assessments, Washington. Economic analyst responsible for describing the affected economic environment and discussing the operational, construction, and financial impacts of the different alternatives.

D Street Grade Separation Project, Tacoma, Washington. Economic analyst responsible for describing the affected economic environment and discussing the operational, construction, and financial impacts of the different alternatives.

Benefit/Cost Analyses for Transportation Projects in Washington and Wisconsin. Economist responsible for conducting benefit/cost analyses for transportation projects in Washington and Wisconsin. Worked on benefit/cost studies for the Interstate 405 Multimodal Corridor Study (Washington), Bridge the Valley Corridor Project (Washington), and Park East Freeway Project (Wisconsin). Tasks have included data collection, model development, and documentation of the results.

David T. Reynolds, P.E.

Office Location:	Bellevue, Washington
Education:	M.S., Civil Engineering, University of Washington B.S., Civil Engineering, Washington State University
Registrations:	Professional Engineer: Alaska, Oregon, Washington CH2M HILL Certified Project Manager

Related Experience:

- ✓ Technical expert in wastewater treatment and wastewater residual solids
- ✓ Project administrator, project manager, and senior consultant on a wide range of wastewater projects for municipal clients in Washington, Oregon, Idaho, and Alaska
- ✓ Developed solids handling system concept for West Point secondary treatment facilities design
- ✓ Expertise in CFR 503 regulations and anaerobic digestion technologies

Mr. Reynolds is a senior project manager with the Water Group in CH2M HILL's Seattle office. He is a technical expert in wastewater treatment and, in particular, wastewater residual solids. He has served as project administrator, project manager, and senior consultant on a wide range of wastewater projects for municipal clients in Washington, Oregon, Idaho, and Alaska. As a project administrator, he oversees the execution of engineering work and advises clients with regard to selecting the best options for successful project completion. His working knowledge of wastewater treatment allows him to quickly focus on potential treatment alternatives.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Developed costs for Spokane's Riverside Park Water Reclamation Plant to provide coagulation, sedimentation and effluent filtration and reverse-osmosis treatment to allow evaluation of the economics of phosphorus removal.

LOTT Biosolids Management Plan, Olympia, Washington. Led the technical analysis of biosolids management alternatives. The recommendation included a phased implementation of green waste and biosolids composting using aerated static pile composting. The initial phase included adding a third contractor to two existing contracts with Northwest Cascade, a private composting company, and Burnt Ridge Ranch, a private farm. The evaluation included technical, environmental and public participation elements conducted in a coordinated planning process.

Port Townsend Composting Project, Washington. Project manager for planning, permitting, design, construction management, operator training and startup of an aerated static pile composting project that composts biosolids, green waste, and septage. Odor control is accomplished with a biofilter. The product meets all EPA 503 requirements easily. Public reaction to the project and the product has been extremely favorable.

Bremerton Silviculture Land Application, Washington. Project manager for the study, development, and implementation of an innovative silviculture application program for biosolids. This project won a Consulting Engineering Council of Washington award for excellence. Design criteria development, site selection, onsite investigations, and application techniques were part of his responsibilities. Senior consultant for a new city-owned site and sludge management plan.

Comprehensive Solid Waste Management Plan (CSWMP), Spokane County, Washington. Solids task leader for the organics sections of the 1997 Spokane County CSWMP. Wrote a description

of existing system needs and opportunities, identified new technologies, and recommended system improvements.

Yakima Regional Wastewater Treatment Plant NPDES Permit, Preston, Gates and Ellis, Seattle, Washington. Project manager for review of the Yakima Regional Wastewater Treatment Plant's NPDES permit with special emphasis on ammonia and metals. Worked closely with Ecology and the City of Yakima develop an approach to an NPDES permit that met both Ecology's and the City's needs. The next NPDES permit will consummate the analysis and data gathering initiated during the previous NPDES permit review. Lead process engineer for an AKART analysis of options to dispose of Del Monte's industrial wastewater to the City of Yakima's Regional Wastewater Treatment Plant. Developed a solution to treating Del Monte wastewater using the existing City wastewater treatment plant and Pro2D.

LOTT Headworks and Solids Handling Improvements, Olympia, Washington. Project manager for the planning, design, construction, and start-up services for a new high solids dewatering centrifuge. Project costs were significantly reduced by a pilot test of competing centrifuge manufacturers and prepurchase of the centrifuges. Project manager for planning, design, and construction of replacement bar screens. Escalator perforated plate screens will replace existing bar screens.

