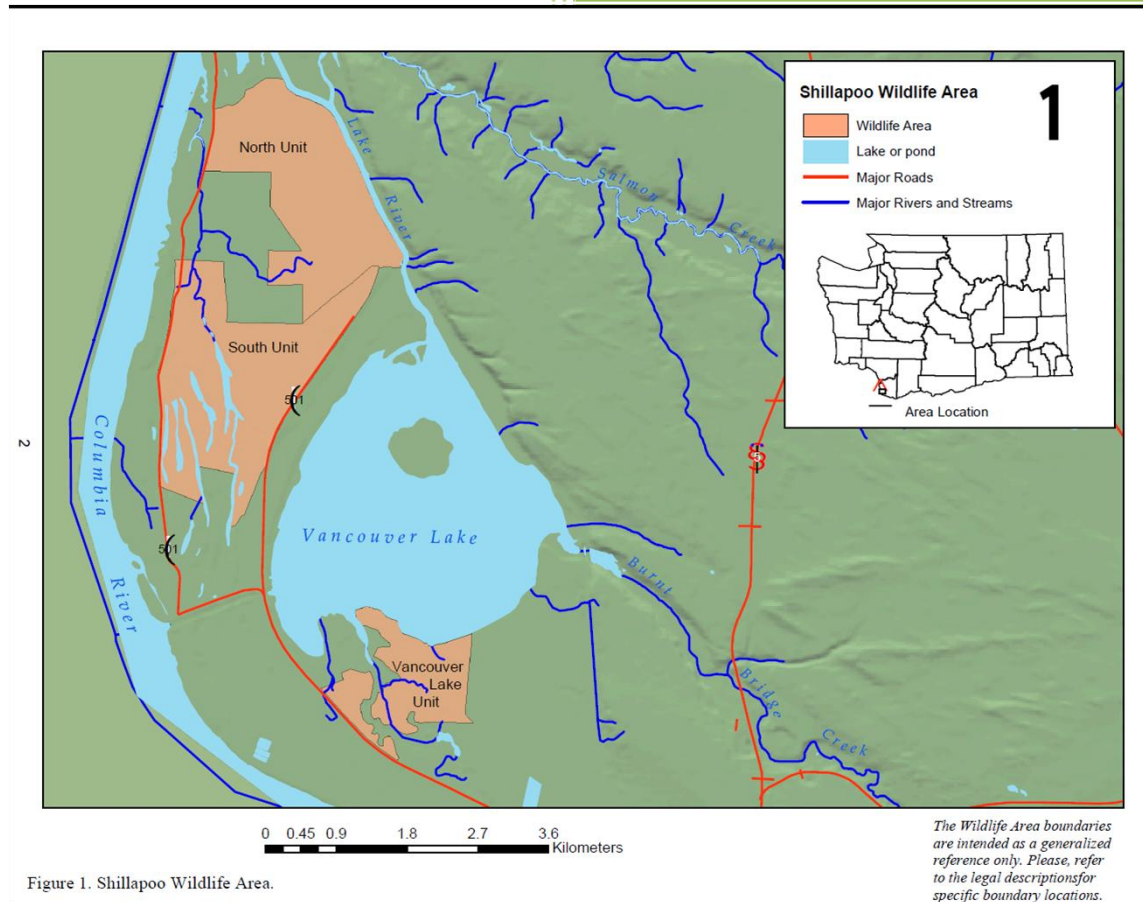


# Literature Review on Floodplain Lakes and Associated Wetlands

# 2011



Steven Vigg, Dawn Phelps,

Alex Uber and Donna

Bighouse

Washington Department of

Fish & Wildlife, Vancouver.

Final Review Draft

12/27/2011

# LITERATURE REVIEW DOCUMENT -- 12-27-2011

Steve Vigg, Dawn Phelps, Alex Uber, and Donna Bighouse

Washington Department of Fish & Wildlife, Vancouver

## Table of Contents

|                                                                                                                                                                                                                                                        |    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| List of Figures .....                                                                                                                                                                                                                                  | iv |
| List of Tables .....                                                                                                                                                                                                                                   | iv |
| Acknowledgements.....                                                                                                                                                                                                                                  | iv |
| Recommended Citation for This Report .....                                                                                                                                                                                                             | v  |
| Introduction .....                                                                                                                                                                                                                                     | 1  |
| Part I. Literature Review information previously provided by WDFW to the Action Agencies on Shillapoo Lake: .....                                                                                                                                      | 1  |
| Shillapoo Scoping Report (Uber and Vigg 2011).....                                                                                                                                                                                                     | 1  |
| 11-7-2010 WDFW Briefing Paper (Vigg and Uber 2010).....                                                                                                                                                                                                | 1  |
| Brian Zabel (Corps technical lead for the Shillapoo pre-feasibility study) requested a statement of WDFW’s policy position, goals and objectives for the Shillapoo Anadromous Fish Restoration project; and WDFW provided the following response:..... | 4  |
| Part II. Update of Literature Review on Floodplain Lakes and Wetlands .....                                                                                                                                                                            | 6  |
| A. Vancouver Lake and Sturgeon Lake are not examples of currently naturally functioning floodplain Lakes. ....                                                                                                                                         | 6  |
| Vancouver Lake.....                                                                                                                                                                                                                                    | 6  |
| Sturgeon Lake .....                                                                                                                                                                                                                                    | 11 |
| B. Water Control Structures, Weirs and Tide Gates Restrict Hydrology of Sloughs and Lakes – and result in favoring exotic species and excluding Anadromous Salmonid Juveniles .....                                                                    | 13 |
| Reference Suite 1. Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands (Poirier et al. 2006; Johnson et al. 2007a, 2007b, 2009a) .....                                                                                     | 13 |
| Reference Suite 2. Julia Butler Hansen National Wildlife Refuge: Assessment of Fishes, Habitats, and Tide gates in sloughs on the Mainland. 2007, 2008 (Johnson et al. 2009b).....                                                                     | 16 |
| C. LCREP and PNNL Reference Sites – Campbell Lake, Franze Lake and Cunningham Lake – are representative of the potential Shillapoo Lake Ecosystem .....                                                                                                | 20 |

|                                                                                                                                                                                                                                                                                                                |    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Reference Suite 3. Lower Columbia River Ecosystem Monitoring Project Annual Reports for Years 1-5. Prepared by the Lower Columbia River Estuary Partnership for the Bonneville Power Administration (LCREP 2004; Lear et al. 2005, 2006; LCREP 2007; Jones et al. 2007; Jones et al. 2008; Jones et al. 2010). | 20 |
| Reference Sites monitored by the Estuary Partnership and PNNL are Analogs of Expected Aquatic vegetation communities in Shillapoo Lake Basin and associated wetlands.                                                                                                                                          | 22 |
| D. Dispelling the myth that the limnetic area of Shillapoo Lake will be devoid of aquatic life.                                                                                                                                                                                                                | 24 |
| Potential Fish & Wildlife Problem – Hypothesis: adult carp will disrupt the re-connected floodplain ecosystem and eliminate aquatic plants and thereby reduce waterfowl production.                                                                                                                            | 25 |
| Potential Fish & Wildlife Problem – Hypothesis: the re-connected floodplain ecosystem will result in stranded anadromous salmonid juveniles.                                                                                                                                                                   | 26 |
| Potential Fish & Wildlife Problem – Hypothesis: juvenile salmonids will not utilize seasonal floodplain and associated wetlands; and if anadromous juvenile salmonids enter these floodplain ecosystems they will be lost to predation by birds and piscivorous fish.                                          | 27 |
| Conference Call with Cynthia F. Baker, Ph.D – notes by Steve Vigg, WDFW 12-20-2011                                                                                                                                                                                                                             | 28 |
| E. Examples of the importance of floodplain wetlands and shallow lakes -- Summary of findings by Cynthia F. Baker (2008) and Julie Henning (2006).                                                                                                                                                             | 30 |
| Cyndi Baker (Ph. D. Dissertation 2008)                                                                                                                                                                                                                                                                         | 30 |
| Julie Henning (2006) North American Journal of Fisheries Management 26:367–376.                                                                                                                                                                                                                                | 35 |
| F. Cultural Resources – Importance of Floodplain Lakes to Native Americans in the Lower Columbia River.                                                                                                                                                                                                        | 37 |
| G. Shillapoo WLA ‘Open Water Habitat Area’ calculation review (Alex Uber, WDFW)                                                                                                                                                                                                                                | 37 |
| References                                                                                                                                                                                                                                                                                                     | 42 |
| Attachment 1. Vancouver Lake -- Annotated Bibliography (Source StreamNet).                                                                                                                                                                                                                                     | 47 |
| Books and Technical Reports:                                                                                                                                                                                                                                                                                   | 47 |
| Journal Articles:                                                                                                                                                                                                                                                                                              | 84 |
| Websites:                                                                                                                                                                                                                                                                                                      | 86 |

## List of Figures

|                                                                                                                                                                                                                                              |    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 1. Shillapoo Wildlife Area (source Burns 2007).....                                                                                                                                                                                   | 9  |
| Figure 2. Area map of Tenasillahe Island and Welch Island showing locations of reference sloughs (LWS, SWS), treatment sloughs (LTS, STS) and sample reaches within sloughs (Johnson et al. 2009). ....                                      | 14 |
| Figure 3. Area map of JBHNWR National Wildlife Refuge showing the location of sloughs and sample reaches (red circles) surveyed in 2007 and 2008. Black, red and blue lines indicate closed, gated and reference sloughs, respectively. .... | 19 |
| Figure 4: Map of LCREP sampling sites throughout the LCRE by year and monitoring type. ....                                                                                                                                                  | 21 |
| Figure 5. A cross-sectional diagram of habitat types at various elevations in an estuary (based on Procter et al. 1980a).....                                                                                                                | 23 |
| Figure 6. Dominant aquatic plants at Cunningham Lake, Campbell Slough and Franz Lake (Borde et al. October 26, 2010 Presentation to Scientific Work Group. ....                                                                              | 24 |
| Figure 7. Mean water temperature in degrees centigrade by month at each reference site (Jones et al. 2010). ....                                                                                                                             | 27 |

