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PUBLIC UTILITY DISTRICT

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April 16, 2015

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
Mail Code: DHAC, PJ-12
888 First Street, N.E.
Washington, D.C. 20426

RE: Priest Rapids Hydroelectric Project P-2114-252 Compliance Filing – Article 401(a)(15) Implementation Feasibility Study Plan and Article 405 Investigation of Habitat Modifications in the Wanapum Tailrace

Dear Secretary Bose:

The Federal Energy Regulatory Commission (FERC) issued the Priest Rapids Hydroelectric Project License No. P-2114 (Project) on April 17, 2008. Article 401(a)(15) of the FERC license order required that the Public Utility District No. 2 of Grant County, Washington (Grant PUD) file for FERC approval, within four years of issuance date of the license, an Implementation Feasibility Plan (IFP). The IFP is a requirement contained within the license as well as supplemental agreements and authorizations incorporated into the license by FERC. These agreement and authorizations include the Washington Department of Ecology (WDOE) 401 Water Quality Certification (WQC) for the Project, as well as the Hanford Reach Fall Chinook Protection Program (HRFCPP).

Prior to the IFP Grant PUD, in consultation with the Fall Chinook Work Group (FCWG), was to develop a Implementation Feasibility Study (IFS: Section 6.3(7)(a) of the WQC). As part of the IFS, Grant PUD was required to investigate the feasibility of modifying the Wanapum Dam tailrace to increase the amount of fall Chinook salmon spawning habitat (License Article 405). Given the similar nature and interconnections between the various requirements (IFS, IFP, and License Article 405) and the ultimate objective – minimizing impacts to fall Chinook and their habitats within the Hanford Reach – Grant PUD in coordination with its consulting parties, developed an integrated phased plan approach.

Based on the results of studies conducted during the phased plan and through discussions with the FCWG, which is comprised of interested stakeholders including Alaska Department of Fish and Game (ADFG), Washington Department of Fish and Wildlife (WDFW), Douglas County Public Utility District (DPUD), Columbia River Inter-Tribal Fish Commission (CRITFC), National Marine Fisheries Service (NMFS), Bonneville Power Administration (BPA), Yakama Nation (YN), Chelan County Public Utility District (CPUD), U.S. Fish and Wildlife Service (USFWS), and the Wanapum people, it was determined that Grant PUD is already implementing measures that avoid, reduce, and/or mitigate for adverse impacts on

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fall Chinook in the Hanford Reach. Therefore, at this time, Grant PUD and the FCWG are not recommending additional measures or changes to the HRFCPPA.

On August 11, 2014, Grant PUD, with the support of the FCWG, made a request to WDOE to combine the IFS and IFP into a single document. The WDOE granted this request in a letter dated September 2, 2014. (Appendix C).

The draft IFS/IFP was distributed on November 11, 2014 to the FCWG and interested stakeholders for a 90 day review and comment period. Comments were requested by February 13, 2015. Comments were received from WDFW, ADFG, PNNL, BioAnalyst, NOAA Fisheries, CRITFC, Mainstem Fish Research, and USFWS. A summary table of all comments received and Grant PUD's responses to those comments are included in Appendix B of the final IFS/IFP. The final IFS/IFP was submitted on April 6, 2015 for WDOE review and on April 13, 2015 WDOE approved the IFS/IFP (Appendix D).

FERC staff with any questions should contact Fish, Wildlife and Water Quality Manager, Tom Dresser, at 509-754-5088 Ext. 2312 or tdresse@gcpud.org.

Sincerely

Ross Hendrick
License Compliance Manager

CC: FCWG
WDOE

Effects of the Hanford Reach Fall Chinook Protection Program on Fall Chinook Salmon in the Hanford Reach – Summary, Conclusions, and Future Monitoring

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and
Todd N. Pearsons

Public Utility District No. 2 of Grant County, Washington

April 2015

Acknowledgements

We thank the many individuals that have contributed to the years of collaboration, study development, and research that was required for the evaluation of the Hanford Reach Fall Chinook Protection Program. Members of the Fall Chinook Working Group, first convened in July of 2008, have met on monthly basis to recommend and guide the research that was needed for a comprehensive evaluation of the Protection Program on fall Chinook salmon in the Hanford Reach. Contributors to the Fall Chinook Working Group have included representatives from Washington Department of Ecology, Washington Department of Fish and Wildlife, Alaska Department of Fish and Game, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Columbia River Inter-Tribal Fish Commission, the Yakama Nation, Bonneville Power Administration, Chelan County PUD, Douglas County PUD, Mid-Columbia Hourly Coordination with facilitation from Tracy Hillman of BioAnalysts. This report benefited greatly from reviews by Tracy Hillman (BioAnalysts), John Clark (Alaska Department of Fish and Game), Paul Hoffarth (Washington Department of Fish and Wildlife), Paul Wagner (National Marine Fisheries Service), Steve Haeseker (U.S. Fish and Wildlife Service), Jeff Fryer (Columbia River Inter-Tribal Fish Commission), Geoff McMichael (Mainstem Fish Research), and Ryan Harnish (Pacific Northwest National Laboratories).

Executive Summary

A new operating license for the Priest Rapids Project (PRP) was issued by the Federal Energy Regulatory Commission (FERC) on April 17, 2008. As part of the licensing process, the State of Washington Department of Ecology (WDOE) issued a 401 Water Quality Certification (401 Certification) for the PRP. Conditions of the Water Quality Certification required that Public Utility District No.2 of Grant County, Washington (Grant PUD) develop a study plan with the objective of better understanding whether hydroelectric operations under the Hanford Reach Fall Chinook Protection Program Agreement (HRFCPPA) are causing significant harm to designated uses in the Hanford Reach and identify Grant PUD's contribution to those impacts. The Fall Chinook Work Group (FCWG) developed and prioritized a list of 22 potential studies to help inform whether hydroelectric operations under the HRFCPPA are causing significant harm to fall Chinook salmon in the Hanford Reach (Langshaw and Pearsons 2009).

A phased approach was used to examine effects on productivity, and if necessary, implement studies to examine the source and mechanism for those effects. All 22 proposals were considered during development of a cohesive, phased study plan that considered effects in a population context. The general approach was to conduct a productivity assessment in Phase 1 to identify beneficial or limiting factors for fall Chinook in the Hanford Reach. The second phase was to identify the source and magnitude of effects in life stages where productivity limitations were identified. The third phase was to identify and, if appropriate, suggest implementation of reasonable and feasible measures to avoid, reduce, or mitigate for adverse effects. During implementation of the phased plan, Grant PUD participated in, funded, or co-funded projects that partially or fully met the primary objectives identified for 18 of the 22 proposals (82%) that were initially prioritized by the FCWG. Eight projects that were not initially considered for the phased plan were implemented as part of the adaptive management process for the HRFCPPA.

This document is the culmination of many years of effort and more than 26 studies that were dedicated to adaptively managing the HRFCPPA. Grant PUD has fulfilled all of the regulatory requirements that related to the HRFCPPA in the 401 Certification and PRP License. The major findings were that productivity of fall Chinook salmon from the Hanford Reach: 1) is very high relative to other Chinook populations, 2) was increased substantially by implementation of the Vernita Bar Settlement Agreement (VBSA) and the HRFCPPA, and 3) was not negatively associated with flow variables influenced by changes made to hydrosystem operations under the VBSA and HRFCPPA. Furthermore, losses of fall Chinook salmon due to stranding and entrapment were small relative to total pre-smolt production. Most importantly, the extensive research and analyses conducted over the past several years indicate that the HRFCPPA is meeting its primary objectives of reducing high elevation spawning, redd desiccation, and flow fluctuations during the period when fry are susceptible to stranding and entrapment. No significant adverse effects from the HRFCPPA were identified. In fact, the HRFCPPA appears to have significantly improved the productivity of fall Chinook salmon in the Hanford Reach from the pre-VBSA time period. Thus, no modifications to the HRFCPPA were necessary at this time. Furthermore, Grant PUD is mitigating for losses of fall Chinook salmon by producing 5.6 million smolts annually at Priest Rapids Hatchery. Moving forward, Grant PUD and other signatories are dedicated to successful implementation and adaptive management of the HRFCPPA into the future.

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1.0 Introduction

The Hanford Reach Fall Chinook Protection Program Agreement (HRFCPPA) contains constraints on dam operations designed to provide protections for fall Chinook salmon (*Oncorhynchus tshawytscha*) that spawn and rear in the Hanford Reach of the Columbia River. A new operating license for the Priest Rapids Project (PRP), which includes the Priest Rapids and Wanapum dams and reservoirs, was issued by the Federal Energy Regulatory Commission (FERC) on April 17, 2008. As part of the licensing process, the State of Washington Department of Ecology (WDOE) issued a 401 Water Quality Certification (401 Certification) for the PRP. Conditions within the 401 Certification require that Public Utility District No. 2 of Grant County, Washington (Grant PUD) develop a study plan with the objective of better understanding whether hydroelectric operations under the HRFCPPA are causing significant harm to designated uses in the Hanford Reach and identify Grant PUD's contribution to those impacts. Furthermore, the Fall Chinook Work Group (FCWG) was developed to provide consultation for requirements in the 401 Certification that relate to the Hanford Reach. The initial step for completing a study plan to meet the objectives of the 401 Certification was to compile a list of potential studies that were considered and prioritized by the FCWG (Langshaw and Pearsons 2009). The 22 studies identified and prioritized by the FCWG were considered during development of a comprehensive phased plan that was structured on the principles of adaptive management and met all of Grant PUD's study requirements related to the HRFCPPA (Langshaw and Pearsons 2010).

The principles of adaptive management are the foundation of the HRFCPPA, the Priest Rapids Project Salmon and Steelhead Settlement Agreement (PRPSSSA), and the PRP License. The most current and best available scientific information and analysis are the standard of care that is applied to the adaptive management process. Guidelines for the adaptive management process are outlined in section 4.3 of the PRPSSSA:

> *The sequence of adaptive management steps include: (1) problem assessment, (2) project design, (3) implementation, (4) monitoring, (5) evaluation, and (6) adjustment of future decisions.*

These six steps were integrated into a three phased study. The general approach was to conduct a productivity assessment in Phase I to identify beneficial or limiting factors for fall Chinook salmon in the Hanford Reach. The second phase was intended to identify the source and magnitude of effects in life stages where productivity limitations were identified. The third phase was to identify and, if appropriate, suggest implementation of reasonable and feasible measures to avoid, reduce, or mitigate for adverse effects. This document describes the results of the phased study and the implementation plan for future monitoring. The review of this document by the FCWG and approval by WDOE and FERC will complete the study requirements of the 401 Certification, HRFCPPA, and PRP License under adaptive management principals outlined in the PRPSSSA.

1.1 Study Requirements

The phased study plan was designed to address study requirements related to the HRFCPPA within the PRP License, 401 Certification, and HRFCPPA. Section C.6.c. of the HRFCPPA required a study to estimate fry losses in the Hanford Reach due to stranding and entrapment:

> *During the Rearing Periods of 2011, 2012, and 2013, the Parties will also meet to develop a follow-up monitoring program to estimate fry losses. This monitoring*

program will be designed according to protocols developed from 1999 to 2003 or alternatively with different methods developed by the Parties.

The 401 Certification included additional study requirements related to the HRFCPPA and provided a general framework for implementation. The basic framework was to develop a group of stakeholders (i.e., Fall Chinook Work Group) to assist with consultation, identify Grant PUD's contribution to flow fluctuations in the Hanford Reach, monitoring to better understand the impacts, and identifying implementation measures to mitigate for adverse effects from the HRFCPPA.

The FCWG was formed in 2008 and met monthly, with few exceptions. Meeting agendas and final minutes can be found on Public Utility District No. 2 of Grant County, Washington's (Grant PUD's) website (http://www.grantpud2.org/rc/). The FCWG is comprised of Grant PUD and interested stakeholders with the most consistent participation from Alaska Department of Fish and Game (ADFG), Washington Department of Fish and Wildlife (WDFW), Douglas County Public Utility District (DPUD), Columbia River Inter-Tribal Fish Commission (CRITFC), National Marine Fisheries Service (NMFS), Bonneville Power Administration (BPA), Yakama Nation (YN), Chelan County Public Utility District (CPUD), U.S. Fish and Wildlife Service (USFWS), and the Wanapum people. The FCWG's primary roles include study identification and prioritization, as well as review, comment, and approval of study plans, designs, and reports.

The HRFCPPA is a key component of Grant PUD's protection and mitigation for fall Chinook salmon. As such, evaluation and adaptive management of the HRFCPPA was incorporated into the PRP License. Support and coordination from other hydrosystem operators are necessary to meet constraints on dam operations at Priest Rapids Dam under the HRFCPPA. Thus, it was important to identify Grant PUD's contribution to any effects from the HRFCPPA and was required by Section 6.3(3) of the 401 Certification:

> *If the best available science shows that flow fluctuations allowed under the existing Hanford Reach Agreement, or as exist if such agreement is replaced, modified, or terminated, are causing significant harm to designated uses in the Hanford Reach, and the Project contributes to such flow fluctuations, then the Grant PUD shall to the extent reasonable and feasible adaptively manage Project operations to address its contribution.*

In some cases, identifying the impacts from flow fluctuations can be straightforward. However, identifying Grant PUD's contribution to those flow fluctuations and the proportionate impacts can be more difficult. Section 6.3(5) of the 401 Certification identified a basic approach to determine Grant PUD's contribution:

> *Grant PUD shall determine the contribution of the Project, if any, by comparing the flow fluctuation existing under the Project to the modeled flow fluctuation that would exist if the dams and reservoirs were absent.*

A study to investigate Grant PUD's contribution to flow fluctuations was initiated in 2007 and a draft report was distributed to the FCWG in 2008. The FCWG provided extensive comments and requested additional simulations and analyses. Further analyses and revisions were completed and the final report (Langshaw and Duvall 2010) was approved by WDOE in 2010. This report provided a better understanding of flow dynamics in the Hanford Reach, identified Grant PUD's contribution, and provided context for future studies.

A majority of the studies completed as part of the phased plan were to address Section 6.3(6) of the 401 Certification. This section included requirements for identifying potential studies, prioritizing studies, planning, identification of funding sources, development of study designs, and reporting. Given that 22 studies were proposed and prioritized by the FCWG in the first step, a comprehensive approach was required to ensure implementation of the required studies was efficient and effective. This led to development of the phased study plan.

The final requirements of the 401 Certification (Section 6.3(7)) related to the HRFCPPA are to identify, plan for, and implement any necessary adaptive management measures:

> *Based on the results of the above studies and other existing information on impacts of flow and flow fluctuations on fall Chinook Grant PUD, in consultation and coordination with the FCWG, shall evaluate potential measures to avoid, reduce, or mitigate such adverse impacts and, if appropriate, provide for implementation of such reasonable and feasible measures in cooperation with other affected entities.*

The Implementation Feasibly Study (IFS) in Section 6.3(7)(a) of the 401 Certification requires identification, evaluation of feasibility, and reporting on:

> *potential measures that may avoid, reduce, or mitigate the adverse impacts on fall Chinook in the Hanford Reach.*

Development of the IFS and a plan for implementation (i.e., Implementation Feasibility Plan (IFP); Section 6.3.7(b) of the WQC) were to occur during the final phase of the three-phased approach. Together, the IFS and IFP would address all the 401 Certification requirements related to fall Chinook salmon spawning and rearing in the Hanford Reach.

Based on the results of studies conducted during the phased plan and through discussions within the FCWG, it was determined that Grant PUD is already implementing measures that avoid, reduce, and/or mitigate for adverse impacts on fall Chinook in the Hanford Reach. Therefore, at this time, Grant PUD and the FCWG are not recommending additional measures or changes to the HRFCPPA. On August 11, 2014, Grant PUD, with the support of the FCWG, made a request to WDOE to combine the IFS and IFP into a single document. The WDOE granted this request in a letter dated September 2, 2014. The following document represents the combined IFS/IFP and is intended to complete the study requirements of the 401 Certification, HRFCPPA, and the PRP License.

1.2 Study Area and Background

The Hanford Reach is located on the Columbia River in southeast Washington State. The Hanford Reach extends from Priest Rapids Dam at river kilometer (Rkm) 639 (and below the Priest Rapids Project Boundary) downstream for 82 kilometers to the head of McNary Pool (Rkm 557) near Richland, Washington (Figure 1). On June 9, 2000, Presidential Proclamation 7319 established the 78,900 hectare (195,000 acre) Hanford Reach National Monument (Monument), which includes the Columbia River. The Monument boundary is about 4.8 kms downstream of Priest Rapids Dam. This designation continues the protection of the Hanford Site and Hanford Reach that began during World War II when the Hanford Nuclear Reservation was established for the production of nuclear weapons. The USFWS co-manages the Monument under existing agreements with the Department of Energy.

The Hanford Reach is the most productive mainstem spawning area for fall Chinook salmon in the entire Columbia River basin and supports the largest spawning population of fall Chinook salmon in the Pacific Northwest (Huntington et al. 1996, Dauble and Watson 1997). This productivity is particularly significant considering that most naturally spawning anadromous fish populations of the Columbia River Basin have declined.

Priest Rapids Dam, at the head of the Hanford Reach, is part of the seven dam hydroelectric complex on the mid-Columbia River that includes Wanapum, Rock Island, Rocky Reach, Wells, Chief Joseph, and Grand Coulee dams (Figure 1). This seven dam complex is operated under a load following strategy to meet electrical demand in the Pacific Northwest. Hydropower generation through these projects largely governs stream flow in the Hanford Reach. The mid-Columbia projects are part of the larger Columbia River hydropower system and are operated under the terms of an international treaty and other agreements that affect river flows and natural resources. These include the Columbia River Treaty between the United States and Canada, the Pacific Northwest Coordination Agreement, Mid-Columbia Hourly Coordination Agreement (HCA), and the Hanford Reach Fall Chinook Protection Program Agreement (HRFCPPA).

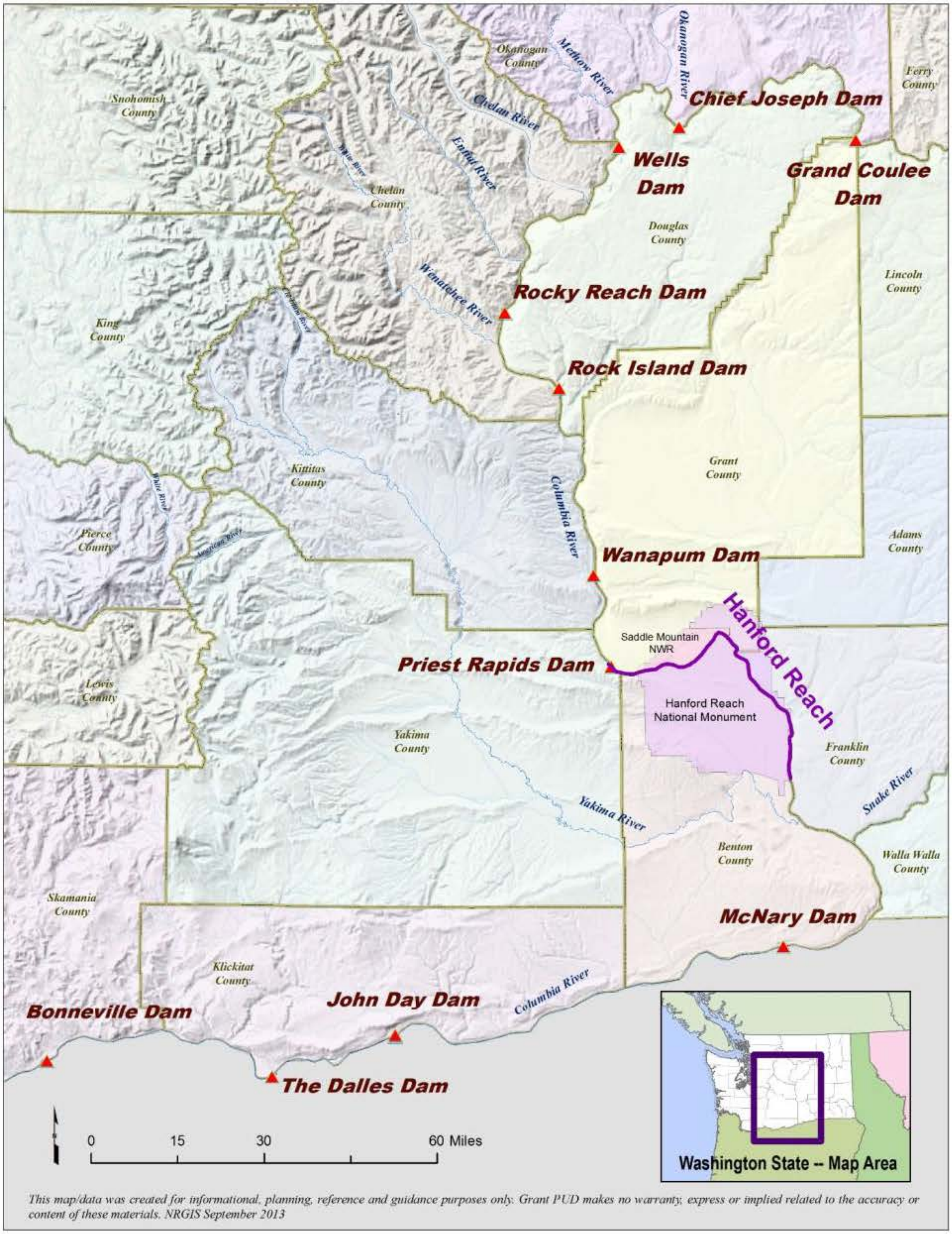

Figure 1 **Dams on the U.S. portion of the mainstem Columbia River and Hanford Reach.**

Before the construction of major dams and water storage projects, Columbia River stream flows at the site of Priest Rapids Dam were lowest during the winter (December-March). Snowmelt increased flows in the spring and early summer with peak flows typically occurring in June. Flows then decreased in the fall before returning to low winter flows. Little daily or hourly fluctuation in stream flow occurred under pre-dam conditions. Completion of the Columbia River hydropower and flood control system has altered the annual hydrograph by reducing peak spring flows, increasing average minimum flows, and shifting the period of lowest flow from winter to autumn (further detailed in Section 3.2).

Operation of the mid-Columbia River projects to meet power demand (load following) can also result in substantial hourly and daily fluctuations in discharge. Historically, this would lead to widespread dewatering of redds and regular stranding and entrapment of juvenile fall Chinook salmon in the Hanford Reach. The effects of dam operations on spawning and survival during incubation were initially studied from 1978 through 1983. The results of these studies were used to develop experimental protection measures that were first implemented in 1983. Protections were refined during the next several years and in 1988 the Vernita Bar Settlement Agreement (VBSA) was signed by Grant PUD, CPUD, DPUD, BPA, NMFS, WDFW, the Oregon Department of Fish and Wildlife, the YN, the Confederated Tribes of the Umatilla Indian Reservation, and the Confederated Tribes of the Colville Reservation (CTCR). The VBSA represented the first formal actions to reduce the impacts of load following on fall Chinook salmon that spawn in the Hanford Reach.

The primary objective of the VBSA was to minimize desiccation of fall Chinook salmon redds until fry could emerge the following spring. This was achieved by manipulating flows to minimize spawning above the elevation of 70 kcfs (1,982 m^3/sec) at Vernita Bar so that water levels could be maintained through the end of emergence. Flow was and continues to be manipulated by using the HCA and reverse load factoring (RLF) at the Priest Rapids Project.

Under normal load following operations, flows are higher during daylight hours when electrical demand (i.e., load) is highest. Spawning was thought to occur mainly during daylight hours, coinciding with higher flows. To protect against high elevation redd construction and subsequent desiccation, RLF reverses the normal load following pattern during the spawning period (mid-October through late-November). Low flows are maintained during daylight hours to limit opportunities for spawning at higher elevations. Flows are then increased at night to create enough reservoir capacity to maintain low flows the following day.

While the VBSA was an important step in reducing the impacts of load following on Chinook salmon spawning on Vernita Bar, adaptive management led to development of the HRFCPPA. The HRFCPPA provides additional protections to reduce the impacts of load following on juveniles during early-rearing periods. The HRFCPPA, as a successor agreement to the VBSA, was completed in April of 2004 with Grant PUD, CPUD, DPUD, BPA, WDFW, NMFS and CTCR. Subsequent to the 2004 execution, the USFWS and YN also signed onto the agreement.

The HRFCPPA further reduced the effects of load following on fall Chinook salmon by providing constraints on discharge minimums and/or fluctuations from Priest Rapids Dam during spawning, incubation, emergence, and early rearing. Prior to the Interim Hanford Reach Juvenile Fall Chinook Protection Program (1999-2003) and the HRFCPPA (2004 to present), typical project operations resulted in fluctuations as great as two meters/hour (seven feet/hour) and four meters (13 feet) in a 24-hour period in the Priest Rapids Dam tailrace during the fall Chinook salmon emergence and rearing period (Nugent et al. 2002). Operations under the HRFCPPA have reduced flow fluctuation below Priest Rapids Dam to typically less than one meter/hour and less than 2 meters in a 24-hour period. Fluctuating spring flows can cause the stranding or entrapment of rearing juveniles following emergence. Stranding occurs when fish are trapped on or under streambed substrates as water elevation drops. Fish are entrapped when they stay in pools that become isolated as river levels decline. Fish mortality in entrapments primarily occurs when water temperatures reach lethal levels, fry are unable to avoid predators, or the entrapments drain before river levels rise again (Nugent et al. 2002).

2.0 Conceptual Framework for the Study Plan

The FCWG identified and prioritized a wide variety of proposals (Appendix A). However, conducting a suite of disconnected mechanistic studies without an overarching framework has limited utility and is likely inefficient. Simply implementing the proposals that were the highest priorities for the FCWG may have provided a variety of interesting data, but without the proper context, they likely would not have provided the information necessary to complete the objectives of the 401 Certification and contribute to adaptive management of the HRFCPPA. Thus, life cycle and population contexts were considered during development of a plan to investigate the effects of the HRFCPPA on Chinook salmon that spawn and rear in the Hanford Reach.

The life cycle of fall Chinook salmon is complex and hydroelectric operations under the HRFCPPA affects only a portion of fall Chinook salmon freshwater life stages. The life history strategy for fall Chinook salmon is to emigrate out of the Hanford Reach as subyearlings. Thus, the period that fall Chinook salmon are exposed to hydroelectric operations in the Hanford Reach is from adult migration during beginning in August through out-migration of their offspring the following summer (June-August). The HRFCPPA reduces the effects of load following for each broodyear from the time fish begin spawning (mid-October) through the time when fish move out of near-shore areas (approximately mid-June; Figure 2). During that time fish transition through multiple life stages and are exposed to a variety of conditions, which can influence survival and ultimately population productivity (Figure 3). Furthermore, compensatory ecological mechanisms can occur between life stages such that impacts occurring earlier may not be manifested at later life stages (Figure 4; Sundström et al. 2013). As a result, it is important to recognize that the Priest Rapids Project operations under the HRFCPPA are only one of several factors affecting the abundance and productivity of fall Chinook in the Hanford Reach.

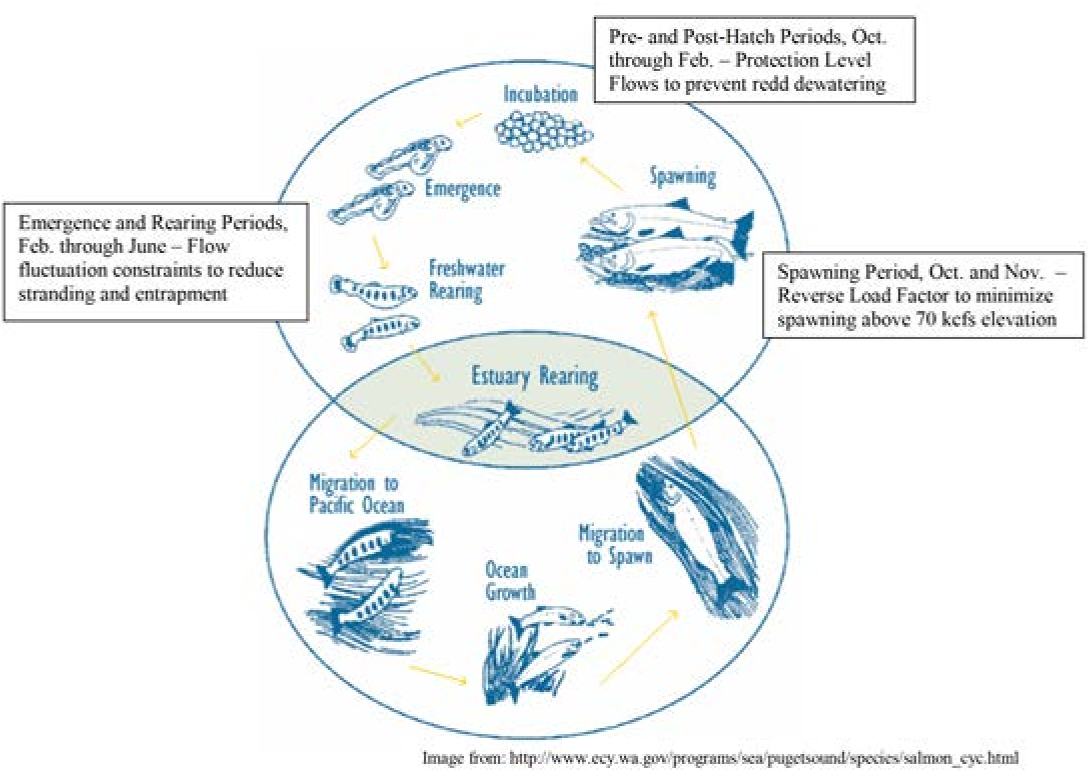

Figure 2 Timing of fall Chinook salmon life cycle and general protections provided by the Hanford Reach Fall Chinook Protection Program.

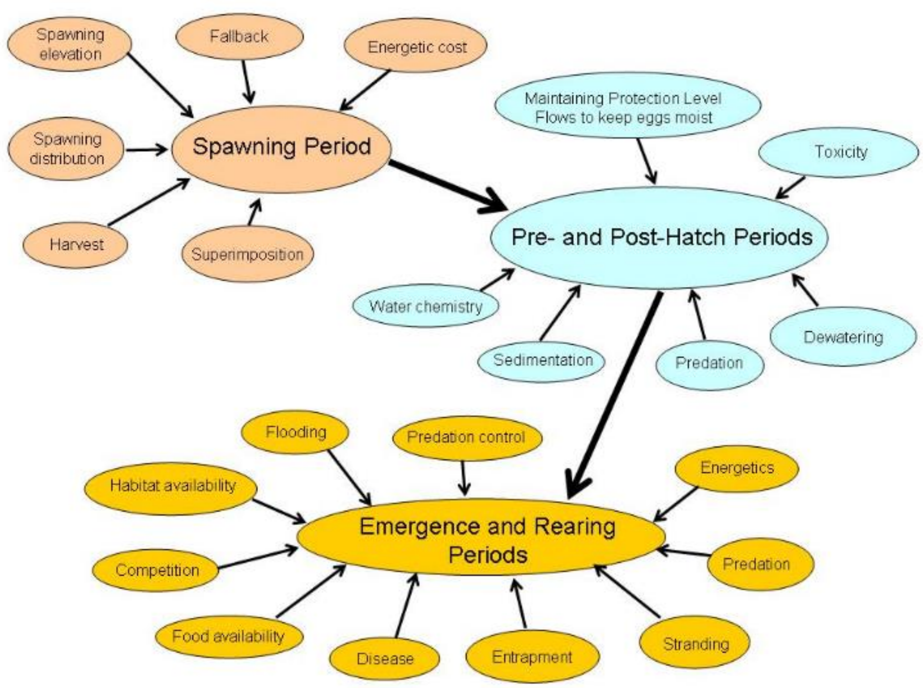

Figure 3 Major issues that can influence survival during each life stage under the Hanford Reach Fall Chinook Protection Program.

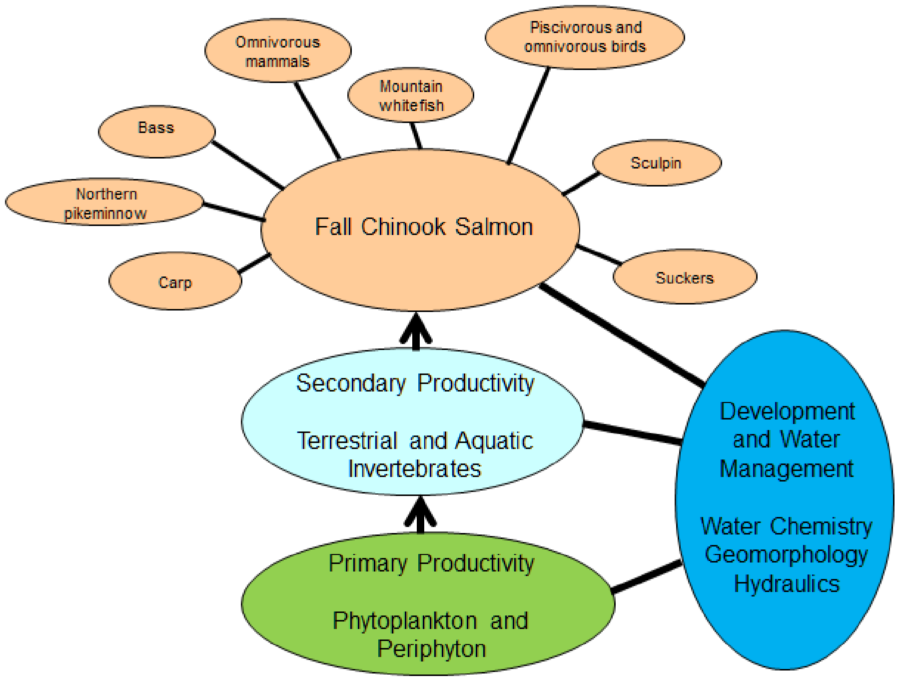

Figure 4 Major food web interactions related to fall Chinook salmon in the Hanford Reach. This is a simplified version of food web interactions presented by (Naiman et al., 2012).

Because the life cycle of salmonids is so complex and they experience a myriad of factors that influence survival, it is critical to evaluate effects of the HRFCPPA in the context of overall population productivity (e.g. adult-to-smolt or adult-to-adult). The objective of focusing studies on productivity was to identify limiting life stages. Mechanistic studies could then be used to help identify actions or protections to address the limiting factors, if any, were identified in the productivity analysis. This strategy naturally lent itself to a phased approach, where life stage specific productivity was examined first (Figure 5). The second phase was to pursue mechanistic studies in areas where significant impacts to productivity were identified. The final phase was to implement sections 6.3.3 and 6.3.7 (i.e., Implementation Feasibility Study and Plan) of the 401 Certification by identifying and implementing reasonable and feasible measures to avoid or mitigate for adverse impacts to fall Chinook salmon from the HRFCPPA. This phased approach followed the adaptive management process, as defined in the PRPSSA, which is the foundation for all protections and mitigation provided by the PRP License.

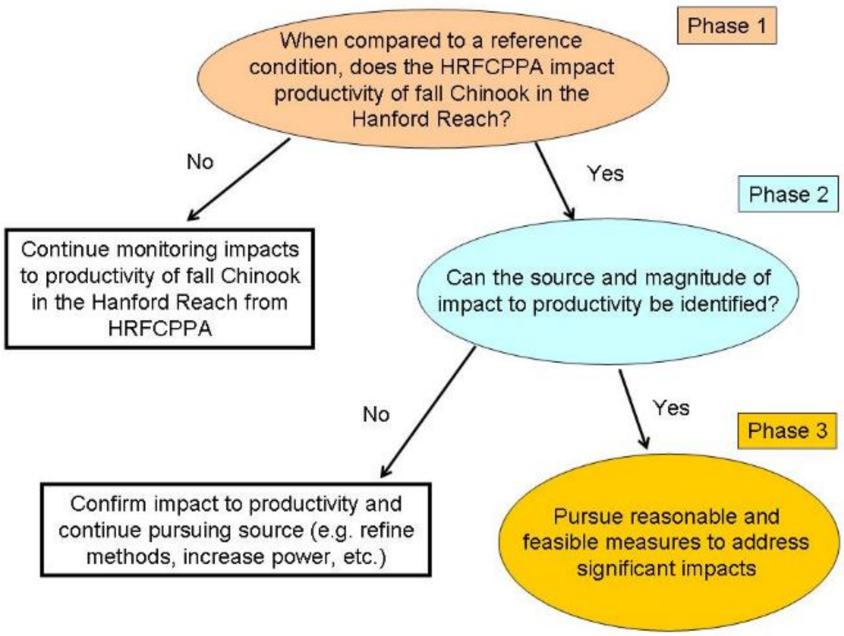

Figure 5 Conceptual framework for the phased study plan to identify and adaptively manage for impacts to fall Chinook salmon in the Hanford Reach.

While some studies were implemented prior to approval of the phased plan, the final plan was approved by WDOE on July 28, 2010. The initial Phase I studies confirmed productivity and survival of fall Chinook salmon is high in the Hanford Reach and did not identify any negative effects of the HRFCPPA. However, several more studies were implemented to address uncertainties and seek additional insight that could be used for adaptive management and to refine protections provided by the HRFCPPA. The remainder of this document details results of studies implemented under the plan and other relevant studies, provides a synthesis on productivity in the Hanford Reach, and describes an implementation plan for future monitoring related to fall Chinook salmon protections and mitigation provided by Grant PUD.

3.0 Flow Conditions in the Hanford Reach

Understanding flow conditions in the Hanford Reach is critical to evaluate any effects from, and adaptively manage, the HRFCPPA. Hydrodynamic modeling is used to generate data for physical conditions that are critical for many past, present and future studies in the Hanford Reach. The one- and two-dimensional Modular Aquatic Simulation System models (i.e., MASS1 and MASS2) were used to generate data on flow conditions in the PRP and Hanford Reach. To ensure the best possible data are available for projects implemented under the phased plan, Grant PUD funded updates and validation of the MASS1 and MASS2 models for the Hanford Reach. The following section is a brief overview of results from some of the projects and includes excerpts and/or executive summaries from the reports completed for each project. Citations are included for reference.

3.1 Hydrodynamic Model Synthesis for Hanford Reach Habitat and Hydrologic Evaluations

Given that precise and accurate data are critical to evaluate the effects of the HRFCPPA, Grant PUD funded updates and validation of the existing hydrodynamic models for the Hanford Reach.

To ensure appropriate context is available for hydrologic and habitat evaluations, discharge was compiled for the site of Priest Rapids Dam from 1917 through 2012 (Figure 6). The following text and figures are from the final report that was prepared to describe the methods and provide an overview of results from a project to update and run the hydrodynamic models developed for the Hanford Reach (Niehus et al. 2014):

> The Hanford Reach, located in south-central Washington State, is the only remaining unimpounded reach of the Columbia River in the United States upstream of Bonneville Dam. The Columbia River upstream of the Hanford Reach is heavily regulated by upstream storage reservoirs (Grand Coulee Dam and several Canadian impoundments) and six run-of-river hydroelectric projects in the United States. Priest Rapids Dam at river kilometer (rkm) 639.1 directly regulates flow into the Hanford Reach. Relatively large diel fluctuations in discharge are required during some seasons to meet electricity demand and flood-control objectives. These discharge fluctuations are known to impact downstream fish populations consequently, many research studies have investigated the mechanistic relationships between fish and flow in the Hanford Reach.
>
> Currently, constraints on Priest Rapids Dam discharge are implemented to protect the freshwater life stages of Hanford Reach fall Chinook salmon. However, a thorough understanding of the mechanisms between salmon and Priest Rapids discharge is not possible without adequate data describing the physical characteristics (i.e., including fish habitat) of the river. Because detailed hydrodynamic and water temperature data are very expensive to collect in the field, it is most cost effective to simulate such data using one- and/or two-dimensional physics-based models to provide data for the Hanford Reach. To provide these needed data, Battelle was contracted by Public Utility District No. 2 of Grant County to update and apply two hydrodynamic and water temperature models to quantify 94 years of water velocity, river stage, and water temperature in the Hanford Reach.
>
> The Modular Aquatic Simulation System in Two Dimensions (MASS2) model was applied to the entire 97 km (60 mi) of the Hanford Reach to simulate time-varying, depth-averaged river velocity, stage, and temperature. The computational mesh had an average resolution of about 10 m. Simulated water elevation (stage), velocities, temperatures, and shoreline locations were compared with observed data with good agreement.
>
> The Modular Aquatic Simulation System in One Dimension (MASS1) model was applied to the 168 km of the Columbia River from Priest Rapids Dam to McNary Dam, which includes the Hanford Reach. MASS1 was applied primarily to supply the downstream surface water elevation boundary condition for MASS2. Stages, velocities, and temperatures simulated with MASS1 were compared with observed data with good agreement.
>
> Both models were used to simulate 94 years (1917 through 2011). MASS1 simulation results, including cross-section–averaged water-surface elevation, temperature, discharge, and velocity, were saved at hourly intervals. MASS2 simulation results, which included, for each cell, the velocity components, depth,

temperature, and a flag indicating whether the cell was wet or dry, were also saved at hourly intervals. MASS2 simulation results were analyzed to classify dewatered and entrapped areas due to discharge fluctuations. The estimated areas were summed for each hourly time slice, and a cumulative sum was made for each year.

The data from the model simulations have been archived and will be used in related research projects in the Hanford Reach.