Spokane Program Management, Spokane, Washington. Process engineer for the development of design of solids and liquids processes. Solids processes included gravity belt cothickening of primary and secondary solids, anaerobic digestion, and belt filter press dewatering of biosolids. Liquids conceptual design included chemical primary treatment, CSO treatment using ballasted sedimentation, activated sludge with fine bubble diffused air in deep aeration basins and high-efficiency blowers, addition of anoxic selectors and nitrification and phosphorus removal using alum, effluent filtration with potential for future reuse, and UV disinfection. Developed innovative recuperative thickening approach using existing dissolved air flotation thickeners that have reduced overall polymer costs and reduced biosolids production by over 15 percent with no increase in labor requirements.

Fairwood Lagoons Decommissioning, Spokane County, Washington. Senior consultant for decommissioning the Fairwood wastewater lagoons. Work involved senior oversight on a review of existing data on sludge and groundwater in the area, a summary of pertinent regulations and permit requirements, preparation of a sludge sampling and testing plan, preparation of a biosolids application operations plan, and a disposal site permit application.

Spokane Advanced Wastewater Treatment Plant Aeration System Upgrade, Washington. Project manager for process selection and design of the aeration system for this 40-mgd AWT plant. The existing slow-speed mechanical surface aerator is being replaced with a fine-bubble diffused-air system. The design includes instrumentation and control and analysis and selection of blower technology. The system was selected for high-efficiency operation and minimum maintenance.

Seattle Metro Sludge Management Plan, Washington. Managed the sludge management plan in the early 1980s. The evaluation included analysis of various methods of beneficial use of biosolids and analysis of sludge processing alternatives at both the Renton and West Point wastewater treatment plants.

Water Program Initiation, Seattle, Washington. Initiated Seattle Metro water reclamation/reuse program to contribute to the optimal use of limited water supplies in the region. Water supplies in the utility are constrained by instream resource needs and an unusual seasonal availability of water.

John F. Spencer

Office Location: Bellevue, Washington

Education: M.S., Regional Planning and Resources Development
B.A., Urban Planning

Registrations: N/A

Related Experience:

- ✓ Currently managing a UAA focused on a portion of the Spokane River in Washington
- ✓ Previous work at the Washington Department of Ecology, Seattle Metro and Snohomish Public Utility District resulted in many successful projects delivered within challenging environmental conditions
- ✓ Specializes in utility management, water quality law and regulatory analysis, planning processes, and collective bargaining
- ✓ Conducted numerous "competitive assessments" and benchmarking studies in his utility management and consulting practice

Mr. Spencer has more than 31 years of experience in public utility and related management. As director of CH2M HILL's Competitive Solutions practice, he provides innovative leadership by bringing together years of hands-on utility management with current organizational theory and problem-solving skills. His experience as a wastewater and electric utility director provides a unique background in the provision of public utility services in today's competitive world. He has led competitive assessments and developed and implemented transforming business planning processes in his own and client utilities. He has been successful in achieving cost-saving goals in a tripartite setting of labor, management, and government regulation. Prior to joining CH2M HILL, Mr. Spencer served as the Director of the Water Pollution Control Department of Seattle Metro, now the King County Wastewater Treatment Division.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Serving as project manager for a UAA that will determine what the existing and attainable uses of the river and reservoir are, and to define DO criteria that would be protective of those uses. This was necessary because it appeared that the currently designated uses were not appropriate, and hence the associated DO criteria also needed to be refined. Although the UAA is still underway, it is hoped that refinement of the uses and criteria will lead to development of a DO TMDL that will be focused on attainable conditions and a more rational outcome than forcing dischargers out of the river at extreme costs.

Bond Feasibility Study and CSO Benchmarking Report, Portland Bureau of Environmental Services, Oregon. Preparation of a bond feasibility report which documented the maintenance and operation practices, capital improvement program management, asset conditions, and financial condition of the utility. The study also reviewed Portland's Combined Sewer Overflow program in light of recent EPA audit of the program and prepared a benchmark report on how well Portland's program compares with other comparable sized agencies in the nation.

Brightwater Siting Project, Seattle, Washington. Principal-in-charge and project manager for the siting project and a member of the Brightwater Project Executive Committee, which is overseeing the project implementation. Providing leadership for the regulatory and permitting process requirements and advising on the siting decision criteria.

West Point Secondary Treatment Plant, Seattle, Washington. Managed the siting of King County's (formerly Seattle Metro) largest wastewater treatment plant to comply with state and federal regulations, negotiating a $30-million mitigation plan/siting agreement with local jurisdictions. Took a direct role in setting a vision for the West Point Treatment Plant mitigation design insisting on an integrated approach to the engineering, architecture, and landscape architecture that would create a "world class" urban asset for Seattle and the region.