## List of Tables

|                                                                                                                                                                                                                                     |    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Table 1. Species composition (by weight and number) during the 1998 fish survey in Vancouver Lake...                                                                                                                                | 10 |
| Table 2. Vancouver Lake commercial carp fishery; source Bruce Baker, WDFW 12-20-2011.....                                                                                                                                           | 11 |
| Table 3. Percentage of total fish by native and non-native taxa (excluding sticklebacks) that were captured in Tenasillahe Island and Welch Island sloughs, 2006 (Johnson et al. 2007a). ....                                       | 15 |
| Table 4. Species type and percentage (number) of total fish captured (all sampling methods combined) in two closed sloughs (Indian Jack and Winter), two gated sloughs (Duck Lake and W259+50) and two reference sloughs, 2008..... | 18 |
| Table 5: Summary of sampling effort by site and year(s) for LCREP sites where data were collected in 2009. ....                                                                                                                     | 21 |
| Table 6. Preferred water temperatures for juvenile salmonid rearing. ....                                                                                                                                                           | 34 |

## Acknowledgements

This report is a product of BPA contract # 54137, Project 2010-070-00, titled: WA Estuary MOA Project Scoping & Implementation; Jason Karnezis, BPA Project Manager. The information presented in this report is based on a review of existing WDFW reports, technical documents from various entities, published literature, and a StreamNet Bibliography on Vancouver Lake.

The WDFW team also conducted an interview with Cynthia F. Baker on 12-20-2011 – concerning the content of her Ph.D. Dissertation on floodplain ecosystems; Dr. Baker reviewed the Personal Communication citations and approved our use of excerpts from her Dissertation. In general, the Washington Estuary MOA team is funded by BPA to evaluate the potential for Estuary Habitat Project Development – that would result in a successful habitat restoration implementation that, in turn, would result in biological benefits for anadromous salmonid species in the Lower Columbia River and Estuary.

### **Recommended Citation for This Report**

Vigg, S., D. Phelps, A. Uber, and D. Bighouse. 2011. Literature Review on Floodplain Lakes and Associated Wetlands. Prepared for Bonneville Power Administration. Jason Karnezis, BPA Project Manager. Contract # 54137. Prepared by Washington Department of Fish & Wildlife, Vancouver, Washington. 86 pages.

## Introduction

On 12-14-2011, the Action Agencies (AAs) had a conference call with Phil Trask and Steve Vigg (WDFW) to discuss the WDFW Shillapoo Floodplain Restoration Project -- relative to PC Trask's (and CREST) proposal to do restoration work at Vancouver Lake, and a potential \$536 project at Sturgeon Lake. One outcome of this meeting was an assignment to conduct a Literature Review of Floodplain Lakes.

The Context of this literature review is appropriate SBU scoring for the proposed Shillapoo Lake Restoration Project. Also related is Brian Zabel's Technical Review of the proposed Shillapoo Feasibility Study and the Corps SBU Estimate on Shillapoo (with Trask influence) that will be presented by the Corps at a meeting on January 5, 2012 -- relative to the Federal Determination of Interest on the WDFW-sponsored Shillapoo Basin Floodplain Reconnection.

# WDFW's Literature Review on Floodplain Lakes and Associated Wetlands

---

## Part I. Literature Review information previously provided by WDFW to the Action Agencies on Shillapoo Lake:

### ***Shillapoo Scoping Report (Uber and Vigg 2011)***

- This scoping report includes a review of the previous feasibility study on the Shillapoo Wildlife Area: Columbia River Ecosystem Restoration at Shillapoo Lake (Northwest Hydraulic Consultants 1998).

### ***11-7-2010 WDFW Briefing Paper (Vigg and Uber 2010).***

WDFW reviewed three major estuary research projects that evaluate suites (multiple sites) of naturally functioning Columbia River tidally influenced wetland habitat reference suites (groups of reference sites) -- as a basis for comparison to pre- and post-restoration sites. USFWS research at Reference suites #1 and #2 documented that water control structures favor non-native species and restrict anadromous salmonid juveniles; while natural sloughs and shallow lakes

without control structures favor native fish communities including juvenile salmonids. This pattern was also documented by Hudson et al. (2010) in a pre-restoration study of 418 acres of tidal wetlands on the Bandon Marsh National Wildlife Refuge (Coquille River and estuary system) – anadromous salmonids were found in all areas sampled (i.e., Fahys Cr., Redd Cr., Reference site, and mainstem Coquille); however, carp and other nonnative species were only found in areas behind existing dike structures.

Research by a multi-agency research conducted at Reference suite #3 illustrates the type of aquatic community that we can expect to develop in the Shillapoo Lake Basin and adjacent wetlands.

### **Reference Suite 1. Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands (Poirier et al. 2006; Johnson et al. 2007a, 2007b, 2009a)**

In this study Welch Island is a naturally functioning tidally influenced wetland reference site – with evaluation done in a large slough and a small slough. Welch Island has no evidence of anthropomorphic impact and the sloughs have unobstructed connection with the Columbia River. In contrast the water flow and fish passage of the two (large and small) Tenasillahe Island slough sites were obstructed by tide gates and has historically had anthropomorphic impacts. Excluding sticklebacks – tide gated Large Tenasillahe slough had only 18.9% native and 81.1% non-native fish, while the natural Large Welch Slough had the opposite pattern with 95.3% native and only 4.7% non-native fish species.

### **Reference Suite 2. Julia Butler Hansen National Wildlife Refuge: Assessment of Fishes, Habitats, and Tide gates in sloughs on the Mainland. 2007, 2008 (Johnson et al. 2009b)**

Eight wetlands on Julia Butler Hansen National Wildlife Refuge were studied in this pre-536 Tide Gate Project evaluation (Figure 2). This study assessed and described baseline conditions within four sloughs with existing tide gates and four sloughs without water control structures, prior to habitat restoration work tentatively scheduled to begin in summer 2009. The four tide-gated sloughs -- Brooks, Duck Lake, W201+30, and W259+50 -- have tide gates that control the discharge of water from the mainland interior. The four closed sloughs are: Ellison, Hampson, Indian Jack and Winter. These sloughs are not connected to the Columbia River and its side channels because of flood control levees. Two naturally functioning tidally influenced wetlands – are compared to the 8 anthropogenic impacted sloughs. Sloughs on the Refuge islands – Price Island (Steamboat slough) and South Hunter Island (east-side slough) – are adjacent to mainland JBHNWR are relatively pristine. These Island sloughs are not diked or controlled by tide gates and have unimpeded connection to surrounding waters and tidal action. Hunter Island has no evidence of anthropomorphic impact and the sloughs have unobstructed connection with the Columbia River.

**Reference Suite 3. Lower Columbia River Ecosystem Monitoring Project Annual Reports for Years 1-5. Prepared by the Lower Columbia River Estuary Partnership for the Bonneville Power Administration (LCREP 2004; Lear et al. 2005, 2006; LCREP 2007; Jones et al. 2007; Jones et al. 2008; Jones et al. 2010).**

In this long-term LCREP monitoring study, several naturally functioning tidally influenced wetlands are studied by an inter-agency science team to evaluate estuarine habitat conditions relative to aquatic vegetation communities, anadromous salmonid communities and a suite of environmental conditions including Columbia River stage and frequency of inundation.

Three important outcomes of the LCREP Ecosystem Monitoring Program are<sup>1</sup>:

- The only comprehensive assessment of juvenile salmonid habitat in Columbia River estuary (combined look at food web, fish usage, vegetation and water column conditions at each site);
- Assesses habitat capacity, opportunity and realized function of estuarine habitats;
- Yields reference site data for implementation and evaluation of restoration actions.

Following hydrologic reconnection of Shillapoo Lake, an emergent wetland plant community will become re-established and replace the current agricultural use of the lake basin. With draining (and pumping) of the lake basin discontinued, it is expected that the lake will maintain a minimum lake level depending on river inflow (based on the invert of the channel) as well as groundwater inflow; i.e., it will not desiccate on a seasonal basis as it does now. Therefore a permanent aquatic community – plants, plankton, benthic invertebrates, amphibians, and fish – will be sustainable on a long-term basis. An illustration of the spectrum of habitat types that typically occur in a saline Columbia River estuary is presented below (Figure 4; source: LCREP Conceptual Model). The eelgrass habitat type is not present in tidally influenced areas upstream of the salt intrusion zone of the Columbia River. The dominant emergent aquatic plants at Cunningham Lake and Campbell Slough (Reach F) and Franz Lake (Reach H) are (Figure 5; Leary et al. 2006; Borde et al. 2010):

- Reed canary grass (*Phalaris arundinacea*) at upper-elevations
- Wapato (*Sagittaria latifolia*) at mid-elevations, and
- Common spikerush (*Eleocharis palustris*) at lower elevations

---

<sup>1</sup> Catherine Corbett, October 26, 2010 presentation to the Science Work Group.