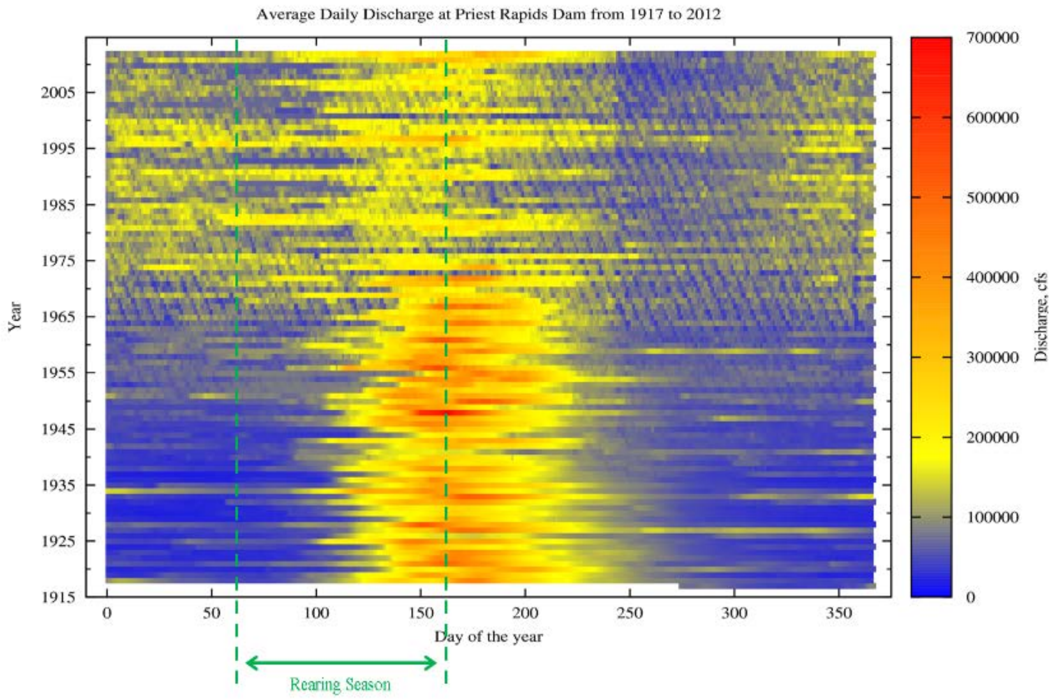

Figure 6 **Mean daily discharge at Priest Rapids Dam from 1917 to 2012 (Figure 15 in Niehus et al. 2014).**

3.2 Changes to the Hydrograph

Development and operation of the hydrosystem has dramatically altered the hydrograph of the Columbia River, which can have dramatic effects on the physical, biological, and ecological processes. Historically (i.e., 1917-1941), the Spawning Period[1] was on the descending limb of the hydrograph with a mean discharge of 53 kcfs (Figure 7). Generally, discharge continued to decrease throughout the Incubation Period and reached the annual minimum in February (mean 34.5 kcfs). Since implementation of the VBSA, the annual minimum shifted to September and discharge during the spawning and incubation periods is approximately double the level of historical conditions (mean 101 and 78.8 kcfs, respectively). The magnitude of hourly and daily fluctuations in discharge has also changed over the last 50 years. Discharge can naturally change rapidly in small rivers but change more gradually in large rivers like the mainstem Columbia

[1] Traditionally, Grant PUD has capitalized HRFCPPA flow constraint periods, e.g. Spawning Period, Rearing Period, etc. The capitalization of periods differentiates the protection flow periods from general salmon life stages. This format will continue throughout this document.

River. After operation of PRD began in 1959, hourly and daily discharge fluctuations increased dramatically (Figure 8) to follow the pattern of demand for electricity (i.e., load following). Demand for electricity is variable, but is generally greater during morning and late-afternoon hours (Figure 9). The daily pattern of fluctuations during the Spawning Period was modified with implementation of the VBSA in 1988. RLF is now used to influence the distribution of spawners by maintaining relatively low and stable daytime flows. Consequently, nighttime flows can be relatively high and variable. The implications of these alterations to the hydrograph for fall Chinook salmon in the Hanford Reach will be discussed in later chapters.

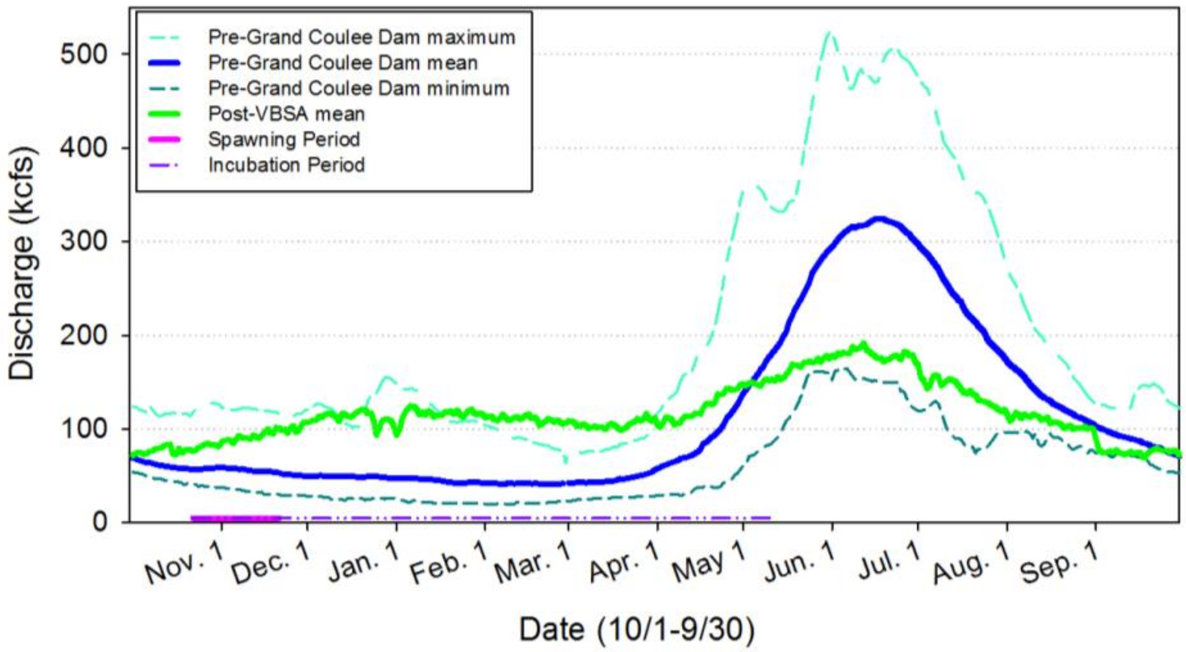

Figure 7 **Mean daily discharge at the site of Priest Rapids Dam during the pre-Grand Coulee Dam (1918-1941) and the post Vernita Bar Settlement Agreement (1988-2014) eras. The start date is shifted to October 1st to reflect the life cycle of fall Chinook salmon in the Hanford Reach and the range of conditions that each brood year experience.**

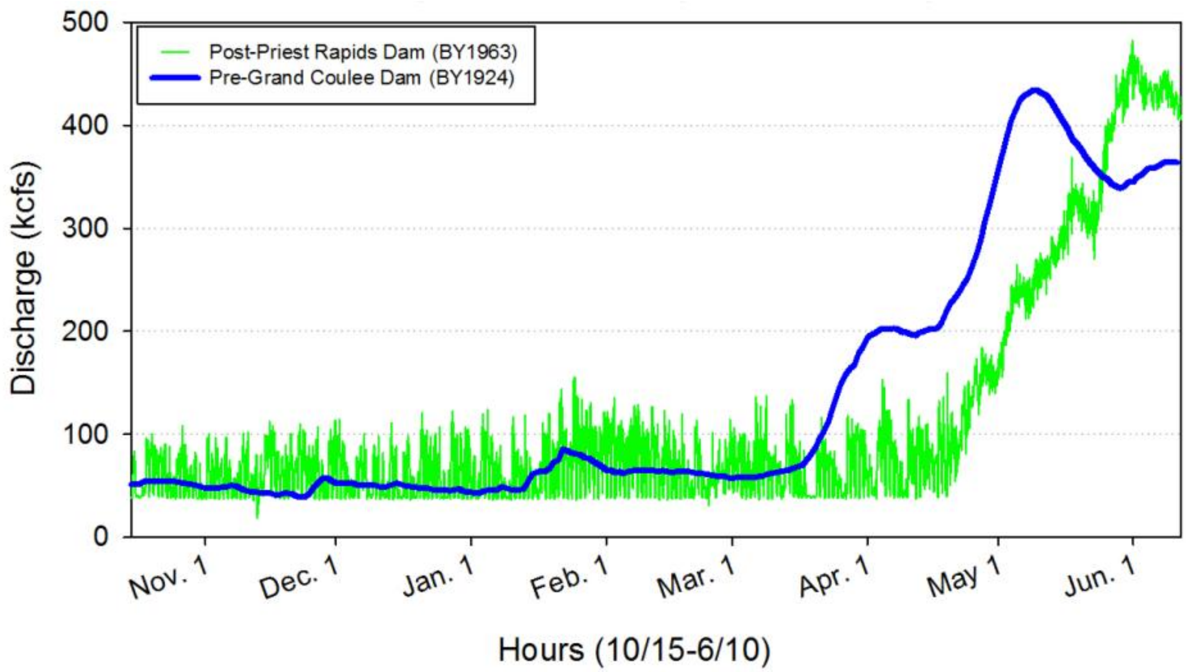

Figure 8 **Mean hourly discharge at the site of Priest Rapids Dam during pre-Grand Coulee Dam (1918-1941) and the post Vernita Bar Settlement Agreement (1988-2014) eras. The start date is shifted to October 1st to reflect the life cycle of the fall Chinook salmon in the Hanford Reach and the range of conditions that each brood year experiences.**

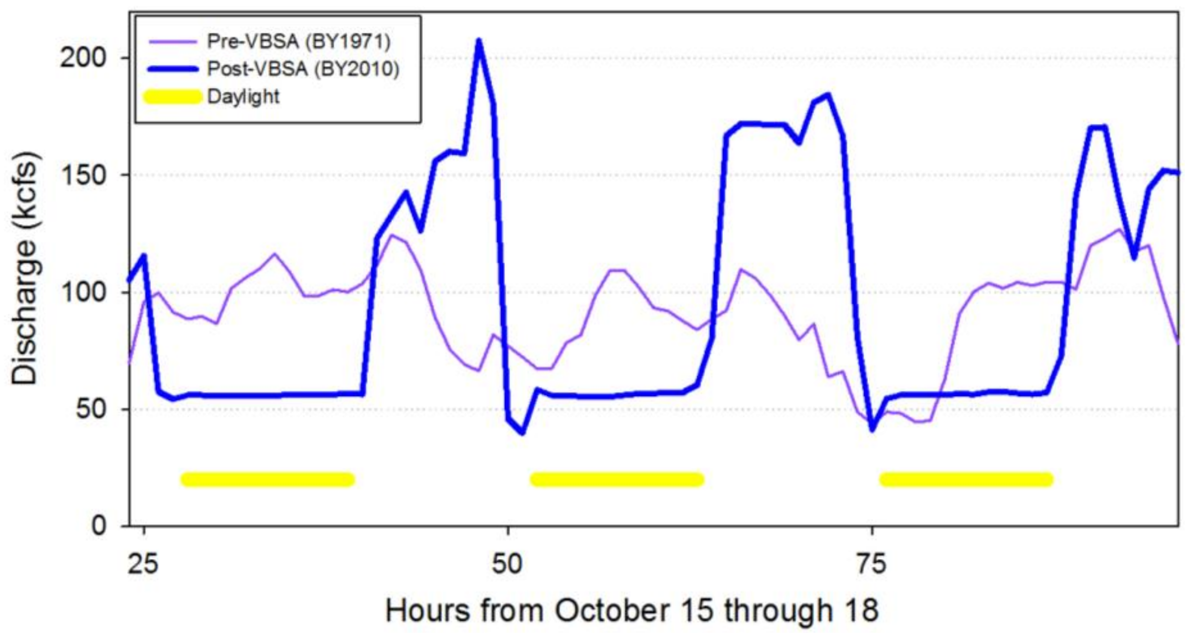

Figure 9 **Mean hourly discharge during October 16-18 of the pre- and post-Vernita Bar Settlement Agreement eras. Traditional load following was used during brood year 1971 and Reverse Load Factoring was used during brood year 2010. The two years are representative of conditions during each era and were selected because mean discharge was similar during this week. The yellow lines denote daylight hours.**

3.3 Evaluation of Grant PUD's Contribution to Flow Fluctuations in the Hanford Reach

One of the primary objectives of the HRFCPPA is to reduce the magnitude of flow fluctuations in the Hanford Reach during the Rearing Period. A key component of the WDOE's 401 Water Quality Certification was to evaluate Grant PUD's contribution to those flow fluctuations. The MASS1 model was used to simulate flow conditions in the Hanford Reach for the years 2004 through 2008. The investigation confirmed that the Priest Rapids Project is contributing to meeting two of the primary objectives of the HRFCPPA. The evaluation showed that flow fluctuations in the Hanford Reach were smaller during the Rearing Period and larger during the Spawning Period as a result of operations by Grant PUD under the HRFCPPA. The reduction in flow fluctuations during the Rearing Period reduces fry and pre-smolt susceptibility to stranding and entrapment. The increase in flow fluctuations during the Spawning Period were a result of RLF, which is intended to promote spawning below the 70 kcfs elevation. The magnitude of fluctuations were the greatest in the tailrace of Priest Rapids Dam and dissipate as flows move downstream (Figure 10). While circumstances during individual days or weeks can lead to instances where metrics for the 'without Project' scenario were less than the 'with Project' scenario, overall, the HRFCPPA reduced: 1) stage fluctuations, 2) total stage decreases, 3) mean daily ramping rates, and 4) total unwatered shoreline area. The following text and figures are from the final report that was prepared to investigate flow fluctuations in the Hanford Reach and address Section 6.3.5 of the WDOE's 401 Water Quality Certification (Langshaw and Duvall 2010):

Using the Modular Aquatic Simulation System 1D Hydrodynamic model (MASS1), data were produced for two scenarios at four output locations in the Hanford Reach area of the Mid-Columbia River. The first scenario (Current) modeled the existing conditions of the Project operating under the requirements of the Hanford Reach Fall Chinook Protection Program Agreement (HRFCPPA). The second scenario (Unimpounded) was based on a hypothetical situation assuming Priest Rapids and Wanapum dams did not exist and the Columbia River flowed freely through that section of the river. Discharge and water surface elevation (i.e., stage) were generated using the MASS1 model. River stage throughout the Hanford Reach is highly correlated with discharge from Priest Rapids Dam (r^2 = 0.99). So for consistency and easier comprehension, river stage was used for all analyses. Hydroelectric operations at Priest Rapids Dam during the fall Spawning Period and the spring Hatching and Emergence Periods greatly influenced the results of the Current scenario during the years 2004 through 2008.

During the Rearing Period for the years 2004 through 2008, the HRFCPPA resulted in mean daily stage fluctuations that were reduced from the Unimpounded scenario by 27.8%, 26.3%, 30.9%, and 30.1% at Vernita Bar, Coyote Rapids, and the 100-F and Ringold Areas, respectively. The total and mean daily stage decrease was reduced from the Unimpounded scenario by 21.3%, 31.4%, 38.6%, and 37.5% at Vernita Bar, Coyote Rapids, and the 100-F and Ringold Areas, respectively. The magnitude of the mean daily negative ramping rate [i.e., rate of decrease in river stage] (feet/hour) was reduced from the Unimpounded scenario by 23.0%, 32.4%, 39.2%, and 40.4% at Vernita Bar, Coyote Rapids, and the 100-F and Ringold Areas, respectively. The magnitude of the maximum daily negative ramping rate (feet/hour) was reduced from the Unimpounded scenario by 11.5%, 29.4%, 38.4% at Coyote Rapids, and the 100-F and Ringold Areas, respectively. The Unimpounded scenario resulted in a maximum daily negative ramping rate that was 21.3% less than the Current scenario at Vernita Bar.

In addition to comparisons of flow conditions, an assessment of stranding and entrapment susceptibility was made by estimating area of unwatered shoreline. During 2006 and 2007, the Unimpounded scenario resulted in slightly less unwatered shoreline area (4.9% and 4.1% respectively) during the Rearing Period. However, operations under the HRFCPPA resulted in 22.4%, 19.3%, 1.3% and 7.6% less unwatered shoreline area during 2004, 2005, 2008 and all years combined, respectively.

Flow constraints under the HRFCPPA depend on the magnitude of inflows into the Project. Patterns of flow fluctuations, total stage decreases, and ramping rates had the same general pattern during the Rearing Period for the years 2004 through 2008. When constraints are less than or equal to 40 kcfs, metrics from the Current scenario were less than the Unimpounded scenario [e.g., Figure 11]. Metrics under the Current scenario were approximately equal to the Unimpounded scenario when daily delta constraints were 60 kcfs. When constraints were for 150 kcfs minimum discharge, metrics under the Current scenario were greater than the Unimpounded scenario. Because the upper constraints occur less frequently and the magnitude of difference between the two scenarios is relatively high for the lower constraints, metrics for the Current scenario were less than the Unimpounded scenario when data were combined.

While the trends by constraints are clear, the relationship between Project inflows and the difference between the Current and Unimpounded scenarios is relatively weak. The magnitude of difference between the two scenarios is likely influenced by inconsistent conditions (e.g., load demand, reservoir levels, weather conditions, etc.) that lead to high variation. While circumstances during individual days or weeks can lead to instances where metrics for the Unimpounded scenario are less than the Current scenario, overall, the HRFCPPA provides for reduced stage fluctuations, total stage decreases, mean daily ramping rates, and total unwatered shoreline area. Thus, Grant PUD's contribution to flow fluctuations in the Hanford Reach during the Rearing Period is to provide greater protections than if the Project were absent.

During the Spawning Period for the years 2004 through 2008, the Unimpounded scenario resulted in mean daily stage fluctuations that were reduced from the Current scenario by 43.9%, 44.5%, 38.4%, and 33.6% at Vernita Bar, Coyote Rapids, and the 100-F and Ringold Areas, respectively. The total and mean daily stage decrease was reduced from the Current scenario by 57.2%, 52.0%, 45.7%, and 43.2% at Vernita Bar, Coyote Rapids, and the 100-F and Ringold Areas, respectively. The mean daily negative ramping rate (feet/hour) was reduced from the Current scenario by 52.1%, 42.1%, 37.7%, and 37.1% at Vernita Bar, Coyote Rapids, and the 100-F and Ringold Areas, respectively. While Spawning Period operations under the HRFCPPA result in greater daily stage fluctuations, total stage decreases, and mean daily ramping rates, the difference between the Current and Unimpounded scenarios is a direct result of meeting the current fisheries management objectives. The objective of the HRFCPPA during the Spawning Period is to minimize redd formation above 70 kcfs elevation. This objective is achieved by intentionally keeping daytime discharge low and creating large and rapid changes in discharge during the transition from nighttime to daytime hours. Thus, Grant PUD's contribution to the flow fluctuations in the Hanford Reach during the Spawning Period is to provide conditions that better meet the management objective of minimizing high-elevation spawning.

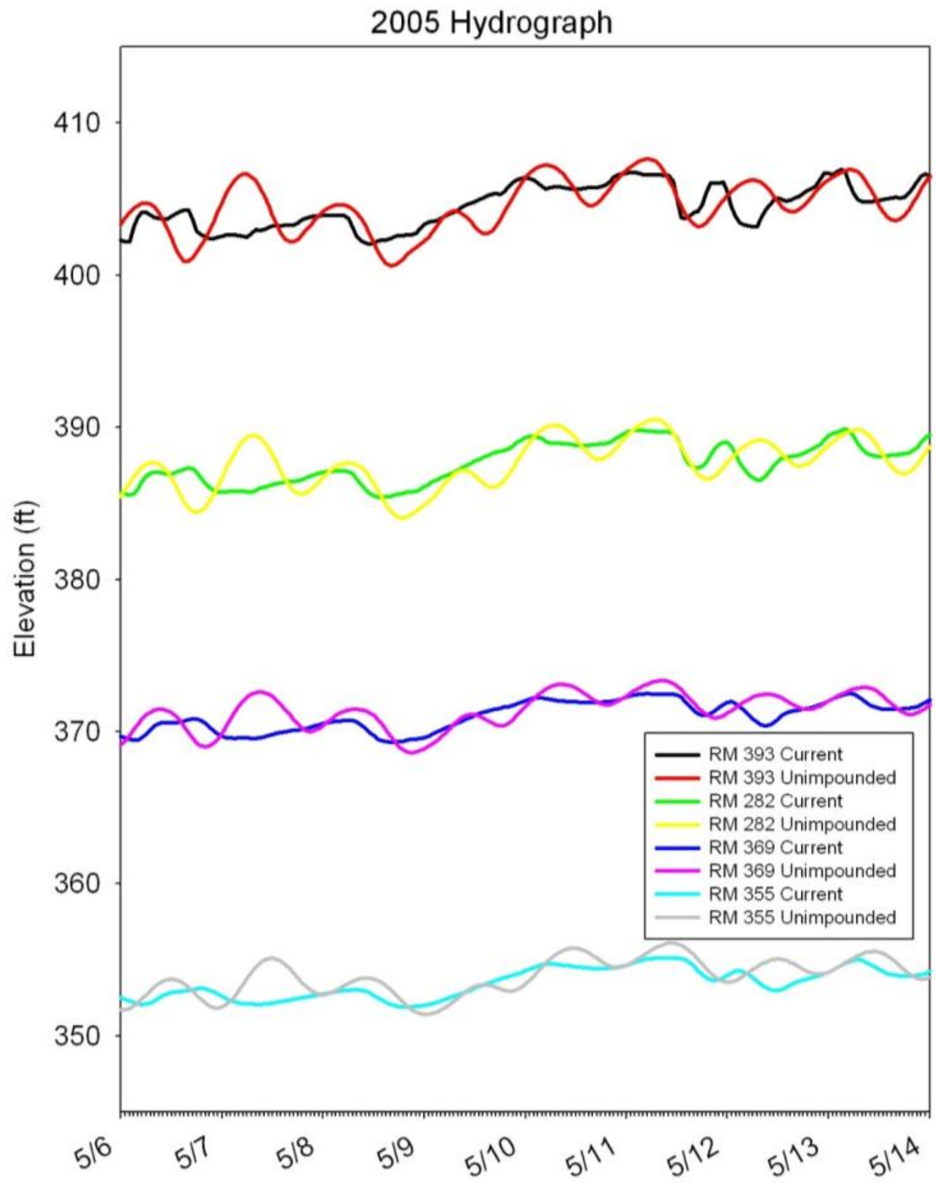

Figure 10 **Mean hourly stage during May 6 through May 13, 2005 based on the MASS1 Model under Current and Unimpounded scenarios at Vernita Bar, Coyote Rapids, 100-F Area, and Ringold Area of the Hanford Reach. Daily delta constraints during this week were 30, 30, 30, 40, 60, 60, 40, and 60 kcfs. The 40 kcfs constraints were exceeded by 11.9 kcfs on May 12. The shape of the lines illustrated the relative difference between the two scenarios and attenuation of stage changes as flows move downstream through the Hanford Reach (Figure 10 from Langshaw and Duvall 2010).**

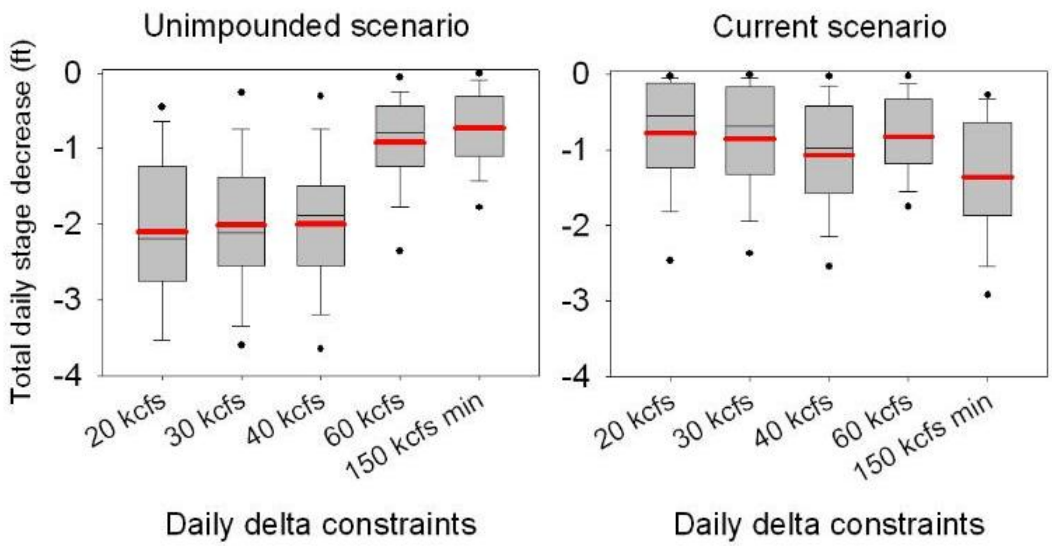

Figure 11 Total daily stage decreases during the Rearing Period under the Current and Unimpounded scenarios at the 100-F Area by daily delta constraints (2004-2008). Daily stage decrease is less under the Current scenario at the 20, 30, and 40 kcfs constraint. At the 60 kcfs constraint the change in stage is similar. At the 150 kcfs constraint the daily stage decrease is slightly higher under the Current scenario. (Figure 23 from Langshaw and Duvall, 2010).

4.0 Productivity Assessment and Related Studies

A life cycle approach was used to develop a comprehensive plan to evaluate the effects of the HRFCPPA on fall Chinook salmon in the Hanford Reach. An evaluation of freshwater productivity was the foundation of the phased study plan and was used to guide implementation of subsequent studies. This section is focused on the results of the productivity assessment and related studies.

4.1 Expert Panel Review of the Productivity Assessment

The productivity assessment completed in Phase I was the foundation of the phased plan. Given the critical importance of the assessment, an Expert Panel was convened in November of 2010 to critique the proposed methods and ensure the best available data and methods were used. Panelists were nominated and approved by the FCWG and invited to participate in the review of the productivity assessment. The panel was comprised of experts in salmonid science with a broad range of technical expertise (e.g., ecology, genetics, statistics, etc.) from a wide geographic area (i.e., California to Alaska). A two-day workshop with the Expert Panel provided valuable insight for the FCWG and many of the panel's recommendations were incorporated into the productivity assessment. The panel's review helped improve the methodologies of the productivity assessment and helped evaluate and/or address concerns about age and gender ratios, fecundity, survival bias of tagged fish, variance estimates, non-stationarity in spawner-recruit functions, reference populations, tag detection bias, and fallback. A copy of the panel's report (Hankin et al. 2011) and responses to their comments are included in Appendix A of the productivity assessment (Harnish et al. 2012).

4.2 Productivity Assessment – Effect of Priest Rapids Dam Operations on Hanford Reach Fall Chinook Salmon Productivity and Estimation of Maximum Sustainable Yield, 1975-2004

A life stage approach was used to evaluate the effects of the HRFCPPA on fall Chinook salmon in the Hanford Reach. Given the potential for compensatory survival response, the fundamental question was whether overall survival is affected by the HRFCPPA. Thus, a productivity assessment was completed for multiple life stages to investigate the effects of hydropower operations. The key finding of the assessment were that the VBSA appears to have increased the pre-smolt/egg productivity of fall Chinook and the current levels of pre-smolt/egg and adult/spawner productivity are high compared to many other fall Chinook salmon populations. The following text is the executive summary from the final report (Harnish et al. 2012) that was the basis for a subsequent peer-reviewed publication (Harnish et al. 2014):

> We used stock–recruit analyses to determine the effect of Priest Rapids Dam operations on the productivity of the Hanford Reach fall Chinook salmon population for brood years (BY) 1975–2004. Productivity was defined as the number of pre-smolts (recruits) produced from a BY divided by the egg escapement (stock) present to produce that brood. This definition of productivity ensured that only the life stages expected to be directly affected by Priest Rapids Dam operations in the Hanford Reach were considered. The Ricker model was fit to the data, and residuals were used to identify BY of above- and below-average pre-smolt/egg production. In addition, analysis of covariance (ANCOVA) was used to determine whether a difference existed in the productivity parameter (Ricker α) between pre- and post-Vernita Bar Settlement Agreement (VBSA) periods. Pre-smolt/egg estimates were regressed against a host of dam operation and environmental variables to identify variables that may have affected pre-smolt/egg production. The Ricker AR [Autoregressive]1 model was fit to adult/spawner data to estimate the spawning escapement required to achieve maximum sustainable yield (S_{MSY}).
>
> The average pre-smolt/egg production was 0.292 for the pre-VBSA period (BY 1975–1988) and 0.402 for the post-VBSA period (BY 1989–2004). A significant difference ($P = 0.03$) was observed in the proportion of pre- and post-VBSA BY that resulted in above- and below-average pre-smolt productivities. Of the 14 pre-VBSA BY, five resulted in above-average pre-smolt production. In comparison, 12 of the 16 post-VBSA BY resulted in above-average production. Results from the ANCOVA also indicated that pre-smolt productivity was significantly higher during the post-VBSA period than the pre-VBSA period ($P = 0.02$). The increase in productivity was most notable at egg escapement less than or equal to about 100 million eggs (about 42,000 adults). Above this escapement, pre-smolt/egg production was similar between the periods. Linear regression analyses indicated pre-smolt/egg production was positively correlated with the variability in discharge during incubation ($P < 0.001$).
>
> Using the entire 30-year data set, we estimated S_{MSY} to be 37,639 adult spawners with a Ricker α value of 17.59 adults/spawner. This S_{MSY} estimate is well above the minimum escapement goal of 28,800 adults currently used by the Washington Department of Fish and Wildlife to manage this population. An investigation of

the adult/spawner stock–recruit relationship between the pre- and post-VBSA periods indicated the average number of adults produced per spawner decreased from 5.75 to 2.83 from the pre- to post-VBSA period. Fitting stock–recruit models to each period produced much higher adult/spawner Ricker α values for the pre-VBSA period (α = 31.28) than post-VBSA (α = 10.27). The pre-VBSA α estimate is about six times higher than what is typical for most Chinook salmon stocks, indicating it may not be a reasonable estimate. The data used to estimate escapement and adult recruits for the pre-VBSA period are potentially of lower quality than those used for the post-VBSA period, which may have biased S_{MSY} and α estimates high. Additionally, exploitation rates were high during much of the pre-VBSA period, which can bias productivity estimates high. Therefore, it is possible that the difference in adult/spawner productivity we observed between the two time periods is more apparent than real. Bayesian regressions fit to the pre- and post-VBSA adult/spawner data indicated a lack of statistical significance in adult/spawner productivities between the two time periods. Results from our analyses suggest S_{MSY} for the Hanford Reach population may be better represented by the post-VBSA estimate of 31,110 adults.

The VBSA, which placed constraints on flow fluctuations from Priest Rapids Dam during spawning and incubation, appears to have increased pre-smolt/egg productivity of the Hanford Reach fall Chinook salmon population [Figure 12]. Current levels of pre-smolt/egg and adult/spawner productivity are high compared to many other fall Chinook salmon populations. Although we observed an apparent decline in adult/spawner productivity from the pre- to post-VBSA period, improving pre-smolt/egg productivity may ultimately result in more adults returning per spawner. Over the 30-year period we investigated, brood years that had above-average pre-smolt/egg productivity were more likely to have above-average adult recruits/spawner.

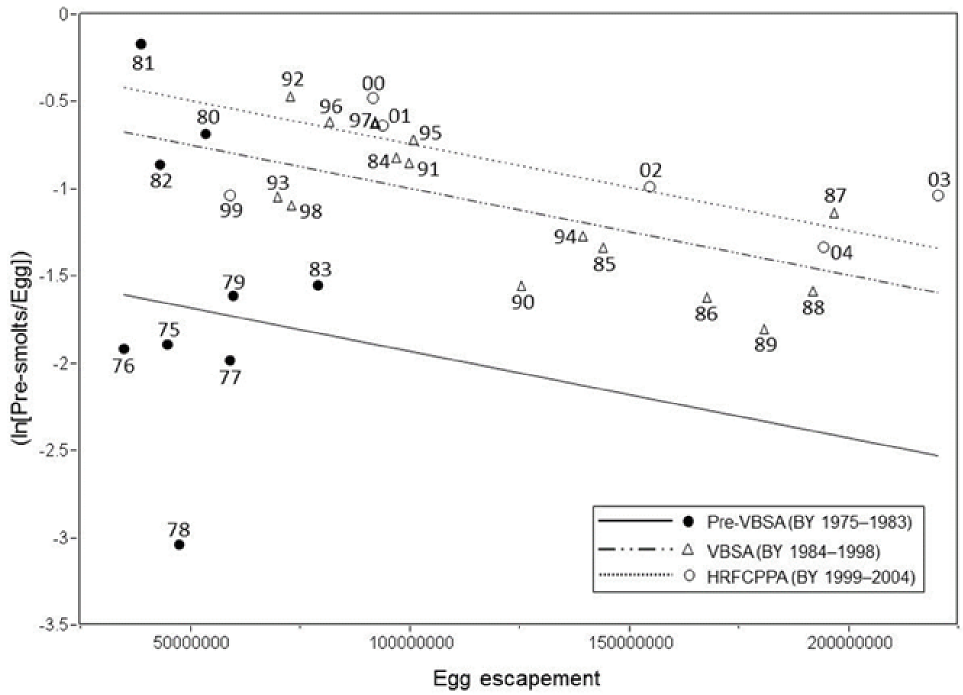

Figure 12 Plot of log transformed egg-to-presmolt survival (Ln [Presmolts/Egg]) ANCOVA for modeled Ricker recruitment functions using egg escapement as the covariate to compare productivity (y intercept) among pre-VBSA (BY 1975-1983; solid circles, solid line), VBSA (BY 1984-1998; open triangles, dash-dot-dot dashed line), and HRFCPPA (BY 1999-2004; open circles, dotted line) periods for the Hanford Reach fall Chinook salmon stock. The corresponding BY is displayed next to each point. (Figure 6 in Harnish et al. 2014).

4.3 Evaluation of Fall Chinook Salmon Fallback at Priest Rapids Dam

Dam counts are used to estimate escapement of fall Chinook salmon in the Hanford Reach and were critical for the productivity assessment that was completed during Phase I. Fallback rates were identified as a critical uncertainty by the Expert Panel, so existing data were compiled to assess fallback and reascension at Priest Rapids Dam. Data relating to fallback at Priest Rapids Dam are relatively limited, but analyses identified five or six anomalous years where fallback was relatively high. Evidence suggests fall Chinook salmon from Priest Rapids Hatchery likely contributed to the high fallback rates during these years. WDFW had already developed correction factors for several of the anomalous years. Additional analyses provided support for these correction factors and they were used for the escapement estimates during the productivity assessment. The recommendations in the report to PIT-tag more fish from Priest Rapids Hatchery and install a PIT-tag array at the hatchery channel were subsequently implemented. A automated PIT array was installed in the Priest Rapids Hatchery outfall channel in 2012 and the PIT tagging rate at Priest Rapids Hatchery was increased. Details on PIT tagging are available in the Priest Rapids Hatchery annual monitoring and evaluation report. The following text is the executive summary from the final report (Mueller et al. 2012):

Battelle–Pacific Northwest Division was requested by the Public Utility District No. 2 of Grant County to summarize the current state of knowledge regarding the known amount of fallback and reascension of fall Chinook salmon (*Oncorhynchus tshawytscha*) at dams that may influence the escapement estimates to the Hanford Reach of the Columbia River. A literature search was conducted to determine all known fall Chinook salmon fallback and reascension rates compiled from studies conducted at McNary, Ice Harbor, and Priest Rapids dams.

We also conducted queries of the PIT Tag Information System (PTAGIS) to compile all known passive integrated transponder (PIT) tag detections in fishways at the three dams to determine adult fall Chinook salmon passage and reascension rates at these fishways. Reascension rates of fall Chinook salmon were estimated to be 1.7% at Ice Harbor Dam, 0.8 % at McNary Dam, and 5.6% at Priest Rapids Dam based on PIT tag data. Of the reascensions recorded at Priest Rapids Dam from 2003 through 2010, 53% were those of adult fish PIT-tagged at Priest Rapids Dam, Bonneville Dam, or other locations on the lower Columbia River during the year of adult return. In addition to the reascension corrections that were applied at each dam to determine a dam count adjustment, an interdam loss of 5% was used based on conversion rates in the lower Columbia and Snake rivers for fall Chinook salmon.

We also summarized relevant PIT tag data from Battelle survival studies conducted during 2001–2003 and in 2005 in which sub-yearling fall Chinook salmon were PIT-tagged and released at various locations in the Hanford Reach and upstream of Priest Rapids Dam. Adult returns of these fish were detected upstream to Wells Dam for all but the 2001 year release group. Of the PIT-tagged adult fall Chinook salmon returning from these juvenile releases, which passed McNary Dam in all years (n = 513), mean percentages of 65% were detected at Priest Rapids Dam, 38% at Rock Island Dam, and 5% at Wells Dam. Additional queries were made to determine adult detections of Battelle-released sub-yearlings in the lower Snake River in 2006 and 2007.

The reascension rate at Priest Rapids Dam was compared to the total number of adults returning to the Priest Rapids Hatchery from 2003 through 2010. No significant relationship was apparent between the two variables. We also examined the reascension rate relative to project operations (hourly discharge) for a 12-h period after the fish passed through the fishways. No trend in the data was observed from 2003 through 2010, although the majority fell back when total dam discharge was 100 kcfs or more.

Of the juvenile fish that were PIT-tagged and released from Priest Rapids Hatchery, only a few adults were typically detected in the Priest Rapids Dam fishways in a given year. This is due to the relatively low number of fish that received PIT-tags at the hatchery (~3,000/year). The proximity of the Priest Rapids Hatchery return channel to the dam, along with the water intake for the hatchery in the Priest Rapids forebay, likely contributes to an increase in returning fish that bypass the hatchery return channel and continue migrating upstream of the dam.

A separate assessment was made to develop an alternative estimate of escapement to the Priest Rapids Pool using 6 years of aerial imagery to determine redd numbers downstream of Wanapum Dam. The estimated redd counts were expanded to account for redd overlap, deepwater spawning, and all other known fates. This method resulted in escapement estimates that were an average of 18% less than those developed with adult counts at the dams. Large differences are an indicator that significant fallback occurred. During four of these years, the fallback rate averaged 24%, which was significantly higher than the rate determined by PIT-tag reascensions. Using the adjusted rates that were applied to the dam counts from 1964 through 2010, the mean reduction in the Washington Department of Fish and Wildlife Hanford Reach escapement estimate was ~ 3,600, and ranged from 270 in 1997 to 13,844 in 2000.

To improve the fallback and reascension estimates to determine adult escapement to the Hanford Reach, several options could be considered. These include installing a sonar system (DIDSON) with specialized software to the overflow spillbay weir or installing a plate PIT-tag detection system along the base of the weir to determine fish passing downstream, increasing the number of fish PIT-tagged at the Priest Rapids Hatchery, and installing PIT-tag detectors at the hatchery entrance.

4.4 Evaluation of Hanford Reach Fall Chinook Salmon Life Cycle Productivity and Population Dynamics Using a Production Simulation Model (aka HierARCHY)

The primary reason for developing the production simulation model was to evaluate the relative effects of alternative operations considered during the adaptive management process. Version 1.0 of HierARCHY was completed in 2012. Survival rates from HierARCHY were correlated with survival rates from the productivity assessment (r^2=0.32) but the model did not include some critical ecological interactions (e.g., habitat selection, density dependence, etc.). Daily mortality rates and emigration timing were the fundamental drivers of production in the model and were primarily a function of fish body size. Given that water temperature was the primary driver of growth in the model, the model appears particularly sensitive to timing of spawning. Modeled survival rates for all life stages were very strongly correlated with the Julian date of peak spawning (r^2=0.93 to 0.98). Survival rates increased with the Julian date of peak spawning, unless the winter has a particularly long cold spell (e.g., several weeks < 3-4°C) in which case the opposite effect occurred. Given the limitations of the model (e.g., temperature driven, ecological interactions, and density dependent mortality, etc.) and that alternative operations are not being considered at this time, HierARCHY is not currently being used. The following text is the abstract from a presentation at the 2011 annual meeting for the American Fisheries Society and a brief summary of results from the preliminary sensitivity analyses (Bellgraph et al. 2011):

> Flows at Priest Rapids Dam on the Columbia River, U.S.A. are currently managed to protect the spawning, incubation, and rearing life-stages of Hanford Reach fall Chinook salmon. However, a thorough understanding of the relationship between flow and freshwater life-stage dynamics limits the ability of fisheries managers to evaluate alternative flow scenarios on fall Chinook salmon productivity. To understand these relationships, an individual-based model is being created that links the temporal and spatial variability of habitat in the Hanford Reach to the population dynamics of each freshwater life stage of fall Chinook salmon. The model is divided into spawning adult, in-gravel eggs and alevin, and free-swimming juvenile life-stages. Life-stages are further divided into sub-models that explicitly delineate critical components of each life-stage. Habitat inputs (e.g., depth, velocity, bed slope, substrate type, and temperature) needed for each sub-model are obtained through a dynamic link with a 2-dimensional

hydrodynamic model with computational cells at 5–10-m resolution. Outputs include estimates of production and mortality rates by source (e.g., desiccation, high temperature, stranding, and predation) for each life-stage. A critical advantage of this modeling approach is that predictions are available at a variety of scales, which provide critical checkpoints for model validation and calibration, and allow the user flexibility to investigate an array of scenarios. Upon completion, this model will inform conservation and management of Hanford Reach fall Chinook salmon, which are considered one of the most productive Chinook salmon stocks of North America. Challenges and innovations associated with model development will be presented to benefit those developing similar models for other species and areas.

5.0 Annotated Bibliography and Recent Studies by Each Life Stage

The Hanford Reach is one of the most intensively studied large river reaches in the world. Given the breadth of studies and complexities of ecosystem processes, an annotated bibliography was developed for literature relevant to fall Chinook salmon in the Hanford Reach. One of the primary objectives of the annotated bibliography was to collect and organize the relevant literature to create a common knowledge-base and serve as a resource for the FCWG and the Expert Panel as they worked on the phased study plan. This section is focused on studies or additional analyses that were completed subsequent to distribution of the annotated bibliography.

5.1 Annotated Bibliography

An annotated bibliography was developed in 2010 and distributed to the FCWG and the Expert Panel. In total, 304 citations from 237 sources were included in the annotated bibliography. The following summary was condensed from the introduction section of the annotated bibliography (Goodman et al. 2010b):

> An annotated bibliography was completed and represents the results of a review of literature relevant to fall Chinook salmon in the Hanford Reach of the Columbia River. The purpose was to provide background information that will support Hanford Reach fall Chinook salmon research and to provide an informative, common resource to the Fall Chinook Working Group and Expert Panel members. Peer-reviewed publications, technical reports, technical memoranda, and other reports from various sources were included in the bibliography. Citations were organized by the following seven main areas of salmonid research: Adults, Egg to Fry, Flow Fluctuations, Hatcheries, Hydrology, Juveniles and Productivity. The final two sections provide a complete list of summaries of the articles cited in the bibliography and a key word index.
>
> Each section begins with a synthesis of the information derived from the literature review, followed by a list of references grouped by topic (e.g., escapement is a topical subheading under the Section 2.0: Adults). The narrative provided at the beginning of each section describes the relevance of the particular subject area to fall Chinook salmon in the Hanford Reach and the key findings, recurring themes, and agreement in results among literature reviewed. Each citation in the bibliography has a link to a summary page, which includes the citation for the document, key words describing the research, species studied, years of study, objectives of the research, and a 3/4-page summary of the research.

In summarizing the cited documents, the authors attempted to provide the purpose of the study, a brief description of the methods used, and a discussion of the results of the research (especially those relevant to fall Chinook salmon). In general, the summaries represent their interpretation of the research; however, in some instances, abstracts and excerpts from reports were transcribed directly to avoid misinterpretation. On each summary page, a link to an electronic copy of the cited document is provided.