Utility Worker Contract Negotiations. Negotiated a "breakthrough" contract with International Brotherhood of Electrical Workers to achieve significant flexibility in work rules, crew size, work hours, standby crews, and emergency call-out provisions.

South Division Plant, King County, Renton, Washington. While Director at Seattle Metro, responsible for two project expansions at King County's South Division Plant at Renton. Developed concepts for this plant and negotiating the mitigation agreement with the City of Renton. As urban development moved in around the plant, development of the campus-like layout and surrounding mitigation evolved to create an urban asset in Renton.

Solids Processing Facilities Improvement Facilities Plan, Metropolitan Council of Environmental Services, Minneapolis–St. Paul, Minnesota. Managed the preparation of a facilities plan to select a solids processing technology and site for the Council's 250-mgd wastewater treatment plant proposed solids processing facilities. The project was developed in response to the aging and high maintenance cost of the existing multiple hearth incinerators and to air quality noncompliance issues. The project is one of the largest capital projects the Council is implementing for its wastewater utility; it is also one of the more controversial, due to the sensitive choice between incinerators, dryers, and land application of sludge. The facility plan had a budget of $1.8 million with a fast-track schedule of 1.5 to 2 years. Mr. Spencer completed the facility plan on schedule and under budget.

King County Infiltration and Inflow (I/I) Program Development Study, King County, Washington. Played a key role in the first phase of the project, facilitating the involvement of the 32 component wastewater agencies and assisting King County in assessing policy and regulatory aspects of I/I control. CH2M HILL was retained by King County in 1998 to provide engineering support to initiate the Regional I/I Control Program. The initial phase of this project, which is expected to last through the year 2010, calls for the assessment of 32 local sewer districts that operate as "tributaries" within the County system. Phase II of this program will be the design and construction of local projects that are deemed regionally significant and cost-effective.

Development of Strategic Water Quality Management Plan, Seattle Public Utilities, Seattle Washington. Assisted Seattle Public Utilities (SPU) in developing a Strategic Water Quality Management Plan to more effectively use SPU's resources to meet the challenges they face as a utility. The Strategic Water Quality Management Plan outlines a framework for improving integration of SPU's water resources programs using a watershed approach. This integrated approach will allow the utility and the City to creatively address their multiple water quality challenges, both on an individual watershed scale and citywide.

Loop IV Routing Selection Process, Anchorage Water and Wastewater Utility, Anchorage, Alaska. Managed the decision process for the final selection of the Loop IV water supply pipeline project, the last major and most controversial element of the Anchorage Water Supply loop system. The project made use of extensive public involvement, a mayoral appointed advisory committee and decision modeling tools to arrive at a preferred routing alignment for this last phase of the loop project.

Honolulu Board of Water Supply Long-Range Facilities Plan, Hawaii. Benchmarking and process evaluation task manager for the comprehensive evaluation of the entire water system for the Honolulu Board of Water Supply. The plan included a benchmarking study of peer agencies to determine best practices and a program process evaluation to determine resource requirements to implement a long-range repair and replacement program.

Competitiveness Assessment, Miami-Dade Water and Sewer Department, Florida. Directed management consulting services for preparation of competitiveness assessment, which identified cost-saving opportunities for WASD in numerous areas, including maintenance management and gas and electrical energy. Directed the development of an Automation Master Plan for the Department's water and wastewater treatment plants.

Electric and Water Supply Utility Management, Snohomish County, Washington. Managed the electric and water supply utility for Snohomish County. Reorganized the utility's management structure; revised the labor negotiations process; created high-

involvement employee processes; guided rate equity and cost-of-service studies through policy deliberations with the PUD commission; and reorganized the energy dispatch/crew dispatch center. Mr. Spencer also structured the PUD's capital improvement program at $50 million yearly with financing that included both long- and short-term borrowing and an interest rate swap to lower overall utility debt service.

Water Program Initiation, Seattle, Washington. Initiated Seattle Metro water reclamation/reuse program to contribute to the optimal use of limited water supplies in the region. Water supplies in the utility are constrained by instream resource needs and an unusual seasonal availability of water.