**Brian Zabel (Corps technical lead for the Shillapoo pre-feasibility study) requested a statement of WDFW's policy position, goals and objectives for the Shillapoo Anadromous Fish Restoration project; and WDFW provided the following response:**

1. Regarding the “without-MOA 536 Project” Condition: With respect to anadromous fish, the answer is simple à zero biological benefits (or SBUs) for the 13 ESA-listed salmon stocks. Obviously the non-536 project (or previously proposed non-anadromous “ecosystem” project) condition also corresponds to a zero percent (0%) increase in anadromous fish benefits compared to baseline. One of the factors that actually maximizes the SBU score for the proposed 536 Shillapoo Anadromous Fish Restoration Project is that the initial (current) baseline is zero (w/r/t various anadromous fish metrics such as physical/biological rearing habitat, production, or survival). Many other estuary restoration projects have a current baseline of appreciable anadromous salmonid presence/production/survival benefits corresponding to a significant accessible anadromous fish habitat / existing fish community. For example, ERTG questioned the net enhancement benefits of the proposed 536 Hump-Fisher Project since the existing baseline was assumed to be significantly above zero.
2. Regarding the WDFW goals/positions on the 536 Estuary MOA anadromous fish restoration project at Shillapoo – within the context of the ongoing WDFW management of the Wildlife Area à the Department-wide position is articulated in the two letters of sponsorship and intent from Guy Norman, Regional Director to Colonel Miles, dated June 10, 2010 and November 8, 2010 {see Appendix 1 of the Shillapoo Scoping Report (Uber and Vigg 2011)}.
3. In the June 10, 2010 letter, three questions were identified during internal WDFW coordination meetings. These questions were subsequently addressed, using latest available scientific data, in a 11-7-2010 WDFW Briefing Paper (Vigg and Uber 2010).
  - a. Identify, compile and contrast all available “Reference Site” information in adjacent Columbia River floodplain areas with a focus on the future conditions (after habitat restoration) – in terms of aquatic vegetation communities, fish and wildlife communities, and ecosystem dynamics.
  - b. Identify habitat restoration alternatives, and evaluate a range of potential wildlife, fish, and aquatic habitat benefits, as well as a range of potential impacts.
  - c. Identify data gaps, outstanding questions, and additional critical uncertainties (for Phase 2 of the Feasibility Study).
4. The information provided in the 11-7-2010 briefing paper (Vigg and Uber) provided support for WDFW's position confirming our desire to move forward with the 536 Feasibility Study – as articulated in the November 8, 2010 letter from Guy Norman, WDFW Regional Director:

***“We are confident that restoration alternatives can be developed for the Shillapoo Lake reconnection project that will provide significant benefits to***

***ESA listed anadromous fish. We plan to work with our federal partners and the public during the feasibility study to ensure that a preferred alternative that provides biological benefits to fish is consistent with other management objectives associated with the Shillapoo Wildlife Area.”***

## Part II. Update of Literature Review on Floodplain Lakes and Wetlands

### ***A. Vancouver Lake and Sturgeon Lake are not examples of currently naturally functioning floodplain Lakes.***

Vancouver Lake and Sturgeon Lake are currently not naturally functioning floodplain lakes and wetlands because both of these lakes suffer from several of the following anthropogenic factors resulting in artificial limitations on ecosystem function:

- Existing dikes, levees, and sedimentation restrict natural flooding
- Tide gates and control structures restrict natural water inflow-outflow and corresponding fish passage.
- These artificial hydraulic restrictions result in a dominance of exotic fish species (e.g., cyprinids, ictalurids and centrarchids) and restricted access and capacity for juvenile salmonids.
- Municipal run-off, domestic sewage, contaminants, agricultural impacts including pesticide use and nutrient loading.
- Blue-green algal blooms resulting from excessive nutrient (e.g. phosphorus) levels.
- Poor environmental conditions for juvenile salmonids caused by high Biological Oxygen Demand (BOD) and out-of-balance food web.

### **Vancouver Lake**

Vancouver Lake has a long history of water quality problems, excessive nutrient loading, contaminants and blue-green algal blooms (refer to StreamNet Annotated Bibliography, Attachment 1).

Flushing Channel and Tide gates – the flushing channel was constructed by the Corps to alleviate water quality problems and lack of hydraulic circulation in Vancouver Lake. The Flushing Channel was not designed as an anadromous fish restoration project and it does not function to

enhance anadromous fish habitat in Vancouver Lake – in terms of free passage access or production habitat capacity.

### **Municipal run-off, domestic sewage, contaminants**

The Washington Department of Ecology is finishing a toxicity study on the lake showing that addressed the five 303d water quality listings - factors degrading the water quality in the lake, including Total Phosphorus, Fecal Coliform, Toxaphene, 2,3,7,8-TCDD, and Dieldrin (Ecology 2008 Water Quality Assessments).

Vancouver Lake is a very shallow with a mean depth of less than 3 feet. The sources for Vancouver Lake's water include: Lake River; Salmon Creek – that flows into Lake River downstream from Vancouver Lake; a flushing channel (equipped with tide gates to control flows) from the Columbia River near the southwest shoreline; and Burnt Bridge Creek (Figure 1). Due to seasonal variation in relative Columbia River stages and Vancouver Lake levels – Lake River experiences intermittent flow reversal and flows *into* Vancouver Lake for considerable periods of time. Burnt Bridge Creek winds about ten miles through Vancouver's residential areas; and prior to the 1980s, this creek was neglected and a major source of pollution for the lake.

In reviewing a Bibliography on Vancouver Lake Watershed, including Burnt Bridge Creek, Flushing Channel, Lake River and Salmon Creek (dated 12/19/2011), there are over 200 books and technical reports related to these systems (Attachment 1). Although a great deal of work has been completed on the water quality at Vancouver Lake in the past, there are so many contributing factors influencing the water quality in the lake that the USGS is currently working on a comprehensive water flow study to be completed in 2013.

Ongoing turbidity problems, extensive shallow depths, and a lack of aquatic vascular plant structure have diminished the variety of wildlife species and more recent surveys showed the most abundant fish (by mass and numbers) were brown bullhead, white crappie, black crappie, and common carp; with less abundant populations of channel catfish, largemouth bass, bluegill, pumpkinseed, yellow perch, naturalized goldfish, northern pikeminnow, American shad, mosquito fish, largescale sucker, and freshwater sculpin. Relatively few juvenile salmonids exist in Vancouver Lake – and are generally distributed close to the flushing channel and other tributary inflows.

Suburbanization of its watershed area led to an increase in water pollution. Surface runoff brought increased sediment while residential septic tank drain fields, and increased use of fertilizers rich in nitrogen and phosphorus contributed to eutrophication of Vancouver Lake. DDT was also used for mosquito control until its effects on fish and birds became apparent, and the county discontinued it ([http://en.wikipedia.org/wiki/Vancouver\\_Lake](http://en.wikipedia.org/wiki/Vancouver_Lake), 12/20/2011).

A long history of industry and metropolitan areas runoff entering Burnt Bridge Creek, Lake River, and at times, effluent from the Salmon Creek wastewater treatment plant – are just a few of the factors that cumulatively degraded the water quality and increased the contaminated sediment load into Vancouver Lake. From the runoff and sediments, the high nutrient loads in the lake promote algal growth and productions of blue-green algal blooms. Since cyanobacteria such as *Anabaena*, *Microcystis aeruginosa* and *Cylindrospermopsis raciborskii* may produce neurotoxins such as cylindrospermopsin – the lakes deteriorated water quality is also a human health hazard from time to time. Organic pollution in the sediments increases the Biological Oxygen Demand (BOD) which in turn reduces the dissolved oxygen for fish. Juvenile salmonids are especially sensitive to low DO levels; Henning et al. (2006) found that decreased DO levels was a major factor causing salmonids to emigrate from the emergent wetlands in the Chehalis River floodplain.

### **Fish Habitat and Species Composition**

Vancouver Lake and its tributary, Burnt Bridge Creek, provide a poor environment for juvenile salmonids. Caromile et al. (2000) described the habitat of Vancouver Lake:

Vancouver Lake is a 2,286-acre shallow water body with a mean depth of 0.6 meters and a maximum depth of 1.8 meters (Figure 1; Source Burns 2007).

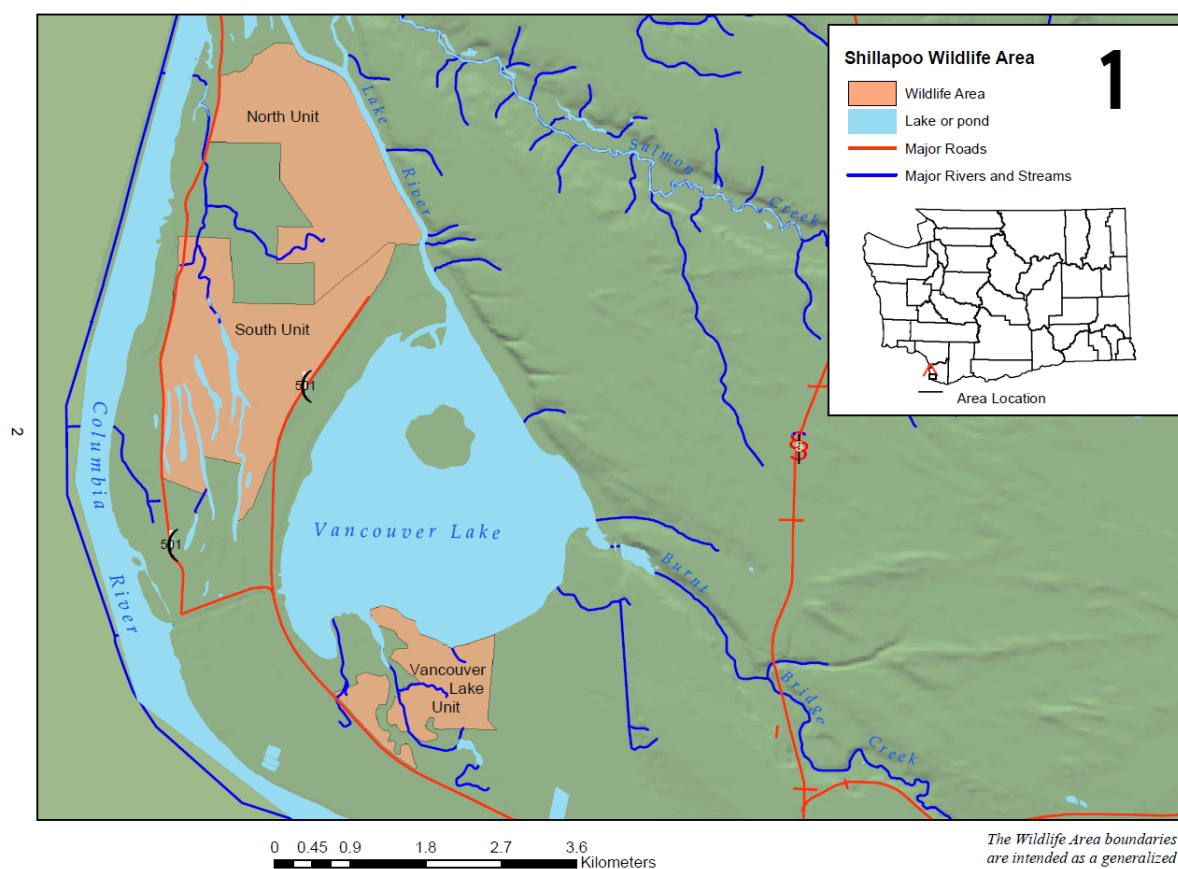


Figure 1. Shillapoo Wildlife Area.