5.2 Spawning Period

The overarching objective of the HRFCPPA is to provide a balance between the benefits of hydroelectric generation and protections for fall Chinook salmon that spawn in the Hanford Reach. The basic approach is to reduce high elevation spawning, protect redds from desiccation, and reduce losses of fry due to stranding and entrapment. RLF is used throughout the Spawning Period (mean Oct. 22 - Nov. 22; Langshaw and Hoffarth 2013) to limit spawning in areas above 70 kcfs elevation so that a greater number of redds can be more efficiently protected until emergence is completed. Several studies relating to spawning habitat and Spawning Period operations (i.e., RLF) were considered during development of the original phased plan. While all the effects of RLF are not known, it appears to be meeting the primary objective of influencing the distribution of redds and reducing the number that are constructed at high elevations to minimize redd desiccation. In addition to meeting the primary objective of reducing mortalities due to dewatering, RLF does not appear to be negatively affecting productivity. Physical and biological data for the Spawning Period were not correlated with productivity of fall Chinook salmon in the Hanford Reach (Harnish et al. 2012). During the spawning season current operations and protections consistently provide a higher base flow than during the pre-hydrosystem period. This section describes the results of recent studies related to the Spawning Period of fall Chinook salmon in the Hanford Reach.

5.2.1 Hydrograph

The primary alterations to the hydrograph during the Spawning Period are discharge volume and fluctuations. Discharge volume during the Spawning Period is approximately double the level of historical conditions (53 vs 101 kcfs; Figure 13). Hourly discharge fluctuations have increased throughout development of the hydrosystem. Fluctuations during the pre-hydrosystem era were small and generally limited to gradual changes from large rain events. During the hydo-development era, fluctuations increased as river levels were managed to follow demand for electricity. After implementation of the VBSA (i.e., 1988), daytime flows are intentionally kept relatively low and stable (e.g., 50-70 kcfs) and nighttime flows are dramatically increased (e.g., can exceed 180 kcfs) to balance inflows with outflows.

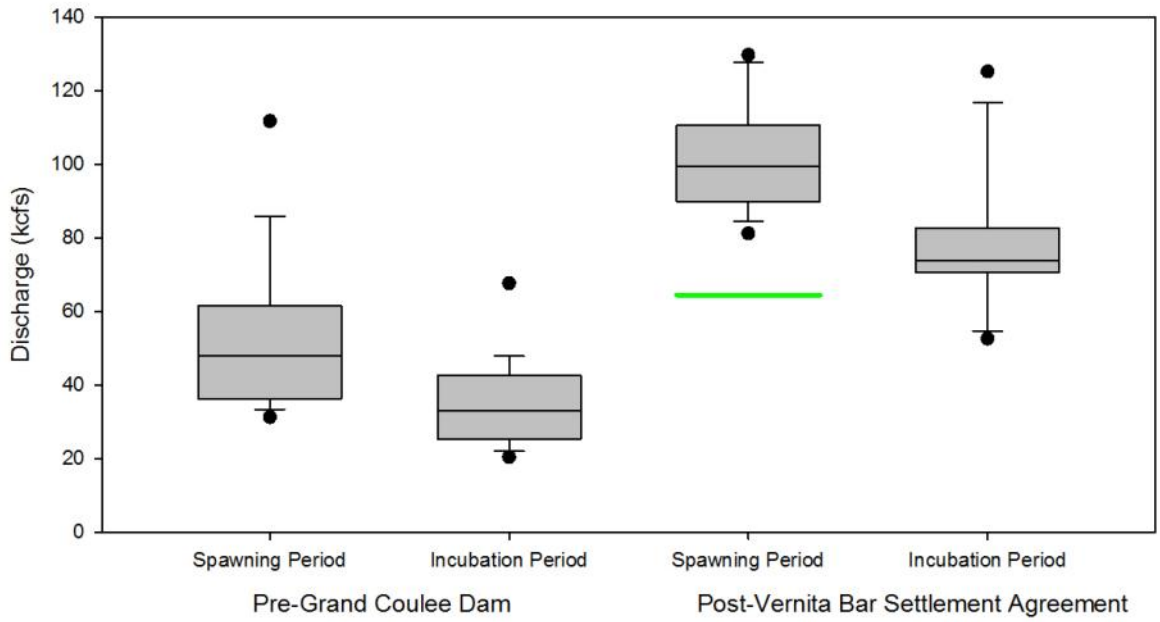

Figure 13 Mean weekly discharge during the Spawning and Incubation periods. The pre-Grand Coulee Dam era (brood years 1917-1941) represents Columbia River conditions with little or no manipulation for water management or generation of electricity. The post-VBSA era (1988-present) represents conditions with significant manipulation for water management and generation of electricity, but after discharge constraints were implemented to protect fall Chinook salmon in the Hanford Reach. The green line represents the mean Critical Elevation and indicates the level minimum discharge constraints intended to protect the vast majority of redds (e.g.,>97% during 1991, 1994, 1995, and 2006).

5.2.2 Spawning Habitat Availability

Several projects have attempted to identify the suitability and quantity of spawning habitat for fall Chinook salmon in the Hanford Reach. Significant relationships have been identified between redd location and physical conditions, which allows for development of models that can effectively predict spawning habitat availability (Geist et al. 2000, 2008, Hatten et al. 2009). Predicting more area of suitable habitat than is occupied (i.e., error of commission or false positives) is a common problem with habitat models and can result in overestimates of suitable habitat. For example, using a logistic regression model to predict where fall Chinook salmon would spawn, Geist et al. (2000) over predicted (error of commission) spawning area by 30-60%.

Recent spawning habitat models were developed from data collected during years (i.e., 1994, 1995, 2004, and 2005) with moderate escapement levels (< 71,000 adults). Redd construction expanded into previously unused areas with the record spawning escapement (~157,000 adults) in 2013 (Figure 14; Lindsey and Nugent 2014). Given that flow conditions during the spawning periods were not significantly different across years, some of the "error" may reflect the effect of density on site selection. It is difficult to determine the relative importance of spawner density on site selection because it is impractical to collect data at the appropriate scale for some important factors that are currently not measured (i.e., inter-gravel conditions) (McRae et al. 2012).

Furthermore, the temporal scale of data collection hinders investigation of the mechanisms for selecting spawning sites.

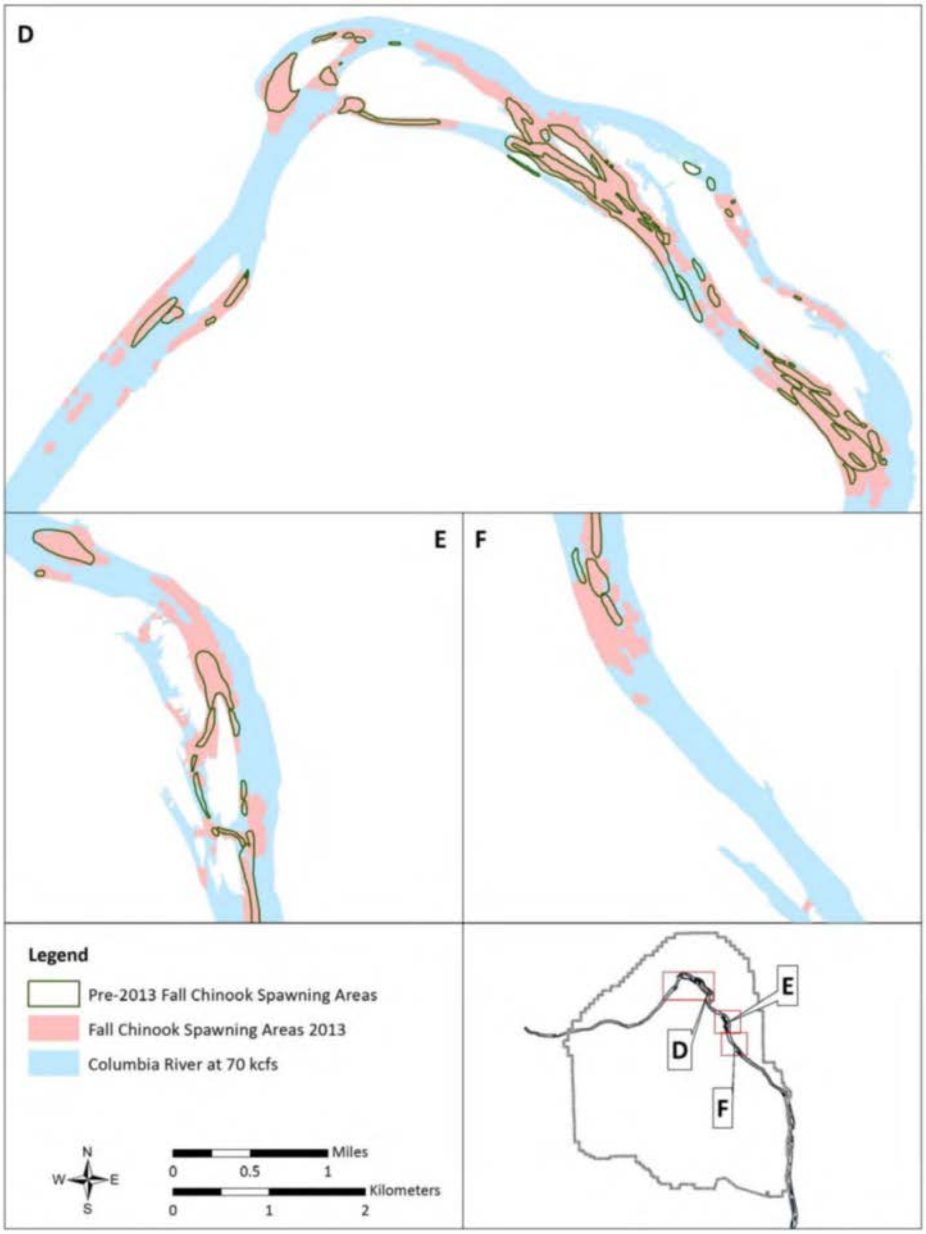

Figure 14 Spawning area in the middle section of the Hanford Reach during 2013 (Figure 11 from Lindsey and Nugent 2014). The pink represent areas where redds were identified from aerial photographs taken during 2013. The green outlines are areas where redds were identified from aerial photographs taken during previous years.

While several studies have investigated spawning habitat availability, they are all hampered by the same fundamental issue – the timing of individual redd construction was unknown. Redd presence/absence for each habitat cell is measured at the end of the spawning season. Conditions at each location are then summarized across weeks or months to identify variables that are correlated with redd presence/absence. Given that adults frequently move prior to spawning and may not visit a particular location until redd construction begins (Duvall 2008), indices of site conditions measured at weekly or monthly scales likely do not reflect the actual conditions that determine whether a site is selected or not. This limits investigations of mechanisms for redd site selection, but spawning habitat models are still relatively accurate and can provide for robust comparisons.

In general, the strongest predictors for current habitat models are related to depth (>1 m), velocity (1-2+ m/s), and geomorphology (slope and proximity to islands or bars). Incorporating variables to account for changing hydraulic conditions (i.e., "persistence" in Hatten et al. 2009 and "dynamic" in Geist et al. 2008) significantly improved the predictive performance of habitat models. However, the dynamics of depth and velocity at a particular location are a function of bathymetry, discharge and time. Given that flow variables are summarized across weeks or months, it is unclear whether fish are selecting for more stable conditions or that persistence/dynamic variables are better indicators of more favorable geomorphic features, substrates, and velocities. Regardless of mechanism for site selection, existing spawning habitat models provide an opportunity for relative comparisons of habitat conditions under different hypothetical scenarios.

While there are no data on spawning distribution during constant flows, spawning habitat models were used to evaluate hypothetical steady-state scenarios with data collected during 2004 (Hatten et al. 2009). Median discharge during peak spawning in 2004 was approximately 80 kcfs. Under the hypothetical steady-state scenario the authors predicted a relatively steady increase in suitable habitat until it leveled off at approximately 110 kcfs (Figure 15). They predicted that approximately 1,350 ha of suitable habitat would be available for spawning if flows were a constant 80 kcfs, which equates to approximately 29% of the total surface area in the Hanford Reach or 154 m^2 per spawner in 2004.

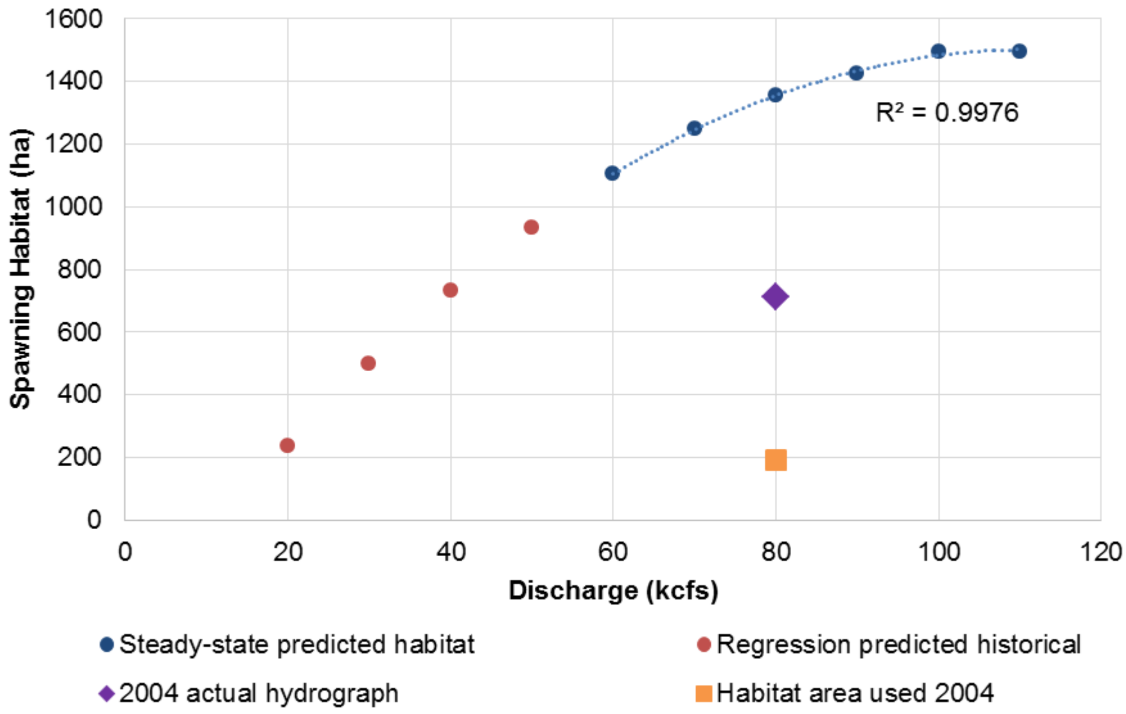

Figure 15 Approximate estimates of spawning habitat generated from data presented by Hatten et al. (2009). Median discharge during peak spawning was approximately 80 kcfs during 2004. Regression was used to extend habitat area predictions for discharge in the 20-60 kcfs range.

Regression can be used to extend the authors estimates of habitat area for relative comparisons of steady-state conditions in the range of historical discharge. The minimum steady-state discharge modeled was 60 kcfs, which was slightly more than the mean discharge during the Spawning Period (53 kcfs) prior to development and operation of Grand Coulee Dam (1942). The extrapolation of the steady-state model predictions resulted in 1,048 ha of suitable habitat that would be available during an average year and 636 ha that would be available during the Spawning Period with the lowest discharge (i.e., 36 kcfs in 1936). Under low flow conditions, it was predicted that approximately 14% of the surface area would be suitable habitat.

Redd distributions also provide an opportunity for comparisons of changes to available spawning habitat over time. Of the 4,797 redds identified on Vernita Bar in 1991, 1994, 1995, and 2006, approximately 63% were deeper than the 40 kcfs elevation (Figure 16). Redd locations above 40 kcfs were spatially confined and generally more densely spaced, suggesting there may be limited or less preferable spawning habitat above the 40 kcfs elevation.

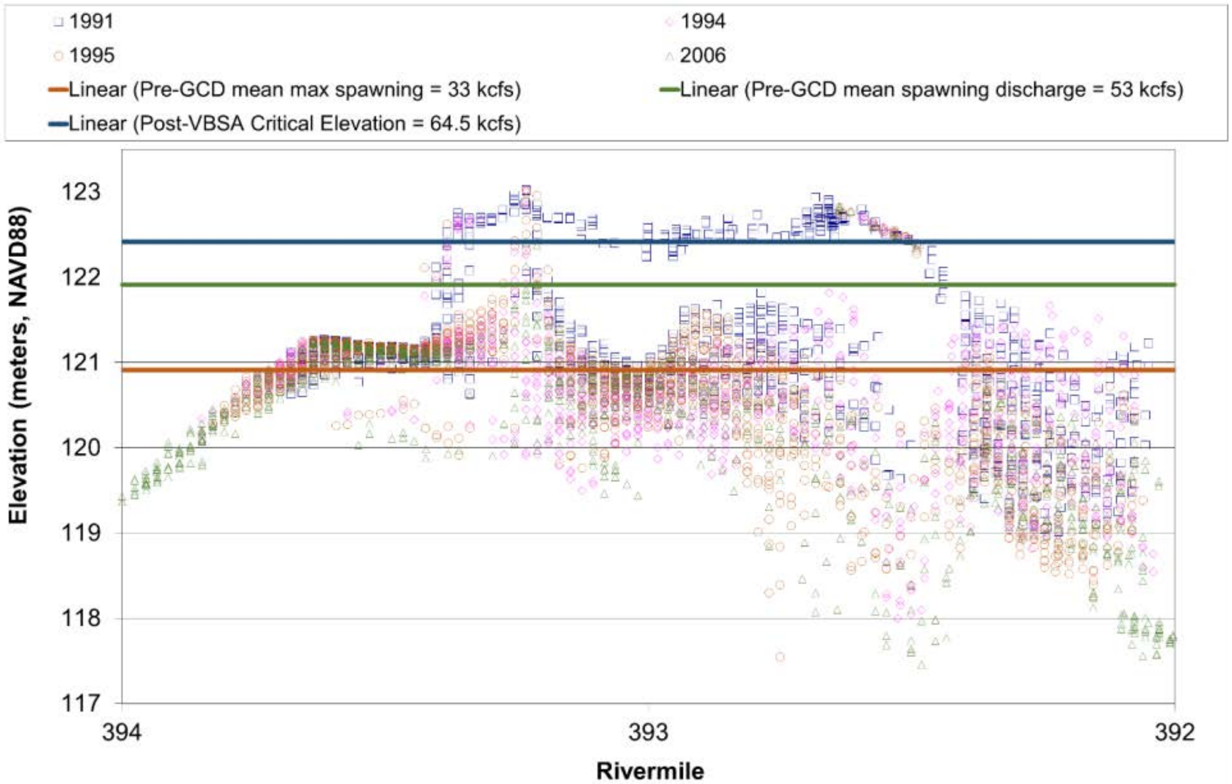

Figure 16 Redd distribution on Vernita Bar during 1991, 1994, 1995, and 2006. A total of 4,797 redds were identified and mapped from geo-referenced aerial photographs. The green and orange lines represent the mean water surface elevation and likely maximum spawning elevation during the pre-Grand Coulee Dam era (brood years 1917-1941). The blue line represents the mean Critical Elevation during the post-VBSA era.

Previous researchers incorporated persistence/dynamic variables and improved predictive performance of spawning habitat models; however, the models did not consider the potential for differential selection of redd locations. Discharge constraints during the Spawning Period may provide the opportunity for differential selection of redd locations because the flows are dramatically different during the day and night when fish are selecting habitats to spawn. RLF requires that daytime discharge remain relatively low and stable (i.e., 55-70 kcfs), which can cause peak nighttime flows to be 2-3 times higher than daytime flows. This provides the potential for fish to select spawning habitats under very different flows, and thus, may provide for the use of different elevations within the 24-hour cycle. Spawning habitat simulations have not been completed to evaluate the degree that areas of suitable conditions overlap, but flow characteristics can provide a relative comparison of how conditions change.

Hydraulic simulations were completed for the entire Hanford Reach (Niehus et al. 2014) and a random day was selected (11/10/01) for this analyses. Daily minimum and maximum depths and velocities were summarized for 10,000 random cells. The mean difference between the daily minimum and maximum depth and velocity was 2.2 m (range 0.0-3.2 m) and 0.3 m/s (range 0-3.3 m/s), respectively (Figure 17). The difference between daytime and nighttime conditions may help explain the fertilization timing pattern observed during the egg-to-fry survival study conducted on Vernita Bar in 2010. Naturally produced redds were sampled (n=18) between 40-60 kcfs elevation and approximately 78% of the eggs were fertilized at night (Oldenburg et al. 2012).

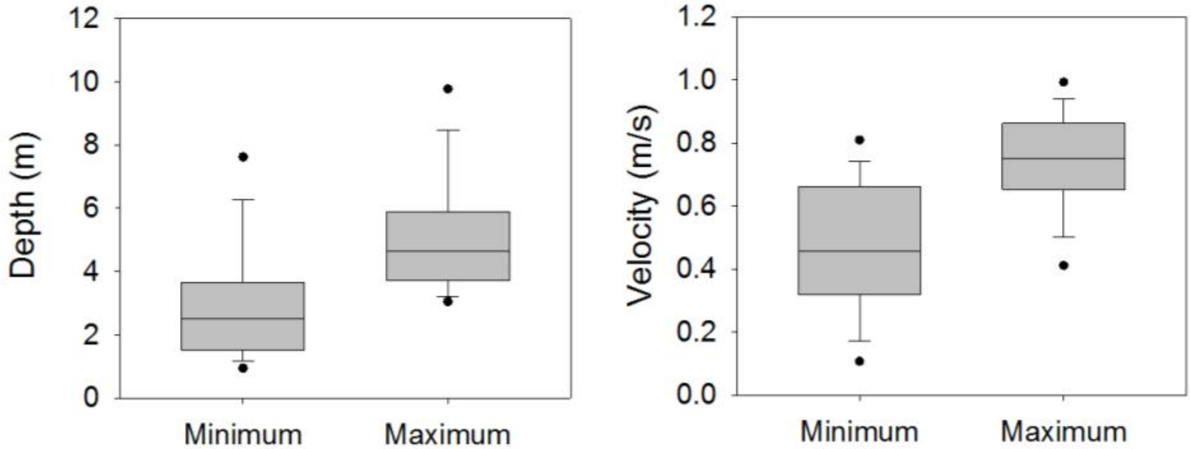

Figure 17 MASS2 depth and velocity output for 10,000 random habitat cells on 11/10/2001. The boxes represent the 25th to 75th percentiles for the daily minimum and maximum values for each cell.

5.2.3 Feasibility of Spawning Habitat Enhancement in the Tailrace of Wanapum Dam

Article 405 of the PRP License required that Grant PUD investigate and consider spawning habitat enhancement in the tailrace of Wanapum Dam as part of the IFS:

> *As part of the Implementation Feasibility Study required under section 6.3(7)(a) of the water quality certification, the licensee shall investigate the feasibility of modifying the Wanapum dam tailrace to increase the amount of fall Chinook salmon spawning habitat.*

The following text is the executive summary from the report to investigate the feasibility of enhancing spawning habitat in the tailrace of Wanapum Dam (Geist et al. 2011):

> Battelle–Pacific Northwest Division was requested by the Public Utility District No. 2 of Grant County to summarize the current state of knowledge regarding the amount of spawning habitat presently available in the tailrace of Wanapum Dam suitable for fall Chinook salmon (*Oncorhynchus tshawytscha*) and to review potential methods to increase the quantity of high quality spawning habitat in that area. A study conducted in the Wanapum Dam tailrace in 2000–2002 showed that nearly all the high-quality fall Chinook salmon spawning habitat was located on the Barge Dock Bar about 2 km downstream of Wanapum Dam. This area has been used consistently for spawning by fall Chinook salmon, and there appears to be a demarcation in habitat use on the Barge Dock Bar that could not be explained by a model using standard habitat variables (water velocity, water depth, riverbed surface substrate size, or riverbed slope).
>
> Although more recent modeling of fall Chinook salmon spawning habitat use in the Hanford Reach of the Columbia River suggests that velocity persistence and

variability should be included in fall Chinook salmon spawning habitat suitability models, it is unlikely that these variables would improve model predictions in the Wanapum Dam tailrace because there are no obvious hydraulic controls on the Barge Dock Bar that would cause velocity persistence or variability to differ from one part of the Barge Dock Bar to another. Rather, we would argue that an underlying geomorphic explanation appears more likely. When the substrate data from the riverbed surface of spawning areas was compared to that of non-spawning areas on the Barge Dock Bar, spawning sites had smaller substrate than non-spawning sites. Confirming whether these differences in substrate size correspond to differences in substrate permeability has been difficult because the hydraulic conditions on the Barge Dock Bar make it difficult to assess substrate permeability using standard methods. However, indirect measurements of substrate permeability using temperature and water-level data recorders, along with direct measurements of permeability from a side channel used for spawning, imply that substrate quality is one explanation for the differences in habitat use on the Barge Dock Bar.

Recent studies of substrate size and distribution suggest that the Wanapum Fish Bypass has not altered hydraulic conditions sufficiently to affect substrate grain-size distribution on the Barge Dock Bar. Thus, present-day substrate quality may still be a factor limiting the amount of high quality fall Chinook salmon spawning habitat in the Wanapum Dam tailrace. Increasing the quantity of fall Chinook salmon spawning habitat on the Barge Dock Bar may be possible by improving the quality of riverbed substrate in adjacent non-spawning areas on the Barge Dock Bar. Improved substrate quality may include smaller and more mixed grain sizes and increased riverbed permeability. Achieving this goal of improving substrate quality may be possible through a combination of gravel augmentation and riverbed surface scarification. However, a gravel augmentation or scarification project in a river as large as the Columbia has not previously been completed and assessed for success. As such, considerable uncertainty exists on whether these techniques will substantially increase the quality or quantity of fall Chinook salmon spawning habitat in the tailrace of Wanapum Dam.

5.2.4 Evaluate and Quantify the Effects of Redd Superimposition

There is some evidence that redd superimposition occurs for fall Chinook salmon in the Hanford Reach. Fall Chinook salmon redds in the Hanford Reach can form contiguous areas or “clusters” (Geist and Dauble 1998, Visser et al. 2002) and fertilized eggs as old as 26 days have been captured in drift-nets (Oldenburg et al. 2012). This suggests that some level of superimposition is occurring in the Hanford Reach but the cause and magnitude are not known. Some level of superimposition is not uncommon for salmonids particularly where there is a preference to construct redds in clusters or patches. Proximity is an important factor for redd site selection and it appears to be more complex than simply the quality or availability of habitat (Essington et al. 1998, Isaak et al. 2007, Mull and Wilzbach 2007, Youngson et al. 2011, Gortázar et al. 2012). Nevertheless, it is safe to assume that redd superimposition is positively correlated with adult female escapement. If escapement levels continue to be as large as were observed in 2013 and 2014, some increased level of superimposition would be expected. However, the effect of superimposition on productivity, if any, will remain uncertain until data on adult returns from broodyears 2013 and 2014 are available. The monitoring and evaluation program for the HRFCPPA, which includes a productivity assessment (see Section 7.3.2), intends to capture these effects. Until then, previous work on spawner density and habitat can provide some context about the relationship between habitat selection, competition, and redd superimposition

Using female population size, average redd area, and spawning habitat area, Fleming and Gross (1989) developed average and episodic competition indices to estimate the magnitude and frequency that the area of suitable spawning habitat is exceeded by the minimum area necessary to accommodate spawning females. Competition index values greater than 1.0 indicate spawning habitat requirements exceed availability and would lead to increased competition and could be an indicator of potential for superimposition. Average competition index (AC) values ranged from 0.21 to 3.53 (median 1.25) for coho salmon spawning in 11 streams in Puget Sound and British Columbia (Fleming and Gross 1989). In contrast, competition index values for fall Chinook salmon spawning in the Hanford Reach are low (0.09-0.69). We applied the most extreme approach to estimate the competition index for the Hanford Reach by using the record number of spawning females in 2014 (78,836) and the lowest estimate for area of habitat that was actually used for spawning (i.e., 2004; Hatten et al. 2009). Even using this extreme approach, the competition index value for the Hanford Reach is less than those reported for 10 of the 11 streams studied in Puget Sound and British Columbia.

Incomplete spawning, or egg retention, is another method that is being used to monitor the relationship between spawning escapement and limitations on spawning habitat. The record return in 2013 had elevated rates of incomplete spawning. As described below, this was likely due to both the large spawning escapement and high percentage of hatchery fish in the return. Incomplete spawning will continue to be monitored and data will be reported on annually. The following text is an excerpt from the “Spawn Success Section” of a memo that was developed following the 2013 return year to summarize existing data on egg retention or other evidence of redd superimposition (Hoffarth 2014):

> All “in-sample” females recovered during stream surveys in the Hanford Reach are dissected to determine egg retention. This provides an indication of spawn success. Eggs are not counted or weighed during this process. Egg retention is based on a rough estimate of the proportion of eggs remaining in the female, 0%, 25%, 50%, 75%, or 100%. If no eggs or minimal numbers of eggs are retained, the Chinook is recorded as 100% spawned. If all eggs are retained, the Chinook is recorded as “unsuccessful”. From 2004 to 2012, spawn success averaged 98% with 97% of the female Chinook categorized as completely spawned. Spawn success for fall Chinook in the Hanford Reach has been very high and very consistent between years ranging from 97.4% to 99.2% with a large proportion of the fish sampled having little to no egg retention.
>
> In 2013 spawn success declined to 90% with 78% of the Chinook categorized as completely spawned. The 2013 escapement was the largest escapement to the Hanford Reach on record dating back to 1964. In addition, 28% of the fall Chinook escapement was hatchery origin that also led to an increase in the proportion of Age 3 females (24%), both atypical for the Hanford Reach population. The reduction in spawn success in 2013 was likely a combination of the two factors, high escapement and a large percentage of hatchery origin fall Chinook in the escapement.

Further evidence of redd superimposition during 2013 is provided by aerial photos of the Hanford Reach (Lindsey and Nugent 2014). Redd densities were particularly high in some spawning areas (Figure 18) and it appears that fish spawned in previously unused areas (Figure 14). However, there is no evidence that operations under the HRFCPPA caused increased densities. Rather, increased redd densities and spawning in previously unused areas can likely be attributed to the large adult return to the Hanford Reach that exceeded the 10-year average return of 62,000 by nearly 300% and URB returns to McNary Dam (455,000 adults) exceeding the management goal of 60,000 by over 750%.

Figure 18 Redd cluster with high degree of superimposition (Figure 9 in Lindsey and Nugent 2014). Redds are lighter colored and visible because the substrate and periphyton are disturbed during construction.

5.2.5 The Effect of Different Flow Regimes on Movement and Behavior of Fall Chinook Salmon

The HRFCPPA provided an opportunity to investigate alternatives to RLF for Spawning Period operations during 2005 and 2006. Alternatives to RLF could be considered for implementation if they were equally successful at minimizing high elevation redds. The information collected during these evaluations described how spawning females responded to fluctuating flows and RLF. For example, the observation that females ceased digging at discharges greater than 100 kcfs could be useful in the future if alternatives to RLF are evaluated. The evaluations were completed during pursuit of a Master's degree at Central Washington University and the following text is the Abstract from the thesis (Duvall 2008):

> The Hanford Reach is the last major segment of suitable spawning habitat for fall Chinook salmon on the Columbia River. Two experimental flow regimes were tested at Vernita Bar (upper end of the reach), to assess their effects on spawning, movement, and behavior of Chinook salmon while minimizing high elevation spawning on Vernita Bar. Minimizing redd elevation reduces the risk of mortality from dewatering to incubating eggs and emerging fry. Behavioral spawning patterns, redd positions, and redd-site fidelity were examined in the context of variable flow.
>
> Priest Rapids Dam currently uses a Reverse Load Factoring (RLF) regime during the fall spawning period, which reduces power generation during the day and increases production during darkness, with the assumption that salmon do not spawn at night. The purpose of RLF is to influence redd location and placement on Vernita Bar by discouraging egg dewatering from high elevation spawning. In the fall of 2005, a study was performed to identify possible nighttime spawning behavior using acoustic telemetry, dual frequency identification sonar (DIDSON), and underwater video. The load-following regime tested in that year was a reversal of normal RLF operation, and was chosen to evaluate potential impacts of diel flow patterns on the elevation of redd construction on Vernita Bar. In 2006, another project was completed, which incorporated discharge peaking from the Dam during daylight hours also to discourage high elevation spawning. The objective for river operation during this experiment was to provide conditions for maximum spawning potential in areas where protection could be maintained during incubation and emergence periods. To achieve that result, hours of consecutive, low, stable flow for the majority of the day were combined with one or two short periods of relatively high discharge.
>
> In the 2005 study, it was found that as flow increased, fish moved towards Vernita Bar and vice versa. Results also showed that female Chinook salmon actively dig redds at night although mean digging rates may be influenced by different flow regimes. Redd surveys showed high elevation redds were constructed during pre- and post-RLF flow regimes, but fish ceased digging in these locations at flows exceeding 100 kcfs. There was an inverse relationship between flow elevation and digging, with fish ceasing to dig during high flows and resuming with reduced flows.
>
> The 2006 results suggested that increases in extended peaks during spawning caused an increase in high-elevation redds. It was determined that increasing the number of consecutive hours of stable flow for both pre- and post-peak periods, and reducing the duration of peaks will likely reduce high-elevation spawning.
>
> The 2005 load following regime was unsuccessful in minimizing high-elevation redds; however, the peaking regime did have approximately the same number of redds at risk compared to RLF operations. Results suggest the peaking regime merits future consideration for operations at Priest Rapids Dam.

5.2.6 Effects of Minimum Flow Regimes on Fall Chinook Spawning at Vernita Bar 1978-1982

Prior to development of the VBSA, studies were conducted on Vernita Bar to better understand the effects of hydroelectric operations on fall Chinook spawning. Studies were conducted over several years and were used to inform development of constraints and protections in the VBSA. The original report (Chapman et al. 1983) does not have an Abstract so the following text is the summary from the Annotated Bibliography (Goodman et al. 2010b):

> This report summarizes research conducted from 1978 to 1982 on the effects of frequent flow reductions due to hydropower operations on spawning and incubation of fall Chinook salmon at Vernita Bar in the Hanford Reach of the Columbia River. The objectives of this study were to: 1) estimate the abundance and distribution of Vernita Bar fall Chinook salmon redds at various flow levels (i.e., 36, 50, and 70 kcfs), 2) assess the physical and chemical characteristics of the intragravel environment at Vernita Bar; 3) estimate the success of egg incubation and embryo survival at Vernita Bar, and 4) evaluate options for enhancement of fall Chinook salmon spawning success at Vernita Bar.
>
> The distribution and abundance of fall Chinook redds at Vernita Bar was estimated using aerial counts and ground surveys. Ground surveys included measurement of redd characteristics and excavation. Gravel composition, available depths, and water velocities were also reported. Aerial counts of fall Chinook salmon redds at Vernita Bar ranged from 862 to 3,242 across years. The average redd size was 17 m^2 at Vernita Bar. Eggs were found in redds at an average depth of 19 cm (range, 10−33 cm) in redd excavations. Some redds were constructed in less than 24 hours, and several were constructed between successive nighttime low flow periods. Redd distribution was influenced by flows. Significant correlations were found between mean daily discharge and percentage of redds above the 36 kcfs water surface elevation; more spawning occurred above the 36 kcfs level when mean daily discharge was greater. However, redd placement above the 70 kcfs level did not increase when high flows (i.e., > 85 kcfs) were sustained. Redd overlap was not observed in 1978, 1979, and 1980, but likely occurred in 1981 and 1982 when the number of spawners was high. Superimposition was more likely for redds built early in the season as early-spawning females die and cannot defend their redds from late spawners.
>
> Permeability, water level, apparent velocity, temperature, and dissolved oxygen were measured to assess intragravel conditions at Vernita Bar. Flow reductions resulted in lowering of the surface of intragravel water; however, there was a time lag of several hours between the drop in water surface elevation and the drop in intragravel water elevation. Gravel permeability at Vernita Bar was low compared to that in other Chinook salmon spawning areas and varied with elevation; permeability was generally lower at higher elevations. No freezing temperatures were observed and dissolved oxygen levels were generally adequate for fall Chinook salmon incubation (i.e., > 8 ppm).

Daily discharge reduction to 36 kcfs (up to 33 reductions per year) did not significantly reduce survival of incubating embryos at the 50 and 70 kcfs levels, as estimated by redd excavations. Nonetheless, embryo survival was slightly lower at the 70 kcfs level than at the 36 kcfs level. The incubation environment at the 70 kcfs level may be slightly less desirable than that at the 36 kcfs level due to reduced permeability and greater proportion of fines found at 70 kcfs.

5.3 Incubation – Pre- and Post-Hatch Periods under the HRFCPPA

The primary objective of the HRFCPPA protections during incubation is to prevent mortalities from desiccation. Redd distribution on Vernita Bar is used to establish the Critical Elevation each year and redds below that level are protected throughout the end of emergence (mean = May 13th). Prior to hatching (mean = December 3rd), embryos can withstand extended periods of dewatering if the relative humidity remains near 100% (Neitzel and Becker 1985). Thus, Pre-Hatch Period constraints are based on the duration of low discharge from PRD and Post-Hatch Period constraints are based on inter-gravel water levels on Vernita Bar. Post-Hatch Period constraints are continued until emergence begins (mean = March 18th). Multiple studies indicate that survival from spawning to emergence is high and that constraints of the HRFCPPA are effective and provide sufficient protections for a vast majority of redds in the Hanford Reach (Chapman et al. 1983, 1986, Oldenburg et al. 2012). This section describes the results of recent studies during the Pre- and Post-Hatch periods of juvenile fall Chinook salmon in the Hanford Reach.

5.3.1 Investigation of Egg-to-Fry Survival Rates and the Effects of Flow Variation on Hatching Success

Fall Chinook salmon fry production in the Hanford Reach and how the HRFCPPA affects survival from spawning to emergence were critical uncertainties prior to completing the Phase I studies. Several studies related to spawning and survival of embryos were recently completed and culminated with a study to measure egg-to-fry survival rates and forms of production loss for fall Chinook salmon in the Hanford Reach. The following text is the executive summary from the final report (Oldenburg et al. 2012):

> The Hanford Reach is the most productive spawning area for fall Chinook salmon (*Oncorhynchus tshawytscha*) in the mainstem Columbia River and supports one of the largest spawning populations of fall Chinook salmon in the Pacific Northwest. The Public Utility District No. 2 of Grant County (Grant PUD) owns and operates Priest Rapids Dam, which marks the upstream boundary of the Hanford Reach. Grant PUD is pursuing an effort to examine the effects that hydroelectric operations from Priest Rapids Dam have on the productivity of Hanford Reach fall Chinook salmon. Among the factors affecting fall Chinook salmon productivity, one key knowledge gap exists from the point when adult female Chinook salmon discharge eggs until the emergence of fry from redds (egg-to-fry survival). Thus, the primary goal of this research was to estimate the egg-to-fry survival of fall Chinook salmon within the Hanford Reach of the Columbia River.
>
> Survival was estimated as the product of two independent survival estimates occurring during the egg-to-fry period. The first objective was to estimate survival from the time of fertilization until eggs were 378 degree days old (degree days are

the sum of mean daily temperatures [°C] over a given period of time). The second objective was to estimate survival from 378 degree days until the expected time of emergence (i.e., 900 degree days). The product of estimates obtained from Objectives 1 and 2 provided the estimated overall egg-to-fry survival of fall Chinook salmon. However, other sources of loss (e.g., eggs swept from redds during deposition or burial, eggs swept from redds by scour or superimposition, egg predation, and alevins that become entombed within redds) can occur during the egg-to-fry period and were not accounted for through Objectives 1 and 2. Therefore, a third objective of this study was to qualitatively evaluate sources of loss related to eggs being swept from redds and egg predation.

Survival from fertilization until 378 degree days was estimated using eggs sampled from natural redds in the Hanford Reach of the Columbia River. Researchers excavated one pocket from each of 52 redds and sampled the first 100 eggs they found before re-burying each redd. Eggs were preserved in Stockard's solution and returned to the Battelle Aquatics Research Laboratory (ARL) where they were examined under a microscope to identify whether they were living or dead at the time of sampling, and to identify the stage of development of each egg. Time of fertilization was estimated for each egg based on stage of development and the thermal history of the Columbia River.

Survival from 378 degree days until emergence was estimated by rearing eggs in cylindrical egg tubes (CETs) until the estimated time of emergence (e.g., 900 degree days) and then quantifying survival within each CET. Three treatments were evaluated: eggs reared in the Hanford Reach at Vernita Bar, eggs reared in the Hanford Reach at Island Four, and eggs reared in the ARL. Further, elevation was nested within treatment for the two field treatments (i.e., Vernita Bar and Island Four). Columnar and subterranean water temperatures and water surface elevations were monitored at both field sites prior to and throughout the study.

Sources of mortality not accounted for by Objectives 1 and 2 were qualitatively evaluated through drift net sampling, underwater observation, and evaluation of the gastric contents of species that may have preyed on fall Chinook salmon eggs. Drift nets deployed at Vernita Bar on November 7 and 14, 2010, were fished from 3 to 46 h and sampling rate (i.e., eggs sampled per hour) was evaluated. Underwater observation was used to document potential predator species (e.g., mountain whitefish Prosopium williamsoni, largescale sucker Catostomus macrocheilus, and white sturgeon Acipenser transmontanus) at or near redd locations during the time of fall Chinook salmon fertilization events. Potential predator species were sampled in spawning areas within the Hanford Reach and their gastric contents were evaluated. Aquarium nets were used to collect sculpin Cottus spp. Mountain whitefish, largescale sucker, and common carp Cyprinus carpio were sampled by spearfishing.

Mean survival (±95% confidence interval) among natural redds sampled during Objective 1 was 97.6% ± 5.6% and varied from 85.2% to 100.0% within redds. Eggs varied from 2 to 192 degree days of age at the time of sampling. Fertilization rate was estimated to be 97.8%. The oldest redd sampled was fertilized 192 degree days prior to sampling; thus, extrapolation was used to estimate survival to 378 degree days. Survival from fertilization to 378 degree days was estimated to be 96.0%. Among redds sampled for which eggs had been fertilized less than 21 degree days prior to sampling, 78% were estimated to have been fertilized nocturnally.

Eggs reared in Objective 2 CETs were 924, 903, and 984 degree days old when survival was quantified for the Vernita Bar, Island Four, and ARL treatments, respectively. Based on stage of yolk absorption, it appears that alevins from all three treatments were physiologically ready to emerge at the end of the rearing period. Cylindrical egg tubes reared at the highest elevations at Vernita Bar experienced highly dynamic incubation conditions due to dewatering and low-water events. These 6 CETs experienced complete mortality and were excluded from remaining analyses. Incubation conditions among all remaining Vernita Bar (N = 9), Island Four (N = 13), and ARL (N = 5) CETs were relatively stable. Mean survival among Vernita Bar CETs (63.9% ± 7.2%; excluding high-elevation CETs) was significantly ($\alpha = 0.05$) less than survival within Island Four (84.5% ± 6.1%) and ARL (86.6% ± 3.6%) treatment CETs. Elevation did not explain a significant amount of variability in survival within field treatments. The estimated survival from 378 degree days until emergence between field treatments was 74.2%. Thus, the estimated overall egg-to-fry survival rate (i.e., the product of survival rates estimated by Objectives 1 and 2) was 71.2%.