Greg White

Office Location:	Portland, Oregon
Education:	M.S., Oceanography (emphasis on fisheries) B.S., Fishery Science
Registrations:	Washington Department of Natural Resources Watershed Analysis Certification NAUI Scuba Diving Certification, Open Water II

Related Experience:

- ✓ 19 years of experience in fisheries management strategy and policy development, with expertise in aquatic habitat and watershed impacts assessment and evaluation
- ✓ In-depth experience in fisheries management strategy and policy development, with expertise in aquatic habitat and watershed impacts assessment and evaluation
- ✓ Extensive National Pollution Discharge Elimination System, U.S. Army Corps of Engineers 404, Clean Water Act (401), and National Environmental Policy Act (NEPA) permitting and permit compliance experience
- ✓ Extensive Endangered Species Act consultation and compliance experience.
- ✓ Conducts various studies and participates in environmental assessments and environmental impact statements for proposed actions to fish habitat and populations, particularly salmonid species

Mr. White is a fisheries biologist with extensive experience in National Environmental Policy Act (NEPA) permitting, Endangered Species Act (ESA) compliance, fisheries policies, fish habitat evaluations and restoration, water quality, population dynamics, and ecology. Much of his aquatic ecology work has involved salmonids, including salmonid species listed under the federal ESA. He has supervised and conducted numerous and extensive salmonid stream and lake surveys, habitat evaluations, aquatic resource inventories, and water quality assessments in Oregon, Washington, Alaska, New Mexico, Texas, and Virginia.

Mr. White's responsibilities include project management, permitting and regulatory compliance, study design, data analysis and interpretation, laboratory management, and data collection. He has managed and conducted studies as part of environmental impact statements and resource inventories in Oregon, Washington, Alaska, New Mexico, Texas, and Virginia. Mr. White has made policy and management recommendations based on environmental regulation evaluation and analyses and field surveys and analyses in accord with the Clean Water Act, NEPA, ESA, Resource Conservation and Recovery Act (RCRA), and best management practices (BMP) guidelines to local, state, and federal agencies. He works closely with clients and agencies to resolve environmental conflicts and develop management strategies to meet the needs of the client and comply with local, state, and federal regulations.

Project Experience

Spokane River and Long Lake Reservoir UAA, Washington. The objective of this UAA is to describe the existing and attainable aquatic life uses of the river and reservoir, and to define dissolved oxygen criteria that are protective of those uses. The UAA includes detailed information on the scientific basis for the recommended uses and criteria, and on the options and costs associated with implementation of the recommended standards. The UAA was sponsored by a consortium of municipalities and industries in the watershed, both in Idaho and Washington. The need for the UAA was prompted an ongoing DO TMDL being developed by the Washington Department of Ecology. Fisheries biologist for the Spokane River UAA which required evaluating past, current, and future fisheries and beneficial uses of the Spokane River in eastern Washington. Fisheries and macroinvertebrate data for the Spokane River was evaluated, summarized, and data gaps were identified. Evaluation of data included analyzing potential future fish and beneficial use including

water quality attainability given the many parameters including agency resource management goals, hydrology, reservoir management, and land use that affect fish, beneficial use, and water quality in the basin.

Fisheries Task Manager, NPDES Permit Application Projects, Clean Water Services and City of Troutdale, Oregon. Fisheries task manager for the Rock Creek and Durham: Clean Water Services, and City of Troutdale projects, which required U.S. Army Corps of Engineers 404 wetland removal/fill and Clean Water Act (401) permits in addition to NPDES permits. Required identifying water quality and ESA constraints and negotiating with Oregon Department of Environmental Quality (DEQ) and other regulatory agencies, including the Oregon Department of Fish and Wildlife, U.S. Army Corps of Engineers, and National Marine Fisheries Service (NMFS). Prepared biological assessments, in compliance with Section 7 of the ESA, addressing potential impacts to listed or proposed fish species. The receiving waters are the Tualatin, Sandy, and Columbia rivers.

Fisheries Task Leader, Scoggins Dam Water Supply Feasibility Study, Washington County, Oregon. This project involves evaluating the feasibility of potentially raising Scoggins Dam to increase the reservoir storage capacity. Fisheries habitat surveys were completed on major tributaries of Hagg Lake, including Scoggins Creek. In addition, steelhead redd surveys were conducted in Scoggins Creek downstream of Scoggins Dam.

Instructor, Fisheries Portion of Stream Restoration Workshop, Clean Water Services and Stop Oregon Litter and Vandalism (SOLV). Led workshop, which was hosted Clean Water Services and SOLV. The course provided enhancement training to local Tualatin watershed agency personnel interested in increasing their technical knowledge and effectiveness with large-scale community-based projects and permitting. The fisheries portion of the course emphasized salmonid ecology, fish habitat, salmonid habitat requirements by life stage, water quality, geographical differences in habitat, elevational habitat differences, priority enhancement/restoration areas, enhancement/restoration techniques, and monitoring.