The Wildlife Area boundaries are intended as a generalized reference only. Please, refer to the legal descriptions for specific boundary locations.

*Figure 1. Shillapoo Wildlife Area (source Burns 2007).*

Historically it was connected to the Columbia River via Mulligan Slough, and exited through the Lake River to the north. Other sources of surface water inflow are from Burnt Bridge Creek and an unnamed tributary on the eastern shore. The littoral zone is wide and flat, much of it becoming exposed muddy flats at low tide. The substrate is uniformly hard sand and silt, with no gravel or rock bars, and only limited large wood structure. The lake suffers from a high amount of suspended solids, mostly colloidal material possibly stirred up by tidal, wind, and wave action. The high turbidity and low light penetration results in low primary productivity and few, if any aquatic plants. Overall a near complete lack of complex habitat providing no refuge for younger fish to escape predation and providing no plant growth for insects to colonize and provide food.

In a fish survey of Vancouver Lake during a 1982-84 evaluation of the effects of the Flushing Channel, Knutzen and Cardwell (1984) found that the lake's fish population were dominated in numbers by black and white crappie, and in weight by carp. At the same time, the adjacent Columbia River samples were dominated in number of fish by American shad, threespine stickleback, and Chinook salmon juveniles; and in overall weight by largescale sucker, carp, and peamouth. The majority of sea-ward migrating salmon and trout juveniles passing downstream in April or May remain offshore and do not encounter the flushing channel. The predominantly subyearling Chinook salmon migrating in June and July occur closer to shore than coho salmon, steelhead, and yearling Chinook – but relatively few apparently entered the Vancouver Lake (Knutzen and Cardwell 1984)

Knutzen and Cardwell (1984) attributed the congregation of salmon and trout at the flushing channel-lake confluence in late-June and July 1984 to an attraction to the cooler Columbia River water entering at the flushing channel. In recent years, this is the area that Region 5 Inland fisheries staff frequently encounter juvenile salmonids during electrofishing sampling (Stacie Kelsey, WDFW, personal Correspondence).

In an intensive fish survey in 1998, Caromile et al. (2000) observed that although carp probably account for the highest biomass in Vancouver Lake, the sampling effort quantified brown bullhead catches as the highest biomass of 12 fish species captured by all sampling methods (Table 1).

*Table 1. Species composition (by weight and number) during the 1998 fish survey in Vancouver Lake.*

---

| Species              | Species Composition |      |             |      |                    |     |
|----------------------|---------------------|------|-------------|------|--------------------|-----|
|                      | by Weight           |      | by Number   |      | Size Range (mm TL) |     |
|                      | (kg)                | (%w) | (#)         | (%n) | Min                | Max |
| Brown bullhead       | 28.7                | 32.1 | 338         | 28.3 | 101                | 290 |
| White crappie        | 20.0                | 22.4 | 422         | 35.3 | 48                 | 193 |
| Common carp          | 12.3                | 13.8 | 19          | 1.6  | 230                | 457 |
| Largemouth bass      | 8.2                 | 9.2  | 22          | 1.8  | 64                 | 640 |
| Black crappie        | 7.6                 | 8.5  | 182         | 15.2 | 65                 | 234 |
| American shad        | 6.6                 | 7.4  | 106         | 8.9  | 91                 | 264 |
| Goldfish             | 3.4                 | 3.8  | 26          | 2.2  | 100                | 272 |
| Yellow perch         | 1.1                 | 1.2  | 35          | 2.9  | 80                 | 180 |
| Bluegill             | 0.8                 | 0.9  | 29          | 2.4  | 30                 | 183 |
| Northern pike-minnow | 0.5                 | 0.5  | 3           | 0.3  | 25                 | 280 |
| Pumpkinseed          | 0.2                 | 0.2  | 13          | 1.1  | 37                 | 121 |
| Sculpin              | >0.1                | >0.1 | 1           | 0.1  | 91                 | 91  |
| <b>Total</b>         | <b>89.3</b>         |      | <b>1196</b> |      |                    |     |

A commercial fishery for carp has existed in Vancouver Lake since the late-1960's. It is an ethnic fishery that centers around religious holidays. Yearly catch and effort statistics are inconsistent due to lack of monitoring. The following catch statistics are for 2010 to 2011 (Bruce Baker, WDFW 12-20-2011):

*Table 2. Vancouver Lake commercial carp fishery; source Bruce Baker, WDFW 12-20-2011.*

| Year | Number of Fishers | Number of Trips | Number Carp | Weight Carp (Lbs) | By-catch                      |
|------|-------------------|-----------------|-------------|-------------------|-------------------------------|
| 2010 | 5                 | 8               | 1,634       | 8,533             | 2 sturgeon, 4 catfish         |
| 2011 | 5                 | 10              | 629         | 4,345             | 2 bass, 5 sturgeon, 1 catfish |

## Sturgeon Lake

Sturgeon Lake is 3200 acres in surface area; it is owned and managed as wildlife refuge by Oregon Department of Fish and Wildlife (ODFW). The lake borders and is connected to Multnomah Channel via the Gilbert River, and connected to Columbia River by Dairy Creek. Sturgeon Lake is an integral part of the Pacific flyway for pacific coast migratory waterfowl, and could be important rearing habitat for upriver stocks of ESA-listed salmon, white sturgeon and lamprey – if Columbia River access were restored and resultant flow-through ameliorated water

quality problems. It is considered by ODFW to be one of the biologically significant natural aquatic wildlife habitats in the state. Sturgeon Lake is identified in the Oregon Conservation Strategy as a "conservation opportunity area" and restoring flushing flows to the lake for salmon habitat restoration is specifically named as a state strategy.

The U.S. Army Corps of Engineers built an 18-mile levee in 1949 to prevent annual flooding of more than 11,000 acres of agricultural land. That project severely restricted natural flows to Sturgeon Lake leading to increased sedimentation and greatly reduced aquatic habitat function. While a federally-funded project re-opened the channel from the Columbia River via Dairy Creek in 1989, subsequent floods blocked the creek's mouth and reversed efforts to restore flow.

Sedimentation in the lake has been a problem for the past four decades according to an Environmental Assessment sponsored by West Multnomah Soil & Water Conservation District WMSWCD in 1987. Sturgeon Lake has become an off-channel sedimentation basin for suspended sediment from the Willamette and Columbia Rivers. Diking, dredge spoil disposal, blocking of creeks, and reservoir flood control operations have contributed to this change. In addition to rapid sedimentation and locally encroaching shore vegetation, water quality in the lake is poor due to relatively large amounts of organic matter and seasonally high bacteria levels (Klingeman 1987).

Sediment- laden water enters Sturgeon Lake through the Gilbert River whenever the Willamette and Columbia River rises appreciably due to storm runoff. Typically the rivers remain high for many days and there is time for extensive sedimentation to occur. Wind waves cause turbidity and currents that, along with tidal action, distribute sediment and organic matter throughout the lake.

A study monitoring the differences in relative abundance of juvenile salmonids in Sturgeon Lake before and after completion of the Dairy Lake bypass channel was completed by ODFW in November 1992 (Ward and Rien 1992). This study found that the Dairy Creek bypass channel increased the abundance of juvenile salmonids in Sturgeon Lake. They found juvenile salmonids near the entrance to Sturgeon Lake at the Gilbert River in each year sampled. Juvenile salmonids were also found in the Dairy Creek bypass channel in 1992, after the bypass was opened. Chinook salmon were the most prevalent salmonid species collected in the samples and generally were collected near the entrances to Sturgeon Lake. The benefits described above have been reversed since the bypass channel is now blocked.

ODFW speculated that juvenile salmonids entering Sturgeon Lake through the Dairy Creek bypass channel might be subjected to delays in migration or exposed to high water temperatures. The bypass channel flows through a culvert under a road crossing and therefore the fluctuating flows in the Columbia River could temporarily strand juvenile salmonids in the bypass channel

or force them to migrate through Sturgeon Lake to the Gilbert River. It was noted that water temperatures have reached 22C in the channel and 25C in Sturgeon Lake, higher than desirable for salmonids (Brett 1952). ODFW found no evidence of predation on juvenile salmonids in Sturgeon Lake, however it was noted that their sampling was limited.

On-going Columbia River dredging/deepening, larger ship traffic and wave action, upriver dam operations and other natural causes have changed the river hydrology so that technical re-evaluation and analysis is now needed before anything can be done to re-open Dairy Creek. Recently West Multnomah Soil & Water Conservation District WMSWCD and ODFW received \$42,500 (in addition to \$25,000 of WMSWCD's funding) from the Oregon Watershed Enhancement Board for a feasibility study and are currently working with US Army Corps of Engineers through the Section 1135 authority to bolster that amount (soon to be changed to the Section 536 program according to the Corps (Donna Bighouse, WDFW personal communication Michelle Rhodes, Corps of Engineers). Funding would be used to analyze new alternatives -- in addition to Dairy Creek -- that might halt or even reverse sedimentation and restore water flow to this important ecosystem. The Sturgeon Lake Restoration Planning Group plans to have design alternatives for the restoration project in the next couple of years.