Drift nets sampled an average of 12.9 ± 24.1 eggs per hour and the maximum number of eggs sampled within a 24-h drift net deployment was 728. Sampling rate among drift net deployments was highly correlated with the estimated maximum near-bed velocity at drift net locations. Sampling rate dramatically increased when maximum near-bed velocity approached 1.0 m/s. Eggs sampled by drift nets varied in age (days since fertilization) from < 1 day old to 26 days old.

Fall Chinook salmon fertilization events were observed by snorkelers on two occasions. No potential predator species were observed near the redds during these events. It is not known whether the presence of the snorkelers altered the behavior of potential predators. White sturgeon were observed in fall Chinook salmon spawning areas on 81 occasions through 67 h of observation. Many of these sturgeon were estimated to be two to three meters in length and were located in shallow (e.g., < 2 m deep) water on or near fall Chinook salmon redds. On three of those occasions, white sturgeon were observed actively pumping substrate from within salmon redds. Mountain whitefish (N = 9), largescale sucker (N = 29), sculpin (N = 6) and carp (N = 1) were sampled for gastric evaluation. Mountain whitefish contained 14.0 ± 24.7 eggs per fish and typically contained enough fall Chinook salmon eggs that their stomachs appeared distended. Largescale suckers and sculpin contained an average of 0.4 and 0.3 salmon eggs per fish, respectively. The gastrointestinal tract of the carp contained 132 fall Chinook salmon eggs. However, carp were rarely observed near fall Chinook salmon redds.

The overall estimated egg-to-fry survival rate of 71.2% includes only those eggs that were buried and remained within redds until the time of emergence and that were never dewatered or nearly dewatered throughout the study. Based on the results from the unburied eggs and predation studies, we hypothesize that a biologically meaningful amount of loss may have occurred that was not accounted for by the "overall" survival estimate. However, we were unable to quantify these "other" losses in a manner that would place them in a workable context so that survival rates could be appropriately adjusted. Further, our estimate of egg-to-fry survival also did not account for losses of alevins that were unable to emerge and died within redds (entombed alevins), which may have been another meaningful source of loss.

Figure 19 Percent of eggs by redd (ranked by age [degree days] with redds becoming progressively older from left to right) that were determined to be living or dead at the time of sampling, and those whose status was unable to be determined due to an obstructed view of the embryo or cellular structure (i.e., "Unknown"; Figure 13 in Oldenburg et al. 2012).

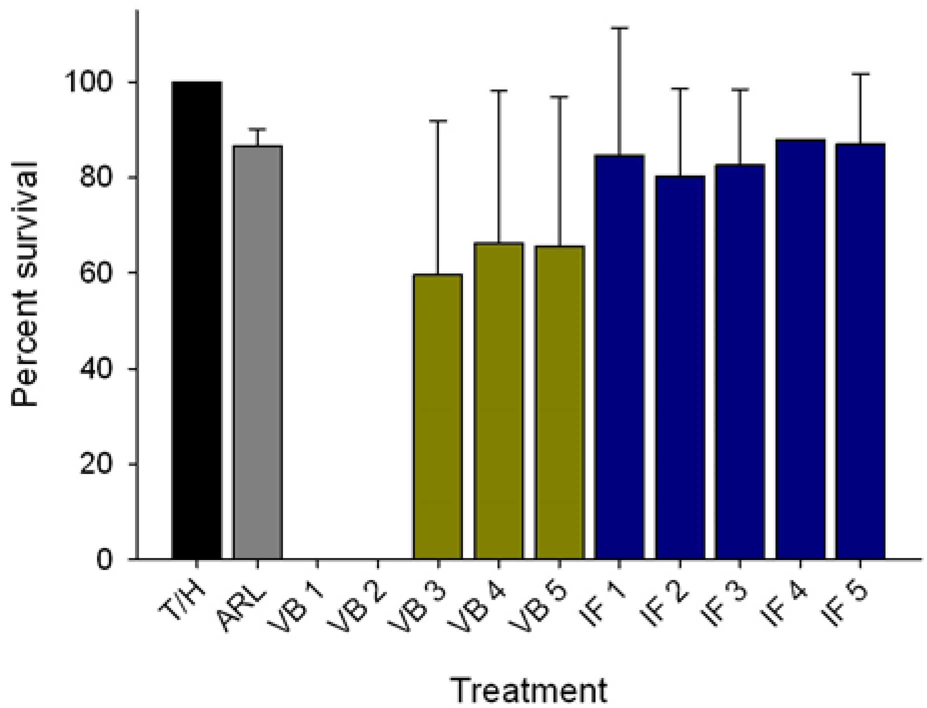

Figure 20 **Mean percent survival among the ARL treatment and field treatment row combinations (Vernita Bar [VB] and Island Four [IF]). Rows were ordered from 1 to 5 from the highest to the lowest elevation within each field treatment. Survival within the transportation and handling (T/H) CET is provided. Error bars indicate 95% confidence intervals (Figure 28 in Oldenburg et al. 2012).**

With the exception of two replicate groups on Vernita Bar (i.e., VB1 and VB2), survival rates were high and relatively consistent across and within sites (Figure 19). The two anomalous replicates were the only groups that experienced significant temperature increases (Figure 21). Given the air and surface water temperatures in December, the temperature increases are an indicator of upwelling groundwater. Data were collected from shallow monitoring wells near Priest Rapids Hatchery to investigate whether groundwater with low levels of dissolved oxygen (DO) could be a plausible cause of the mortalities in these replicates. A sensor was lowered 25 feet into one of the monitoring wells and DO was measured at 30 minute intervals during July 24-26, 2012. Dissolved oxygen ranged from 0.68 to 1.78 mg/l (mean 1.5 mg/l) and confirmed that shallow groundwater near Vernita Bar has lethally low levels of DO (Langshaw 2012, unpublished data). Temperature and DO sensors were buried in artificial redds on Vernita Bar during 2012 to further investigate low DO as the mechanism for the observed mortality.

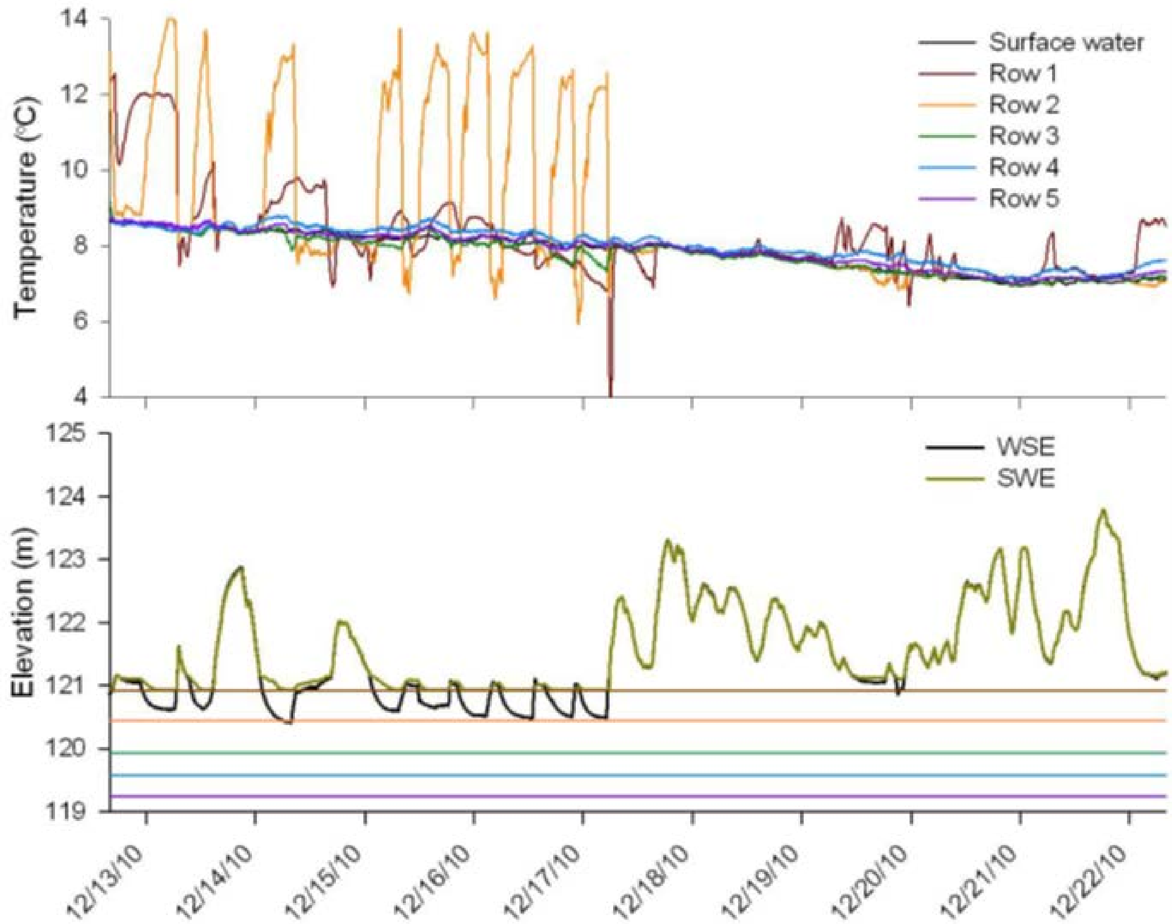

Figure 21 **Vernita Bar water surface elevation (WSE, based on data from the low elevation dual logger), subsurface water elevation (SWE, based on data from the high elevation dual logger) relative to CET Row 1, and water temperature throughout the first 10 days of the study. Horizontal lines in the elevation panel demonstrate the elevations at which CET rows were located. Water temperature was measured within CETs at each elevation row within the Vernita Bar treatment. Surface water temperature was measured within the water column at Vernita Bridge. Rows 1 and 2 experienced 100% mortality. This is Figure 23 from Oldenburg et al. (2012).**

Patterns of temperature and DO observed on Vernita Bar in 2012 were consistent with other research. Vertical hydraulic gradient (VHG) between surface and hyporheic water can indicate potential upwelling (positive values) and down-welling (negative values) sites. While the magnitude of effect can differ by depth or location, VHG can be significantly influenced by fluctuations in stage at some locations (Figure 22) (Geist 1999, Geist et al. 2002, 2011, Hanrahan 2008). In the fall (September 28 – November 11) of 2012 the dynamics of stage and DO in the intergravel spaces was evaluated by deploying six sensors on Vernita Bar (Figure 23). The sensors were buried on transect perpendicular to flow 30 cm deep at the 45, 50, 55, 60, 65, and 70 kcfs elevations. Similar to previous studies (e.g., Figure 22), the dynamics of inter-gravel conditions differed between locations on Vernita Bar. Interestingly, DO patterns were dramatically different even though adjacent sensors were less than 5 m apart. The sensor at 45 kcfs elevation appeared to have continuity with surface water throughout the monitoring period

(Figure 23). Shortly after the water surface elevation dropped, upwelling groundwater caused the DO levels at 50 kcfs to drop. Daytime discharge during this period was approximately 60 kcfs and the sensor at that elevation appeared to be influence by upwelling when nighttime flows increased. The sensor at 65 kcfs elevation appear to be in continuity with the surface water for several hours after flows decreased and then began to be influenced by upwelling groundwater. Thus, DO dynamics appear to be related to down/upwelling and the redd elevation relative to the water surface. Furthermore, low DO levels are the likely cause of the complete mortality observed in the two replicates on Vernita Bar.

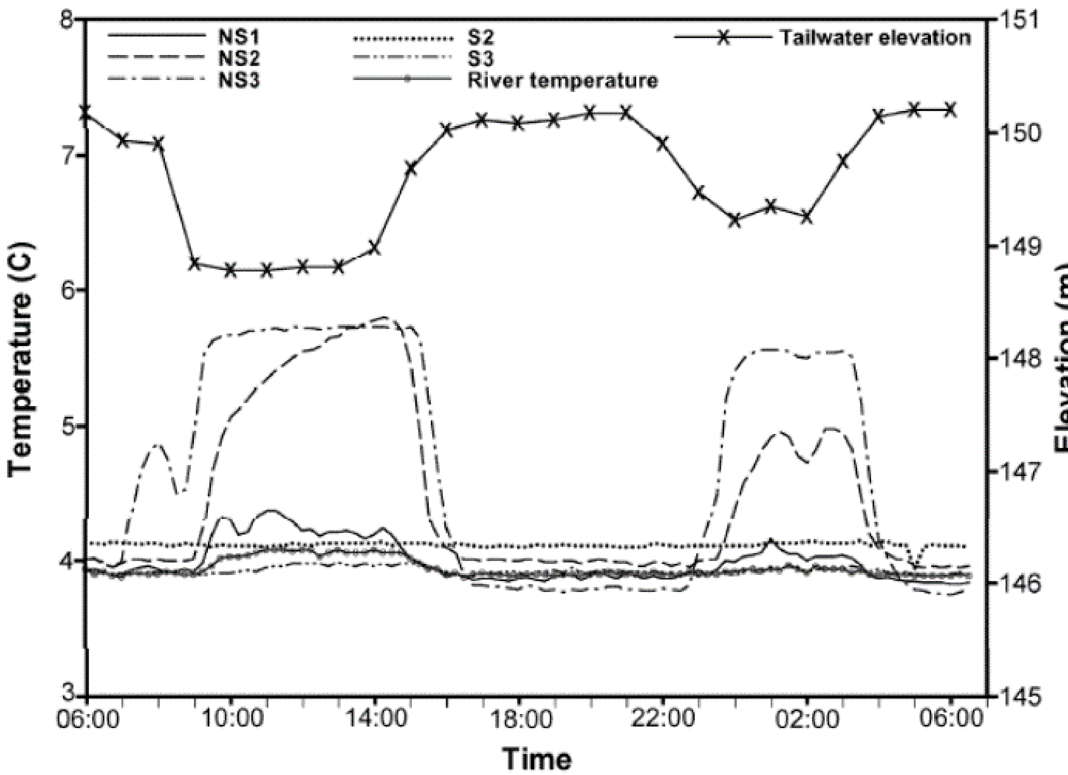

Figure 22 **Water temperature of the river and riverbed within a spawning (S) and a non-spawning (NS) area on the Barge Dock Bar during a 24-h period in February 2002 (Figure 5 from Geist et al. 2011)**

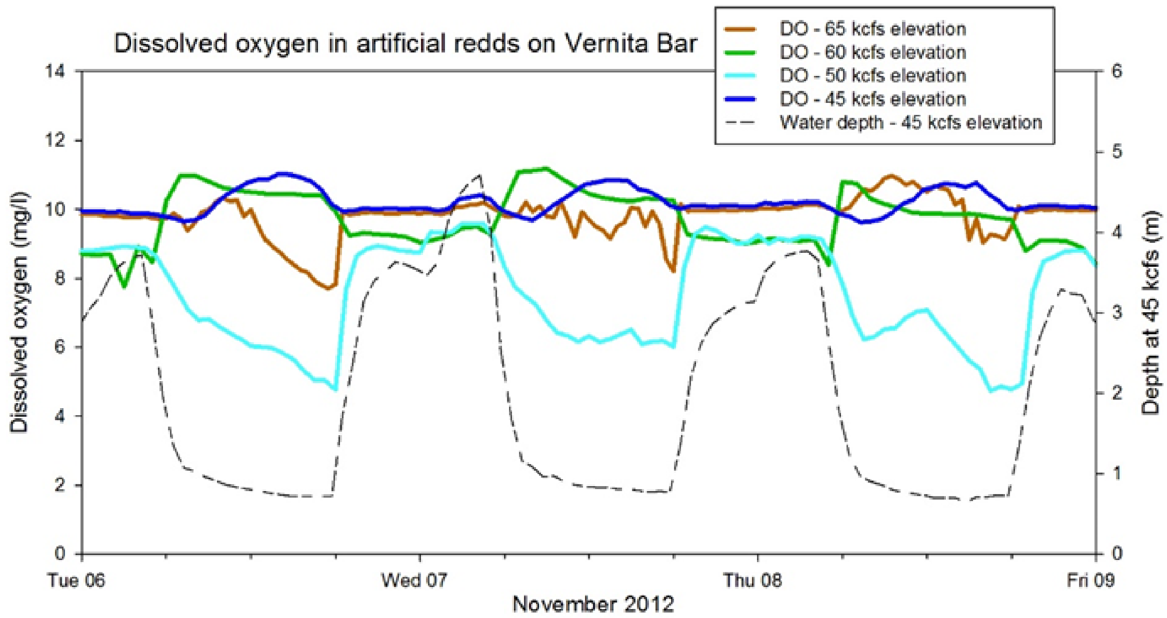

Figure 23 Dissolved oxygen levels in artificial redds on Vernita Bar during November 2012. The hashed line represents the estimates of water depth of the sensor at 45 kcfs elevation. The artificial redd at 45 kcfs elevation had good connectivity with surface water and the other artificial redds had varying degrees of interaction between surface water and groundwater.

5.3.2 Feasibility of Quantifying Eggs in Fall Chinook Salmon Redds

Prior to implementation of the full egg-to-fry survival study during Phase I, several projects were completed to investigate the feasibility of quantifying eggs in redds on Vernita Bar. The methods that were investigated included manually removing and sorting and using hydraulic pressure to excavate redds. From these evaluations it was determined that the manual method was the most effective means to quantify eggs in redds. The following text is the executive summary from the final report (Oldenburg et al. 2009):

> Discharge from Priest Rapids Dam inundates the vast majority of fall Chinook salmon redds on Vernita Bar through the incubation and emergence periods. However, redds at higher elevations on the bar periodically become dewatered as a function of dam operations. The number of eggs in fall Chinook salmon redds on Vernita Bar is unknown, and assumptions of egg numbers in these high-elevation redds have been based on the fecundity of female Chinook salmon spawned at Priest Rapids Hatchery. The objective of this study was to develop a method with which to quantify the number of eggs in high-elevation redds on Vernita Bar.
>
> A viable method for manually removing and sorting substrate and eggs from desiccated redds was developed. Ten artificial redds were constructed containing known numbers of eggs. The manual method was used to quantify the number of eggs in these redds. Nineteen of twenty egg pockets were found, and the mean percentage egg recovery (± SE) was 94.7% ± 3.2%. Mean percentage of eggs

recovered from artificial redds when all egg pockets were found was 97.8% ± 0.7%. These results suggest that the manual method is effective for quantifying eggs in high-elevation redds. This method will aid researchers in determining the number of eggs present in high-elevation redds and in estimating egg-to-fry survival of fall Chinook salmon. Hydraulic pressure was also used to excavate inundated redds, but the method proved ineffective.

5.3.3 Pilot Study for Using Cylindrical Egg Tubes to Investigate Egg-to-Fry Survival

A pilot study was conducted to evaluate methodologies for estimating egg-to-fry survival in the Hanford Reach using cylindrical egg tubes (CET). A key finding of this project was that protocols for egg fertilization and handling had a significant effect on mortality rates. Protocols were modified and contributed to the successful investigation of egg-to-fry survival in Phase I. The final report did not include an executive summary, but the following text is from the discussion section from the final report (Goodman et al. 2010a):

> After fertilization, the eggs used in this study were counted into 100-egg lots, transferred to transport containers, driven down rough gravel roads, and some were placed into CETs along with substrate. Thus, mechanical shock resulting from the handling and transportation of eggs during the hours immediately following fertilization likely contributed to the high mortality rates observed within CETs and incubation trays. However, survival to hatch was also poor for eggs that remained at PRH (in incubation trays) and experienced less mechanical shock (i.e., were not transported in vehicles); therefore, it is likely that low fertilization success also contributed to the high mortality rates observed. Regardless of the cause of initial mortality, the egg-to-fry survival estimates produced during this study were clearly confounded by this high initial mortality. Thus, egg-to-fry survival of naturally produced Chinook salmon is likely much greater than the survival of the individuals used in this study. For example, McMichael et al. (McMichael et al. 2005) estimated mean fall Chinook salmon egg to fry (ETF) survival at 29.2% (range, 16.9−66.6%) downstream of Wanapum Dam in the Columbia River.
>
> Mean survival of fall Chinook salmon embryos was slightly higher in laboratory CETs than in Vernita Bar CETs. However, variability was high among female groups and the sample size at the ARL was low (i.e., N = 9 at the ARL compared to N = 27 at Vernita Bar). Thus, the accuracy of these survival rate estimates is questionable and inferences based on these data should be avoided pending collection of additional data.
>
> Water temperature gradient measurements within artificial egg pockets at Vernita Bar showed that water temperatures at fall Chinook salmon egg pocket depth (i.e., 18 to 43 cm beneath the riverbed surface (Chapman 1988) were greater than surface water temperatures. Thus, degree day estimates for incubating fall Chinook salmon embryos based on surface water temperature at Vernita Bar could lead to inaccurate estimates of emergence timing. Increased water temperatures at Chinook salmon egg pocket depth compared to surface water temperature have been documented in other fall Chinook salmon spawning areas

(e.g., the Snake River (Hanrahan 2007)). In the current study, we used surface water temperature as a surrogate for riverbed temperature at fall Chinook salmon egg pocket depth at Vernita Bar resulting in underestimation of the degree days experienced by fertilized eggs in CETs at the time of retrieval. However, the range of development observed for alevins and fry (i.e., from alevins with large yolk sacs to buttoned-up fry) recovered from the CETs deployed at Vernita Bar after 900 DDs (as estimated from surface water temperature) was within the target range. Because no evidence of mortality was found for alevins or fry in CETs (i.e., all alevins and fry recovered from CETs were assumed to be alive due to the absence of fungus on these fish and the lack of decomposition), all alevins and fry observed in recovered CETs could be assumed to have survived until emergence. Thus, 900 DDs based on surface water temperature provided a reasonable estimate for survival to emergence for fall Chinook salmon embryos in this study. Earlier removal would have resulted in fewer fry at the buttoned up stage (i.e., ready to emerge), and a later removal may have resulted in mortality due to the inability to emerge and begin exogenous feeding.

The mean percentage of fertilized eggs that were not recovered (i.e., found as dead eggs, embryos, alevins, or fry) from CETs retrieved from Vernita Bar was 19%, indicating that some eggs and embryos had decomposed, were removed from CETs, or were damaged beyond recognition during the 143- to 151-day period between burial and retrieval. In comparison, the mean percentage of fertilized eggs that were not recovered from CETs in the artificial stream at the ARL was 4%. The sources of egg disappearance (e.g., decomposition, predation, etc.) were not documented. Larger egg predators (e.g., sculpin) could not access the eggs in CETs because the CETs were constructed with fine mesh. However, macroinvertebrates and leeches were present in all CETs recovered from Vernita Bar and may have consumed live or dead eggs and contributed to egg loss. Macroinvertebrates and leeches were not present in CETs at the ARL. Thus, the disparity in egg recovery rates between CETs at Vernita Bar and CETs at the ARL might be related to egg consumption by macroinvertebrates and leeches.

5.3.4 Evaluation of Egg-to-Fry Survival Study Methodologies

Egg-to-fry survival methodologies were further evaluated in the relatively controlled setting of the discharge channel of the Priest Rapids Hatchery. This project was completed during pursuit of a Master’s degree at Central Washington University and the following text is the Abstract from the thesis (Lauver 2012):

Fall Chinook salmon (*Oncorhynchus tshawytscha*) egg-to-fry survival study methods were evaluated in the Priest Rapids Hatchery discharge channel by comparing dissolved oxygen levels and hyporheic flow between artificially and naturally created egg pockets. Additionally, fry growth metrics and egg-to-fry survival from Whitlock-Vibert egg boxes and cylindrical egg tubes were compared. No statistically significant differences were detected in dissolved oxygen levels between artificial and natural egg pockets, or with fry growth metrics or egg-to-fry survival between Whitlock-Vibert egg boxes or cylindrical egg tubes. Quantitative differences in hyporheic flow between artificial and natural egg pockets were statistically significant. However, it is concluded that artificially constructed fall Chinook salmon egg pockets are representative surrogates for naturally constructed fall Chinook salmon egg pockets, and that Whitlock-Vibert egg boxes and cylindrical egg tubes produce similar numbers of fry in similar condition when conducting egg-to-fry survival studies.

5.3.5 Photographic Index of Fall Chinook Salmon Embryonic Development

An important component of the egg-to-fry survival investigations was the development of methodologies to identify the date of fertilization. A detailed study of embryo development was completed and a comprehensive photographic index of development was published. This index and subsequent research led to development of a detailed model to pinpoint the date and time of fertilization for embryos that are collected in the Hanford Reach (Oldenburg et al. 2012). The following text is the Abstract from the photographic index (Boyd et al. 2010):

> Knowledge of the relationship between accumulated thermal units and developmental stages of Chinook salmon embryos can be used to determine the approximate date of egg fertilization in natural redds, thus providing insight into oviposition timing of wild salmonids. However, few studies have documented time to different developmental stages of embryonic Chinook salmon and no reference color photographs are available. The objectives of this study were to construct an index relating developmental stages of hatchery-reared fall Chinook salmon embryos to time and temperature (e.g., degree-days) and to provide high-quality color photographs of each identified developmental stage.
>
> Fall Chinook salmon eggs were fertilized in a hatchery environment and sampled approximately every 72 hours post-fertilization until 50% hatch. Known embryonic developmental features described for sockeye salmon were used to describe development of Chinook salmon embryos. A thermal sums model was used to describe the relationship between embryonic development rate and water temperature. Mean water temperature was 8.0°C (range, 3.9°C–11.7°C) during the study period. Nineteen stages of embryonic development were identified for fall Chinook salmon; two stages in the cleavage phase, one in the gastrulation phase, and sixteen stages in the organogenesis phase. The thermal-sums model used in this study provided similar estimates of fall Chinook salmon embryonic development rate in water temperatures varying from 3.9°C–11.7°C (mean, 8.0°C) to those from several other studies rearing embryos in constant 8°C water temperature.
>
> The developmental index provides a reasonable description of timing to known developmental stages of Chinook salmon embryos and was useful in determining developmental stages of wild fall Chinook salmon embryos excavated from redds in the Columbia River. This index should prove useful to other researchers who wish to approximate fertilization dates of Chinook salmon embryos obtained from natural redds, assuming the thermal history of embryos is known.

5.4 Emergence and Rearing Periods

Chinook salmon require approximately 900-1000 accumulated temperature units (ATUs) to mature and begin emerging from redds (Murray and Beacham 1987, Oldenburg et al. 2012)

2012). Just prior to emergence (mean = March 18th) alevins begin to migrate up through the gravels. To ensure that alevins are protected during this life-stage, minimum flow constraints under the HRFCPPA shift from inter-gravel (15 cm below the Critical Elevation) water depth to water surface elevation. Minimum discharge constraints are continued through 1000 ATUs from the end of spawning to provide enough time for all fry to emerge. Daily discharge delta constraints at Priest Rapids Dam are implemented after emergence begins to reduce flow fluctuations that can lead to fry stranding on dewatered substrates or entrapment in isolated pools. Daily delta constraints are based on inflows to Wanapum Dam during the previous day or BPA forecasted weekend flows for Chief Joseph Dam, including side flows (i.e. tributary inflows). Daily delta constraints are continued until 400 ATUs after the end of emergence (mean = June 14th) to ensure fry have moved off shore. Some fry rear in the near shore areas, but they move off shore as they grow and are less susceptible to stranding or entrapment as the season progresses. This section describes the results of recent studies during the Emergence and Rearing periods of juvenile fall Chinook salmon in the Hanford Reach.

5.4.1 Stranding and Entrapment

Dam operations to generate electricity when power generation is needed cause fluctuations in water levels that dewater shorelines that can strand or entrap fall Chinook salmon fry in the Hanford Reach. The primary period of susceptibility to stranding and entrapment coincides with the pattern of emergence (Hoffarth et al. 2003, 2014) that generally begins in March, peaks in April, and ends in May (Langshaw and Hoffarth 2013). Estimates vary for the fork length at which susceptibility declines, but can be as low as 45 mm with very few fish collected that are greater than 60 mm (Wagner et al. 1999; Hoffarth et al. 2003; Anglin et al. 2006). Efforts to quantify losses of fall Chinook salmon in the Hanford Reach that were due to stranding and entrapment were completed during seven years of research between 1998 and 2013 (reviewed in McMichael et al. 2006a, Hoffarth et al. 2012, 2013, 2014). Annual loss estimates ranged between approximately 500,000 in 2013 and 6.8 million in 2003. However, population-level context is critically important when considering total loss (McMichael et al. 2006a, Hoffarth et al. 2014) as annual pre-smolt abundance is estimated to range between 21 and 78 million (Harnish et al. 2012) since implementation of the 1988 VBSA.

5.4.1.1 HRFCPPA Stranding and Entrapment Monitoring

The HRFCPPA establishes the obligations of the signatories with respect to the protection of fall Chinook salmon in the Hanford Reach. As stipulated in Section C.6.c. of the HRFCPPA:

> *During the Rearing Periods of 2011, 2012, and 2013, the Parties will also meet to develop a follow-up monitoring program to estimate fry losses. This monitoring program will be designed according to protocols developed from 1999 to 2003 or alternatively with different methods developed by the Parties.*

In cooperation with multiple agencies, WDFW has conducted extensive assessments in the Hanford Reach to quantify the relationships among instream flows, flow fluctuations, and stranding and entrapment mortality of fall Chinook salmon (reviewed in McMichael et al. 2006a). In 2010, staff from WDFW, Grant, USFWS, US Geological Survey (USGS), and Battelle−Pacific Northwest Division (Battelle) attended several meetings to build upon prior work and develop a study design that would meet the requirement to estimate fry losses. This study panel reviewed the data collection, methods, analyses, and results of stranding and entrapment studies conducted in the Hanford Reach from 1999 to 2007. A study plan to estimate fry losses during 2011-13 was finalized in September 2010, approved by FERC, and implemented in 2011. The study design was slightly refined in 2012 and 2013 to improve sampling efficiencies. Detailed methods and analyses can be found in each annual report (Hoffarth et al. 2012, 2013, and 2014). This section provides a general summary of the data and results reported in the annual reports.

A total of 1,967 plots were sampled for stranding during the three seasons (Table 1). A total of 168 fry were located; mean density = 16.2 fry/hectare. We estimated that a total of 60,596 hectares of substrate were dewatered during the three seasons and resulted in the mortality of approximately 945,000 juvenile fall Chinook salmon with an annual mean mortality of 314,987 juvenile Chinook salmon (Table 1).

Table 1 Summary of stranding results from 2011-2013. Detail can be found in the annual reports (Hoffarth et al. 2012, 2013, and 2014).

Year	Number of Plots sampled	Number of fry located	Mean fry/hectare	Total mortality estimate (95% confidence interval)
2011	374	49	21	407,579 (130,246-948,868)
2012	865	67	11	354,208 (164,156-558,073)
2013	728	52	16	184,123 (79,149-488,088)
Total	1,967	168	49	945,910
Mean	656	56	16.2	315,303

We estimated that a total of 562,018 entrapments were created during the three seasons. A total of 2,630 entrapments were sampled and 7,330 Chinook salmon juveniles were collected (Table 2). Abundance of recovered juveniles was heavily skewed towards zero (88%; Figure 24) with a mean density of recovered juveniles being 2.8 fry/entrapment (Table 2). We estimated a total of 1.8 million juvenile Chinook salmon mortalities were caused by entrapment with a mean of 617,564 per year. Combining the stranding and entrapment losses results in a mean of approximately 933,000 juvenile Chinook salmon mortalities each year. Even when combined, losses from stranding and entrapment are relatively small compared to the mean annual estimate of pre-smolt production in the Hanford Reach since implementation of the VBSA (i.e., 2.2% of 42.4 million; Figure 25).

Table 2 Summary of entrapment results form 2011-2013. Details can be found in the annual reports (Hoffarth et al. 2012, 2013, and 2014).

Year	Number of entrapments sampled	Number of entrapments that contained fry	Number of fry recovered	Mean Chinook per entrapment	Total mortality estimate (95% confidence interval)
2011	573	59	802	1.4	297,844 (230,256-482,775)
2012	1,378	120	4,611	3.4	1,281,417 (-83,112-5,514,367)
2013	679	128	1,917	2.8	267,453 (134,851-485,255)
Total	2,630	307	7,330	2.8	1,846,714
Mean	877	102	2,443	2.8	615,571

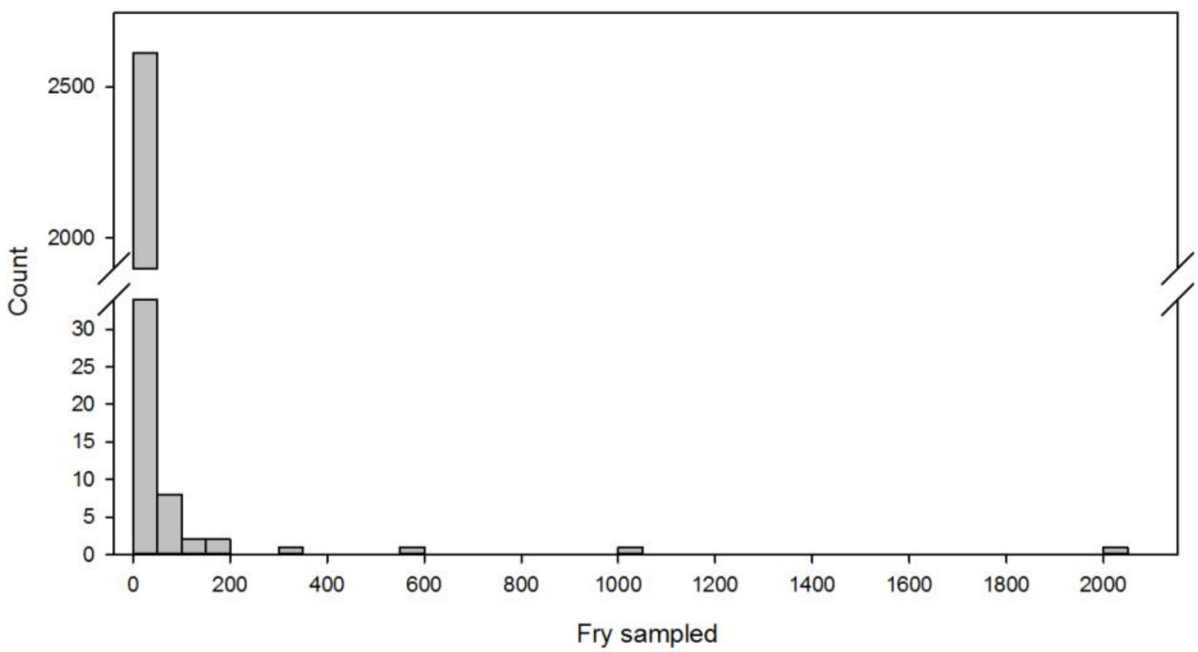

Figure 24 Histogram of Chinook salmon fry abundance in sampled entrapments. No fry were found in approximately 88% of the entrapments that were sampled.

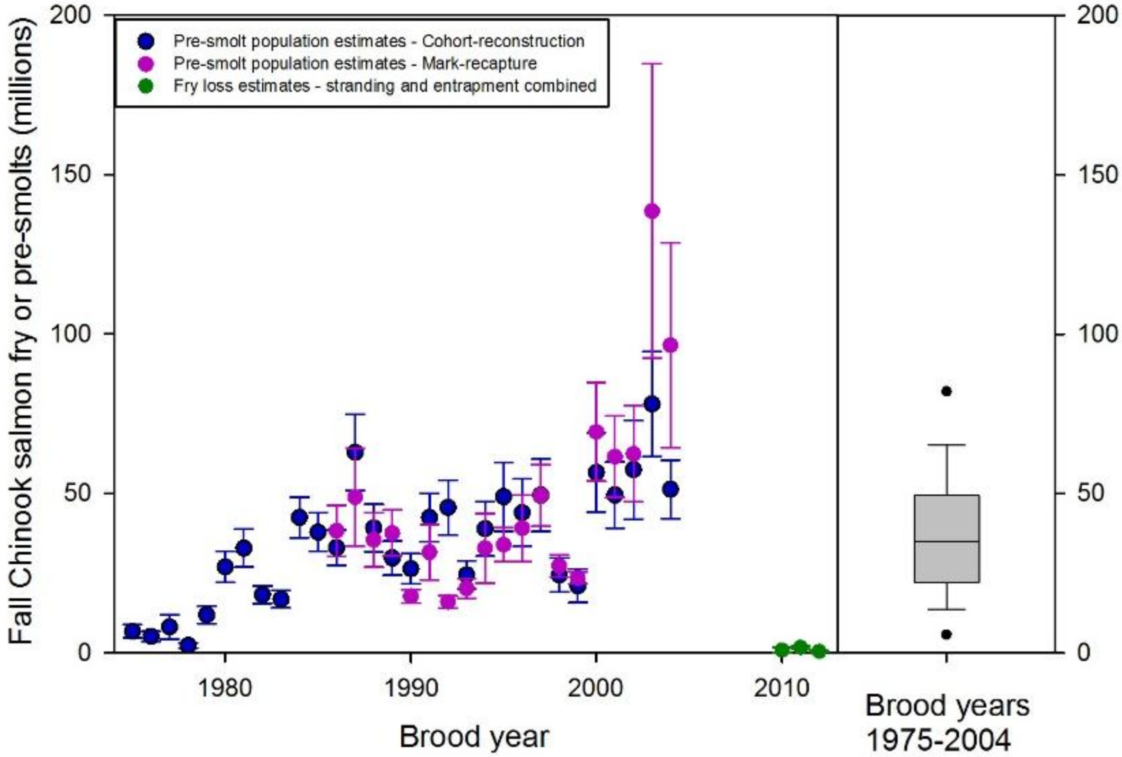

Figure 25 **Estimates of Chinook salmon pre-smolt abundance from the productivity assessment (Harnish et al. 2012) in the Hanford Reach and fry mortality as a result of stranding and entrapment. The box plot represents the 25th – 75th percentiles of pre-smolt estimates from the cohort reconstruction. The medians for the entire data set and the post-VBSA era is 36.3 and 45.0 million, respectively.**

5.4.1.2 Data Mining for Stranding and Entrapment

Significant negative effects to juvenile fall Chinook salmon productivity were not identified during Phase I (see Section 4.2). Pre-smolt productivity was not correlated with variables related to stranding and entrapment (Harnish et al. 2012). After completing the three years of stranding and entrapment field evaluations, Grant PUD agreed to further examine relationships between flow fluctuations and stranding and entrapment through data mining and statistical modeling. Evaluating the relationship between flow fluctuations and stranding or entrapment is difficult and generally restricted to controlled experiments in laboratory settings. Given the difficulties and limited potential for significant new insights from field and/or lab studies, mining the existing dataset was viewed as the most likely avenue to identifying relationships between hydrology and stranding and entrapment. The number of stranding and entrapment studies completed in the Hanford Reach, extensive data collection, and recent improvements to hydraulic modeling provided the opportunity to examine relationships between the physical environment and stranding or entrapment of juvenile fall Chinook salmon.

Entrapment studies conducted during 2007, 2011, 2012, and 2013 were used for data mining because the methods and data collected were similar. A total of 5,935 entrapments were sampled during these four years and MASS2 hydraulic simulations were used to generate data on environmental conditions associated with each entrapment. Because the abundance of fry in entrapments is heavily skewed towards zero and because entrapments can result from fixed and random effects, non-parametric mixed models, such as the Zero-inflated Poison (ZIP) models and Hurdle models, were identified as the most appropriate tools for analyzing the dataset. The ZIP models are based on the assumption that zeros in the dataset have two sources; a 'structural source' and a 'sampling' or random source (Shin 2012). For example, some entrapments without fish may occur because fish were not present at that site, i.e. sampling or random source of zeros. The remaining zeros result from other 'structural' factors (e.g., magnitude of flow fluctuation). Hurdle models are based on the assumption that all zeros only result from structural sources (Shin 2012). The ZIP and Poisson hurdle models produced similar results; however, only those from ZIP are presented here because the assumption that zeros result from a single structural source was likely invalid.

Environmental data from the MASS2 output were compiled for the habitat cells at each site that an entrapment was sampled. Abundance of fish in each sampled entrapment was the dependent variable. The zip and hplogit commands (Stata 13.1) were used to develop models from the independent variables listed in Table 3. Model fit was compared using Akaike's information criterion (AIC) and Vuong statistics were used to determine whether the zero-inflated model was a better fit than a simple Poison regression.

Table 3 Table of variables used for ZIP and Poisson hurdle models.

Variables	Definition	Included in final model
ChinookTotal	Total Chinook collected in the entrapment	Dependent
TransID	Transect 1-360 (250 meters each)	Y – inflation variable
JulianDate	Date of sampling	Y – inflation variable
Area	Water surface area of transect	
AreaChange	Change from previous hour	
Depth	Thalweg depth of transect	Y
DepthChange	Change from previous hour	Y
Velocity	Depth averaged velocity of transect	
VelocityChange	Change from previous hour	
TopwidthChange	Change from previous hour	
SumDepthIncrease	Depth increase before created	Y
SumAreaDecrease	Area decrease before sampling	Y
SumTopwidthDecrease	Topwidth decrease before sampling	Y
Size	Estimated size when created (categories 1-5)	Y
DurationWet	Total hours wet before created	
DurationDry	Total hours between creation and sampling	
HourCreated	Hour of day created	
HourSampled	Hour of day sampled	
HourMaxDepth	Hour of peak discharge before created	
HourMinDepth	Hour of min discharge before sampled	

The best fitting model explained 38% of the variation in the dataset ($p<0.001$) with an AIC value of 33.811 and z of 3.29 for the Vuong test ($p<0.001$). All the independent variables in the best fitting models were intuitive. The most significant factors for entrapment appear to be related to timing, entrapment size and location, and the magnitude of flow fluctuations. Timing is intuitive because discharge and the abundance of susceptible fry generally increase throughout the early part of the season. The magnitude of flow fluctuations generally increases with discharge and more entrapments are created. The middle section of the Hanford Reach includes most of the spawning habitat, so more fry are available to be entrapped. The geomorphology in the middle section is also more complex and contains more habitat related to flow refugia that is critical early rearing habitat (e.g., gradual slopes, sloughs, islands, etc.). Entrapment size is also intuitive because large entrapments are generally found in areas with more complex habitats. Large entrapments also have greater surface area, which increases the probability that randomly distributed fish will be entrapped. Furthermore, small entrapments cannot physically contain as many fish.