Tualatin River Watershed Council, Oregon. Member of this council, which completed an action plan for the Tualatin Basin. Provided direction, technical information, professional expertise, and review input. Currently actively involved in implementing the action plan, which includes prioritizing stream reaches throughout the basin for restoration using an innovative prioritization matrix that he helped develop. Previously has served as chairman of the Watershed Action Plan subcommittee, member of the council's Technical Advisory Committee (TAC), and liaison between the council and the TAC.

Environmental Construction Manager, Barney Reservoir Expansion, Barney Reservoir Joint Ownership Commission, Hillsboro, Oregon. Environmental construction manager, which included providing oversight and guidance on environmental issues and coordinating among state and federal agencies, the project owner, and contractors. Designed and constructed stream restoration along 3,000 feet of the Middle Fork North Fork Trask River. Also provided oversight of wildlife and wetland mitigation activities.

Fisheries Biologist, Stream Corridor Enhancement Plan, Ash Creek in Urban Washington County, Oregon. Manager and fisheries biologist for implementing the plan, which provided creek bank erosion control, filtering of storm flows in the creek, and shading for stream temperature reduction. The project benefited fisheries, water quality, and flood management in Ash Creek and downstream areas. The project also increased neighborhood understanding of the creek system and promoted stewardship.

Task Manager, Aquatic Resources, Wastewater Facility Expansion and NPDES Permitting, City of Dallas, Oregon. Task manager for the aquatic resource portion of the expansion. Project involves discharge to a stream that has been placed on the 303(d) list and supports petitioned ESA and state-sensitive anadromous fish species. Required conducting environmental risk assessments and providing environmental documentation supporting policy decisions and regulatory compliance relating to fish passage statutes and Oregon DEQ NPDES regulations. The permit also included obtaining a waiver of state temperature standards, which required approval by the DEQ Commission, the policy and administrative body of DEQ. This was the first permit of its type to be authorized in Oregon.

Fisheries Task Manager, Mercer Reservoir Expansion Project, City of Dallas, Oregon. Fisheries task manager for the project, which involves increasing the city's municipal water supply by expanding the reservoir capacity, and evaluating alternatives for constructing another reservoir on the system. The stream system supports ESA and state-sensitive anadromous fish species. This task involves collecting and analyzing data to support environmental assessments and providing environmental documentation supporting policy decisions and

regulatory compliance relating to Oregon fish passage statutes and the ESA.

Fisheries Task Manager, Environmental Review Services Project, City of Eugene, Oregon. Fisheries task manager to determine federally listed, proposed, or candidate species use as well as other natural resources use/presence within the Eugene area. Conducted an assessment of city practices and policies and evaluated these practices and policies for compliance with the ESA and other federal, state, and local legal requirements. Evaluated impacts of city actions on the environment and developed an overall City environmental management system for use in future years.

Cogeneration Plant Outflow Pipelines, CRSS, Southwestern Washington. Managed, supervised, and conducted aquatic surveys, and prepared aquatic resource inventory and potential impact reports of the associated EIS, to assess fisheries habitat and potential near the proposed plant and for the associated water intake and outflow pipelines that could affect numerous streams and rivers. Possible impacts and fisheries production in potentially affected systems were assessed for compliance with NEPA, the Clean Water Act, BMP, and NPDES guidelines and procedures with recommendations for enhancement opportunities and mitigation measures addressed. Impacts to anadromous and resident salmonid species and Washington and federal species of concern were emphasized. All stream crossings required agency review for the instream work permits, including Hydraulic Project Approvals (HPAs).

Cogeneration Plant Natural Gas Pipeline, Westinghouse, Southwestern Washington. Managed, supervised, and conducted aquatic surveys to assess fisheries habitat and potential near a proposed plant, and for the associated 50-mile natural gas pipeline that crosses numerous streams, rivers, and wetland areas. Also prepared an aquatic resource inventory and impact reports for the associated EIS. Assessed possible impacts and fisheries production in potentially affected systems with regard to NEPA, the Clean Water Act, NPDES, and BMP guidelines and procedures. Recommended site-specific enhancement opportunities and mitigation measures to minimize or alleviate negative impacts to fisheries, emphasizing anadromous and resident salmonid species as well as Washington and federally designated species of concern. Provided information and assisted in obtaining required HPA for instream work.