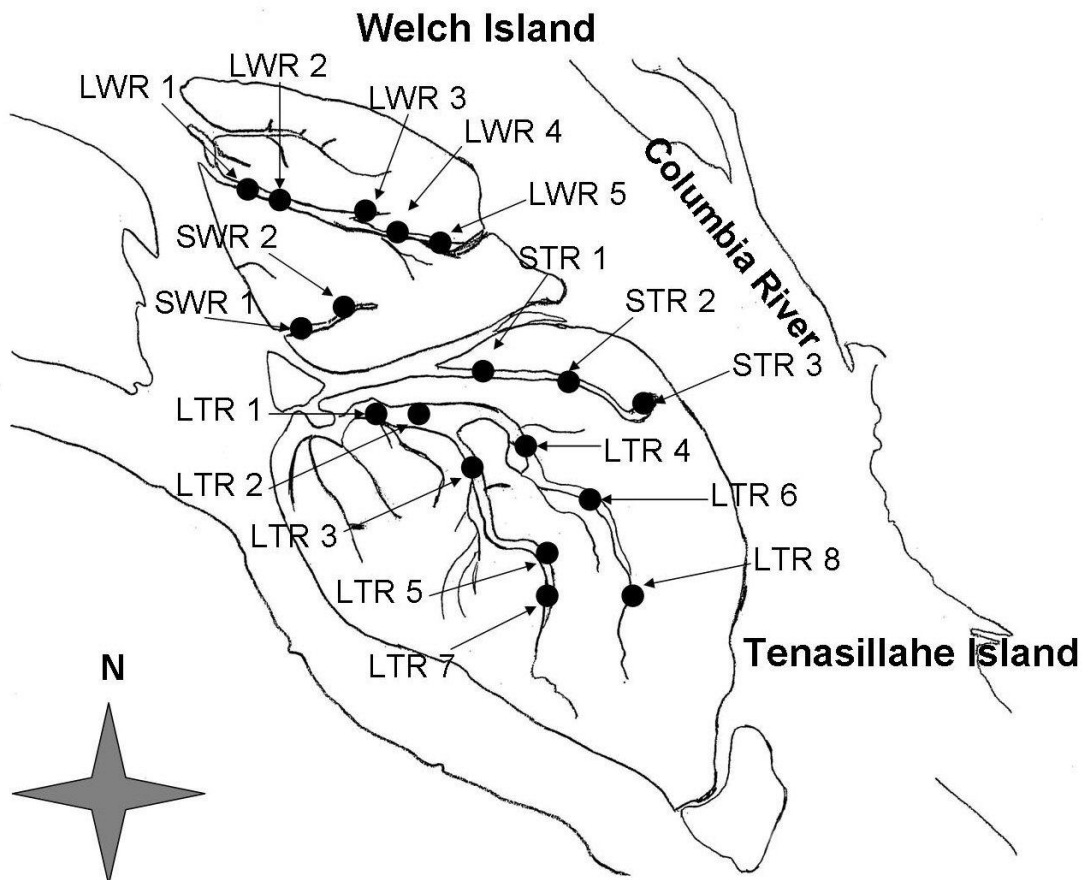
Some of the alternatives discussed to date include the removal of a large sand shoal that is migrating into the channel. This alternative will also require the re-analysis and construction of a 200-ft long rock jetty, designed for phase three of this project by the Corps of Engineers to keep sediment from building up again. It is to be constructed in the Columbia River just downstream of the Dairy Creek channel. Other possible actions include: reconstructing log debris deflection boom and attaching them to existing pilings at the channel entrance, repairing or replacing culverts on Reeder Road damaged by the 1996 flood, and removing logs and fine sediments that have accumulated in 900 feet of channel between Reeder Road and the sand shoal at the mouth.

### ***B. Water Control Structures, Weirs and Tide Gates Restrict Hydrology of Sloughs and Lakes – and result in favoring exotic species and excluding Anadromous Salmonid Juveniles***

#### **Reference Suite 1. Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands (Poirier et al. 2006; Johnson et al. 2007a, 2007b, 2009a)**

In this study Welch Island is a naturally functioning tidally influenced wetland reference site – with evaluation done in a large slough and a small slough (Figure 1). Welch Lake is within the USFWS Lewis and Clark National Wildlife Refuge. Welch Island has no evidence of anthropomorphic impact and the sloughs have unobstructed connection with the Columbia River. In contrast the water flow and fish passage of the two (large and small) Tenasillahe Island slough

sites were obstructed by tide gates and has historically had anthropomorphic impacts. Tenasillahe Island is managed for Columbia whitetail deer.



**Figure 2. Area map of Tenasillahe Island and Welch Island showing locations of reference sloughs (LWS, SWS), treatment sloughs (LTS, STS) and sample reaches within sloughs (Johnson et al. 2009).**

Excluding sticklebacks – tide gated Large Tenasillahe slough had only 18.9% native and 81.1% non-native fish, while the natural Large Welch Slough had the opposite pattern with 95.3% native and only 4.7% non-native fish species. For a detailed review of the fish species composition and catch-per-unit-effort in obstructed versus (predominantly exotic species) versus natural sloughs (more abundant juvenile salmonids) as documented by USFWS studies (Johnson et al. 2007) – refer to the data summaries in Vigg and Uber (2010). The following bullets summarize main points:

- A total of 25,596 fish representing 16 taxa were collected from 18 sample reaches between 27 March and 26 May 2006.
- Threespine stickleback (*Gasterosteus aculeatus*) was the most abundant fish collected, representing over 97% of the total catch.
- Two hundred seventy-nine salmonids representing three species were collected. Chinook salmon, *Oncorhynchus tshawytscha* dominated salmonid collections followed by chum salmon, *Oncorhynchus keta* and coho salmon, *Oncorhynchus kisutch*.
- There are fundamental differences in species composition and relative abundance between Tenasillahe Island and Welch Island sloughs. The greatest overall species richness occurred in un-gated large Welch slough (12 species) followed by large Tenasillahe slough (10 species).
- A higher percentage of non-native species were captured in both Tenasillahe Island sloughs (tide gated) compared to both Welch Island sloughs (natural).
- Juvenile salmonid access to Tenasillahe Island sloughs is limited. Current tide gates do not allow salmonids to have regular access to the island sloughs and may not allow them to have any access. One Chum and one Chinook salmon juvenile were captured in STS during a time when the tide gate was blocked open for maintenance. These were the only salmonids captured to date within either Small or Large Tenasillahe sloughs.
- Relative abundance of fish was higher in Welch Island sloughs than Tenasillahe Island sloughs. These differences are likely related to Tenasillahe Island sloughs lack of tidal influence; and the water quality parameter values such as temperature and DO resulting from limited water exchange in addition to access issues caused by tide gates.
- This contrasts with both Large and Small Welch Island sloughs where juvenile salmonids were captured at all sampling locations.
- Tide gates had a significant influence on fish community structure.
- Haskell *et.al* (2004) found that juvenile Chinook salmon would swim against the prevailing tide to enter freshwater sloughs not controlled by tide gates. However, little evidence exists suggesting juvenile salmonids will access traditional tide gate controlled sloughs.

*Table 3. Percentage of total fish by native and non-native taxa (excluding sticklebacks) that were captured in Tenasillahe Island and Welch Island sloughs, 2006 (Johnson et al. 2007a).*

| Slough                         | Percent native | Percent non-native |
|--------------------------------|----------------|--------------------|
| Large Tenasillahe (tide gates) | 18.9           | 81.1               |
| Small Tenasillahe (tide gates) | 80.0           | 20.0               |
| Large Welch (natural)          | 95.3           | 4.7                |
| Small Welch (natural)          | 83.0           | 17.0               |

## Reference Suite 2. Julia Butler Hansen National Wildlife Refuge: Assessment of Fishes, Habitats, and Tide gates in sloughs on the Mainland. 2007, 2008 (Johnson et al. 2009b)

Eight wetlands on Julia Butler Hansen National Wildlife Refuge were studied in this pre-536 Tide Gate Project evaluation (Figure 2). This study assessed and described baseline conditions within four sloughs with existing tide gates and four sloughs without water control structures, prior to habitat restoration work tentatively scheduled to begin in summer 2009. Preliminary data was gathered March through June and yielded pre-construction information concerning: adult salmonid presence, tide gate function and accessibility, fish presence, community structure, habitat use and aquatic habitat conditions within the sloughs.

The four tide-gated sloughs -- Brooks, Duck Lake, W201+30, and W259+50 -- have tide gates that control the discharge of water from the mainland interior. Brooks Slough has three 1.5 x 1.5 meter, top-hinge aluminum tide gates. Duck Lake has a single 1.8 meter diameter, top-hinge steel tide gate. W201+30 has a 1.2 meter diameter side-hinge aluminum tide gate equipped with a cam and float system that holds the gate partially open during incoming tide until the float system disengages the cams and allow the gate to close completely. W259+50 has a 1.5 x 1.5 meter, top-hinge wooden tide gate.

The four closed sloughs are: Ellison, Hampson, Indian Jack and Winter. These sloughs are not connected to the Columbia River and its side channels because of flood control levees (Figure 2)

Two naturally functioning tidally influenced wetlands –are compared to the 8 anthropogenic impacted sloughs. Sloughs on the Refuge islands – Price Island (Steamboat slough) and South Hunter Island (east-side slough) – are adjacent to mainland JBHNWR are relatively pristine. These Island sloughs are not diked or controlled by tide gates and have unimpeded connection to surrounding waters and tidal action. Hunter Island has no evidence of anthropomorphic impact and the sloughs have unobstructed connection with the Columbia River. All of these sloughs are on or adjacent to the Julia Butler Hansen USFWS Wildlife Refuge which is managed for Columbia whitetail deer.