While all the significant variables are intuitive, we were unable to develop models that accurately predicted fry abundance within individual entrapments. The modeled mean number of fry per entrapment is similar to the original dataset (11.7 vs. 12.2 respectively). However, the model does not accurately capture the frequency distribution of the original dataset (14.8 vs. 83.1% zeros, respectively; Figure 26). Furthermore, the maximum number of fish sampled in an entrapment was an order of magnitude higher than the modeled values (2,175 vs. 295, respectively). Therefore, the models evaluated have limited applicability due to the abundance of zeros or non-detects coupled with the apparent stochasticity of the presence of fry.

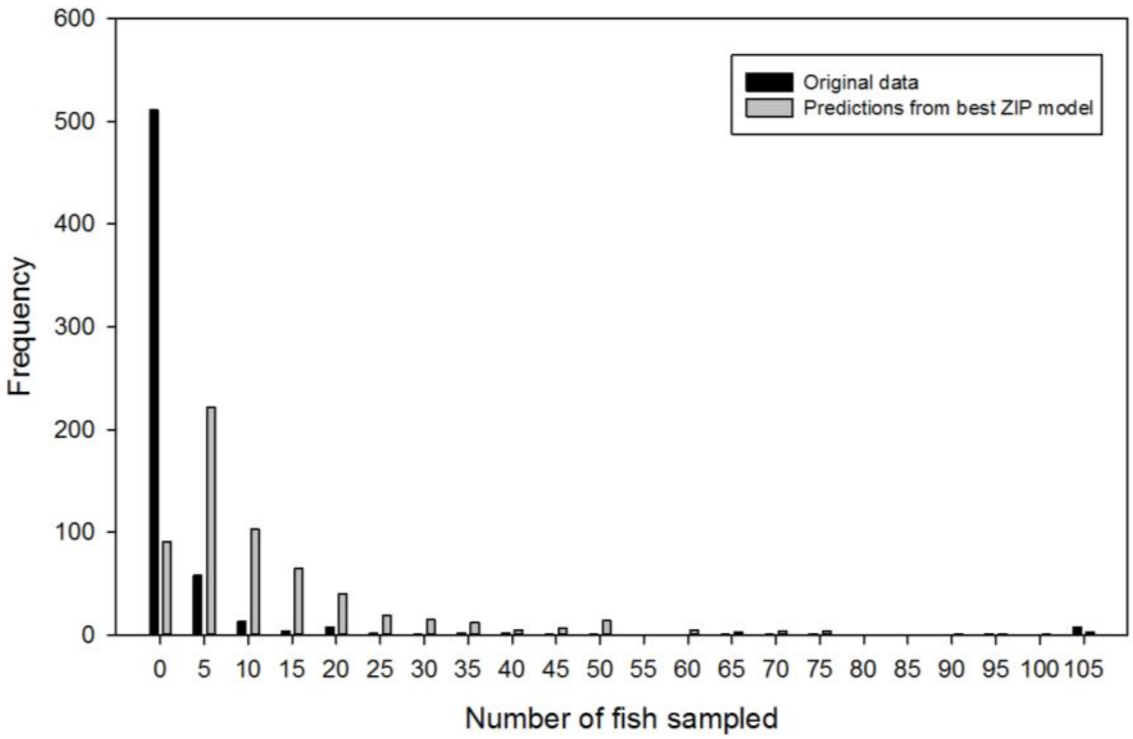

Figure 26 Histogram of original 2007 entrapment dataset and predictions from the best fitting ZIP model.

5.4.2 Predation

Data collected from natural-origin juvenile fall Chinook salmon PIT-tagged in the Hanford Reach indicated that survival from tagging to McNary Dam is particularly low (e.g., median survival to McNary Dam = 0.35; Figure 27). Evidence suggests predation could be a significant source of mortality for fall Chinook salmon smolts as they leave the Hanford Reach. The FCWG expressed interest in pursuing an investigation into potential sources of predation in the lower Hanford Reach and Lake Wallula (i.e., reservoir of McNary Dam). Grant PUD's mitigation requirements related to predation are extensive (i.e., avian and northern pikeminnow programs; GCPUD 2012) but limited to the Priest Rapids Project area. Thus, Grant PUD did not pursue or co-fund investigations into sources or magnitudes of predation on fall Chinook salmon downstream of the project area (i.e., Hanford Reach and Lake Wallula). To support this request by the FCWG, a report was developed that summarized available information related to predation in the Hanford Reach and Lake Wallula. Subsequent to the synthesis report an acoustic-telemetry project was developed by PNNL and co-funded by the Pacific Salmon Commission (Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund) and the Priest Rapids Coordinating Committee (No Net Impact fund) to investigate the location and magnitude of losses during emigration from the Hanford Reach to McNary Dam. This section summarizes the predation synthesis report and acoustic telemetry study.

5.4.2.1 Predation Synthesis Report

A comprehensive report was developed to investigate potential sources and magnitude of predation on fall Chinook salmon in the Hanford Reach and Lake Wallula. The following text and figures are from the final report that was prepared to compile the best available information on predation between Priest Rapids and McNary dams (Rizor et al. 2014):

> Over the past decade, results of PIT tagged, natural-reared fall Chinook salmon migrating downstream through the Hanford Reach and Lake Wallula and surviving to McNary Dam has been significantly low [Figure 27]. The mean survival estimate of natural-reared subyearling fall Chinook salmon migrating through this stretch of the Columbia River is 35%, which is derived from PIT tag studies conducted by various entities between 1993 and 2013 (e.g., McMichael et al. 2006b, Fryer 2012, Dehart 2012). The reason for low survival is largely unknown and predation has been suspected to be a substantial contributing factor. Literature, including peer reviewed publications and white papers, as well as data retrieved from PTAGIS (Pit Tag Information System), Columbia River DART (Data Access in Real Time) and catch records provided by Oregon Department of Fish and Wildlife were reviewed and amalgamated, as applicable to defining predation factors that contribute to the loss of subyearling fall Chinook salmon out-migrating through the Hanford Reach and Lake Wallula.
>
> Factors that have likely contributed to subyearling fall Chinook salmon susceptibility to freshwater predators were examined in the literature and included: aquatic contaminants (e.g., biotic, pathogens, and abiotic, heavy metals) that diminish a fishes ability to detect and avoid predators, preference for habitat with shallow, low velocity waters that are found along shorelines and backwater sloughs and overlap with the distribution of predacious fish (e.g., smallmouth bass), susceptibility to flow fluctuations that can cause stranding and entrapment, implications of size and origin as it relates to survival, migrations that involve movement between the main water channel and shoreline areas, and length of migration during warm water temperatures and low flows. Information on known piscivorous fish and birds in the area of interest were compiled; relevant

distribution, abundance and feeding characteristics along with consumption estimates of subyearling fall Chinook salmon were further examined and reported.

The literature reviewed focused on the predation impacts that northern pikeminnow, smallmouth bass and walleye have on juvenile salmonids, more specifically, on subyearling fall Chinook salmon. Comprehensive predation estimates were available for the John Day Reservoir prior to the initiation of the Northern Pikeminnow Removal Program. Consumption trends including variability in seasonality, composition, and feeding location of these three piscivorous fish were reviewed and indicate that consumption of subyearling fall Chinook salmon by smallmouth bass is of increasing concern.

To quantify possible predation pressure on subyearling fall Chinook salmon in the Hanford Reach and Lake Wallula by piscivorous fish, compiled data on northern pikeminnow, smallmouth bass, and walleye was used to estimate abundance and a bioenergetics model was used to estimate consumption. Between Priest Rapids and McNary dams, the modeled piscivorous fish were estimated to explain, on average, 33% (range 11-100%) of the PIT tagged subyearling fall Chinook salmon mortality. This estimate equates to 6.2-15.4 million smolts consumed per year. Based on these results, smallmouth bass would be the species consuming the largest quantities of subyearling fall Chinook salmon, which further supports that smallmouth bass are, or should be, a species of concern for resource managers. Furthermore, within this area of interest, there was limited data available on the abundance, distribution and diet of channel catfish and therefore it could not be evaluated in the bioenergetics modeling exercises. But, what is known from past research is that there is enough data to hypothesize that channel catfish are widely distributed throughout the area of interest and may also be a substantial predator of subyearling fall Chinook salmon. To achieve additional confidence and more accurately direct management decisions, reach-specific field studies that would result in current data were suggested.

It is difficult to quantify a percentage of impact that predatory birds impose on the subyearling fall Chinook salmon population in the Hanford Reach and Lake Wallula. Little effort has been focused on investigating the impacts to this non-listed Evolutionary Significant Unit (ESU). Based on available data, approximately 1% of subyearling fall Chinook salmon has been consumed annually by Caspian terns, double-crested cormorants, American white pelicans and gulls. This estimate is low, as deposition rates of PIT tags from consumed smolts are largely unknown. There is no consumption information for the large population of gulls on Island 20 and tag depositions by American white pelicans (loafing in particular) is not well understood.

Management of piscivorous fish species may be the most viable option to increasing smolt survival based on the findings of this report. The Northern Pikeminnow Sport Reward Fishery Program (NPSRFP) has been regionally considered a success and in 2012, there was an estimated 35% program-wide reduction in predation on salmonids compared to pre-program level estimates. A removal program may be a viable option for non-native fish in the Hanford Reach and Lake Wallula, such as the target removal of smallmouth bass, walleye and perhaps channel catfish.

Before management actions occur, a better understanding of reach-specific biotic-parameters for piscivorous fish is needed. Current comprehensive data of abundance, distribution and diets are required for the Hanford Reach and Lake Wallula. This baseline data could be collected through an indexing study using mark and recapture techniques and would corroborate the assumptions of the bioenergetics model used in this report. More importantly, indexing would also give resource managers a better understanding of other piscivorous fish populations, such as channel catfish population dynamics, and could be used as a reference point to gauge the effectiveness of additional management actions. Furthermore, diet analysis as a secondary objective would assist in modeling and would result in a less variable estimate of total consumption.

The literature reviewed as outlined in this document, indicates that predation does not constitute the entire survival deficit that subyearling fall Chinook salmon incur between the Hanford Reach and McNary Dam. However, an annual range of predation consumption estimates through the bioenergetics modeling has outlined that predatory fish could explain at least half of the losses of natural-reared fall Chinook salmon (average annual loss has been 65%) may be due to predation by smallmouth bass, northern pikeminnow and walleye. In addition, other piscivorous fishes and waterbirds are also consuming subyearling fall Chinook salmon but is assumed to be at a lesser degree.

More precise data on subyearling fall Chinook salmon migration rates from the tailrace of Priest Rapids Dam to McNary Dam may assist in illuminating issues with subyearling fall Chinook salmon survival in the Hanford Reach. Currently there is no reach-specific information on survival, such as survival in the Hanford Reach versus Lake Wallula; however, a study was initiated during 2014 and will be of vital use to determine where the majority of subyearling fall Chinook salmon losses are occurring and the appropriate steps toward prevention that might be taken.

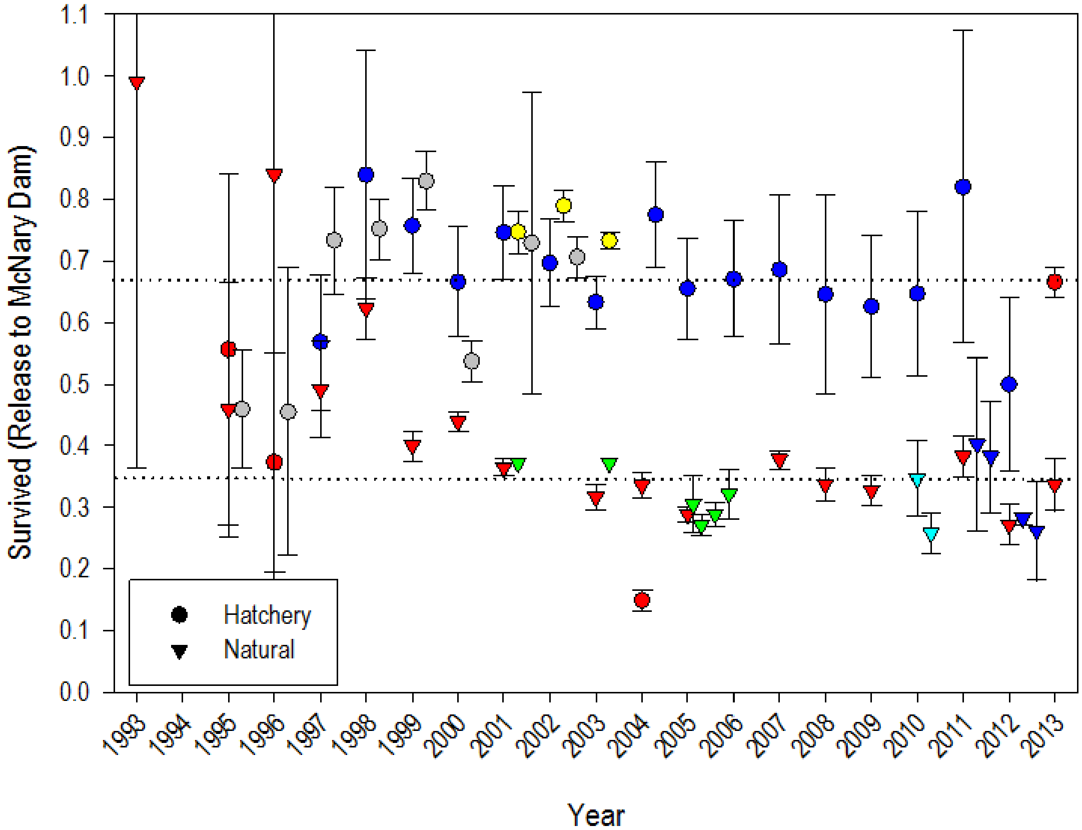

Figure 27 **Survival estimates and standard error from release to detection at McNary Dam of (1) Priest Rapids Hatchery-reared subyearling fall Chinook salmon (●) (2) Ringold Hatchery-reared subyearling fall Chinook salmon (●) and (3) naturally-reared subyearling fall Chinook salmon that were collected, tagged and released in the Hanford Reach (▼). Median survival for each origin is displayed as a dotted-line (hatchery-reared fish at 67% and natural-reared fish at 35%). Survival data were retrieved from DeHart 2012b and 2013 (blue), McMichael et al 2004 (yellow), McMichael et al 2006a (green), Fryer 2012(cyan) and remaining points were analyzed through Columbia Basin Research DART/SURPH (red and gray) (Figure 2 from Rizor et al. 2014).**

5.4.2.2 Juvenile Acoustic-Telemetry Studies

Following the synthesis report, an acoustic-telemetry project was developed by PNNL and co-funded by the Pacific Salmon Commission (Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund) and the Priest Rapids Coordinating Committee (No Net Impact fund). The Juvenile Salmon Acoustic Telemetry System (JSATS) was used to estimate reach survival for natural- and hatchery-origin smolts during emigration through the Hanford Reach to McNary Dam. The following text is the executive summary from Harnish et al. (2014):

> The population of fall Chinook salmon that inhabits the Hanford Reach comprises the majority of the Columbia Upriver Bright (URB) stock and is one of the most productive Chinook salmon stocks in the Pacific Northwest. Recent studies indicated that much of the high productivity of the population may be attributed to

very high survival during early freshwater life stages within the Hanford Reach. However, some evidence suggests significant mortality of smolts occurs over a short period of time and distance as they migrate from the Hanford Reach to McNary Dam. Large populations of piscivorous fishes and birds inhabit the Columbia River and may be responsible for this mortality. We implanted 200 wild Hanford Reach and 200 Priest Rapids Hatchery (PRH) URB fall Chinook salmon with acoustic transmitters and estimated their survival through multiple reaches of the Columbia River to identify mortality “hot spots” and to help classify the putative source(s) of mortality.

Acoustic-tagged wild Hanford Reach fall Chinook salmon had an estimated survival probability of 0.50 from release to McNary Dam. This estimate is considerably higher than was observed in 2014 for the group of wild Hanford Reach fall Chinook salmon juveniles implanted with passive integrated transponders (PIT-only; S = 0.34). The large discrepancy between survival estimates derived from acoustic-tagged versus PIT-only groups is likely a result of the difference in fish size between groups. We attempted to minimize the effect of the transmitter on the performance of implanted fish by only tagging fish that measured ≥80 mm FL; whereas, fish as small as 60 mm FL were implanted with PIT tags. As we demonstrated, survival of these fish is strongly, positively correlated with fish length. Therefore, we expect that the survival of the overall population of juvenile wild Hanford Reach fall Chinook salmon through the study area was substantially lower than it was for acoustic-tagged fish. However, we believe that the relative losses of tagged fish by reach were representative of the overall population.

Acoustic-tagged PRH smolts also had an estimated survival probability of 0.50 from release to McNary Dam; albeit over a longer reach than was traversed by the wild group. This estimate is substantially lower than what was observed for PIT-only PRH smolts in 2014 (S = 0.66). The difference in survival between groups of acoustic-tagged and PIT-only PRH fall Chinook salmon juveniles may have been the result of a reduction in performance of acoustic-tagged fish caused by the tagging procedure or presence of the tag, and/or a result of acoustic transmitter loss (i.e., tag shedding). Although results from a 60-day laboratory study conducted at PNNL found a very high rate of fish survival (99.2%) and tag retention (100%) of 126 fish implanted with the same transmitter and surgical technique, we observed relatively high post-tagging, pre-release mortality for the group of PRH fall Chinook salmon we implanted with acoustic transmitters for the in-river survival evaluation described in this report.

Because reaches differed in length, survival is better compared among reaches on a per-kilometer basis to identify potential mortality “hot spots”. Survival-per-kilometer (S_{km}) was generally lower in the transition area between the Hanford Reach and McNary Reservoir, within McNary Reservoir, and in the upper half of John Day Reservoir (down to Crow Butte) than in reaches located downstream of Crow Butte. The lowest S_{km} was observed in the immediate forebay of McNary Dam for both wild and hatchery fish. As expected, travel rates were fastest in flowing reaches (i.e., Hanford Reach and dam tailraces) and slowest through reservoirs. We observed a significant, positive relationship between the probability of survival to McNary Dam and fish length.

Data from this study and others indicate much of the mortality incurred by URB fall Chinook salmon juveniles between Priest Rapids and Bonneville dams can likely be attributed to predation from resident piscivorous fish. Analyzing 8 years of data, we observed no significant relationship between the survival of PIT-only wild Hanford Reach fall Chinook salmon to McNary Dam and the size of the primary avian predator nesting colonies located in McNary Reservoir. We also did not observe mortality "hot spots" in the reaches of the Columbia River that contain the largest colonies of predaceous waterbirds. Instead, we observed relatively consistent mortality rates between release and Crow Butte, which is more indicative of predation from piscivorous fish, which are more widely distributed than avian predators. In addition, results of studies conducted to assess avian predation rates have consistently estimated very low predation rates (<2%) on subyearling fall Chinook salmon upstream of Bonneville Dam. Alternatively, predation rates estimated for piscivorous fish suggest they may be consuming 17% of the juvenile salmon that enter John Day Reservoir during June, July, and August, when most salmon smolts entering the reservoir are subyearling fall Chinook salmon.

Our study confirmed that the loss rates of juvenile URB fall Chinook salmon from the Hanford Reach were high in areas where habitat has been influenced by hydropower development and native and non-native predatory fish species. Whereas our study had some limitations due to 1) the size of fish we were able to tag, 2) the potential for a tag or tagging effect on fish performance, and 3) possible tag loss, we believe that the relative loss rates are representative for the wild Hanford Reach and Priest Rapids Hatchery portions of the URB stock. Much of the mortality appears to be concentrated in the river/reservoir transition area where large predator-rich tributaries enter as well as in the immediate dam forebays where travel rates of outmigrating smolts are slowed. Additional work to document how the predation rates we observed in the larger size classes of juvenile URB fall Chinook salmon relate to the overall population, as well as efforts to determine the potential effectiveness of management actions intended to reduce the populations and/or productivity of piscivorous fish species will provide the information necessary to enable managers to design and implement strategies to improve the freshwater survival of this important stock.

5.4.3 Density Dependence

Competition for limited spawning habitat can lead to high rates of redd superimposition or egg retention and can be a source of density dependent mortality (Fukushima et al. 1998; Quinn et al. 2007). At the fry or parr stage, reduced growth rates or survival could result from limited rearing space, food, or cover in years with high juvenile production. In this section we explore the potential mechanisms for density dependent mortality at each freshwater life stage, review existing data that may inform if and how these mechanisms are occurring, and identify the limiting factors that may be controlling the carrying capacity of the Hanford Reach.

The productivity assessment that was completed during Phase I confirmed that productivity of juvenile fall Chinook salmon in the Hanford Reach of the Columbia River is very high (e.g., mean pre-smolts/egg = 0.4; Harnish et al. 2012). The linear relationship between estimates for the number of eggs in females and pre-smolts at the time of tagging is relatively strong (r^2=0.44). However, population dynamics theory suggests resource availability can limit survival and two commonly used models that incorporate density dependent functions (i.e., Ricker and Beverton-Holt) fit the data slightly better (i.e., r^2=0.47; Figure 28). Analyses completed during the productivity assessment suggests density dependent mortality is occurring when adult escapement equates to more than approximately 100 million eggs (~42,000 adults).

Productivity increased by 217% under the VBSA and increased an additional 130% after implementation of the HRFCPP; however the slopes of the modeled Ricker functions did not change significantly from the period before protections began (e.g., brood years 1975-1983 in Figure 12; Harnish et al. 2014). This suggests that, during the years that were evaluated, constraints implemented to provide protections during the spawning, incubation, and fry life stages increased survival but did not affect the factors leading to density dependent mortality.

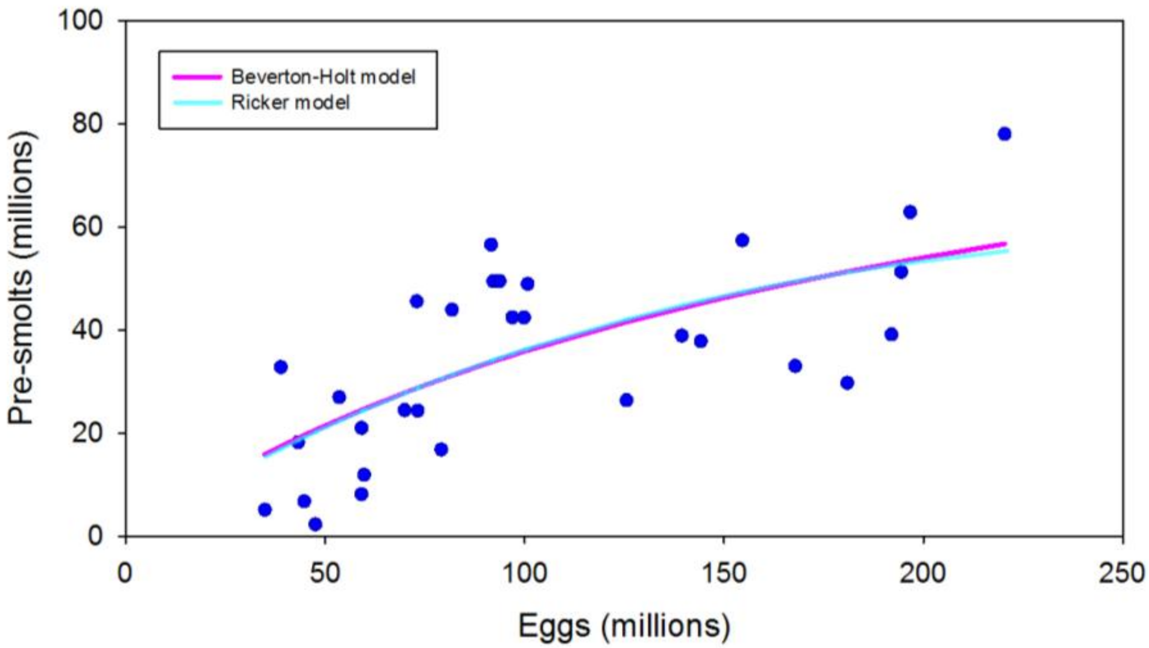

Figure 28 Relationship between estimates of the numbers of eggs in females and pre-smolts used in the productivity assessment (brood years 1975-2004). Ricker and Beverton-Holt models fit the untransformed data slightly better than simple linear regression (r^2 = 0.47 vs. 0.44).

5.4.3.1 Spawning

Spawning in the Hanford Reach consistently occurs in clearly defined clusters with boundaries that are likely influenced by stream flow conditions (Geist et al. 2009; Hatten et al. 2009) and/or behavioral preferences to spawn in close proximity to others (Essington et al. 1998, Isaak et al. 2007, Mull and Wilzbach 2007, Youngson et al. 2011, Gortázar et al. 2012). Density dependent mortality could occur if escapement levels cause spawning to occur in areas of less suitable habitat with low rates of survival to emergence. Spatial patterns of incubation habitat quality have not been studied in the Hanford Reach, but redd density could be a proxy indicator of survival potential. When escapement levels exceed spawning capacities, areas with low redd densities are presumably less favorable habitats. Spawning escapement during 2010 was more than double the estimated carrying capacity so it was expected that some fish would select areas with less suitable habitat. Presumably females would preferentially select the favorable habitats and less suitable habitats would have lower redd densities. However, survival to emergence was high in artificial redds that were constructed in areas with low and moderate redd densities (Oldenburg et al. 2012). These results suggest that areas with high survival potential were still available during periods of relatively high escapement and redd density may not be a good indicator of survival potential.

Competition for specific redd locations or a protracted spawning period could be a source of superimposition, but it is unclear whether the magnitude is sufficient to be the primary source of density dependent mortality. Areas of spawning without defined redd boundaries (i.e., "redd clusters") are evident in aerial photography and visual redd counts (Geist et al. 2008; Hatten et al. 2009; Lindsey and Nugent 2014). During six years of studies on Vernita Bar, researchers found that superimposition generally occurred at the sides of redds without disturbing the egg pockets. While it was not quantified, there was likely "some egg pocket disturbance" in the most heavily used spawning areas during two of the years (Chapman et al. 1986). Some evidence of egg pocket disturbance was also provided by a study in 2010. Egg drift was quantitatively assessed using drift nets to collect eggs suspended in the water column or rolling along the bottom on Vernita Bar (Oldenburg et al. 2012). Successful fertilization was evident in approximately 8% of the eggs sampled in drift nets with stage of development ranging from 0 to 26 days (Oldenburg et al. 2012). While there are several possible mechanisms that lead to drifting eggs, presumably some of the fertilized eggs collected in the drift nets were a result of disturbance from redd superimposition.

While there is some evidence for egg loss from redd superimposition in the Hanford Reach, the level of egg loss is unlikely high enough to produce the significant density dependent mortality that has been observed in other systems. For example, extreme densities of chum spawning (~15,000 in a 125 m study area) led to approximately 30% egg loss and a 43% reduction in productivity (Fukushima et al. 1998). Another study of coho in a small tributary (~3 m wide) with "intense competition" for limited habitat observed frequent reuse of individual redd locations and estimated that 18-29% of redds were destroyed by superimposition (Van Den Berghe and Gross 1989). While some levels of egg loss has been occurring in the Hanford Reach, significant losses have been likely limited to areas with extreme spawning densities and intense competition for preferred habitats. The scale and severity of superimposition required to cause the density dependence documented to date for the entire population are unlikely given the total area of suitable spawning habitat that is predicted to be available in the Hanford Reach.

A study of spawning habitat availability was completed for the Hanford Reach during two years with spawning escapement in the range exhibiting density dependence (i.e., 2004 and 2005). This study developed reach-wide estimates for the areas that were used and that were predicted to be suitable for spawning and provides an opportunity to evaluate spawning densities. Adult escapement was greater than 71,000 during these two years with redds constructed in more than 190 hectares of habitat. Spawning habitat models that were developed for these two years predicted a minimum of 652 hectares of suitable habitat were available for spawning (Hatten et al. 2009). This equates to more than 22 m^2 of spawning habitat that was used and more than 81 m^2 of suitable spawning habitat that was predicted to be available for each adult. The predicted area of suitable habitat for each adult is nearly five times greater than the size of completed redds on Vernita Bar (i.e., 17 m^2; Chapman et al. 1986). Even after accounting for known improvements to errors of commission (see Section 5.2.2), there was still approximately 60 m^2 of suitable spawning habitat that was predicted to be available for each adult. The low spawning densities during previous periods of relatively high escapement suggest competition for suitable areas of spawning habitat is not the likely source of the density dependent mortality observed historically.

Further evidence that spawning habitat is not limited comes from long term redd monitoring in the Hanford Reach (Lindsey and Nugent 2014). The 2013 escapement provided an opportunity to observe redd construction and historically high numbers. Even at a spawning escapement 68,000 adults higher than the previous high (89,300 in 2003), the relationship between redd count and escapement remained linear (Figure 29).

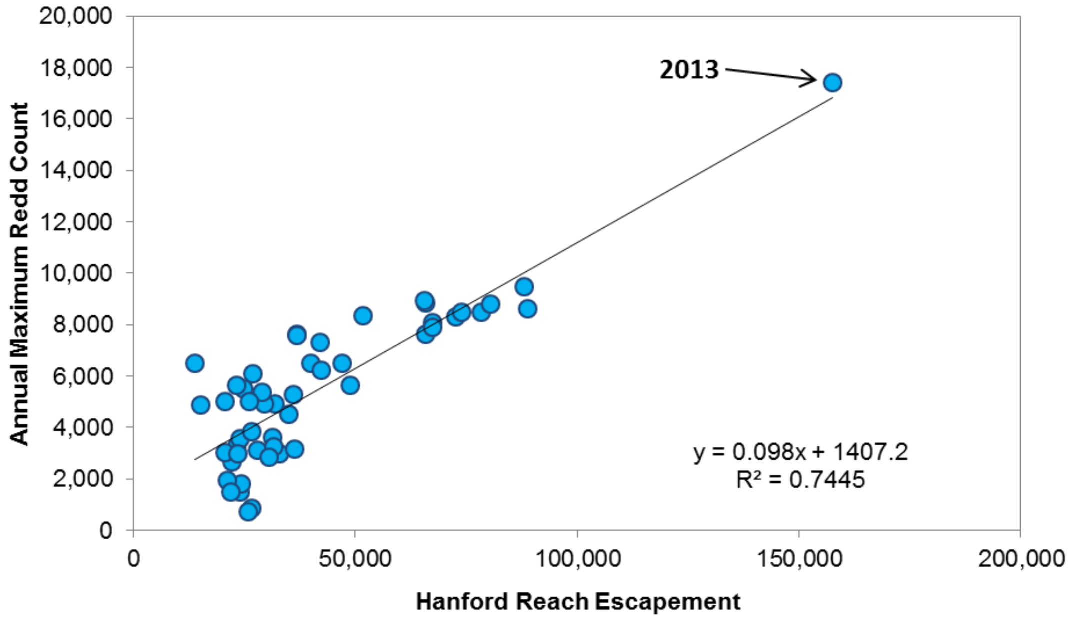

Figure 29 **Relationship between annual visual fall Chinook maximum redd count and estimated Hanford Reach escapement 1964 – 2013 (data from Lindsey and Nugent 2014).**

Incomplete spawning could be a source of density dependent mortality if spawning habitat is limited. A review of data on egg retention in the Hanford Reach revealed that fewer than 5% of females retained any eggs under adult escapements that ranged from 22,272 to 87,696 (Hoffarth 2013). However in 2013, at adult escapement levels 175% higher than the previous largest return year, some level of egg retention was observed in 22% of females (Hoffarth 2014). Egg retention rates for hatchery-origin females were significantly higher than their natural-origin counterparts during 2013, which is consistent with previous research that found hatchery-origin females had higher egg retention rates when spawning densities increased (Fleming and Gross 1993). Prior to 2013, adult escapement exceeded the estimated carrying capacity of the Hanford Reach (mean of 61,293 adults) in six of the eight years where egg retention was recorded. Given that egg retention was low during all but the record return in 2013, it appears incomplete spawning is not the source of density dependence observed historically. However, if escapement continues to exceed 150,000 adults, then egg retention could be a major source of density dependent mortality.

5.4.3.2 Rearing in the Hanford Reach

As discussed above, to date there is limited evidence that spawning has been the primary factor contributing to density dependent mortality prior to 2013. This suggests that the primary mechanisms of density dependent mortality may be occurring sometime after emergence. Environmental conditions could provide insights about mechanisms for the apparent patterns of density dependence. A total of 52 environmental variables characterizing the entire freshwater rearing period were investigated during the productivity assessment (Harnish et al. 2012). Density-independent hydrology variables, including the difference in mean spawning discharge and minimum post-hatch incubation discharge and the ratio of minimum post-hatch incubation discharge to minimum spawning discharge were correlated with egg to pre-smolt survival (Harnish et al. 2012). Fourteen environmental variables specific to early rearing were evaluated and none were correlated with productivity nor was existing data on phenotypic responses (i.e., median date of passage and travel time to McNary Dam; Langshaw unpublished analyses). Thus, there is limited evidence that density dependent mortality is occurring during early rearing.

5.4.3.3 Outside the Hanford Reach

There are several lines of evidence that density dependent mortality is occurring outside the Hanford Reach. Survival of natural-origin pre-smolts to age-2 is negatively correlated with estimates of egg deposition (Figure 30).

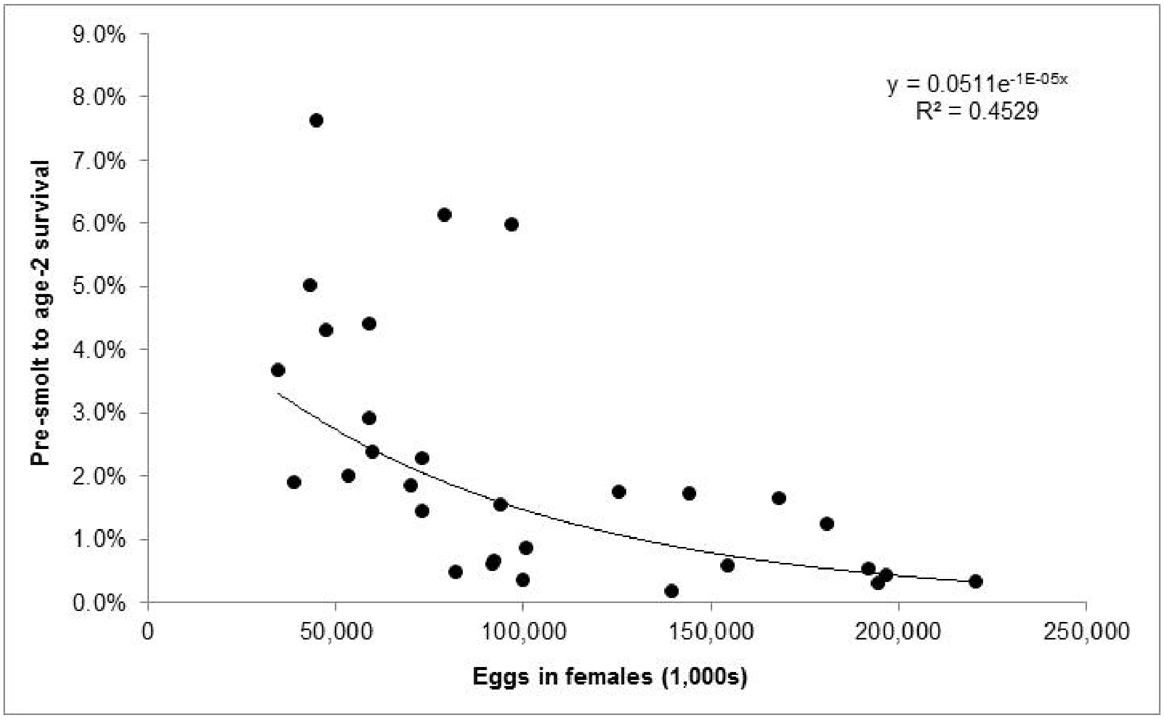

Figure 30 Relationship between estimates of natural origin Hanford Reach pre-smolts and pre-smolt to age-2 survival.

Supporting evidence is provided by studies in the Columbia River estuary and near-shore marine environment. Beginning in 1998, data were collected on the condition factor of sub-yearling fall Chinook salmon in the Columbia River estuary and plume. September condition index, plume volume, and their interaction explain almost all of the variation of adult returns to Priest Rapids Dam (r^2=0.97; Jacobson et al. 2012). While the analyses did not consider earlier recruitment, the authors suggested the observed patterns could result from density dependence or that good ocean conditions lead to higher survival and enable fish in poorer condition to survive. Some of the data were also used to investigate survival mechanisms and several significant relationships were identified between survival and conditions in the river, plume, and ocean environment (Miller et al. 2013). Two outliers were clearly evident in their analyses. Survival was unexpectedly high during emigration year 2001, but favorable ocean conditions likely offset the anomalous discharge and plume conditions caused by drought conditions that year (Miller et al. 2013). The survival index value during emigration year 2008 was inexplicably low given the high discharge and very favorable ocean conditions. The researchers did not consider river conditions during earlier recruitment, which was a limitation in their analyses.

Given the low sample rates in the marine environment, the researchers used summer/fall Chinook salmon counts at Priest Rapids Dam (lagged three years) as an index of survival. Spawning escapement in the Hanford Reach for brood year 2007 (13,887) was the lowest observed since estimates began in 1964. Adult-to-adult recruitment was actually quite high for that brood year with the second highest age-4 spawner abundance since 1975. The high survival was masked by record low spawner abundance and below average jack, age-3, and age-5 components of the return. The researchers identified Pacific Decadal Oscillation (PDO) as a significant explanatory variable for adult returns to Priest Rapids Dam (Miller et al. 2013). The relationship with PDO improves significantly after accounting for prior recruitment (i.e., adult recruits/adult spawners) and the residual shifts from strongly negative to strongly positive (Figure 31). In other words, accounting for previous recruitment explains the anomalous results for brood year 2007 and correlation between environmental conditions and survival. Other ocean indices reported by Miller et al. (2013) are also strongly correlated with abundance of spawning recruits in the Hanford Reach (Figure 32) and provides further evidence that ocean conditions are a significant factor in overall productivity.

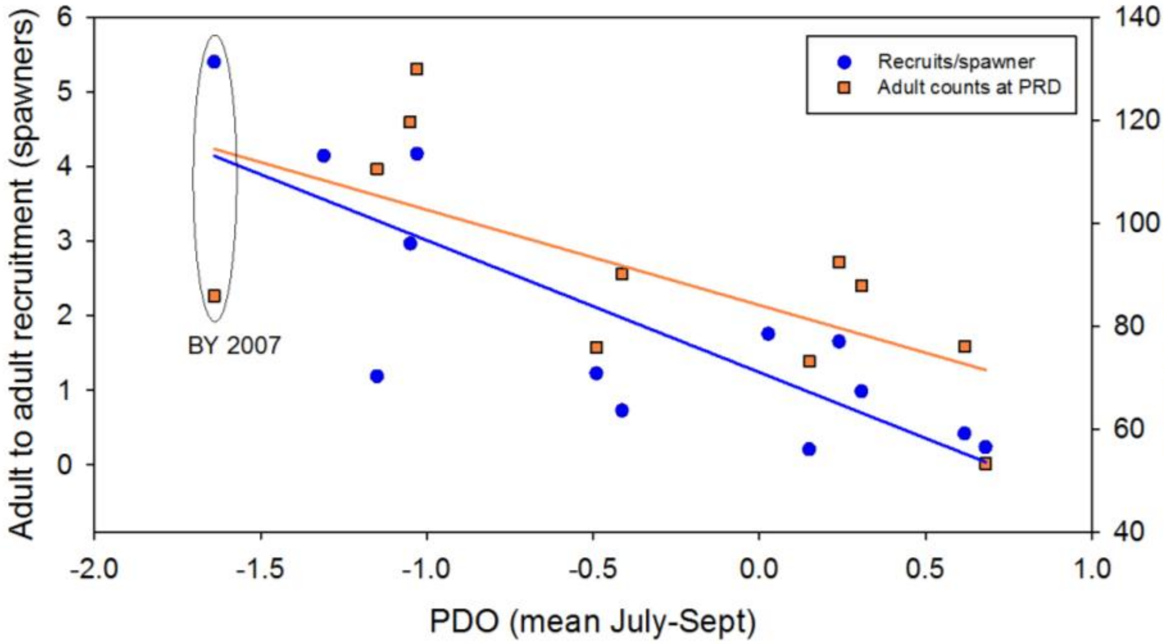

Figure 31 Pacific Decadal Oscillation and recruitment. Recruitment of natural-origin adults from brood year 2007 was particularly low, but is masked by recruits from adjacent brood years if Priest Rapids Dam counts are used. The blue markers represent adult to adult recruitment to the Hanford Reach (r^2=0.63) and the orange squares represent fall Chinook salmon counts at Priest Rapids Dam lagged three years (r^2=0.37).

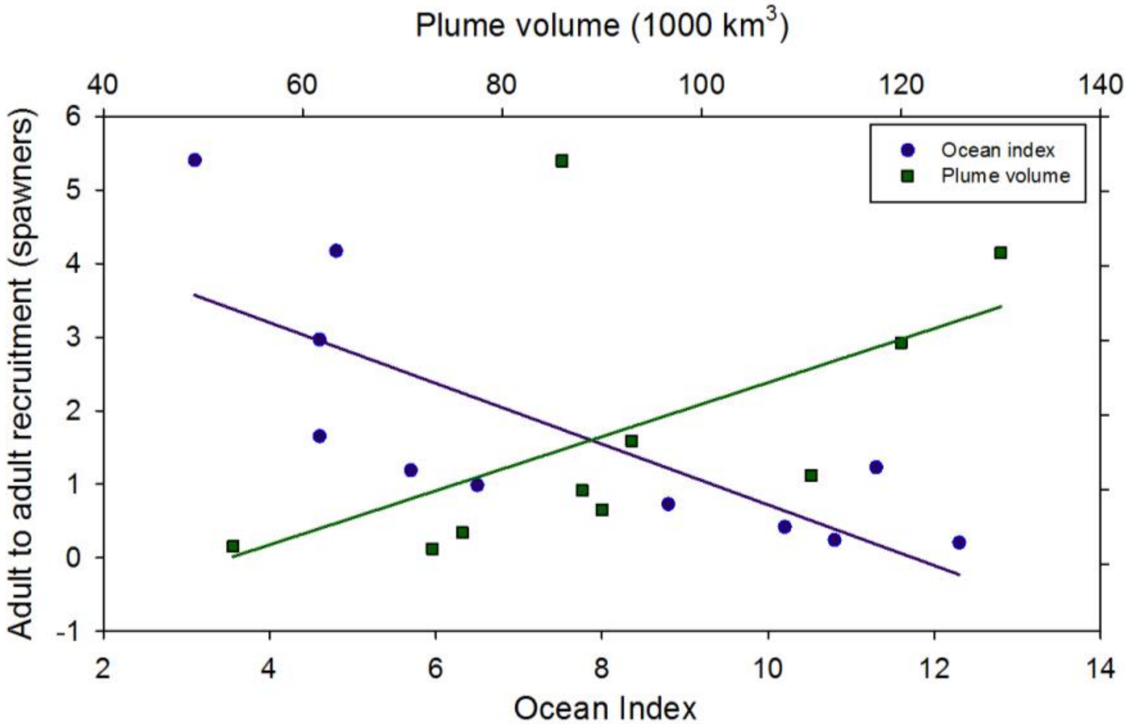

Figure 32 Relationship between recruitment to the Hanford Reach for each brood year (1997-2007) and environmental indices of conditions experience after emigration. Ocean index (purple circles; r^2=0.56) and Columbia River plume volume (green squares; r^2=0.23) values were reported in Miller et al. (2013).

Additional insight on productivity in the Hanford Reach is provided by the marine ecology studies. The marine ecology studies and productivity assessment overlapped for seven brood years. During the three brood years with egg production in the density dependent range, survival to pre-smolt was slightly to moderately below average and pre-smolt abundance was slightly to moderately above average. Condition factor during June was at or below average for those three brood years, but they had some of the highest condition factors during September (Jacobson et al. 2012, Miller et al. 2013). These three years also coincided with poor ocean conditions and survival rates to age-2 were well below average. This pattern is consistent with size selective mortality occurring during their first summer in the ocean. The two brood years with the highest survival rates to age-2 had estimates of egg deposition (59-73 million) that were well below the level expected to cause density dependence. However, they had below average survival to pre-smolt and condition factors. As suggested by the researchers (Miller et al. 2013), this pattern is consistent with that expected when favorable conditions provide for higher survival rates for a population with lower overall fitness. The relatively low number of replicates and mixed-stock sampling in the marine ecology studies limit definitive conclusions about the Hanford Reach, but the patterns of fish condition in the ocean and survival for the Hanford stock based on the Chinook Technical Committee model Hanford Wild (HAN) stock are consistent with a survival bottleneck during their first summer in the ocean. Furthermore, mixed stock sampling suggests the patterns are broad-scale and not limited to fall Chinook salmon from the Hanford Reach. It is also uncertain whether conditions in the Hanford Reach are related to survival patterns later in life.

Survival to age-2 is low for natural-origin pre-smolts during periods when density dependence is apparent, but survival is also low for smolts released from Priest Rapids Hatchery during these same years. Survival of smolts released from Priest Rapids Hatchery was below average during eight years of the ten years that natural-origin fish exhibited density dependent mortality. Survival of natural- and hatchery-origin fish was also strongly correlated during these ten years (r^2=0.78). Pre-smolt abundance is derived from estimates of survival from tagging to age-2, so the location of density dependent mortality cannot be isolated. However, the strong correlation and pattern of the relationship between hatchery- and natural-origin fish suggests experiences and sources of mortality are shared between the two groups. Given that smolts released from Priest Rapids Hatchery migrate through the Hanford Reach and Lake Wallulla relatively quickly (annual mean is 11 days; Dehart 2013), the predominant driver of the relationship between natural- and hatchery-origin survival likely occurs after the fish have migrated past McNary Dam.

The pre-smolt to age-2 survival rates for natural-origin fish were generally higher during low survival years. During mutually high survival years, hatchery-origin fish generally had higher survival rates (Figure 33). This is consistent with patterns of survival observed in estuary and nearshore marine environments, where origin appears to cause differential response to environmental conditions and/or predation (Beamish et al. 2012, Miller et al. 2013, Osterback et al. 2014).

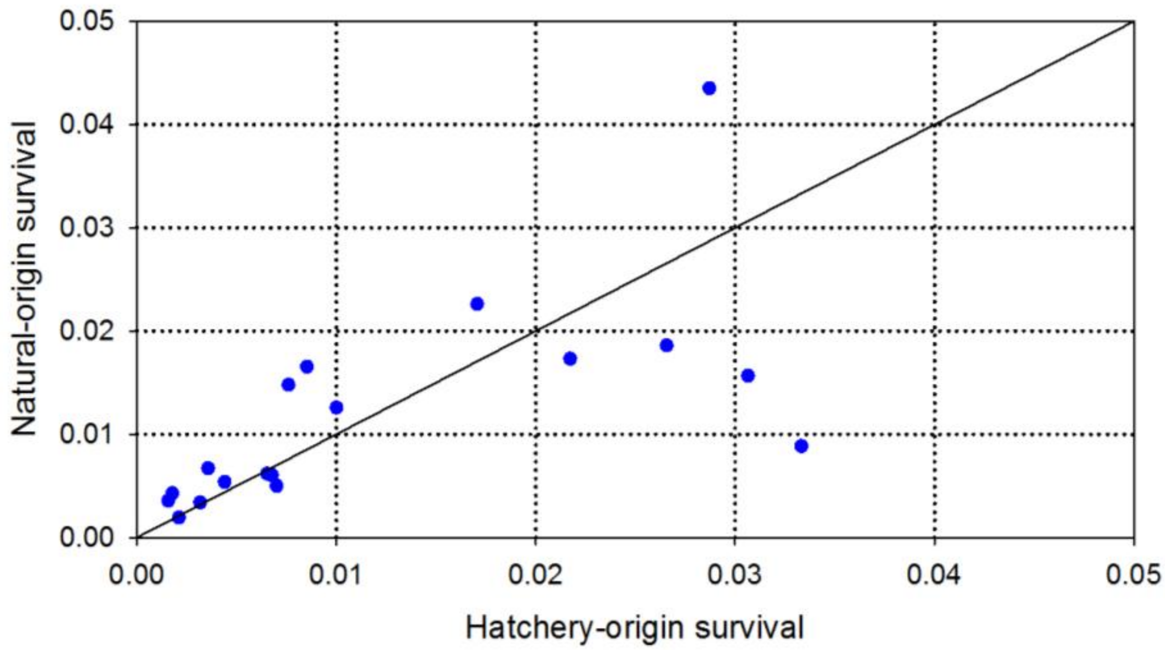

Figure 33 Survival rates to age 2 for natural origin pre-smolts from the Hanford Reach and smolts released from Priest Rapids Hatchery (brood years 1986-2003).

In summary, from the data available to date, it does not appear that operations under the HRFCPPA are contributing to density dependent mortality within the Hanford Reach. An extensive evaluation of the current data available on density dependence has been conducted that identified: 1) evidence for density dependence, 2) spawning escapement that appears to be related to density dependence, and 3) likely limiting life stages. Existing data provide little evidence for density dependence mortality prior to migration to McNary Dam. This is supported by 1) similar slopes of productivity during dramatic changes in periods of hydrosystem operations, 2) correlated survivals of hatchery and natural-origin fish despite hatchery-origin fish spending very short times in the Hanford Reach and numbers released being fairly constant, and 3) relationships between conditions in the Columbia River Plume, ocean, and subsequent recruitment.

While there is no evidence that the HRFCPPA is contributing to density dependence, Grant PUD will continue to monitor and evaluate density dependence in fall Chinook salmon originating in the Hanford Reach primarily by: 1) productivity modeling and 2) egg retention monitoring. Data for these activities will be incorporated into Grant PUD's hatchery monitoring program (see Section 7.3.2 for more details) and the productivity modeling will be completed and reported at five-year intervals.

6.0 Synthesis of Mechanisms for High Productivity

There are a variety of plausible mechanisms to explain why freshwater productivity and capacity of Chinook salmon in the Hanford Reach is high relative to other salmon and steelhead stocks. Fortunately, the Hanford Reach is one of the most studied large river reaches in the world so there is ample information to generate plausible mechanisms (Goodman et al. 2010). This provides for opportunities to posit mechanisms for multiple life-stages in freshwater. In this section, we first briefly compare productivity of the Hanford Reach population to other populations and second we describe plausible mechanisms to explain why the productivity is so high.

After implementation of the VBSA (i.e., brood years 1989-2004) egg-to-pre-smolt survival in the Hanford Reach increased from 29.2% to approximately 40.2% (Harnish et al. 2014). Quinn (2005) compiled stage specific survival estimates for salmon and steelhead from 215 sources, including those in undammed and pristine rivers, and estimated that mean egg-to-smolt survival was 10.4% for Chinook salmon. While there are some notable differences between the datasets (i.e., stream-type and ocean-type were combined, egg-to smolt vs. egg-to-pre-smolt survivals), egg-to-pre-smolt survival in the Hanford Reach is remarkably high. Egg-to-fry survival is a significant portion of overall survival and may be one of the primary sources of high productivity. After accounting for handling effects, survival estimates in the Hanford Reach exceed 70% (Chapman et al. 1983; Oldenburg et al. 2010) and are approximately double those reported for other Chinook salmon stocks (i.e., 38%; Quinn 2005).

Reservoir development for water management and generation of electricity have dramatically changed conditions and habitat for fall Chinook salmon in the Columbia River Basin. Altered flow, sediment, and thermal regimes can affect survival of all freshwater life stages. Fall Chinook salmon currently use approximately 13% of the historical riverine habitat on the mainstem Columbia River (Dauble et al. 2003). With the exception of small areas in the tailraces of some dams, the Hanford Reach is the only remaining riverine habitat in the Columbia River that is accessible to salmon and suitable for salmon production. While somewhat counterintuitive and contrary to some research, hydroelectric development may be contributing to particularly high productivity in the Hanford Reach. This chapter takes a life cycle perspective and examines how current conditions may contribute to the observed high rates of survival and productivity of fall Chinook salmon in the Hanford Reach. However, we recognize that many other factors such as genetics, natural food productivity, water temperature, geomorphology, and placement within the Columbia River Basin are also potentially large contributors to high productivity.

6.1 Spawning

The higher flows during spawning and incubation that have been caused by hydrosystem management likely increased the productivity and capacity of fall Chinook salmon in the Hanford Reach. Prior to development and operation of Grand Coulee Dam, mean discharge during the spawning period was 53 kcfs with a range of 31-119 kcfs (Figure 13 and Figure 34). Spawning habitat monitoring and modeling suggest spawners prefer building redds in water that is deeper than one meter. Thus, most redds would likely have been constructed below the 33 kcfs elevation during an average historical year. In contrast, after implementation of the VBSA, mean discharge during the spawning period was approximately 101 kcfs and minimum discharge constraints prevent reductions below 63.3 kcfs (mean 1988-2013) during the incubation period. The area of suitable spawning habitat is predicted to increase with discharge until leveling off at approximately 110 kcfs (Hatten et al. 2009). Thus, more wetted area and likely more spawning habitat area is currently available during the Spawning Period than during historical conditions in the Hanford Reach.

Current redd distributions can also be used for relative comparisons. Using aerial photography, redds on Vernita Bar were mapped and geo-referenced during four spawning seasons (1991, 1994, 1995, and 2006). Approximately 93% of the observable and mapped redds were below the mean historical spawning flows (53 kcfs) and approximately half (52%) were constructed at elevations that were below the likely limit of preferred spawning depths (i.e., 33 kcfs; Figure 34). Thus, nearly half (48%) of the redds mapped on Vernita Bar were constructed in areas that were inaccessible during an average pre-development year. While the increase in accessible spawning habitat was evident, the estimate of the total number of redds was likely biased low due to the construction of deep water redds in the Hanford Reach, which can be extensive, and are often missed in aerial surveys (Swan 2006).

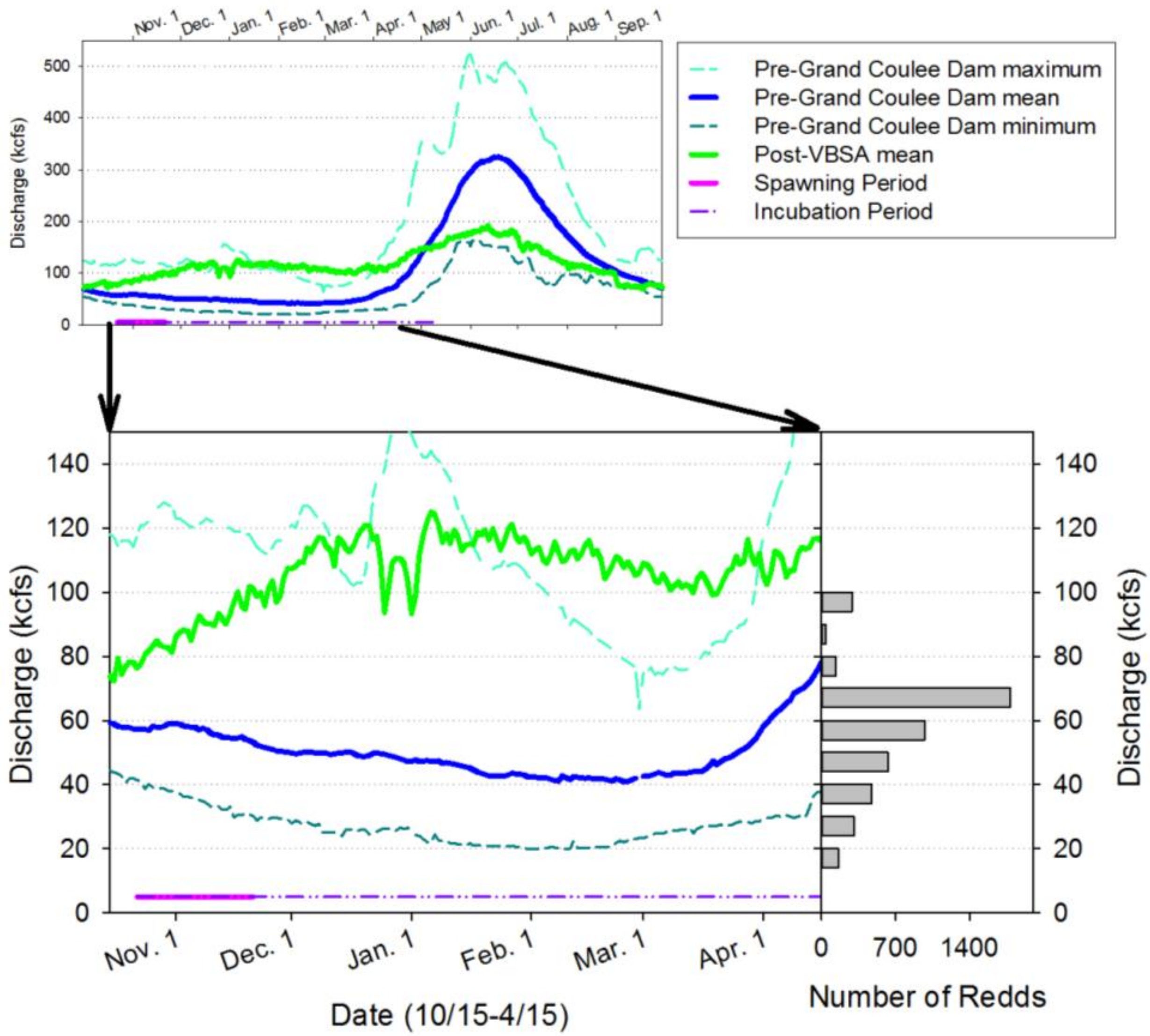

Figure 34 Redd frequency distribution on Vernita Bar relative to mean daily discharge at the site of Priest Rapids Dam during the pre-Grand Coulee Dam (1918-1941) and the post-Vernita Bar Settlement Agreement (1988-2014) eras.

In addition to providing access to more habitat, operations under the HRFCPPA likely provide the opportunity for differential selection of sites for redd construction. RLF requires that daytime discharge remain relatively low and stable (i.e., 55-70 kcfs). In order to balance inflows and outflows, peak nighttime flows are generally higher and are often double daytime flows. This provides the potential for fish to select spawning habitats under very different flows and thus may provide for the use of different elevations within the 24-hour cycle. Spawning habitat simulations have not been completed to evaluate the degree that areas of suitable conditions overlap, but flow characteristics can provide a relative comparison of how conditions change. Hydraulic simulations were completed for the entire Hanford Reach (Niehus et al. 2014) and a random day was selected (11/10/01) for these analyses. Daily minimum and maximum depths and velocities were summarized for 10,000 random cells. The mean difference between the daily minimum and maximum depth and velocity at each cell was 2.2 m (range 0.0-3.2 m) and 0.3 m/s, respectively (range 0-3.3 m/s; Figure 17). Of the cells with daytime depths shallower than one meter, approximately 95% were in the range of suitable depths during nighttime operations. Furthermore, river bathymetry influences how conditions change in response to flow fluctuations. Two habitat cells that contained redds during 2001 are used to illustrate how sites can responded differently to flow fluctuations. The higher elevation redd site had an inverse relationship between depth and discharge (Figure 35). This location was in the preferable depth range (2 – 4 meters) during hours of darkness, but velocities were in the preferred range (1.4 – 2 m/s) during the day (Geist et al. 2000). The lower elevation redd was in deep water at all times, but the preferred velocities occurred at night.

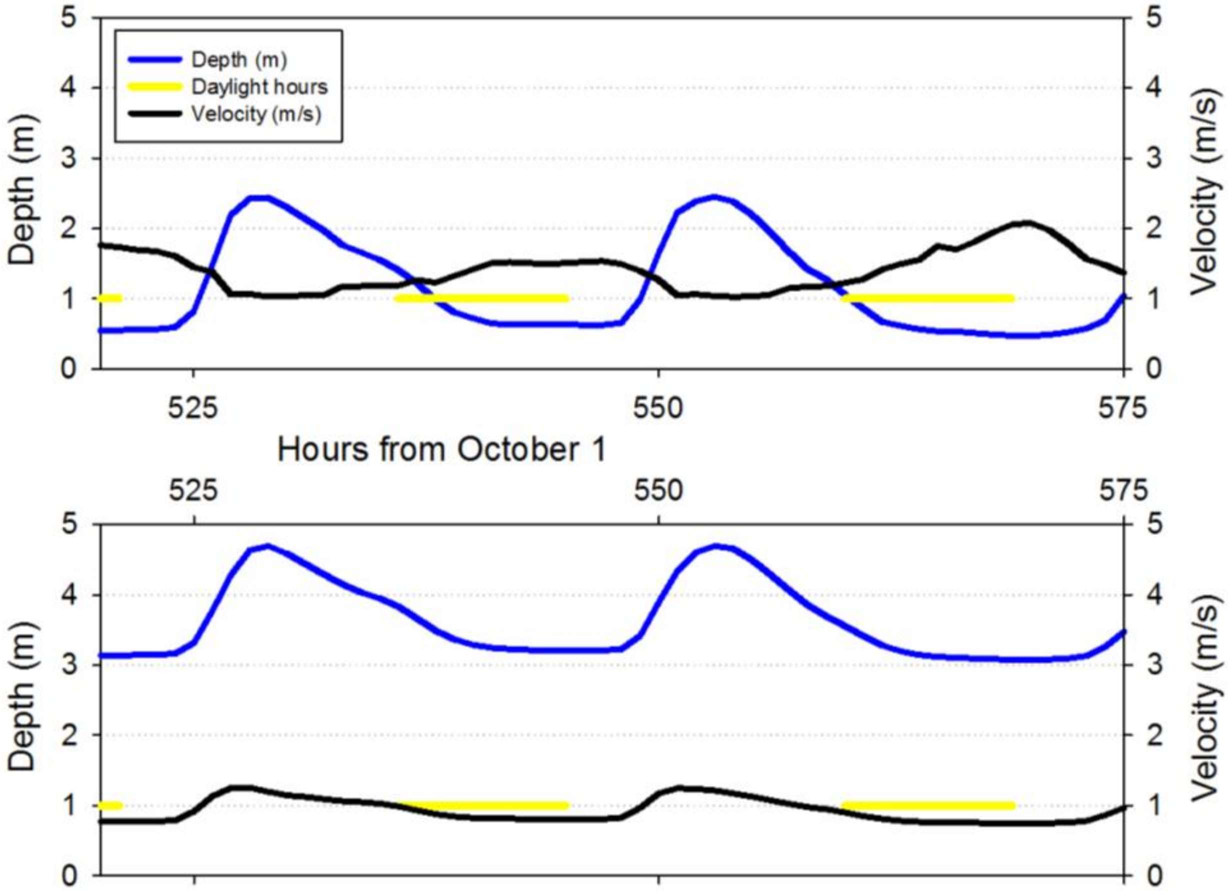

Figure 35 **Depth and near bed velocity at two locations that were selected for spawning during 2001. Conditions are plotted from 10/22/2011 15:00 through 10/24/2001 22:00 when discharge ranged between approximately 46 and 167 kcfs.**

The difference between daytime and nighttime conditions may also help explain the fertilization timing pattern observed during the egg-to-fry survival study conducted on Vernita Bar in 2010. Naturally produced redds were sampled (n=18) between 40-60 kcfs elevation and approximately 78% of the eggs were fertilized at night (Oldenburg et al. 2012). High rates of nocturnal spawning are counter to conventional wisdom and existing research (McMichael et al. 2006a). Given that the area sampled was inundated during day and nighttime hours, it appears that conditions at higher elevations are more conducive for spawning during the higher nighttime flows. This may be because flows help to transport substrate during digging activities by female salmon, deeper water provides more security, and/or selective pressures to reduce the risk of desiccation from flows that historically decrease throughout the incubation period.

6.2 Incubation

In addition to increased spawning habitat availability, hydroelectric development appears to contribute to high survival during incubation. Two studies separated by several decades documented high embryo survival in the Hanford Reach. Naturally produced redds were excavated and artificial redds were constructed on Vernita Bar from 1979 through 1982 (Chapman et al. 1983). There were significant handling effects but survival was high relative to controls (Chapman et al. 1983). Similar methods were used in 2010 on Vernita Bar and near the middle section of the Hanford Reach (Oldenburg et al. 2012). Handling effects were reduced and survival estimates were combined to generate a cumulative egg-to-fry survival estimate of 71.2% (Oldenburg et al. 2012; see Section 5.3 for additional details on both studies).

The mechanisms for high survival rates observed in the Hanford Reach are unknown, but the current management of flows in the Hanford Reach likely reduces the frequency of conditions that would have led to mortality of embryos or alevins under natural flow conditions. These mechanisms include: 1) reduced desiccation of redds, 2) reduced scour of redds, 3) reduced sedimentation in redds, and 4) improved flow exchange within redds. Desiccation of redds during incubation can be a significant source of mortality in rivers that are managed for hydroelectric or irrigation uses (Becker and Neitzel 1985) or in rivers that have reaches that desiccate or freeze after spawning (e.g., Methow River). The VBSA and the HRFCPPA protections include RLF to encourage fish to spawn at lower elevations and subsequent minimum discharge constraints dependent on the elevational distribution of redds to reduce the risk of mortality due to redd desiccation. Prior to the operation of Grand Coulee Dam, winter discharge in the Hanford Reach could be as low as 20 kcfs (1937; Figure 7) with a mean minimum weekly flow of 34.5 kcfs. Approximately 44% of the redds mapped on Vernita Bar were constructed above the mean minimum historical flows (Figure 16). Thus, nearly half of the redds mapped on Vernita Bar were constructed in areas that were historically inaccessible and virtually all of them (i.e., 99.8%) were protected from desiccation.

In contrast to desiccation from low discharge, scour from high discharge can also be a source of mortality prior to or shortly after emergence (Lisle and Lewis 1992, Montgomery et al. 1996). Major storage development in the upper Columbia River has reduced peak discharge and the potential for mortality from scour. Prior to development of the PRP, spring discharge (March-June) in the Hanford Reach could be as high as 690 kcfs (1948) with a maximum weekly mean of 509 kcfs during June. Since implementation of the VBSA, the maximum spring discharge in the Hanford Reach was 455 kcfs (1997) with a maximum weekly mean of 363 kcfs during June. Prior to hydrosystem development, flows could reach levels with significant potential for scour in during the late incubation and early rearing periods.

In addition to decreasing the potential for extreme events that cause mortality, hydroelectric development in some cases may contribute to the quality of conditions within redds. Dams and their reservoirs are known to reduce recruitment of fine sediments to downstream reaches, which can have implications for inter-gravel flows and embryo survival (reviewed in Wood and Armitage 1997). Relatively high survival rates are observed with low amounts of fine sediments (Chapman 1988, reviewed in Kondolf 2000) and survival rates can significantly decrease if fine sediments exceed approximately 15-20% (Holtby and Healey 1986; Magee et al. 1996; Kondolf 2000). Not only is recruitment of fine sediments reduced downstream of hydroelectric dams, variable discharge associated with dam operations influences upwelling, inter-gravel water velocities, and connectivity with the river.

Studies of spawning habitat in the Hanford Reach and elsewhere have identified correlations between spawning site selection and inter-gravel conditions including vertical hydraulic gradient (VHG), DO, inter-gravel velocities, and others (Geist et al. 2000, 2002, 2008, Hanrahan 2006). These inter-gravel conditions can be significantly influenced by flow fluctuations in the Hanford Reach (Geist 1999, Geist et al. 2000, Hanrahan 2008, Oldenburg et al. 2012; also see Section 5.3.1) because down welling pressures increase with stage. The increased interaction with, and influence from, surface water may be the source of the significant positive relationship between discharge variation during incubation and pre-smolt production (Figure 36; Harnish et al. 2012).

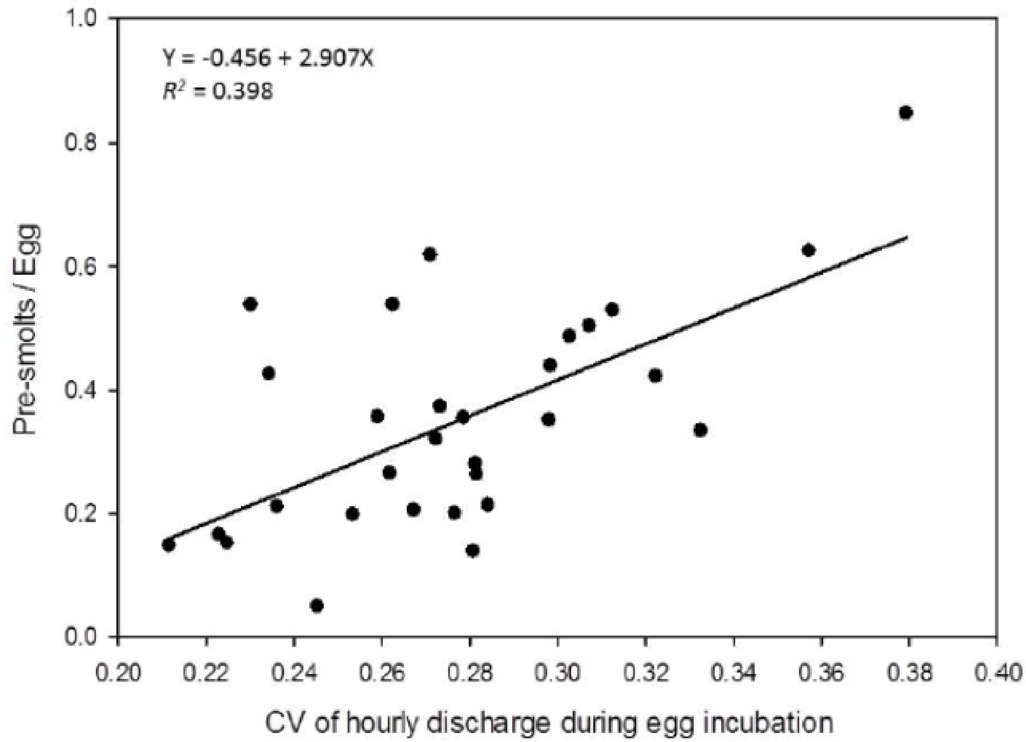

Figure 36 Bivariate relationship between CV of hourly discharge and the number of Hanford Reach pre-smolts produced per egg (Figure 12 in Harnish et al. 2012)

Longer residence groundwater often has low levels of dissolved oxygen and the rate and duration of upwelling can be influenced by hydrological events (Malcolm et al. 2004) and geomorphological controls (Malcolm et al. 2005). Both factors influence the interaction of surface and groundwater and can result in extended periods (e.g., weeks or months), at particular redd locations, with levels of dissolved oxygen that are too low for embryo or alevin survival (Malcolm et al. 2008, Soulsby et al. 2009). Frequent flow fluctuations associated with hydroelectric operation influence the dynamics of DO in redds (see Section 5.3.1) and may prevent extended periods of low DO that can occur as upwelling increases on the descending limb of a normative hydrograph.

6.3 Fry/Parr

The ratio between egg-to-fry and egg-to-pre-smolt survivals indicate that high survival rates continue after fish emerge from the gravels. Food and habitat availability are two likely mechanisms for high survival rates. The effects of flow fluctuations on benthic periphyton and invertebrate assemblages has been well studied with most studies finding reduced abundance, biomass, diversity, and rates of recolonization in the areas that are dewatered (Fisher and LaVoy 1972, Troelstrup and Hergenrader 1990, Blinn and Cole 1991, Benenati et al. 1998, Mosisch 2001). While fluctuations can be detrimental to periphyton and invertebrate production in the areas that are dewatered, few studies consider historical context. Desiccation of substrates for more than 12-24 hours causes significant reductions of periphyton biomass (e.g., >50%; Usher and Blinn 1990, Blinn et al. 1995). Prior to hydrosystem development, minimum discharge in the Hanford Reach occurred in February with extended periods of low flow and minimums reaching 20 kcfs (mean 34.5 kcfs). After long periods of desiccation or freezing, recovery of periphyton and invertebrate assemblages to pre-desiccation levels can take weeks or months (Blinn et al. 1995, Mosisch 2001). Thus, primary and secondary productivity may not have fully recovered before the spring emergence period or the spring freshet began and flows peaked in June. Under current conditions, minimum discharge constraints that began with the VBSA have effectively prevented desiccation of substrates below the Critical Elevation (mean 63.3 kcfs) from December through June. Therefore, flow protections under the VBSA and HRFCPPA have resulted in more of the river-bed to remain wetted and fully colonized during the winter and early spring months (November – April), and in turn to begin producing food as soon as light and temperature conditions become favorable (Figure 37).

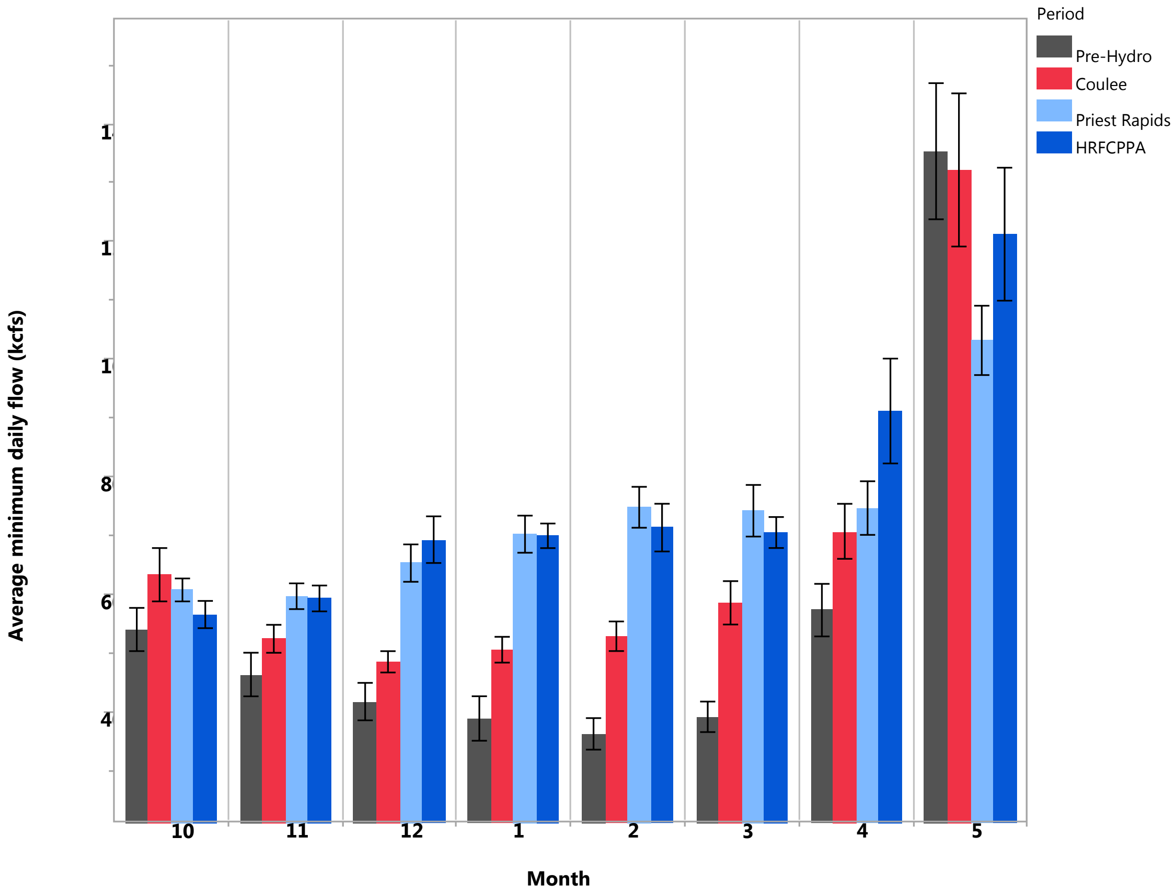

Figure 37 Average monthly minimum flows (from average daily flows) in the Hanford Reach during the months that the HRFCPPA is in effect druing the pre-hydrosystem, Grand Coulee Dam, Priest Rapids Dam, and the HRFCPPA periods. Hydrology data are from the MASS1 model. Error bars are standard errors of the mean.

Flow fluctuations also have the potential to increase productivity of fall Chinook salmon by altering predator distribution and reducing their recruitment. Reservoir development has altered predator distributions with northern pikeminnow concentrated in the tailraces of dams and non-native smallmouth bass concentrated in the reservoirs and forebays of dams (Rizor et al. 2014). Flow fluctuations can alter the efficiency of predators because preferred habitats and conditions change frequently (Pert and Erman 1994, Asaeda et al. 2005). Flow fluctuations can also influence recruitment of predators, particularly smallmouth bass. Changing water levels in the Hanford Reach can desiccate nests, disperse guarding males, change current, increase stranding risk, and/or cause cold water to flood spawning grounds (Montgomery et al. 1980). Incidentally, flow protection under the HRFCPPA that reduced flow fluctuation may inadvertently improve habitat conditions for non-native predators.

6.4 Smolt-Adult

This life-stage is outside of the influence of the PRP and so is not addressed comprehensively in this report. The potential influence of predation and density dependence outside of the project area were discussed in previous sections of this report.

6.5 Summary

Many studies have documented the physical, biological, and ecological effects of hydroelectric development and water management (Cushman 1985, Bunn and Arthington 2002, Magilligan and Nislow 2005, Angilletta et al. 2008, Pahl-Wostl et al. 2013). However, most studies lacked appropriate context and a life cycle perspective. For example, many studies have demonstrated the detrimental effects of dewatering substrates on primary and secondary productivity. Additionally, fluctuation flows can reduce the complexity of the benthic community. However, with the implementation of a Critical Elevation (i.e., minimum flow) under the HRFCPPA, the minimum flows (and wetted area) during the fall-early spring period are greater now than under historical conditions (Figure 37). In summary, the productivity and capacity of the fall Chinook salmon that spawn in the Hanford reach is high and there are plausible mechanisms for each life-stage to explain why conditions under the hydrosystem in general, and under the VBSA and HRFCPPA specifically, have contributed positively to this high productivity (Figure 38). Plausible mechanisms for contributing to high spawning capacity include: 1) more wetted area available during the spawning period and 2) more habitat area suitable for spawning is likely available. Plausible mechanisms for high embryo or alevin survival include: 1) reduced desiccation of redds, 2) reduced scour of redds, 3) reduced sedimentation in redds, and 4) improved flow exchange within redds. Finally, plausible mechanisms for high survival of fry-to-pre-smolt include: 1) increased food availability and 2) reduced predator recruitment. It is possible that the managed flows in the Hanford Reach under hydrosystem development and the HRFCPPA may be contributing to the high productivity observed in the fall Chinook salmon population.

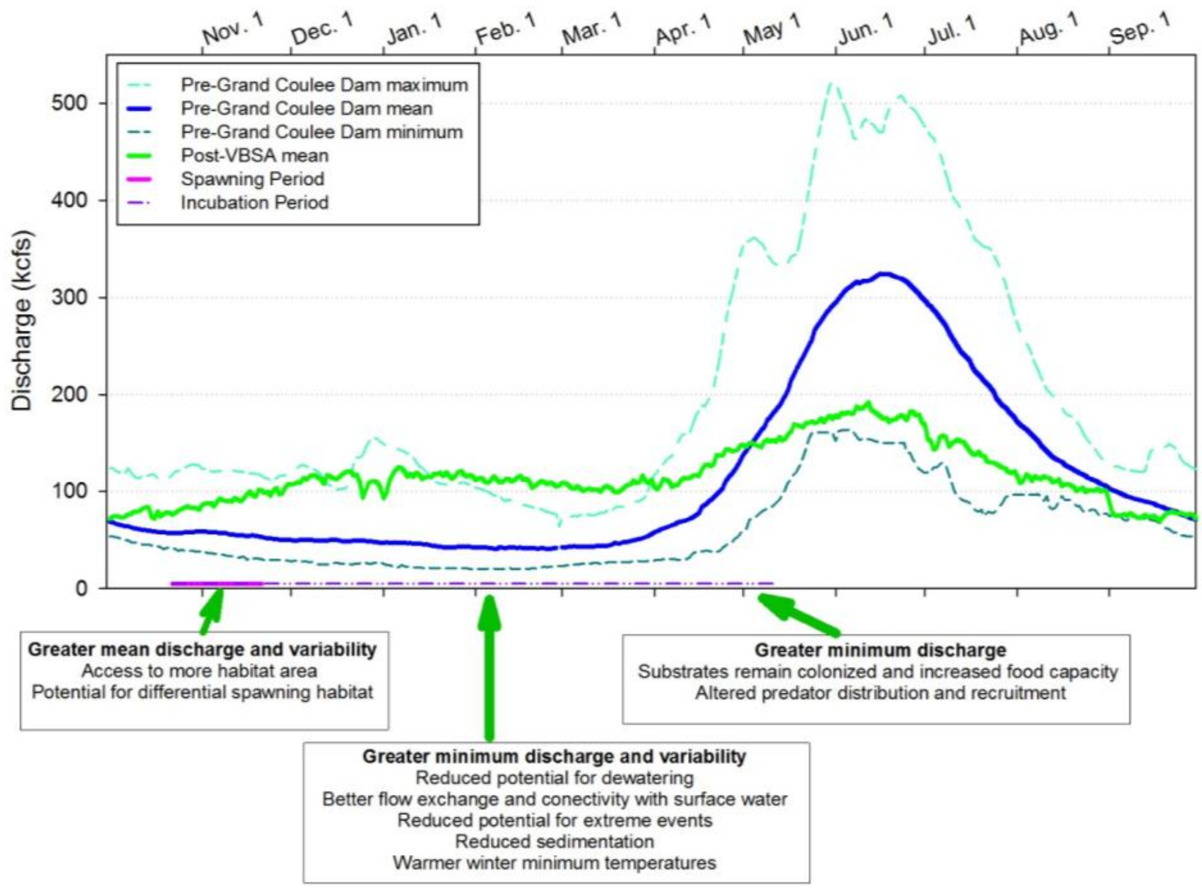

Figure 38 **Summary of potential sources of high productivity of fall Chinook salmon in the Hanford Reach.**

7.0 Adaptive management and the HRFCPPA

The principles of adaptive management are the foundation of the HRFCPPA, PRPSSSA, and PRP License. The primary objective of Section 6.3 of the 401 WQC is to ensure the best available information is developed and used to adaptively manage the HRFCPPA. This section provides an overview of Grant PUD's current mitigations and protections, the adaptive management process, and monitoring activities related to fall Chinook salmon in the Hanford Reach.

7.1 Current Mitigation

The combination of mitigation and protections, provided by Grant PUD, result in No Net Impact to fall Chinook salmon. Mitigation occurs in the form of hatchery production of fall Chinook salmon smolts at the recently renovated Priest Rapids Hatchery. Currently 5.6 million smolts are produced and released from Priest Rapids Hatchery annually to mitigate for inundation of habitat from dam construction and operation, mortality of fish migrating through the project area, and mortalities from stranding and entrapment in the Hanford Reach. The HRFCPPA provides protections in the Hanford Reach to all freshwater life stages of Chinook salmon during periods of susceptibility to desiccation and stranding and entrapment.

7.2 Adaptive Management Process

Adaptive management of Grant PUD's mitigation and protection programs is accomplished through collaborative resource committees comprised of resource managers and/or stakeholders. The committees are generally structured as technical or policy groups focused on broad resource categories (e.g., hatcheries, habitat, mainstem, resident fish, etc.). Representatives have specialized expertise pertaining to each committee. The technical committees generally oversee development, implementation, and adaptive management of mitigation and protection programs. The policy committees are comprised of policy representatives from each Party and designed to make decisions if technical committees cannot reach consensus agreement.

The most current and best available scientific information and analysis are the standard of care that is applied to the adaptive management process. Guidelines for the adaptive management process are outlined in section 4.3 of the PRPSSSA:

> *The sequence of adaptive management steps include: (1) problem assessment, (2) project design, (3) implementation, (4) monitoring, (5) evaluation, and (6) adjustment of future decisions.*

Several different studies with different approaches were completed during the phased study, and provide additional evidence that survival to emigration and freshwater productivity are particularly high for fall Chinook salmon in the Hanford Reach. Given that substantial negative effects from the HRFCPPA were not identified during the phased study, alternative operations and additional protections are not currently being considered. However, Grant PUD is implementing additional monitoring and reporting to supplement ongoing programs so that adaptive management can be implemented in the future.

7.3 Current and Future Monitoring Funded by Grant PUD

Ongoing monitoring is essential to the adaptive management process. Monitoring and evaluation of the HRFCPPA will follow an annual and five-year comprehensive reporting cycle. This section describes activities that will be conducted annually and at each five-year monitoring cycle.

7.3.1 HRFCPPA Annual Monitoring and Reporting

The HRFCPPA requires annual reporting of: 1) Vernita Bar Redd Counts, 2) dates on which the Hatching, Emergence, End of Emergence and End of Rearing Periods occurred, 3) a record of Columbia River flows through the Hanford Reach based on Priest Rapids discharges, and 4) a description of the actual flow regimes from the Initiation of Spawning through the Rearing Period based on available data. Historically, separate reports were prepared by Grant PUD and WDFW to describe dam operations under the HRFCPPA, spawning escapement, and other details about fall Chinook salmon that spawn in the Hanford Reach. To reduce duplication and increase efficiency, the reports were combined into a single comprehensive report co-authored by Grant PUD and WDFW. These reports are produced annually and submitted to the FCWG and Priest Rapids Coordinating Committee (PRCC) for review in October of each year.