Water temperatures in gated sloughs may be more limiting to juvenile salmon than temperatures in reference sloughs (Johnson et al. 2009). This was evidenced by the 7-DADM, a rolling average of 7 consecutive daily maximum temperatures recorded within a stream (Hicks, 2000). Water temperature levels in W259+50, W201+30, Brooks, Hampson, Ellison and Steamboat sloughs remained below the upper threshold level (16C°) until late May or early June. Temperature in Indian Jack and Duck Lake exceeded 16C° in early May. Water temperature in S. Hunting E. was still within the acceptable range when the temperature logger was removed on 13 June. Oxygen concentrations in closed sloughs and one gated slough (Duck Lake) may be more limiting to juvenile salmon than in reference sloughs. Four of the five lowest mean DO%

were measured in closed sloughs. Duck slough (top-hinge, steel gate) mean oxygen concentration was the second lowest of all sloughs.

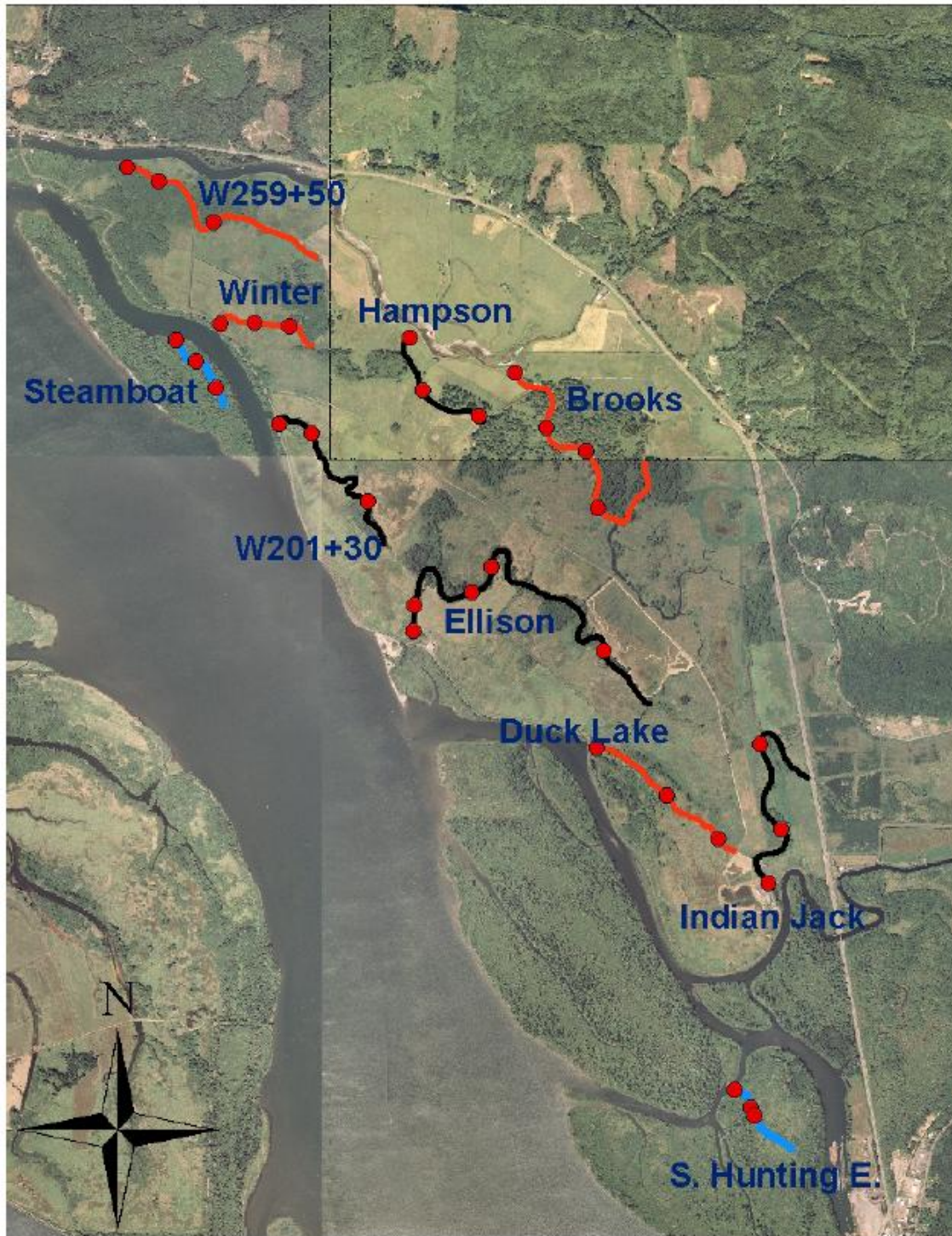
The following bullets summarize species composition fish distribution data from obstructed (gated or closed) sloughs versus natural (reference) sloughs; refer to Table 6 for more details:

- A total of 155 seine hauls were performed in 16 sample reaches in spring 2008. A total of 3,789 fish representing 15 taxa were captured in four main land and two reference sloughs (Table 6).
- Of the total, 96.6% of the fish captured were native species, and 3.4% were non-native.
- Duck Lake Slough (gated) had the most species captured of all sloughs in 2008 with 11 total taxa.
- All fish captured in reference sloughs were native species.
- Juvenile Chinook salmon were captured in all sampled reaches of reference sloughs. No other salmon species were captured in reference sloughs.
- Five of the thirteen species captured in gated sloughs were non-native and six of the nine species captured in closed sloughs were non-native.
- Threespine Stickleback were the most prevalent and most abundant species in all locations, making up 90.5% of the total catch.
- Chinook salmon were the second most abundant fish species captured, making up 2.4% of the total catch. A total of 92 salmonids representing 2 taxa were captured in two mainland and two reference sloughs. Chinook salmon were the most abundant species making up 98.9% of the total salmon catch.
- Juvenile Chinook were captured in all sampled reaches of W259+50 and the lowest most reach (within 50 m of tide gate) of Duck Lake slough. One juvenile coho salmon (FL = 60mm) was captured in the highest reach of W259+50.
- No juvenile salmon were captured in the two closed sloughs sampled in 2008 (Indian Jack and Winter sloughs).
- Juvenile salmonids made up 5.1% of total catch in gated sloughs and 1.5% in reference sloughs. The highest proportion of salmon were captured in W259+50 slough (63.0%), followed by Little Steamboat (23.9%) and S. Hunting E. (12.0%) sloughs.

The pattern of species composition and fish distribution is clear – predominance of exotic fish species in sloughs with artificial control structures and restricted hydrology versus a native fish community – including juvenile salmonids – in natural sloughs with-out control structures and conventional (top-hinge) tide gates (Vigg and Uber 2010 summary of data documented by Johnson et al. 2007, 2009).

*Table 4. Species type and percentage (number) of total fish captured (all sampling methods combined) in two closed sloughs (Indian Jack and Winter), two gated sloughs (Duck Lake and W259+50) and two reference sloughs, 2008.*

| Species             |                 | Closed     | Gated      | Reference   |
|---------------------|-----------------|------------|------------|-------------|
| 3-spine Stickleback |                 | 79.6 (296) | 84.2 (976) | 95.6 (2158) |
| Bluegill            |                 | 0.8 (3)    | 0.2 (2)    | 0.0 (0)     |
| Brown Bullhead      |                 | 0.5 (2)    | 0.0 (0)    | 0.0 (0)     |
| Chinook Salmon      | Total           | 0.0 (0)    | 5.0 (58)   | 1.5 (33)    |
|                     | Unmarked        | 0.0 (0)    | 4.9 (57)   | 1.3 (30)    |
|                     | Adipose clipped | 0.0 (0)    | 0.1 (1)    | 0.1 (3)     |
| Coho Salmon         |                 | 0.0 (0)    | 0.1 (1)    | 0.0 (0)     |
| Common Carp         |                 | 0.0 (0)    | 0.4 (5)    | 0.0 (0)     |
| E. Banded Killifish |                 | 2.7 (10)   | 1.6 (18)   | 0.0 (0)     |
| Largemouth Bass     |                 | 0.3 (1)    | 0.0 (0)    | 0.0 (0)     |
| Largescale Sucker   |                 | 0.0 (0)    | 0.3 (3)    | 0.2 (5)     |
| Northern Pikeminnow |                 | 0.0 (0)    | 0.5 (6)    | 1.3 (30)    |
| Peamouth            |                 | 0.3 (1)    | 1.2 (14)   | 0.9 (20)    |
| Pumpkinseed         |                 | 2.4 (9)    | 1.2 (14)   | 0.0 (0)     |
| Sculpin             |                 | 0.0 (0)    | 3.1 (36)   | 0.3 (7)     |
| Shiner              |                 | 3.0 (11)   | 0.1 (1)    | 0.0 (0)     |
| Starry Flounder     |                 | 0.0 (0)    | 0.0 (0)    | 0.2 (5)     |
| Unknown Sunfish     |                 | 10.5 (39)  | 2.2 (25)   | 0.0 (0)     |



**Figure 3. Area map of JBHNWR National Wildlife Refuge showing the location of sloughs and sample reaches (red circles) surveyed in 2007 and 2008. Black, red and blue lines indicate closed, gated and reference sloughs, respectively.**

### ***C. LCREP and PNNL Reference Sites – Campbell Lake, Franze Lake and Cunningham Lake – are representative of the potential Shillapoo Lake Ecosystem***

**Reference Suite 3. Lower Columbia River Ecosystem Monitoring Project Annual Reports for Years 1-5. Prepared by the Lower Columbia River Estuary Partnership for the Bonneville Power Administration (LCREP 2004; Lear et al. 2005, 2006; LCREP 2007; Jones et al. 2007; Jones et al. 2008; Jones et al. 2010).**