7.3.2 Monitoring and Evaluation of Productivity and the Priest Rapids Hatchery Program

Monitoring and Evaluation of key biological metrics that could be affected by the HRFCPPA will be measured and reported upon as part of Grant PUDs Priest Rapids Hatchery Monitoring and Evaluation Program. Biological metrics will include: productivity, spawning escapement, survival, and egg retention. Grant PUD has guiding principles and approaches for the monitoring and evaluation (M&E) of all of its hatchery programs that are provided in an overarching M&E plan that encompasses all of its programs (Pearsons and Langshaw 2009, Hillman et al. 2013). The first comprehensive sampling for monitoring and evaluation of Priest Rapids Hatchery fall Chinook salmon production began in the fall of 2010. Though the comprehensive M&E programs are relatively recent, WDFW has been conducting monitoring and evaluation of URB fall Chinook in the Hanford Reach dating back to the early 1980's. These monitoring programs contribute information to the sport fishery, hatchery management, and run reconstruction.

The M&E program has nine major objectives related to the production and release of fish from Priest Rapids Hatchery. Major components of the program include abundance and productivity, survival, genetics, phenotypic characteristics, straying, hatchery performance, disease, and ecological interactions. The primary objective of the M&E program is to monitor and identify effects from the hatchery program on the natural population, but a subset of variables related to the HRFCPPA will be included in these reports. Additional data relating to productivity will be collected, analyzed, and reported in each annual report. A comprehensive productivity assessment (e.g. cohort reconstruction) will be updated at five-year intervals. The previous comprehensive productivity assessment evaluated brood years 1975 – 2004 and was reported on in 2012[2]. The next assessment will evaluate brood years 2005 – 2009 and a draft report will be delivered to the FCWG/HRWG in 2017.

Data on egg retention in spawners are collected and reported annually as part of the M&E program for PRH. Methods for data collection were improved during 2014 to help quantify the amount of egg retention (see Section 5.2.2; Hoffarth et al. 2014).

Recent improvements to methods for estimating fallback will also be continued. Accurate dam counts are important for calculating spawning escapement estimates for the Hanford Reach, which are important for hatchery monitoring and harvest management. A PIT-tag antenna array was recently installed in the hatchery outfall channel and additional PIT-tags are being applied to juveniles released from the hatchery and migrating adults. Coded-wire-tag marking, collection, and analyses are part of the hatchery monitoring program and will provide data that are necessary for the productivity assessment. Ongoing collection and archiving otoliths also provide a resource for other studies related to population dynamics and harvest management.

7.4 Studies Related to Population Dynamics and Harvest Management

Approximately 35 studies related to fall Chinook salmon in the Hanford Reach were identified by FCWG members since its inception in 2008. Some of the studies were not funded by Grant PUD because they were related to population dynamics and/or harvest management. While clearly important, funding and implementing these studies are not Grant PUD's responsibility.

8.0 Conclusions

Many studies and monitoring projects have been implemented since concerns first arose about the Priest Rapids Project's effects on fall Chinook salmon in the Hanford Reach. The objective of this document was to complete the study requirements related to the HRFCPPA in the 401

[2] A comprehensive productivity assessment requires data from complete age-class returns (age-5+) as well as coded wire tag recovery and reporting (1 -2 year time lag).

Certification, HRFCPPA, and PRP License under adaptive management principals outlined in the PRPSSSA. This section reviews the regulatory requirements and study results related to adaptive management of the HRFCPPA.

8.1 Section C.6.c of the HRFCPPA

Section C.6.c. of the HRFCPPA required a study to estimate fry losses in the Hanford Reach due to stranding and entrapment. In 2010, a group of key individuals met to review methods used for previous stranding and entrapment studies and develop a study plan. A study plan to estimate fry losses during 2011-13 was finalized in September 2010, approved by FERC, and implemented in 2011. A brief overview of results is provided in Section 5.4.1 and detailed methods and analyses can be found in each annual report (Hoffarth et al. 2012, 2013, and 2014). This study requirement was met when FERC approved the third and final, report in 2014.

Overall, the results were consistent with findings of previous stranding and entrapment studies. Key conclusions previously detailed in this report and the annual reports include:

- Improvements to the study design reduced bias and helped improve precision.
- The number of fish that are stranded or entrapped is related to the magnitude of flow fluctuations, which are reduced by flow constraints in the HRFCPPA
- Losses due to stranding and entrapment are small relative to total fry production in the Hanford Reach.

8.2 Section 6.3(4) of the 401 Certification

Section 6.3(4) of the 401 Certification required that Grant PUD convene the FCWG to serve as an advisory group for requirements in the 401 Certification related to the HRFCPPA. The FCWG's primary roles include study identification and prioritization, as well as review, comment, and approval of study plans, designs, and reports. Additional details can be found in Section 1.1 of this report and on Grant PUD's website (http://www.grantpud2.org/rc/).

8.3 Section 6.3(5) of the 401 Certification

Section 6.3(5) of the 401 Certification required that Grant PUD determine the PRP's contribution to flow fluctuations in the Hanford Reach under the HRFCPPA. A study to investigate Grant PUD's contribution to flow fluctuations was initiated in 2007, a draft report was distributed to the FCWG in 2008, additional analyses and revisions were completed, and the final report was approved by WDOE in 2010. An overview of the report is provided in Section 3.3 of this report and details can be found in the final report (Langshaw and Duvall 2010). Operations under the HRFCPPA were compared to a hypothetical unimpounded scenario and the key findings included:

- Flow fluctuations under the HRFCPPA are smaller during the Rearing Period.
- RLF causes greater flow fluctuations during the Spawning Period.
- The magnitude of fluctuations attenuate significantly as flows move downstream.

The report confirmed that operations under the HRFCPPA are meeting two of its primary objectives. Flow fluctuations are increased during the Spawning Period to promote spawning in deeper waters and fluctuations are reduced during the Rearing Period to reduce stranding and entrapment.

8.4 Section 6.3(6)(a-f) of the 401 Certification

Sections 6.3(6)(a-f) provided a framework for development and implementation of a study plan to ensure the best available science was used to adaptively manage the HRFCPPA. The bulk of this document is related to presenting the science and conclusions developed throughout implementation of studies to meet the requirements in Section 6.3(6). Detailed information can be found throughout this report and in completed reports for individual projects. Key findings include:

- Productivity of fall Chinook salmon from the Hanford Reach is high and was increased under the HRFCPPA.
    - Increased by 217% with implementation of the VBSA and 130% with the HRFCPPA.
- Density dependent mortality is apparent at high spawner abundance.
    - Source and location of density dependence remain unknown.
    - There may be multiple mechanisms resulting in density dependent mortality and these mechanism may be occurring in the freshwater, estuarine, and marine environments.
- Egg-to-fry survival is high.
    - Hydrosystem development and operations may reduce sedimentation, freezing, desiccation, and scour.
    - Flow fluctuations may provide conditions more favorable for survival.
- Hydrosystem development significantly altered the hydrograph and conditions in the Hanford Reach.
    - Fluctuating flows, particularly during the rearing season, results in stranding and entrapment mortality.
    - Flow fluctuations that can result in stranding and entrapment were reduced with the implementation of the HRFCPPA.
    - The wetted area from spawning to emergence (fall-early spring) has increased under the HRFCPPA.
    - Capacity for primary and secondary productivity during winter and at spring emergence may be higher under the HRFCPPA.
- Predation is a potentially significant source of mortality.
    - Hydrosystem development, including fluctuation flows and increased water clarity, may exacerbate the rate of predation particularly from avian predators.
- Fallback at Priest Rapids Dam is related to returns to Priest Rapids Hatchery.
- Context and life cycle perspectives are critical for understanding the effects of resource use and the effectiveness of protections and mitigation.

8.5 Section 6.3(7)(a) of the 401 Certification

The IFS in Section 6.3(7)(a) of the 401 Certification requires identification, evaluation of feasibility, and reporting on potential measures that may avoid, reduce, or mitigate the adverse impacts on fall Chinook salmon in the Hanford Reach. Given that adverse effects from the HRFCPPA were not identified during the phased study, Grant PUD proposed that the IFS and IFP be combined and addressed with this report. The FCWG and WDOE supported the proposal to combine the IFS and IFP into a single report. The draft report was distributed to the FCWG in November 2014 for a 90-day review period.

8.6 Article 405 of the PRP License

As part of the IFS, Article 405 of the PRP License required that Grant PUD investigate and consider spawning habitat enhancement in the tailrace of Wanapum Dam. A feasibility study was completed in 2011. An overview is provided in Section 5.2.3 of this report and details can be found in the original report. Key findings include:

- Salmon consistently spawn in an area with clearly defined boundaries.
- The demarcation in habitat use could not be explained by a model using standard habitat variables.
- Underlying geomorphic features (e.g., substrate size composition) is the likely cause for demarcation.
- Improving substrate quality may be possible through a combination of gravel augmentation and riverbed surface scarification.
- There is considerable uncertainty of success because these types of projects have not been completed in a river as large as the Columbia.

In addition to the feasibility study, redd surveys conducted in the tailrace of Wanapum Dam can be used to inform decisions relating to implementation of habitat enhancements. Aerial surveys have been used to count redds in the tailrace of Wanapum Dam with a maximum of 3,017 redds counted in 2000 (Mueller and Ward 2010). Aerial redd surveys have been conducted in the Hanford Reach since 1948 (Dauble and Watson 1997). The number of redds counted in the Wanapum tailrace during 2000 was greater than counts for the entire Hanford Reach in 44% of the years since 1948. Furthermore, GPUD is already mitigating for inundation of the entire project area, including the Wanapum tailrace, through the production of 5.6 million smolts at Priest Rapids Hatchery. Given the considerable uncertainty of success, magnitude of existing habitat, current mitigation, and lack of adverse effects of the HRFCPPA, a spawning habitat enhancement project will not be implemented in the tailrace of Wanapum Dam as part of the IFP.

8.7 Sections 6.3(7)(c) of the 401 Certification

Section 6.3(7)(b) of the 401 Certification required development of a plan to implement measures that were identified in the IFS and approved for implementation. As stated above, because no significant adverse effects of the HRFCPPA were identified, no measures to alter the HRFCPPA were recommended. This document represents a combined IFS (Section 6.3(7)(a)) and IFP (Section 6.3(7)(b)).

Section 6.3(7)(c) required that Grant PUD proceed with implementation of the approved IFP. The primary objective of the 401 Certification was to ensure the best available science was available to identify adverse impacts from, and adaptively manage, the HRFCPPA. Given that no significant adverse impacts to fall Chinook salmon in the Hanford Reach were identified, no significant changes to the HRFCPPA are required. The final version of this report will be submitted to FERC in April 2015 and will complete regulatory requirements related to the HRFCPPA in the 401 Certification and PRP License.

In conclusion, this document is the culmination of many years and more than 26 major studies that were dedicated to adaptively managing the HRFCPPA. Grant PUD has fulfilled all of the regulatory requirements that were related to the HRFCPPA in the 401 Certification and PRP License. The major findings were that 1) productivity of fall Chinook salmon from the Hanford Reach is high relative to other Chinook salmon populations, 2) was increased by implementation of the VBSA and HRFCPPA, and 3) was not negatively associated with flow variables influenced by hydrosystem operations. Furthermore, losses due to stranding and entrapment were small relative to total pre-smolt production. Most importantly, the HRFCPPA is meeting its primary objectives of reducing high elevation spawning, redd desiccation, and flow fluctuations during the period when fry are susceptible to stranding and entrapment. No significant adverse effects from the HRFCPPA were identified. In fact, the HRFCPPA appears to significantly contribute to the productivity in the Hanford Reach. Thus, no modifications to the HRFCPPA are necessary at this time. Grant PUD will continue to mitigate for unavoidable losses of fall Chinook salmon by producing 5.6 million smolts annually at Priest Rapids Hatchery. Grant PUD and other signatories are dedicated to successful implementation and adaptive management of the HRFCPPA into the future.

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Appendix A
Studies proposed and implemented under the phased plan

Proposal number	Proposal title	Implemented	FCWG priority	Comments
6.1 & 7.1	Effect of Priest Rapids Flows on Productivity of Upriver Bright Chinook & Determine the optimum or maximum sustainable yield of natural spawned fall Chinook from the Hanford Reach and the required escapement of spawning adults	Yes	1	Harnish et al. 2012 & 2014
5.4	Conduct controlled flow fluctuation experiments to identify specific flow bands and fluctuation magnitudes that entrap disproportionately large numbers of juvenile Chinook	Partial	2	Partially implemented - Location, fluctuation magnitude, and flow band were investigated during the data mining effort in Langshaw et al. 2014
5.3	Quantify the effect of flow fluctuations on stranding of juvenile fall Chinook	Yes	3	Part of the 2011-13 stranding and entrapment monitoring reported in Hoffarth et al. 2012, 2013, 1014
4.1 & 4.2	Empirically determine egg to emergent fry survival rates for each of the major spawning sites in the Hanford Reach & Effects of Flow Variation on Chinook Salmon Egg Hatching Success	Yes	4	Oldenburg et al. 2012
3.4	Conduct a case-control spawning study under alternate or Agreement flow scenarios for comparison to the results from the "baseline" spawning study to describe the relative effects of these scenarios	No	5	Was unnecessary - Additional spawning habitat modeling was completed and reported in Langshaw 2012 and further discussed in Langshaw et al. 2014
5.2	Evaluate the entrapment sampling efficiency and accuracy for juvenile fall Chinook	Yes	6	Incorporated into the 2011-13 stranding and entrapment monitoring reported in Hoffarth et al. 2012, 2013, 1014
5.1	Hydrodynamic model synthesis, evaluation and integration into a geographic database for the specific purpose of Hanford Reach habitat and hydrologic evaluations	Yes	7	Niehus et al. 2014
3.1 & 3.2	Spawning Period operational effects on abundance and distribution of redds on Vernita Bar & The effects of fall Chinook redd abundance and distribution on productivity of individual redds	Partial	8	Partially implemented - Some components of redd abundance and productivity were investigated by Oldenburg et al. 2012 and further discussed in Langshaw et al. 2014
7.4	Evaluate the effect of various ramping rates as they relate to the entrapment and stranding of juvenile fall Chinook	Partial	9	Partially implemented - Location, fluctuation magnitude, and flow band were investigated during the data mining effort in Langshaw et al. 2014

3.3	Determine the behavioral components of the spawning process for fall Chinook, and the physical conditions selected by spawners under “normative” (relatively stable) stream flow conditions to derive “true, baseline” habitat requirements	Investigated	10	Investigated - Additional spawning habitat modeling was completed and reported in Langshaw 2012 and further discussed in Langshaw et al. 2014
5.5	Develop an index sampling program including index sampling tools and methodologies that are statistically rigorous for estimating entrapment fates, the total number of entrapped fall Chinook, and juvenile Chinook mortality throughout the Reach and with adequate temporal resolution	Partial	11	The stranding and entrapment datasets are available to implement this when necessary
7.2	Evaluate the feasibility and benefit of re-regulation of stream flows coming into the Priest Rapids Project to change the flow pattern downstream into the Hanford Reach for the benefit of both juvenile and adult fall Chinook	No	12	The IBM (Bellgraph et al 2011) is available to use for evaluating alternative flow scenarios
6.2	Evaluate Hanford Reach fall Chinook life cycle productivity and population dynamics using a production simulation model	Yes	13	Bellgraph et al. 2011
7.3	Relate spawning habitat availability (i.e. carrying capacity) resulting from an array of operational scenarios to the number of fall Chinook spawners (i.e. redds) that could be accommodated	Partial	14	Partially implemented - Additional spawning habitat modeling was completed and reported in Langshaw 2012 and further discussed in Langshaw et al. 2014 Spawning habitat variables were also included in the analyses by Harnish et al. 2012 and 2014
3.7	Investigate, identify, and quantify the extent of deep-water spawning by fall Chinook throughout the Hanford Reach	Partial	15	Some investigation of deep-water spawning was completed and reported in Mueller et al. xx
3.6	Evaluate and quantify the effect of redd superimposition on spawning fall Chinook in the Hanford Reach	Investigated	16	Investigated - Additional spawning habitat modeling was completed and reported in Langshaw 2012 and further discussed in Langshaw et al. 2014
3.8	Evaluate fall back of adult fall Chinook at Priest Rapids Dam	Yes	17	Mueller et al. 2012
3.5	Evaluate the energetic costs of fluctuating flows and the impact of those costs on completion of successful spawning	No	18	
3.9	Hanford Reach adult spawning surveys	Yes	19	Adult spawning surveys are completed under the Priest Rapids Hatchery M&E plan and annual reports Richards and Pearsons 2014
7.6	Hanford juvenile PIT-tag studies	Yes	20	Grant PUD provided additional funding and PIT-tags to support the CRITFC tagging program

7.5	Conduct annual orthophotography for each of the main Hanford Reach fall Chinook spawning sites	No	21	The Department of Energy may begin taking aerial photos more frequently Lindsey and Nugent 2014
7.7	Hanford adult fall Chinook PIT-tag studies	Partial	22	A PIT-tag antenna array was recently installed in the return channel at PRH and additional adults are PIT-tagged as part of the hatchery M&E program
Follow-up from Phase 1	Evaluation of egg retention in female carcasses	Yes		Hoffarth et al. 2014
Follow-up from Phase 1	Synthesis report for predation in the Hanford Reach and Lake Wallula	Yes		Rizor et al. 2014
Follow-up from Phase 1	Investigation of mechanism for density dependence identified in the productivity assessment	Yes		Investigated and discussed in Langshaw et al. 2014
Follow-up from Phase 1	Data mining for insights on stranding and entrapment	Yes		Investigated and discussed in Langshaw et al. 2014
Article 405	Feasibility of spawning habitat enhancement in the tailrace of Wanapum Dam	Yes		Geist et al. 2011
Follow-up from Phase 1	Acoustic telemetry study of reach survival for natural- and hatchery-origin smolts during emigration through the Hanford Reach to McNary Dam	Yes		Harnish et al. 2014b funded by the Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund and the PRCC
Follow-up from Phase 1	Annotated bibliography for studies related to fall Chinook salmon in the Hanford Reach	Yes		Goodman et al. 2010
HRFCPPA	2011-13 stranding and entrapment monitoring under the HRFCPPA	Yes		Hoffarth et al. 2012, 2013, and 2014

Appendix B
Grant PUD Comment and Response Table to the Implementation Feasibility Study and Implementation Feasibility Plan

Table 1. Comment and Response Table to the Draft Implementation Feasibility Study and Implementation Feasibility Plan.

Commenter	Comment number	Section and Paragraph	Comment	Grant PUD Response
Paul Hoffarth (Washington Dept. of Fish and Wildlife)	1	General	Excellent write-up.	Comment appreciated.
Paul Hoffarth (WDFW)	2	§2.0 ¶1	Thus, the period that fall Chinook salmon are exposed to hydroelectric operations in the Hanford Reach is from adult migration during ~~September or October~~ beginning in August through out-migration of their offspring the following summer (June-August).	Text was revised to read: “Thus, the period that fall Chinook salmon are exposed to hydroelectric operations in the Hanford Reach is from adult migration during beginning in August through out-migration of their offspring the following summer (June-August).”
John Clark (Alaska Department of Fish and Game)	1	§3.1 ¶2	Strange us of the term “fisheries”; can this section be altered to say instead something like “fish populations”?	“Fisheries” changed to “fish populations”.
John Clark (ADFG)	2	§5.2 ¶1	Do not need the word “some”, you already use the word” may” in the sentence. While the authors may want to weakly indicate hydro-power operations improve productivity, I think the data is pretty conclusive! Let’s be realistic, in normal rivers and in the Columbia before hydro-power, it is pretty obvious that freeze out of redds was a frequent occurrence.	Removed the word “some”.
John Clark (ADFG)	3	§5.2.1 ¶1	Hence an increase in spawning habitat AND it is protected!! See prior comment. You folks are awfully modest.	Comment noted.

John Clark (ADFG)	4	§5.2.4 ¶1	Not so sure of this conclusion given runs the last couple of years. Suggest modification given recent runs and leave this as an open question.	The conclusions of this paragraph were intended to be focused on the effects of superimposing on productivity. As Mr. Clark pointed out, recent adult returns have been far above the norm, leaving some uncertainty. The text was modified to reflect this uncertainty and how it will be addressed in the future: "Nevertheless, it is safe to assume that redd superimposition is positively correlated with adult female escapement. If escapement levels continues to be as large as were observed in 2013 and 2014, some increased level of superimposition would be expected. However, the effect of superimposition on productivity, if any, will remain uncertain until data on adult returns from broodyears 2013 and 2014 are available. The monitoring and evaluation program for the HRFCPPA, which includes a productivity assessment (see Section 7.3.2), intends to capture these effects. Until then, previous work on spawner density and habitat can provide some context about the relationship between habitat selection, competition, and redd superimposition (Fleming and Gross 1989, Van Den Berghe and Gross 1989, Fukushima et al. 1998)."
John Clark (ADFG)	5	§5.2.4 ¶2	More and larger females in 2014 than in 2013. Can the 2014 data be used to augment or alter this statement?	The text was updated to include the 2014 escapement year. The revised text reads: "In contrast, competition index values for fall Chinook salmon spawning in the Hanford Reach are low (0.09-0.69). We applied the most conservative approach to estimate the competition index for the Hanford Reach by using the record number of spawning females in 2014 (78,836) and the lowest estimate for area of habitat that was actually used for spawning (i.e., 2004; Hatten et al. 2009). Even using this conservative approach, the competition index value for the Hanford Reach is less than those reported for 10 of the 11 streams studied in Puget Sound and British Columbia."

John Clark (ADFG)	6	§5.2.4 ¶5	Again, suggest 2014 data be added.	This text is copied from an annual WDFW memo. At the time of writing, the memo on the 2014 return year was not available. However, these data will be reported on annually as part of Grant PUD's Priest Rapids Hatchery M&E Report
John Clark (ADFG)	7	§5.2.4 ¶6	The fact that the HRFCPPA is not responsible for excessive escapements needs to be augmented. Suggest pointing out the existing escapement goals used by PSC and WDFW and that the high escapement that has likely led to higher egg retention and superimposition are the direct result of the harvest sector not removing these fish from the runs prior to spawning. THIS IS A HARVEST SECTOR ISSUE, NOT A HYDRO OPERATIONS ISSUE, it is advantageous to Grant County to state this in unequivocal terms, not just as a clause in one sentence.	The text was edited to include the 2013 Hanford Reach adult count and URB management goal at McNary Dam. Further discussion of management goals and harvest are beyond the scope of this document- which is to evaluate the potential impacts of the HRFCPPA. The revised text reads: "Further evidence of redd superimposition during 2013 is provided by aerial photos of the Hanford Reach (Lindsey and Nugent 2014). Redd densities were particularly high in some spawning areas (Figure 18) and it appears that fish spawned in previously unused areas (Figure 14). However, there is no evidence that operations under the HRFCPPA caused increased densities. Rather, increased redd densities and spawning in previously unused areas can likely be attributed to the large adult return to the Hanford Reach that exceeded the 10-year average return of 62,000 by nearly 300% and URB returns to McNary Dam (455,000 adults) exceeding the management goal of 60,000 by over 750%."
John Clark (ADFG)	8	§5.4 ¶1	Awkward wording, consider re-phasing.	Text was edited to read: "Just prior to emergence (mean = March 18^{th}) alevins begin to migrate up through the gravels. To ensure that alevins are protected during this life-stage, minimum flow constraints under the HRFCPPA shift from inter-gravel (15 cm below the Critical Elevation) water depth to water surface elevation."
John Clark (ADFG)	9	§5.4.2 ¶1	Again, do not need the word "some" when the word :could is also included in the sentence.	Text was edited to read: "Evidence suggests predation could be a significant source of mortality for fall Chinook salmon smolts as they leave the Hanford Reach."

John Clark (ADFG)	10	§5.4.3.1 ¶3	Is this a word?	"Saltation" is a term typically used in geology to describe a type of particle transport by a fluid. It occurs when a particle or material is picked up and moved by a fluid and then deposited back to the surface. However, for clarity, "saltation" was replaced with "suspended in the water column or rolling along the bottom".
John Clark (ADFG)	11	§5.4.3.1 ¶7	This paragraph uses excellent logic, good job!!!!!	Comment appreciated.
John Clark (ADFG)	12	§5.4.3.3 ¶5	Correct?	The text, describing Figure 33, is correct, however it was edited to add clarity. The revised text reads: "The pre-smolt to age-2 survival rates for natural-origin fish were generally higher during low survival years. During mutually high survival years, hatchery-origin fish generally had higher survival rates."
John Clark (ADFG)	13	§6.5 ¶1	In my opinion, you need to state the obvious, not just hint at it. No need to take such a modest approach.	Mr. Clark's text revision, which removed the clause "It is possible that…" has been accepted. The revised text reads: "The managed flows in the Hanford Reach under the HRFCPP contribute to higher productivities and capacities than what occurred prior to hydroelectric development."
John Clark (ADFG)	14	§7.3.2 ¶2	I strongly disagree with putting this off until 2018. A five-year update should be produced 5 years after the first, ie 2012+5years=2017. Worrying about FINAL CWT data for 6 year olds from BY 2009 is a silly and poor excuse to delay. FURTHER, this analysis should be contracted, not done in-house. If contracted, the results are more likely to be fully accepted and less likely to be considered biased due to being authored by Grant County. Remember, the fact that the analysis was out-sourced and peer reviewed set in place simple acceptance by Grant County and prevented agencies with policy reasons of their own from taking Grant County to task. The expense incurred by Grant County in the last productivity analysis was by far the best money spent and has saved untold arguments and additional expenses.	Grant PUD will produce a draft productivity assessment in 2017 as recommended by Mr. Clark. Grant PUD will not commit to the assessment being conducted by a third party. The PUD reserves the right to make decisions regarding whether to enter into contracts and whom to contract with. Furthermore, Grant PUD must follow legal contracting rules. This is a precedent that Grant PUD implements in all oversight committees. Under any scenario, the productivity assessment, including all data that is used for the assessment, will be made available for peer review and will be completed using accepted scientific practices and standards. .

John Clark (ADFG)	15	§8.1 ¶1	Put appropriate reference in place.	The correct reference was inserted. The revised text reads: "A brief overview of results is provided in Section 5.4.1 and detailed methods and analyses can be found in each annual report (Hoffarth et al. 2012, 2013, and 2014)."
Ryan Harnish (Pacific Northwest National Laboratories)	1	Title	I agree with Tracy on the title change.	Title changed to: "Effects of the Hanford Reach Protection Program on Fall Chinook Salmon in the Hanford Reach – Summary, Conclusions, and Future Monitoring"
Ryan Harnish (PNNL)	2	§3.3 ¶1	Why are life stages capitalized?	Traditionally Grant PUD has capitalized HRFCPPA flow constraint periods, e.g. Spawning Period, Rearing Period, etc. The capitalization of periods differentiates the protection flow periods from general salmon life-stages. A footnote was added to the final report to clarify.
Ryan Harnish (PNNL)	3	§4.2 ¶1	I prefer the title of the report.	The section title was changed to match the title of the report. It now reads: "Effect of Priest Rapids Dam Operations on Hanford Reach Fall Chinook Salmon Productivity and Estimation of Maximum Sustainable Yield, 1975-2004"
Ryan Harnish (PNNL)	4	§5.2.2 ¶1	This was not included in the productivity assessment. Table D.2. of the Harnish et al. (2012) report includes all variables included in the analysis.	This sentence was removed from the text.
Ryan Harnish (PNNL)	5	§5.4.3 ¶1	If this egg estimate is from the productivity assessment it should be stated as eggs in females (not eggs deposited).	Text was revised to read: "The linear relationship between estimates for the number of eggs in females and pre-smolts at the time of tagging is relatively strong (r^2=0.44)."
Ryan Harnish (PNNL)	6	§5.4.3 ¶2	Again, these are eggs in females.	Text was revised to read: "Analyses completed during the productivity assessment suggests density dependent mortality is occurring when adult escapement equates to more than approximately 100 million eggs (~42,000 adults)."

Ryan Harnish (PNNL)	7	§5.4.3 ¶3	Did not change significantly.	Text was revised to include 'did not change significantly' and now reads: "Productivity increased by 217% under the VBSA and increased an additional 130% after implementation of the HRFCPP; however the slopes of the modeled Ricker functions did not change significantly from the period before protections began (e.g., brood years 1975-1983 in Figure 12; Harnish et al. 2014)."
Ryan Harnish (PNNL)	8	§5.4.3 ¶3	This is difficult to evaluate since there were no pre-VBSA years of high escapement.	Agreed. The continuation of a productivity assessment at five-year increments will allow for evaluations at a larger range of escapements. The next assessment, to be completed in 2017, will include the recent and high escapement years. Text was revised to read to clarify: "This suggests that, during the years that were evaluated, constraints implemented to provide protections during the spawning, incubation, and fry life stages increased survival but did not affect the factors leading to density dependent mortality."
Ryan Harnish (PNNL)	9	§5.4.3 ¶4	Maybe I'm not following your logic here but it seems to me that by using tagging to age-2 survival estimates we eliminated this source of density dependence (post HR) from the productivity analysis.	Your logic is correct. This paragraph was deleted.
Ryan Harnish (PNNL)	10	Figure 28	In females.	Caption revised to read: "Relationship between estimates of the numbers of eggs in females and pre-smolts used in the productivity assessment (brood years 1975-2004). Ricker and Beverton-Holt models fit the untransformed data slightly better than simple linear regression (r^2 = 0.47 vs. 0.44)."

Ryan Harnish (PNNL)	11	§5.4.3.2 ¶1	The variable analysis included in the publication indicated the difference in mean spawning discharge and minimum posthatch incubation discharge was negatively correlated with egg-to-presmolt survival and the ratio of minimum posthatch incubation discharge to minimum spawning discharge was positively correlated with survival (in a logistic model). This is likely a better analysis because the incubation period was divided into pre- and post-hatch to better reflect the relative vulnerability during these stages. It doesn't really change the point you are making here but thought I would add my 2 cents.	Text was revised to read: "A total of 52 environmental variables characterizing the entire freshwater rearing period were investigated during the productivity assessment (Harnish et al. 2012). Only density-independent variables, including the difference in mean spawning discharge and minimum post-hatch incubation discharge and the ratio of minimum post-hatch incubation discharge to minimum spawning discharge correlated with survival (Harnish et al. 2012).
Ryan Harnish (PNNL)	12	§5.4.3.3 ¶3	I don't recall this being used previously.	Text was revised to read: "The relatively low number of replicates and mixed-stock sampling in the marine ecology studies limit definitive conclusions about the Hanford Reach, but the patterns of fish condition in the ocean and survival for the Hanford stock based on the Chinook Technical Committee model Hanford Wild (HAN) stock are consistent with a survival bottleneck during their first summer in the ocean."
Ryan Harnish (PNNL)	13	Figure 36	Some would argue that the term "productivity" should only be used in reference to the Ricker alpha value from the S-R relationship (in this case) and should be replaced with egg-to-presmolt survival here (and maybe elsewhere in the report).	The figure caption was revised to read: "Bivariate relationship between CV of hourly discharge and the number of Hanford Reach pre-smolts produced per egg (Figure 12 in Harnish et al. 2012)"
Tracy Hillman (BioAnalysts)	1	§1.1 ¶4	Should this be "Tribe"?	The Wanapum people is the preferred nomenclature.
Tracy Hillman (BioAnalysts)	2	§2.0 ¶4	It would be nice if you could provide a link to a website that contains the 26 or so studies that were conducted as part of this work.	Grant PUD will work towards proving all reports and studies on the committee member accessible Boxnet website.
Tracy Hillman (BioAnalysts)	3	§4.2 ¶4	Because this is the first time AR appears (I think), you should write out Autoregressive (AR).	This text is a direct quote from a publication. The text was revised to read: "The Ricker AR [Autoregressive]1 model was fit to adult/spawner data to estimate the spawning escapement required to achieve maximum sustainable yield (S_{MSY})."

Tracy Hillman (BioAnalysts)	4	Figure 12	Nothing to change here, but one should not extend the regression line beyond the limits of the data. This line should stop somewhere before 100M eggs.	Comment noted. The figure presented is from the Harnish et al. 2012 publication.
Tracy Hillman (BioAnalysts)	5	§4.4 ¶3	Be consistent throughout the report on how you show statistics. r^2 versus r^2. I prefer r^2	All instances were changed to r^2.
Tracy Hillman (BioAnalysts)	6	§5.1 ¶2	Scientific names should occur earlier in the report.	This text is a direct quote from the annotated bibliography and therefore will remain as originally written.
Tracy Hillman (BioAnalysts)	7	§5.2 ¶1	Not sure why the different life stages are capitalized.	Traditionally Grant PUD has capitalized HRFCPPA flow constraint periods, e.g. Spawning Period, Rearing Period, etc. The capitalization of periods differentiates the protection flow periods from general salmon life-stages.
Tracy Hillman (BioAnalysts)	8	§5.2.4 ¶3	Should this be "competition" index? I'm not familiar with "completion" index.	Correct. On the recommendation of John Clark, the analyses was revised by using the 2014 escapement number. Consequently the sentence in question was deleted.
Tracy Hillman (BioAnalysts)	9	§5.3.2	Should this be presented first under 5.3?	Chronologically that may make the most sense. The focus of Section 5.3 was on the effects of the HRFCPPA on incubation. Section 5.3.2 was viewed as background information, and was therefore placed after discussion of the HRFCPPA.
Tracy Hillman (BioAnalysts)	10	§5.3.3	I'm wondering if this should be presented first under 5.3.	See response to comment #9.
Tracy Hillman (BioAnalysts)	11	§5.3.3 ¶2	Not sure, but this may be the first time ETF appears. If so, please write out.	The text was revised to read: "For example, McMichael et al. (McMichael et al. 2005) estimated mean fall Chinook salmon egg to fry (ETF)survival at 29.2% (range, 16.9−66.6%) downstream of Wanapum Dam in the Columbia River."
Tracy Hillman (BioAnalysts)	12	§5.3.4	Present earlier in section 5.3.	See response to comment #9.
Tracy Hillman (BioAnalysts)	13	§5.3.5	Move to the front of section 5.3?	See response to comment #9.
Tracy Hillman (BioAnalysts)	14	§5.4.1 ¶1	References are shown separated with both comma and semi-colons. I prefer semi-colons. Nevertheless, consistency is key.	Fixed for consistency.
Tracy Hillman (BioAnalysts)	15	Table 2	Is it important to show precision of point estimates?	Table 2 now included 95% confidence intervals, as were reported in each of the standing and entrapement annual reports.

Tracy Hillman (BioAnalysts)	16	§5.4.1.2 ¶2	Might be good to explain this.	The text was revised to read: "The ZIP models are based on the assumption that zeros in the dataset have two sources; a 'structural source' and a 'sampling' or random source (Shin 2012). For example, some entrapments without fish may occur because fish were not present at that site, i.e. sampling or random source of zeros. The remaining zeros result from other 'structural' factors (i.e., magnitude of flow fluctuation). Hurdle models are based on the assumption that all zeros only result from structural sources (Shin 2012)."
Tracy Hillman (BioAnalysts)	17	§5.4.2 ¶1	May want to identify the funding entity.	The text was revised to read: "Subsequent to the synthesis report an acoustic-telemetry project was developed by PNNL and co-funded by the Pacific Salmon Commission (Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund) and the Priest Rapids Coordinating Committee (No Net Impact fund) to investigate the location and magnitude of losses during emigration from the Hanford Reach to McNary Dam."
Tracy Hillman (BioAnalysts)	18, 19	§5.4.2.2 ¶5	Comment 18: Should this be "S/km"? Comment 19: See comment above.	This text is a direct copy of the executive summary from Harnish et al. 2014. The authors abbreviated survival per kilometer as S_{km}. The text will remain as written by the original authors.
Tracy Hillman (BioAnalysts)	20	§5.4.3.2	Just curious...Was there any correlation between numbers of fish stranded/entraped and escapement levels?	From our data, there is no correlation between escapement levels and stranding and entrapment mortality. This is likely due to challenges associated with measuring stranding and entrapment mortality and the stochastic nature of the events.

Tracy Hillman (BioAnalysts)	21	§5.4.3.3 ¶3	This may be the first time HAN is identified.	Text was revised to read: “The relatively low number of replicates and mixed-stock sampling in the marine ecology studies limit definitive conclusions about the Hanford Reach, but the patterns of fish condition in the ocean and survival for the Hanford stock based on the Chinook Technical Committee model Hanford Wild (HAN) stock are consistent with a survival bottleneck during their first summer in the ocean.”
Tracy Hillman (BioAnalysts)	22	Figure 36	I think this is survival, not productivity.	The figure caption was revised to read: “Bivariate relationship between CV of hourly discharge and the number of Hanford Reach pre-smolts produced per egg (Figure 12 in Harnish et al. 2012)”
Tracy Hillman (BioAnalysts)	23	§6.3 ¶2	This is interesting. On the one hand, these factors increase fall Chinook survival and productivity; on the other hand, these same factors are bad for predators. This may require more explanation. I'd be tempted to delete these sentences.	This statement was clarified to read: “Changing water levels in the Hanford Reach can desiccate nests, disperse guarding males, change current, increase stranding risk, and/or cause cold water to flood spawning grounds (Montgomery et al. 1980). Incidentally, flow protection under the HRFCPPA that reduced flow fluctuation may inadvertently improve habitat conditions for non-native predators.”
Tracy Hillman (BioAnalysts)	24	8.1	Which section?	Text revised to read: “A brief overview of results is provided in Section 5.4.1 and detailed methods and analyses can be found in each annual report (Hoffarth et al. 2012, 2013, and 2014).”

Paul Wagner (NOAA)	1	Executive Summary	This strikes me as a bit of stretch. I don’t recall this as being part of the productivity study. Even if it was, I don’t believe the data used to conduct the productivity study was anywhere close to a fine enough scale to support this conclusion.	Text was clarified to read: “The major findings were that productivity of fall Chinook salmon from the Hanford Reach: 1) is very high relative to other Chinook populations, 2) was increased substantially by implementation of the Vernita Bar Settlement Agreement (VBSA) and the HRFCPPA, and 3) was not negatively associated with flow variables influenced by changes made to hydrosystem operations under the VBSA and HRFCPPA.” Harnish et al. (2014) characterized the river environment in the Hanford Reach as it related to the egg-to-pre-smolt survival of fall Chinook salmon by quantifying environmental and dam operation variables for each year from 1975 through 2005, a period that covered 30 broods of fall Chinook salmon. The authors identified ten dam operation variables that were hypothesized to have the greatest influence on the egg-to-pre-smolt survival of fall Chinook salmon in the Hanford Reach. The list included variables from each of the life stages expected to be directly affected by Priest Rapids Dam operations in the Hanford Reach (spawning, incubation, and rearing). Of the ten hydrology variables evaluated six varied significantly between periods. All six significant variables were positively related to productivity.

Paul Wagner (NOAA)	2	Executive Summary	~~In fact, the HRFCPPA appears to significantly contribute to the productivity in the Hanford Reach.~~	Text clarified to read: "In fact, the HRFCPPA appears to have significantly improved the productivity of fall Chinook salmon in the Hanford Reach from the pre-VBSA time period." We believe this conclusion is well supported by multiple lines of evidence. As reported in Harnish et al. (2014); "We observed a significant increase in freshwater productivity of fall Chinook salmon in the Hanford Reach following manipulation of discharge fluctuations under the VBSA." And "We also found that constraints on discharge fluctuations during the period of nearshore rearing, as implemented by the HRFCPPA, further increased freshwater productivity of fall Chinook salmon in the Hanford Reach.
Paul Wagner (NOAA)	3	Executive Summary	Since adaptive management is part of this program I would qualify the "no modifications necessary" conclusion.	Agreed. Text modified to read: "Thus, no modifications to the HRFCPPA were necessary at this time."
Paul Wagner (NOAA)	4	§1.1 ¶12	Comment: The fact that the reach has higher productivity than many rivers did not lead to the conclusion that there was no need for further measurers. Text edit:…it was determined that Grant PUD is already implementing measures that ~~best~~ help avoid, reduce, and/or mitigate for adverse impacts on fall Chinook in the Hanford Reach. ~~In fact, there is evidence that the current productivity of fall Chinook salmon is higher than what is found in many normative rivers.~~ Therefore, ~~extensive evaluation of alternative operations and mitigation measures were determined to be unnecessary for the IFS and IFP. Therefore,~~ at this time, Grant PUD and the FCWG are not recommending additional measures or changes to the HRFCPPA.	Changes accepted. Text was modified to read: "…it was determined that Grant PUD is already implementing measures that help avoid, reduce, and/or mitigate for adverse impacts on fall Chinook in the Hanford Reach. Therefore, at this time, Grant PUD and the FCWG are not recommending additional measures or changes to the HRFCPPA."

Paul Wagner (NOAA)	5	§1.2 ¶9	Stating what the current range of fluctuations would be helpful here. It was 13' now it's?	Text was revised to read: " Prior to the Interim Hanford Reach Juvenile Fall Chinook Protection Program (1999-2003) and the HRFCPPA (2004 to present), typical project operations resulted in fluctuations as great as two meters/hour (seven feet/hour) and four meters (13 feet) in a 24-hour period in the Priest Rapids Dam tailrace during the fall Chinook salmon emergence and rearing period (Nugent et al. 2002). Operations under the HRFCPPA have reduced flow fluctuation below Priest Rapids Dam to typically less than one meter/hour and less than 2 meters in a 24-hour period."
Paul Wagner (NOAA)	6	§3.3 ¶3 of quoted text	The double negative used here – "negative ramping rate was less" gives me pause. What does this mean? Could this be rephrased to make it clearer. Or conclude that it was more protective.	In this case, negative ramping rate means the rate of decreasing flow or stage. The following clarification was added to the text: "The magnitude of the mean daily negative ramping rate [i.e., rate of decrease in river stage] (feet/hour) was reduced from the Unimpounded scenario by 23.0%, 32.4%, 39.2%, and 40.4% at Vernita Bar, Coyote Rapids, and the 100-F and Ringold Areas, respectively."
Paul Wagner (NOAA)	7	§3.3 ¶4 of quoted text	Similar to the comment above. Stating with a conclusion that is more or less protective for rearing would helpful.	The introduction to the report summary was revised to read: "The evaluation showed that flow fluctuations in the Hanford Reach were smaller during the Rearing Period and larger during the Spawning Period as a result of operations by Grant PUD under the HRFCPPA. The reduction in flow fluctuations during the Rearing Period reduces fry and pre-smolt susceptibility to stranding and entrapment. The increase in flow fluctuations during the Spawning Period were a result of RLF, which is intended to promote spawning in deeper water."