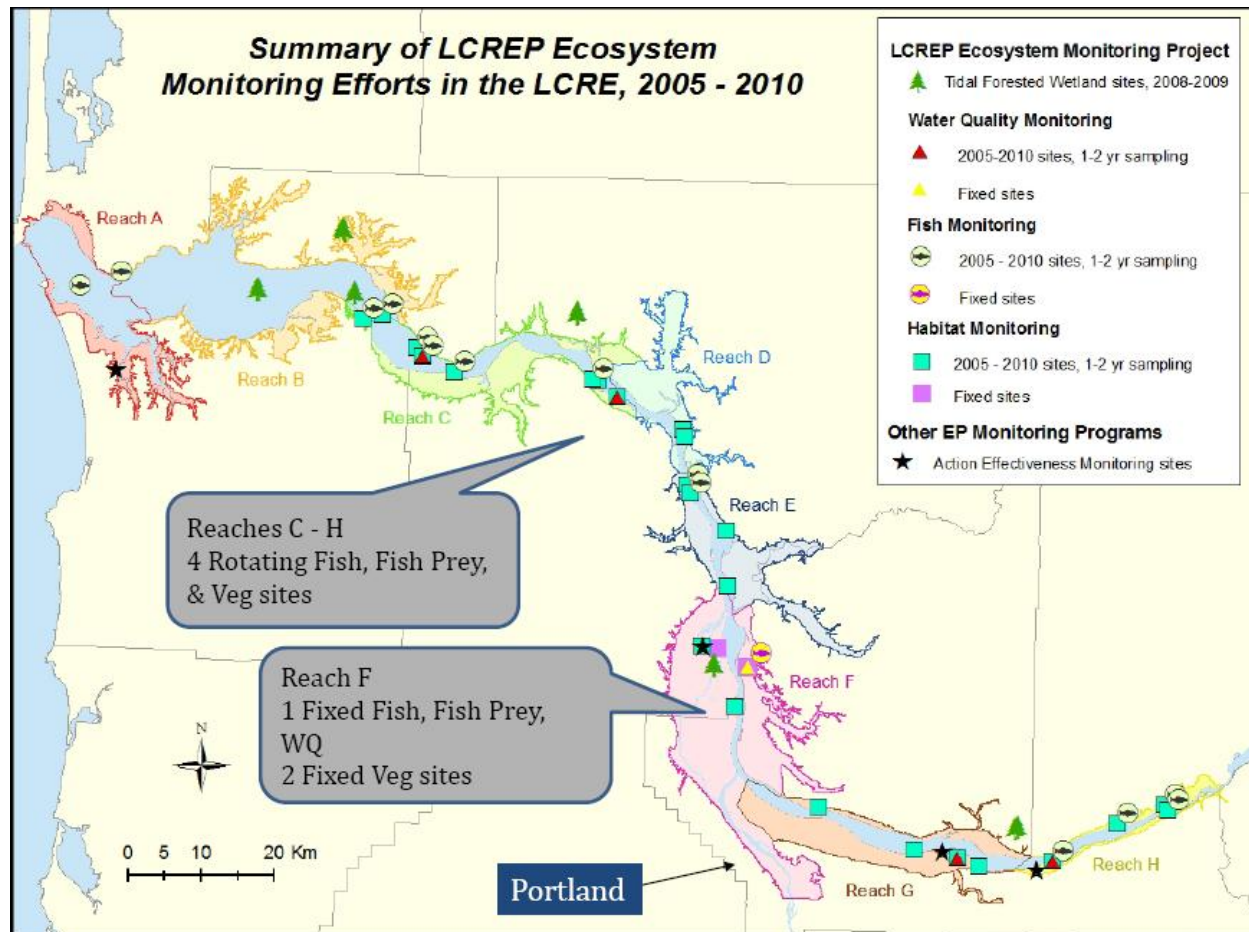
In this long-term LCREP monitoring study, several naturally functioning tidally influenced wetlands are studied by an inter-agency science team to evaluate estuarine habitat conditions relative to aquatic vegetation communities, anadromous salmonid communities and a suite of environmental conditions including Columbia River stage and frequency of inundation. Since 2007, the Phase 2 Ecosystem Monitoring Program consists of the following elements:

- Coordinated Habitat, Fish, and Prey Monitoring at ~4-6 sites annually:
- Vegetation monitoring (% cover along transects, species list, elevation) -4-6 sites
- Sediment grain size along transects -4-6 sites
- Water quality (data loggers) -2 sites
- Fish sampling (species richness, abundance, CPUE, stock identification, length, weight, stomach contents, otoliths for growth rates, marked/unmarked, condition, contaminants) - 5 sites
- Fish prey (taxonomy, abundance, biomass, terrestrial vs aquatic origin) -5 sites
- Primary production/food web –1 site in 2010

In 2009, the LCREP study sites in Reach C -- for monitoring -- were Ryan Island, White Island (part on WDFW Wildlife Refuge), Lord-Walker (or Lord) Island 1, (Columbia Land Trust) and Lord-Walker (or Lord) Island 2. LCREP re-sampled 3 sites -- Campbell Slough (USFWS Ridgefield Wildlife Refuge) and Cunningham Lake in Reach F and Franz Lake, (Pierce National Wildlife Refuge) in Reach H -- where data were previously collected (Table 1; Figure 3).

**Table 5: Summary of sampling effort by site and year(s) for LCREP sites where data were collected in 2009.**

| Reach | Site                   | Vegetation & Habitat | Fish & Prey | Water Quality & Depth |
|-------|------------------------|----------------------|-------------|-----------------------|
| C     | Ryan Island            | 2009                 | 2009        |                       |
|       | Lord-Walker Island 1   | 2009                 | 2009        |                       |
|       | Lord-Walker Island 2** | 2009                 |             |                       |
|       | White Island           | 2009                 | 2009        | 2009                  |
| F     | Cunningham Lake        | 2005-2009            | 2007-2009   |                       |
|       | Campbell Slough        | 2005-2009            | 2007-2009   | 2008-2009             |
| H     | Franz Lake             | 2008-2009            | 2008-2009   |                       |



**Figure 4: Map of LCREP sampling sites throughout the LCRE by year and monitoring type.**

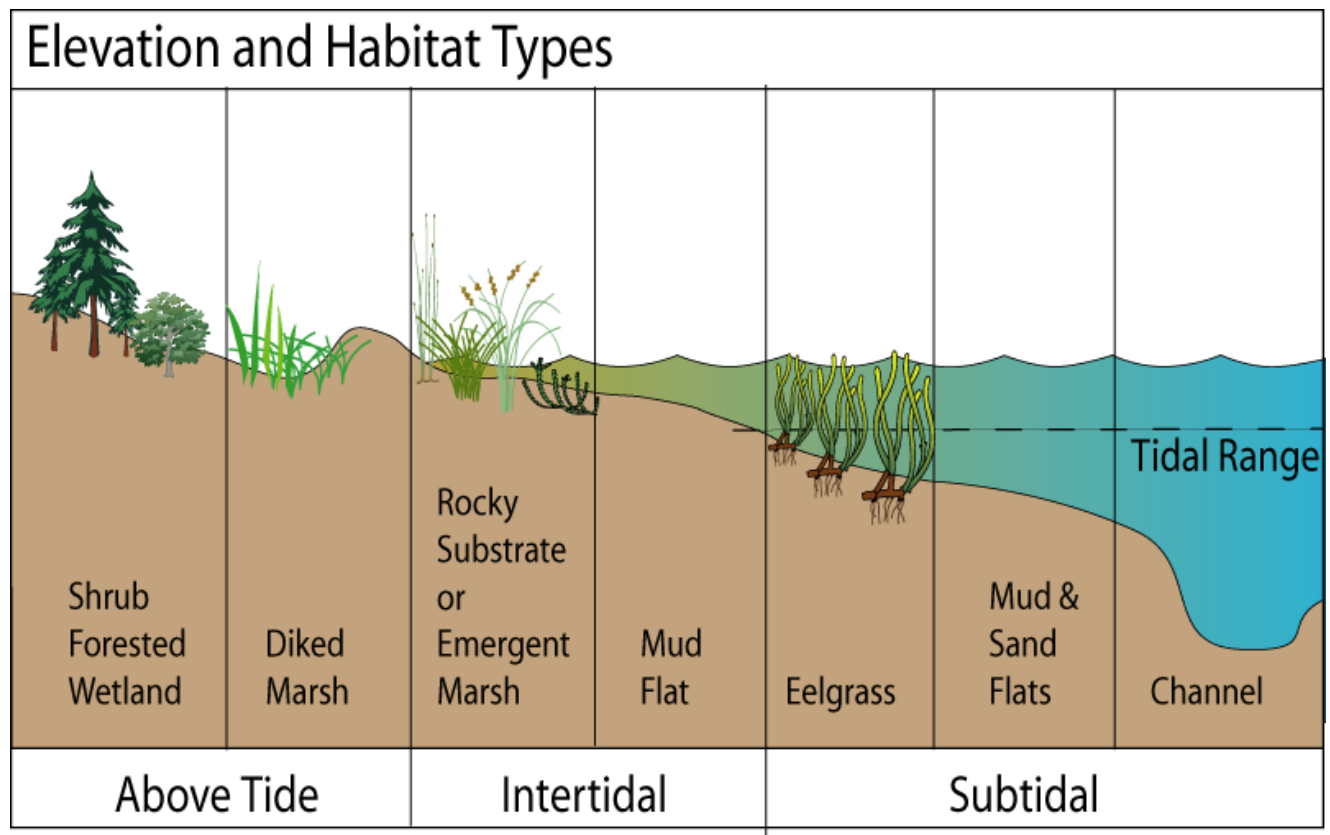
The importance of LCREP Ecosystem Monitoring Program was summarized by Catherine Corbett (October 26, 2010 presentation to the Science Work Group):

- The only comprehensive assessment of juvenile salmonid habitat in Columbia River estuary (combined look at food web, fish usage, vegetation and water column conditions at each site);
- It covers multiple 2008 FCRPS BiOp RPAs and Estuary Module RME actions
- Provides juvenile salmonid stock occurrence, condition, diet and residency;
- Assesses habitat capacity, opportunity and realized function of estuarine habitats;
- Provides key information for regional restoration strategies and salmon recovery planning;
- Yields reference site data for implementation and evaluation of restoration actions.