Paul Wagner (NOAA)	8	Figure 11	The third paragraph on page 16 stated the 60 kcfs band was equal for both unimpounded and current conditions. The graph would suggest the same conclusion. The caption says less. Which is it?	The text in the third paragraph on page 16 is generally describing the patterns observed from all flow fluctuation metrics (flow fluctuations, total stage decreases, and ramping rates) from 2004-2008. The text states that fluctuation metrics are approximately equal at the 60 kcfs constraint. In Figure 11, which is from the flow fluctuation report, is an example of these results. In this example, the mean value at the 60 kcfs is slightly less under the current scenario. The figure caption was revised to read: "Total daily stage decreases during the Rearing Period under the Current and Unimpounded scenarios at the 100-F Area by daily delta constraints (2004-2008). Daily stage decrease is less under the Current scenario at the 20, 30, and 40 kcfs constraint. At the 60 kcfs constraint the change in stage is similar. At the 150 kcfs constraint the daily stage decrease is slightly higher under the Current scenario. (Figure 23 from Langshaw and Duvall, 2010)."
Paul Wagner (NOAA)	9	§4.3 ¶1	The PIT tag detector was installed in what year? How many fish will be PIT tagged at the hatchery? When will data first be available? What is the plan for reviewing the data?	The PIT-tag array in the Priest Rapids Hatchery channel has been in operation since 2012. These data are available on PTAGIS (array ID PRH – Priest Rapids Hatchery Outfall). Currently, approximately 43,000 Priest Rapids Hatchery fish are PIT-tagged annually. PIT-tagging of Priest Rapids Hatchery fish is reviewed annually in the Priest Rapids Hatchery M&E Plan and Report. These plans are reports are available to the FCWG for annual review. The text was revised to read: "The recommendations in the report to PIT-tag more fish from Priest Rapids Hatchery and install a PIT-tag array at the hatchery channel were subsequently implemented. A automated PIT array was installed in the Priest Rapids Hatchery outfall channel in 2012 and the PIT tagging rate at Priest Rapids Hatchery was increased. Details on PIT tagging are available in the Priest Rapids Hatchery annual monitoring and evaluation report."

Paul Wagner (NOAA)	10	§4.4 ¶1	Is this the real reason for not using the model? Productivity is so good it can't be made any better? Or was the model not able to truly inform the management questions due to difficulties and uncertainties of the modeling effort?	There were some limitations to the model, as described in the paragraph after the quoted text from the presentation abstract. This, in addition to the outcome of the productivity analysis, resulted in the model being shelved. If alternative operations are considered in the future, we will revisit the model. To clarify the issues, the text following the quoted text, which details the limitations, was moved up to the introduction.
Paul Wagner (NOAA)	11	§5.2 ¶1	What does historical normative conditions mean? Pre VBSA or pre hydrosystem development. If it was pre hydrosystem development how could you possibly know?	Text was revised to read: "During the spawning season current operations and protections consistently provide a higher base flow than during the pre-hydrosystem period."
Paul Wagner (NOAA)	12	§5.2.2 ¶1	Which of the models was used?	Text was revised to read: "However, no significant relationship was found during the productivity assessment (Section 4.0) where a suite of environmental variables related to spawning (discharge, magnitude and variability of flow, temperature and temperature variability, spawner abundance, etc) were regressed against pre-smolt/egg production (Harnish et al. 2012)."
Paul Wagner (NOAA)	13	§5.2.2 ¶4	What is the point? Did the model underpredict or what? If the point is that the model poorly predicted usable habitat then state it.	Text was revised to read: "While there are no data on spawning distribution during constant flows, spawning habitat models were used to evaluate hypothetical steady-state scenarios with data collected during 2004 (Hatten et al. 2009). Median discharge during peak spawning in 2004 was approximately 80 kcfs. Under the hypothetical steady-state scenario the authors predicted a relatively steady increase in suitable habitat until it leveled off at approximately 110 kcfs (Figure 15)."
Paul Wagner (NOAA)	14	§5.2.2 ¶6	This paragraph suggests a mechanism but it does not clearly state what it is. Elaborating on what condition RLF may be providing would helpful. Yes speculative, but state it as such.	Text revised to read: "Redd locations above the 40 kcfs elevation were spatially confined and generally more densely spaced, suggesting there may be limited or less preferable spawning habitat above the 40 kcfs elevation."

Paul Wagner (NOAA)	15	§5.2.4 ¶2	Some description of what the indices was based on would be helpful. Was it a minimum area per female or what?	Text revised to read: "Using female population size, average redd area, and spawning habitat area, Fleming and Gross (1989) developed average and episodic competition indices to estimate the magnitude and frequency that the area of suitable spawning habitat is exceeded by the minimum area necessary to accommodate spawning females."
Paul Wagner (NOAA)	16	§5.2.4 ¶2	Should that be >55,000?	Correct. The text was updated to include the 2014 escapement year. The revised text reads: "In contrast, competition index values for fall Chinook salmon spawning in the Hanford Reach are low (0.09-0.69). We applied the most conservative approach to estimate the competition index for the Hanford Reach by using the record number of spawning females in 2014 (78,836) and the lowest estimate for area of habitat that was actually used for spawning (i.e., 2004; Hatten et al. 2009). Even using this conservative approach, the competition index value for the Hanford Reach is less than those reported for 10 of the 11 streams studied in Puget Sound and British Columbia."
Paul Wagner (NOAA)	17	§5.2.5 Section Heading	A lot of the studies that follow are just excerpts from the executive summary. Some discussion of whether the study met the objective of the study and a brief discussion on whether the study provided valuable management information would be helpful.	Additional commentary and discussion was added as necessary. As discussed and reviewed during FCWG meeting in 2014, the objective of this section of the report is to provide an overview of the studies that have been conducted in the Hanford Reach. The reports from these studies, where available, will be provided online.
Paul Wagner (NOAA)	18	§5.3.1 ¶4	A more complete description of how this unpublished data was produced would be helpful. I.e. how many sensors were deployed, how far apart were they spaced, were their replicates? How many depths were assessed? What were the dates of data collection?......	The text was revised to read: "In the fall (September 28 – November 11) of 2012 the dynamics of stage and DO in the intergravel spaces was evaluated by deploying six sensors on Vernita Bar (Figure 23). The sensors were buried on transect perpendicular to flow 30 cm deep at the 45, 50, 55, 60, 65, and 70 kcfs elevations."

Paul Wagner (NOAA)	19	§5.3.2 ¶2 of quoted text	So is it feasible to estimate egg deposition in the reach??? Yes, no, maybe so? Which is it.	The methods were intended to evaluate quantifying redds for the egg to fry survival studies. As described in the text, the manual method of counting eggs in redds proved effective; "These results suggest that the manual method is effective for quantifying eggs in high-elevation redds. This method will aid researchers in determining the number of eggs present in high-elevation redds and in estimating egg-to-fry survival of fall Chinook salmon. However the hydraulic method was ineffective." The introductory text was revised to read: "The methods that were investigated included manually removing and sorting and using hydraulic pressure to excavate redds. From these evaluations it was determined that the manual method was the most effective means to quantify eggs in redds."
Paul Wagner (NOAA)	20	§5.3.3 Quoted text	Too much information is provided in this excerpt. A summary would be better. The point is???	The excerpt was shortened.
Paul Wagner (NOAA)	21	§5.4.1.2 ¶5	So does this mean that the model could not predict the estimated loss since a few entrapments are usually responsible for the greatest loss? What's the punchline?	Correct. The following text was added: "Therefore, the models evaluated have limited applicability due to the abundance of zeros or non-detects coupled with the apparent stochasticity of the presence of fry."
Paul Wagner (NOAA)	22	§5.4.2 ¶1	Like how low? A number would be good to calibrate expectations to.	Text was modified to read: "Data collected from natural-origin juvenile fall Chinook salmon PIT-tagged in the Hanford Reach indicated that survival from tagging to McNary Dam is particularly low (e.g., median survival to McNary Dam = 0.35; Figure 27)."

Paul Wagner (NOAA)	23	Figure 27	Shouldn't this be blue?	The figure caption is correct. The circle shaped dots represent hatchery-origin fish survival. The grey circles are survival estimates for fish released from the Ringold Hatchery. The remaining circle dots are survival estimates for fish released from the Priest Rapids Hatchery; the color of the dot indicates the data source.
Paul Wagner (NOAA)	24	§5.4.3 ¶4	So does this suggest that the density dependent mortality is occurring in the plume or first ocean conditions? It might be best to word it such that this is the message and not left to inference.	The text in question was unclear and was deleted. What we are suggesting is that density dependence may be occurring at multiple times and locations, however the exact mechanisms remain unknown. We clarified this argument in Section 8.4. The text reads: • "Density dependent mortality is apparent at high spawner abundance. o Source and location of density dependence remain unknown. o There may be multiple mechanisms resulting in density dependent mortality and that these mechanism may be occurring in the freshwater, estuarine, and marine environments."
Paul Wagner (NOAA)	25	§6.2 ¶3	This is giving an awful lot of credit to the VBSA. The construction of the Canadian treaty projects, Libby Dam, and no extreme event (i.e. 1948) are responsible for the lack of extreme high spring flow events.	In this case, 'historically' was intended to mean pre-hydro. The text was revised to read: "Prior to hydrosystem development, flows could reach levels with significant potential for scour in during the late incubation and early rearing periods."
Paul Wagner (NOAA)	26	§6.2 ¶4	Lack of fines and sediment also have negative effects. The lack of turbity (sic) in the river leads to higher rates of predation due to the increase in clarity (sic).	Agreed. This section of the report is intended to synthesize the potential mechanisms for the observed high productivity in the Hanford Reach during the incubation life-stage. The potential effects of the hydrosystem system, including water clarity and turbidity, were reviewed in the final report on predation in the Hanford Reach (Rizor et al. 2014). See Section 5.4.2 for an overview.

Paul Wagner (NOAA)	27	§6.3 ¶2	The fact that hydro development has created nutrient sinks in the reservoirs and less nutrients available to support primary and secondary productivity is an offsetting issue. The higher productivity than historical is speculation. Also the fluctuations that still do occur under the HRFCPPA are far from optimal for secondary productivity.	We acknowledge in the preceding sentences that hydrosystem development, including flow fluctuations, can be detrimental to the benthic community. This is well supported in the literature and citations are provided. However, in this section of the report, we also intended to synthesize the potential mechanisms for the observed high productivity in the Hanford Reach during the fry/parr life-stage. Given in the increase in base flow during the winter-spring period, and consequently increase wetted width, even with flow fluctuations, it is a reasonable assumption that primary and secondary productivity may be higher now that during the pre-hydrosystem period. Figure 37 was added and the text was revised to read: "Under current conditions, minimum discharge constraints that began with the VBSA have effectively prevented desiccation of substrates below the Critical Elevation (mean 63.3 kcfs) from December through June. Therefore, flow protections under the VBSA and HRFCPPA have resulted in more of the river-bed to remain wetted and fully colonized during the winter and early spring months (November – April), and in turn to begin producing food as soon as light and temperature conditions become favorable (Figure 37)."

Paul Wagner (NOAA)	28	§6.5 ¶1	But the areas that were wet would have remained wet. That is the issue.	Hydraulic modeling of the pre-hydrosystem system has shown that typically the fall, winter, and early spring flows were lower than they currently are. On the other hand, pre-hydrosystem system flows during the spring and summer periods were much higher than under current conditions. We are suggesting that the higher winter flows that are currently experienced, and required under the HRFCPPA, have resulted in a greater wetted streambed during the winter which in turn has increased the primary and secondary productivity during this time period. Figure 37 was added to help illustrate the point. The text was revised to read: “For example, many studies have demonstrated the detrimental effects of dewatering substrates on primary and secondary productivity. Additionally, fluctuation flows can reduce the complexity of the benthic community. However, with the implementation of a Critical Elevation (i.e., minimum flow) under the HRFCPPA, the minimum flows (and wetted area) during the fall-early spring period are greater now than under historical conditions (Figure 37).”
Paul Wagner (NOAA)	29	§6.5 ¶1	This is not due to the VBSA or HRFCPPA.	Text was revised to include general hydrosystem conditions. The revised text reads: “In summary, the productivity and capacity of the fall Chinook salmon that spawn in the Hanford reach is high and there are plausible mechanisms for each life-stage to explain why conditions under the hydrosystem in general, and under the VBSA and HRFCPPA specifically, have contributed positively to this high productivity (Figure 38).”
Paul Wagner (NOAA)	30	§6.5 ¶1	Same comment as above.	See comment above.

Paul Wagner (NOAA)	31	§6.5 ¶1	This is speculative.	Agreed. As stated in the section title and in throughout this section; these are plausible mechanisms that may explain the observed high productivity. The Hanford Reach fall Chinook population has remarkably high freshwater productivity. And the productivity is higher now that it was during the pre-HRFCPPA period. This is a fact supported by peer reviewed publications. In this section of the report we are attempting to explain the potential mechanism behind the high, and increased, productivity under the hydrosystem generally and HRFCPPA specifically.
Paul Wagner (NOAA)	32	§6.5 ¶1	Same comment as above. There was no study to demonstrate this.	Agreed. See comment above.
Paul Wagner (NOAA)	33	§6.5 ¶1	This is speculative as well. There was no study to demonstrate this and the amount of disrupted habitat that occurs due to the operations is speculation.	Agreed. See comment above.
Paul Wagner (NOAA)	34	§7.1 ¶1	Does this include passage of fall chinook through the Wanpum and Priest Rapids projects or just the activities of the VBSA and HRFCPPA?	As defined in the Salmon and Steelhead Settlement Agreement, the Fall Chinook Protection Program is designed to achieve No Net Impact of the operations of the Project on fall Chinook populations in the program area, defined as the Hanford Reach and upstream to the tailrace immediately below Rock Island Dam. NNI shall apply collectively to all fall Chinook including those that originate above and within the program area as a whole.

Paul Wagner (NOAA)	35	§8.4 Bullet 3.2	In text edit in red: "Hydrosystem development and operation may reduce sedimentation, freezing, desiccation, and scour which is beneficial to the egg-to-fry stage, but is likely detrimental to the fry-smolt-adult survival."	We do not agree that the reduction in sedimentation, freezing, desiccation, and scour has been detrimental to fry-smolt-adult survival. However, to address this comment additional text was added. • "Hydrosystem development, including fluctuation flows and increased water clarity, may exacerbate the rate of predation particularly from avian predators." Additional text was also added under the "Hydrosystem development" bullet: • "Fluctuating flows, particularly during the rearing season, results in stranding and entrapment mortality. • Flow fluctuations that can result in stranding and entrapment were reduced with the implementation of the HRFCPPA."

Paul Wagner (NOAA)	36	§8.4 Bullet 4.3	The heading of this section is hydrosystem development, which includes all projects above PRD, making the base case of a natural river environment. There is not sufficient information provided to make the case that current conditions are better than historic. Fish may have spawned deeper, spawned further up in the basin, ….If the point is the HRFCPPA is better under current conditions with all the projects in place then state that. But to infer that the HRFCPPA is better than pre development is not supported.	We are not arguing that current conditions are better than historic conditions. Certainly, the dams and reservoir inundation has greatly diminished the spawning area available to fall Chinook. Fluctuating flows result in stranding and entrapment mortality. However, some of the changes to the hydrograph under current hydro-development may be favorable to fall Chinook and help explain the observed high productivity. Specifically, minimum flows during the spawning and winter period are higher now than under pre-hydrosystem development. This may provide more spawning habitat. The hydrosystem has reduced the frequency of high scouring flows. This has likely reduced the incidence of redd scour. We are proposing that these may be some of the mechanisms that are fostering a productive population in the Hanford Reach. Additional text was added to clarify and add balance: • "Fluctuating flows, particularly during the rearing season, results in stranding and entrapment mortality. • Flow fluctuations that can result in stranding and entrapment were reduced with the implementation of the HRFCPPA. • The wetted area from spawning to emergence (fall-early spring) has increased under the HRFCPPA • Capacity for primary and secondary productivity during winter and at spring emergence may be higher under the HRFCPPA."
Paul Wagner (NOAA)	37	§8.4 Bullet 4.4	Same comment as above	See response above.
Geoff McMichael (Mainstem Fish Research)	1	Executive Summary	Style thing - but I like a 'salmon' after a 'Chinook', except in cases like the name of the work group. Throughout - I won't mark up the rest.	'Salmon' added to text.

Geoff McMichael (Mainstem Fish Research)	2	Executive Summary	effects on?	Text revised to read: “A phased approach was used to examine effects on productivity, and if necessary, implement studies to examine the source and mechanism for those effects.”
Geoff McMichael (Mainstem Fish Research)	3	Executive Summary	Plural.	‘Mechanism’ changed to ‘mechanisms’.
Geoff McMichael (Mainstem Fish Research)	4	Executive Summary	kind of slang - use a more 'official' word?	‘Hydro’ changed to ‘hydrosystem’ throughout the document.
Geoff McMichael (Mainstem Fish Research)	5	Executive Summary	insert - 'the extensive research and analyses conducted over the past several years indicate that'	Text revised to read: “Most importantly, the extensive research and analyses conducted over the past several years indicate that the HRFCPPA is meeting its primary objectives of reducing high elevation spawning, redd desiccation, and flow fluctuations during the period when fry are susceptible to stranding and entrapment.”
Geoff McMichael (Mainstem Fish Research)	6	Executive Summary	insert 'of fall Chinook salmon'	Text revised to read: “In fact, the HRFCPPA appears to have significantly improved the productivity of fall Chinook salmon in the Hanford Reach from the pre-VBSA time period.”
Geoff McMichael (Mainstem Fish Research)	7-9	Table of Contents	Multiple formatting errors.	Errors in formatting corrected for the final.
Geoff McMichael (Mainstem Fish Research)	10	Introduction	a sentence that defines what the PRP is may be helpful for folks not familiar with the area. I.e., Priest Rapids and Wanapum dams and their reservoirs.	Text revised to read: “A new operating license for the Priest Rapids Project (PRP), which includes the Priest Rapids and Wanapum dams and reservoirs, was issued by the Federal Energy Regulatory Commission (FERC) on April 17, 2008.”

Geoff McMichael (Mainstem Fish Research)	11	§1.2 ¶1	most distances in km	Text revised to read: “The Monument boundary is about 4.8 kms downstream of Priest Rapids Dam.”
Geoff McMichael (Mainstem Fish Research)	12	§1.2 ¶3	insert 'typically' to allow for reverse load following op at PRD?	This sentence is describing the typical entire Mid-C operations, which does load follow.
Geoff McMichael (Mainstem Fish Research)	13	§1.2 ¶3	one word below	‘Stream flow’ changed to two words for consistency.
Geoff McMichael (Mainstem Fish Research)	14	§1.2 ¶3	add 'and wildlife'? e.g., waterfowl production, etc...	Text revised to include ‘natural resources’: “The mid-Columbia projects are part of the larger Columbia River hydropower system and are operated under the terms of an international treaty and other agreements that affect river flows and natural resources.”
Geoff McMichael (Mainstem Fish Research)	15	Footer	change footer to 2015 for final?	Updated for final.
Geoff McMichael (Mainstem Fish Research)	16	§1.2 ¶4	Is two words above	‘Stream flow’ changed to two words for consistency.
Geoff McMichael (Mainstem Fish Research)	17	§1.2 ¶4	insert 'the'?	“The” added to precede YN.
Geoff McMichael (Mainstem Fish Research)	18	§2.0 ¶2	missing)	Citation corrected.
Geoff McMichael (Mainstem Fish Research)	19	Figure 4	why does the arrow on terr. inverts point away from FAC?	Figure 4 in the draft document was confusing. This figure was replaced with a more informative food web and water management figure.

Geoff McMichael (Mainstem Fish Research)	20	§2.0 ¶3	, if any, that were identified in the productivity analyses.	Text revised to read: "Mechanistic studies could then be used to help identify actions or protections to address the limiting factors, in any were identified in the productivity analysis."
Geoff McMichael (Mainstem Fish Research)	21	§2.0 ¶3	'Are' to 'were'.	Text changed to 'were'.
Geoff McMichael (Mainstem Fish Research)	22	Figure 6	missing part of citation	Caption fixed to read: "Mean daily discharge at Priest Rapids Dam from 1917 to 2012 (Figure 15 in Niehus et al. 2014)."
Geoff McMichael (Mainstem Fish Research)	23, 24	§3.2 ¶1	Caps?	See Ryan Harnish's comment #2.
Geoff McMichael (Mainstem Fish Research)	25	Figure 7	Missing (.	Parenthesis added to caption.
Geoff McMichael (Mainstem Fish Research)	26	§3.3 ¶1 of quoted text	Superscript?	See Tracy Hillman's comment #5.
Geoff McMichael (Mainstem Fish Research)	27	§4.1 ¶1	When?	Text revised to read: "Given the critical importance of the assessment, an Expert Panel was convened in November of 2010 to critique the proposed methods and ensure the best available data and methods were used."
Geoff McMichael (Mainstem Fish Research)	28	§5.1 ¶1 of quoted text	Italics?	All scientific names are now italicized.
Geoff McMichael (Mainstem Fish Research)	29	§5.2.2 ¶6	Could mention Swan et al paper - and that deep spawning is underrepresented in existing data due to limitations in seeing redds in deep water (cite Visser and Dauble).	While deep water spawning is an important component of Hanford Reach production, this section of the report is describing redd site selection at high elevations, in this case above the 40 kcfs elevation.

Geoff McMichael (Mainstem Fish Research)	30	§5.2.4 ¶1	Use of these citations at the end of this sentence may be misleading readers to think that these papers discussed the probability of spawning density being limiting to HR fall Chinook - when this is not the case.	This sentence, along with the citations, was deleted. See John Clark comment #4 for the revised text.
Geoff McMichael (Mainstem Fish Research)	31	§5.2.4 ¶3	Competition	Revised to read 'competition'.
Geoff McMichael (Mainstem Fish Research)	32	§5.2.4 ¶2 of quoted text	2014 was higher - maybe say up front that this report only deals with data through 2013?	Text was revised to read: "The following text is an excerpt from the "Spawn Success Section" of a memo that was developed following the 2013 return year to summarize existing data on egg retention or other evidence of redd superimposition (Hoffarth 2014):"
Geoff McMichael (Mainstem Fish Research)	33	§5.2.4 ¶2 of quoted text	Insert 'younger'?	This is quoted text from the Hoffarth 2014 memo.
Geoff McMichael (Mainstem Fish Research)	34	§5.3.2	Seems like this should maybe be before the egg to fry section?	See Tracy Hillman comment #9.
Geoff McMichael (Mainstem Fish Research)	35	§5.3.3	Ditto above, maybe put before full egg to fry section?	See Tracy Hillman comment #9.
Geoff McMichael (Mainstem Fish Research)	36	§5.4.1 ¶1	Didn't see a 2006a above here?	Citations corrected.
Geoff McMichael (Mainstem Fish Research)	37	Figure 25	Word cut off on lower line of legend	Legend corrected.
Geoff McMichael (Mainstem Fish Research)	38	§5.4.1.1 ¶7	E.g.?	Text correct, e.g. instead of i.e.

Geoff McMichael (Mainstem Fish Research)	39	§5.4.1.1 ¶9	Insert 'early part of the'?	Text revised to read: “Timing is intuitive because discharge and the abundance of susceptible fry generally increase throughout the early part of the season.”
Geoff McMichael (Mainstem Fish Research)	40	§5.4.2.1 ¶	Hmmm? I would not say that it was that report that resulted in the Northern Fund project? not a biggie though.	Text revised to read: “Subsequent to the synthesis report an acoustic-telemetry project was developed by PNNL and co-funded by the Pacific Salmon Commission (Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund) and the Priest Rapids Coordinating Committee (No Net Impact fund) to investigate the location and magnitude of losses during emigration from the Hanford Reach to McNary Dam.”
Geoff McMichael (Mainstem Fish Research)	41	§5.4.2.2 ¶	Again, I don't agree.	Text was revised to read: “Following the synthesis report, an acoustic-telemetry project was developed by PNNL and co-funded by the Pacific Salmon Commission (Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund) and the Priest Rapids Coordinating Committee (No Net Impact fund).”
Geoff McMichael (Mainstem Fish Research)	42	§5.4.3 ¶4	Effects	Text corrected to read ‘effects’.
Geoff McMichael (Mainstem Fish Research)	43	§5.4.3.1 ¶3	This sentence is unclear/awkward. Not clear if/how it relates to the Hanford Reach.	Text was revised to read: “While there is some evidence for egg loss from redd superimposition in the Hanford Reach, the level of egg loss is unlikely high enough to produce the significant density dependent mortality that has been observed in other systems.”

Geoff McMichael (Mainstem Fish Research)	44	§5.4.3.1 ¶3	Seems premature to me to reach this conclusion. We have seen for years that the spawning habitat models predict much more suitable than is used - even in high escapement years. I think this may be true - but I am not convinced that we have enough data to check it off the list. I'd soften the wording and state that it remains unknown - but data collected to date indicate it may not be the driving force in DD... or something along those lines.	Agreed. The text was revised to be more specific regarding the data collected to date: "While some levels of egg loss has been occurring in the Hanford Reach, significant losses have been likely limited to areas with extreme spawning densities and intense competition for preferred habitats. The scale and severity of superimposition required to cause the density dependence documented to date for the entire population are unlikely given the total area of suitable spawning habitat that is predicted to be available in the Hanford Reach"
Geoff McMichael (Mainstem Fish Research)	45	§5.4.3.1 ¶4	They also saw more area used in a year with lower escapement?? So - I think there are many sources of error in the input data for these models - related to when they can get aerial pics. They also don't have any use data for deep water - which is a huge weakness to these models.	Agreed.
Geoff McMichael (Mainstem Fish Research)	46	§5.4.3.1 ¶6	What do the 2014 data show?	Egg retention data for 2014 was not available at the writing of this report. However, egg retention data will continue to be collected and reported annually in the Priest Hatchery M&E Report, which will be reviewed by the FCWG.
Geoff McMichael (Mainstem Fish Research)	47	§5.4.3.2 ¶1	Seems like a strong word here - related to my comments above. Seems too early to reach this conclusion in the absence of much direct evidence.	The text was revised to reflect that we limiting our discussion to the current the data to date and the word 'likely' was removed: "As discussed above, to date there is limited evidence that spawning has been the primary factor contributing to density dependent mortality prior to 2013. This suggests that the primary mechanisms of density dependent mortality may be occurred sometime after emergence."
Geoff McMichael (Mainstem Fish Research)	47	§5.4.3.3 ¶1	Slang/jargon - what is the real point?	Text was revised to read: "The researchers did not consider river conditions during earlier recruitment, which was a limitation in their analyses."

Geoff McMichael (Mainstem Fish Research)	48	§5.4.3.3 ¶3	Causal or casual? raises the question of why would poor ocean survival conditions be related to the escapement of adults one year prior...? Or if not related - why would they follow the same pattern? Seems like a reach to me - based on how much we don't know about these possible relationships.	The authors were investigating relationships between conditions during early marine rearing and subsequent adult returns to Priest Rapids Dam (Miller et al 2013). We incorporated estimates of spawning escapement and age-specific recruitment to help explain some of the findings by Miller et al. (2013).
Geoff McMichael (Mainstem Fish Research)	49	§5.4.3.3 ¶4	'may occur'?	In this case, we believe ‘likely’ is warranted. In the years where survival to age-2 of the natural population was low, hatchery-origin fish also experienced below normal survival to age-2. Because hatchery origin fish spend so little time in the Hanford Reach after release (as well as natural origin fish after tagging) it is safe to assume that that mechanisms that both populations are experiencing and that are causing the lower than normal tagging to age-2 survival are occurring after they leave the Hanford Reach.
Geoff McMichael (Mainstem Fish Research)	50	§5.4.3.3 ¶6	I know this is what Grant would like to be the case - but I think it may lose some credibility if they take this string stance in the absence of any directed research to answer this question. Obviously, just my opinion.	Text was revised to include ‘from the data available to date’ and now reads: “In summary, from the data available to date, it does not appear that operations under the HRFCPPA are contributing to density dependent mortality within the Hanford Reach.” We believe this is a fair statement. To date, we do not have evidence that operations under the HRFCPPA are contributing to density dependent mortality. We acknowledge that density dependence is occurring and identify the escapement level at which it is occurring. These data were identified through direct research in the productivity assessment. This research also showed, by exhibiting the same spawner-recruit slope pre- and post-HRFCPPA, that the HRFCPPA increased productivity but did not increase the rate of density dependent mortality.

Geoff McMichael (Mainstem Fish Research)	51	§5.4.3.3 ¶6	Insert 'existing information that may be related to' ??	Text revised to include ‘current data available’ and now reads: “An extensive evaluation of the current data available on density dependence has been conducted that identified…”
Geoff McMichael (Mainstem Fish Research)	52	§5.4.3.3 ¶6	Insert 'appear to be related to' ?	Text revised to include ‘appears to be related to’ and now read: “…2) spawning escapement that appears to be related to density dependence, and…
Geoff McMichael (Mainstem Fish Research)	53	§5.4.3.3 ¶7	Insert 'monitoring'?	Text revised to read: “…evaluate density dependence in fall Chinook salmon originating in the Hanford Reach primarily by: 1) productivity modeling and 2) egg retention monitoring.”
Geoff McMichael (Mainstem Fish Research)	54	§5.4.3.3 ¶7	change to 'are indeed'?	This sentence was removed. The revised text reads: “…Grant PUD will continue to monitor and evaluate density dependence in fall Chinook salmon originating in the Hanford Reach primarily by: 1) productivity modeling and 2) egg retention monitoring. Data for these activities will be incorporated into the Grant PUD’s hatchery monitoring program….”
Geoff McMichael (Mainstem Fish Research)	55	§5.4.3.3 ¶7	Harping continues - say what you like - but I am not convinced this occurring outside the Hanford Reach yet. Don't misread me here - I am not lobbying Grant to fund DD studies - others have indicated that they care enough about the productivity of this stock that they are interested in funding work to reduce the uncertainty in this area.	The sentence in question was removed. The revised text reads: “Data for these activities will be incorporated into the Grant PUD’s hatchery monitoring program (see Section 7.3.2 for more details) and the productivity modeling will be completed and reported at five-year intervals.”
Geoff McMichael (Mainstem Fish Research)	56	§6.0 ¶3	Insert 'more' ?	Text revised to read: “This chapter takes a life cycle perspective and examines how current conditions may contribute to the observed high rates of survival and productivity of fall Chinook salmon in the Hanford Reach.”

Geoff McMichael (Mainstem Fish Research)	57	Figure 34	Under represents use of deep water due to bias in data collection. Therefore, over represents benefits of development.	Text describing the figure revised to read: "While the increase in accessible spawning habitat was evident, the estimate of the total number of redds was likely biased low due to the construction of deep water redds in the Hanford Reach, which can be extensive, and are often missed in aerial surveys (Swan 2006)."
Geoff McMichael (Mainstem Fish Research)	58	Figure 35	Maybe shade 'preferred' depth/velocities on these?	Text was revised to describe the preferred depths and velocities. Adding shading to the figure made the figure too complex, in our opinion. The revised text reads: "This location was in the preferable depth range (2 – 4 meters) during hours of darkness, but velocities were in the preferred range (1.4 – 2 m/s) during the day (Geist et al. 2000)."
Geoff McMichael (Mainstem Fish Research)	59	§6.1 ¶4	Should probably be a 2005b for the night spawning activity paper. The other 2005 is the redd cap one - and you already talked about that one.	Citation corrected.
Geoff McMichael (Mainstem Fish Research)	60	§6.2 ¶2	There a cite for this one?	No citation, but commonly known that the upper reaches of the Methow River can dewater and or freeze in the late fall/winter.
Geoff McMichael (Mainstem Fish Research)	61	§6.2 ¶3	Most fish have emerged by June - April may be a better month to look at for the incubation/scour flows.	Agreed, but in this case, we are using June because it is typically the month with the highest weekly flow when emergence is still occurring. High flow years also tend to be colder, which may push emergence further into the year.
Geoff McMichael (Mainstem Fish Research)	62	§6.2 ¶4	Soften to ' may actually'?	Text revised to include 'may contribute' and now reads: "In addition to decreasing the potential for extreme events that cause mortality, hydroelectric development in some cases may contribute to the quality of conditions within redds."

Geoff McMichael (Mainstem Fish Research)	63	§6.3 ¶1	What about that U of I study done in the Hanford Reach with the tiles? Did that ever get written up?	Not that we are aware of.
Geoff McMichael (Mainstem Fish Research)	64	§6.3 ¶1	Cite?	According to Department of Ecology, the Hanford Reach at Vernita Bar has a Water Quality Index (WQI) of > 80. As we understand the WQI this puts the Columbia River at Vernita Bar in the 90th percentile of all streams measured by Ecology. However, because we have only a rudimentary understanding of the WQI and do not want to extrapolate beyond the intent of the WQI, we have removed the sentence from the text.
Geoff McMichael (Mainstem Fish Research)	65	§6.3 ¶1	Mention that HRFCPPA flows may have inadvertently increased predator production?	Text was revised to read: "Incidentally, flow protection under the HRFCPPA that reduced flow fluctuation may inadvertently improve habitat conditions for non-native predators."
Geoff McMichael (Mainstem Fish Research)	66	§6.5 ¶1	Insert e.g.s,?	Citations to examples of studies that have documented the effects of hydroelectric development on aquatic biology are provided, and numerous. Examples of these studies seems unnecessary.
Geoff McMichael (Mainstem Fish Research)	67	§8.4 ¶Bullet 2.1	Agree with this	Noted.
Geoff McMichael (Mainstem Fish Research)	68	§8.4 ¶Bullet 2.2	I am less convinced of this as it is intended (to say DD is happening after Reach). However as written - it is very clear to me that mortality is occurring after they leave the Reach. Possibly reword to be more informative?	Agreed. Text revised to read: "There may be multiple mechanisms resulting in density dependent mortality and that these mechanism may be occurring in the freshwater, estuarine, and marine environments."

Geoff McMichael (Mainstem Fish Research)	69	§8.4 ¶Bullet 4.3	I think this is a stretch - if you looked at rearing season flows - the mean may have been higher than the base flows under the hydro years - for many weeks at a time. This is one area where critics will lose faith in your truthfulness.	Agreed that flows in May-June were typically higher under pre-hydrosystem conditions. However, the basis for our conclusion is that, under the HRFCPPA, winter and spring (November-April) minimum flows are higher now than under pre-hydrosystem years, which allowed for more early productivity during the emergence/rearing periods. Historically, discharge was lowest in February with recorded minimums reaching 20 kcfs (mean 34.5 kcfs). Thus, primary and secondary productivity could not fully recover before the spring freshet began and flows peaked in June. Under current conditions, minimum discharge constraints that began with the VBSA have effectively prevented desiccation of substrates below the critical elevation (mean 63.3 kcfs) from December through June. Therefore, flow protections under the VBSA and HRFCPPA have resulted in more of the river-bed to remain wetted and fully colonized during the winter months, and in turn to begin producing food as soon as light and temperature conditions become favorable. Text was revised to read: o “The wetted area from spawning to emergence (fall-early spring) has increased under the HRFCPPA. o Capacity for primary and secondary productivity during winter and at spring emergence may be higher under the HRFCPPA.” Figure 37 was added to support this conclusion.
Jeff Fryer (Columbia River Inter-Tribal Fish Commission)	1	General	I took a look at it yesterday on a plane and didn't see anything significant to comment on. It looked like a good summary of all the work we've already seen.	Comment appreciated.

Steve Haeseker (USFWS)	1	§5.2.2 Table 1	My comments center on the comparisons of the spawning habitat suitability models that have been developed (Table 1, page 28). There are numerous differences in the extent of the reach that was modeled, with Geist et al. (2008) only modeling 27 rkm of the Hanford Reach compared to the full 90 rkm modeled in Hatten et al. (2009). The extent of the reach modeled by Xie et al. (2008), and the unpublished data of Langshaw et al. (2011) and Bellgraph et al. (2011) are unknown. Because of the different spatial coverages in Geist et al. (2008) and Hatten et al. (2009) it is inappropriate and misleading to compare their predictive performance in terms of overall accuracy or commission errors. In addition, both overall accuracy and commission error rates are a function of the approach used for assigning sampling units (e.g., prediction success rate in Geist et al. (2008) versus classification success rate in Hatten et al. (2009)) and probability cutoff that is used to assign predicted used versus non-used sampling units. Here again there are major differences in the approaches used by the two studies. Geist et al. (2008) used a prediction success rate where sampling unites were ‘‘partially’’ assigned to each outcome based on the modeled probability of belonging to that outcome. In contrast, Hatten et al. (2009) used a classification success rate with a probability cutoff of 0.05. A higher probability cutoff would have reduced the commission errors, but 0.05 was selected because it balanced model sensitivity and specificity, as was recommended by Hosmer and Lemeshow (2000). Because of the different approaches that were used in the two studies to characterize predictive performance, it is inappropriate and misleading to make comparisons between the two. Furthermore, there were substantial differences in the spawning population sizes over the years analyzed by the two studies, further confounding comparisons between them. A proper comparison of performance would require application of the models to the same area of the river, in the same year, using the same approach to characterize overall accuracy, omission error rates, and commission error rates. The data presented in Table 1 and the associated discussion do not provide a proper comparison of performance, and I believe it gives a misleading and erroneous comparison of the models that have been developed. I also question whether it is appropriate to present “unpublished” data in the table for similar reasons as stated above. My recommendation is to delete Table 1 unless an equal comparison of performance can be conducted using the same spatial extent, the same year, and the same approach for characterizing predictive performance.	Table 1 and text comparing models was removed.

Appendix C
Grant PUD 8/14/2014 EOT Request and WDOE 9/2/2014 Approval of EOT

August 11, 2014

Patrick McGuire
Washington Department of Ecology
Eastern Regional Office
4601 N Monroe
Spokane, WA 99205-1295

RE: P-2114-WA - Priest Rapids Hydroelectric Project, extension of time request to complete the Hanford Reach Implementation Feasibility Study

Dear Mr. McGuire;

Public Utility District No. 2 of Grant County, Washington (Grant PUD) respectfully requests an extension of time to complete its Hanford Reach Implementation Feasibility Study (IFS), required per Section 6.3.7(a) of the April 3, 2008 Water Quality Certification (WQC) for the Priest Rapids Hydroelectric Project (Order 4219; amended on March 6, 2008 (Order 5419)). In accordance with Section 6.3.7(a) of the WQC, the IFS is currently due on August 17, 2014 (per letter from Ms. Marcie Mangold of your office on April 18, 2011).

The objective of the IFS is to identify and evaluate the feasibility of potential measures that may avoid, reduce, or mitigate adverse impacts on fall Chinook in the Hanford Reach. Development of the IFS and a plan for implementation (i.e., Implementation Feasibility Plan (IFP); Section 6.3.7(b) of the WQC) are to occur during the final phase of a three-phased approach was developed address all the WQC requirements related to fall Chinook salmon spawning and rearing in the Hanford Reach.

Based on recent discussion within the Fall Chinook Work Group (FCWG), the results obtained through the first two phases of the study are showing that Grant PUD is already implementing measures that best help avoid, reduce, and/or mitigate for adverse impacts on fall Chinook in the Hanford Reach. In fact, there is evidence that current productivity of fall Chinook salmon is higher than what is found in many normative rivers. Therefore, extensive evaluation of alternative operations is unnecessary for the IFS. However, additional monitoring may help inform future adaptive management of the Hanford Reach Fall Chinook Protection Program and will be the major focus of the IFS. Given that the scope of the IFS is reduced significantly, Grant PUD is requesting that the IFS and IFP be combined into one report/plan, which would be due April 17, 2015, in accordance with the current due date for the IFP. The combined report and plan would be broken into three sections: 1) detailed results of studies conducted during the first two phases of the study; 2) the role of adaptive management and the FCWG during future monitoring in the Hanford Reach; and 3) a detailed implementation plan for long-term monitoring of fall Chinook in the Hanford Reach. The following table outlines this request.

ADDRESS PO Box 878
Ephrata, WA 98823

PHONE 509 766 2505
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grantpud.org

Requirement	Current date	Proposed date	Comments
Implementation Feasibility Study	8/17/14	4/17/15	Consultation draft would be provided to WDOE by March 15, 2015 after consultation with the FCWG
Implementation Feasibility Plan	4/17/15	4/17/15	No change; the IFS would be combined with this plan and a consultation draft would be provided to WDOE by March 15, 2015 after consultation with the FCWG

The plan to combine the IFS into the IFP has been discussed with, and supported by, the FCWG.

Any questions on this request should be directed to Tom Dresser at 509-754-5088, Ext. 2312.

Sincerely,

Ross Hendrick
License Compliance Manager

Cc: FCWG

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
4601 N Monroe Street • Spokane, Washington 99205-1295 • (509)329-3400

September 2, 2014

Mr. Tom Dresser
Manager
Fish, Wildlife and Water Quality
Grant County PUD
PO Box 878
Ephrata, WA 98823

RE: Request for Ecology Review and Approval – *Time Extension to Complete the Hanford Reach Implementation Feasibility Study*
Priest Rapids Hydroelectric Project No. 2114

Dear Mr. Dresser:

The Department of Ecology (Ecology) has reviewed the Grant County PUD letter that includes the time extension request to complete the *Hanford Reach Implementation Feasibility Study.* The letter was sent to Ecology on August 11, 2014.

Grant County PUD consulted with the Fall Chinook Work Group and with their support proposes to combine the IFS and IFP into one document. The combined report would then be due on April 17, 2015.

Ecology APPROVES the extension which combines the study and plan into one document and the original Implementation Feasibility Plan due date of April 17, 2015.

Please contact me at (509) 329-3567 or pmcg461@ecy.wa.gov if you have any questions.

Sincerely,

Patrick McGuire

Patrick McGuire
Eastern Region FERC License Coordinator
Water Quality Program

PDM:jab

cc: Ross Hendrick, Grant County PUD
Mike Clement, Grant County PUD
File

Appendix D
WDOE 4/13/2015 Approval of the IFS/IFP

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
4601 N Monroe Street • Spokane, Washington 99205-1295 • (509)329-3400

April 13, 2015

Mr. Tom Dresser
Manager
Fish, Wildlife and Water Quality
Grant County PUD
PO Box 878
Ephrata, WA 98823

RE: Request for Ecology Review and Approval – *Priest Rapids Project Implementation Feasibility Study and Implementation Feasibility Plan – Effects of the Hanford Reach Fall Chinook Protection Program on Fall Chinook Salmon in the Hanford Reach.* Priest Rapids Hydroelectric Project No. 2114

Dear Mr. Dresser:

The Department of Ecology (Ecology) has reviewed the *Priest Rapids Project Implementation Feasibility Study and Implementation Feasibility Plan – Effects of the Hanford Reach Fall Chinook Protection Program on Fall Chinook Salmon in the Hanford Reach* sent via email to Ecology on April 6, 2015.

Ecology APPROVES the *Priest Rapids Project Implementation Feasibility Study and Implementation Feasibility Plan* as submitted. The report was developed in accordance with the Hanford Reach Fall Chinook Protection Plan and fulfills the requirements in Sections 6.3(4), 6.3(5) and 6.3(6) and 6.3(7) of the 401 Certification.

Please contact me at (509) 329-3567 or pmcg461@ecy.wa.gov if you have any questions.

Sincerely,

Pat McGuire

Patrick McGuire
Eastern Region FERC License Coordinator
Water Quality Program

PDM:jab

cc: Ross Hendrick, Grant County PUD