**Reference Sites monitored by the Estuary Partnership and PNNL are Analogs of Expected Aquatic vegetation communities in Shillapoo Lake Basin and associated wetlands.**

Following hydrologic reconnection of the Shillapoo Lake Basin with the Columbia River, an emergent wetland plant community will become re-established and replace the current agricultural use of the lake basin. With draining (and pumping) of the lake basin discontinued, it is expected that the lake will maintain a minimum lake level depending on river inflow (based on the invert of the channel) as well as groundwater inflow; i.e., it will not desiccate on a seasonal basis as it does now. Therefore a permanent aquatic community – vascular plants, periphyton, plankton, benthic invertebrates, amphibians, and fish – will be sustainable on a long-term basis.

An illustration of the spectrum of habitat types that typically occur in a saline Columbia River estuary is presented below (Figure 4; source: LCREP Conceptual Model). The eelgrass habitat type is not present in tidally influenced areas upstream of the salt intrusion zone of the Columbia River.

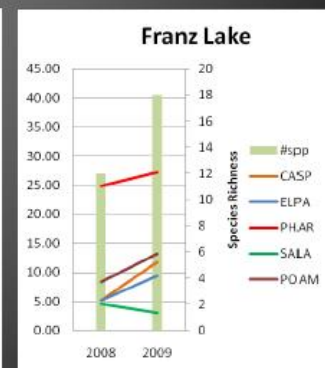
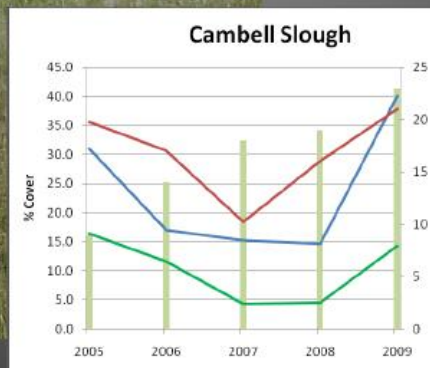
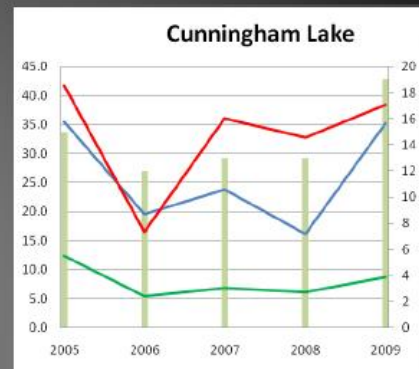
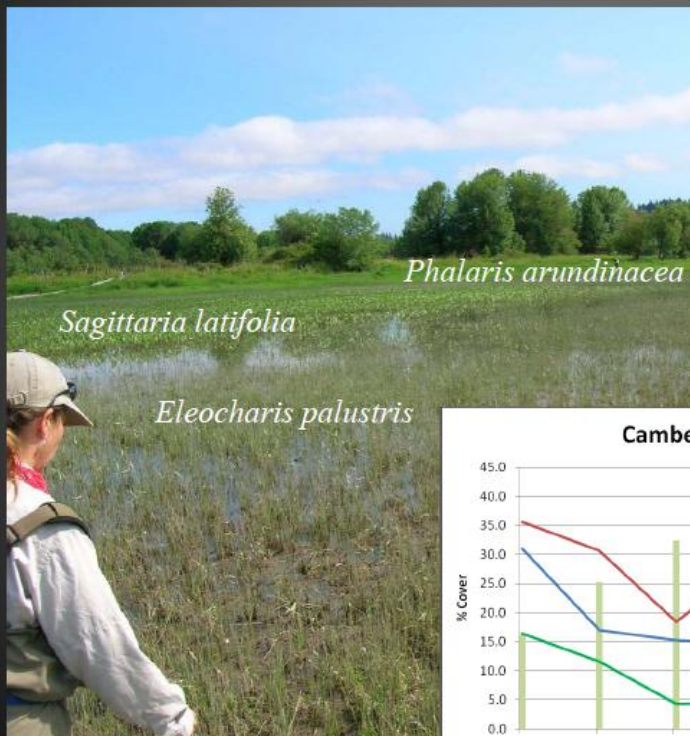


**Figure 5. A cross-sectional diagram of habitat types at various elevations in an estuary (based on Procter et al. 1980a).**

The dominant emergent aquatic plants at Cunningham Lake and Campbell Slough (Reach F) and Franz Lake (Reach H) are illustrated in Figure 5 (Source: Leary et al. 2006; Borde et al. 2010):

- Reed canary grass (*Phalaris arundinacea*) at upper-elevations
- Wapato (*Sagittaria latifolia*) at mid-elevations, and
- Common spikerush (*Eleocharis palustris*) at lower elevations

## Vegetation Cover



**Figure 6. Dominant aquatic plants at Cunningham Lake, Campbell Slough and Franz Lake (Borde et al. October 26, 2010 Presentation to Scientific Work Group).**

### ***D. Dispelling the myth that the limnetic area of Shillapoo Lake will be devoid of aquatic life.***

Prior to 1950, the Shillapoo Lake Basin would have likely been seasonally utilized by juvenile chinook, coho and steelhead when river levels allowed access. Both resident and sea-run cutthroat trout would have likely been present as well. Unfortunately, historical documentation corroborating these inferences is lacking (Burns 2007). Over 900 acres of the existing 1,892 acres within the combined North and South Unit would have been inundated by flood flows from the Columbia River prior to 1950. In addition, over half of the 477 acres contained in the Vancouver Lake Unit would have been backwatered by the lake as flood flows occurred on the Columbia River.

**Potential Fish & Wildlife Problem – Hypothesis: adult carp will disrupt the re-connected floodplain ecosystem and eliminate aquatic plants and thereby reduce waterfowl production.**

In all of the Columbia River Reference sites studied—although carp were present and/or had access – there was no evidence of carp populations dominating the tidally fluctuating wetland sloughs and ponds. Carp have physical access to all these sites, but neither juveniles or adults dominate the abundance or biomass of these natural functioning ecosystems. The evidence suggests that non-native species such as carp are less abundant (relative to native forage species and salmonids) in naturally functioning systems. At the Columbia River sites, more non-native fish species are present in sloughs that are tide gated or closed off from the natural daily (tidal) and seasonal (River stage induced) water level fluctuations.

In a pre-restoration study of 418 acres of tidal wetlands on the Bandon Marsh National Wildlife Refuge (Coquille River and estuary system) – anadromous salmonids were found in all areas sampled (i.e., Fahys Cr., Redd Cr., Reference site, and mainstem Coquille); however, carp and other nonnative species were only found in areas behind existing dike structures (Hudson et al. 2010).

Example Malheur Lake Waterfowl Refuge where Carp Dominate the Ecosystem:

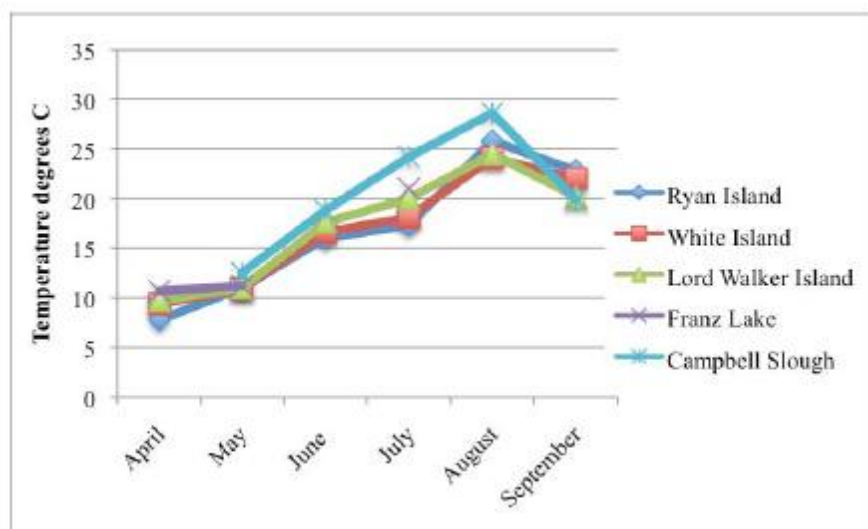
The type of aquatic environments where carp have dominated the biomass of the lake systems are much different than the Columbia River reference site locations.

- Malheur Lake is located 30 miles south of Burns, Oregon; it is a closed basin (small tributary inflow, but no outflow except evaporation).
- Malheur Lake is a 187,000-acre refuge – with open water lake that is 50,000 to 110,000 surface acres in size.
- The average depth of Malheur Lake is only 18 inches – in some areas the depth is relatively stable during the year; other areas can dry up in the summer;
- Summer-fall water temperatures are lethal for salmonids but are optimal for carp.
- No fishing is allowed on this USFWS Wildlife refuge that is managed for waterfowl.
- Carp have been an ongoing problem since 1950 when 1.5 million were killed with rotenone treatment – followed by periodic treatments since.
- The current carp population is believed to be about 1.5 million adult fish and a biomass of about 7 million pounds.
- During summer low-water conditions, carp can out-compete the waterfowl for Sago Pondweed, aquatic invertebrates, insects and other food. Carp also stir up sediment on the lake bottom, increasing turbidity and diminishing the sunlight necessary for the growth of lake grasses.

- In some years, migratory waterfowl, shore birds and colonial waterbirds darken the sky above Malheur Lake during their annual stop on the Pacific flyway. Duck production alone averaged more than 110,000 annually with a peak of 139,000 in 1946.
- In 2010, waterfowl production was down 75 percent at the refuge and visiting bird numbers have fallen by several million a year, according to the Fish and Wildlife Service.
- However in 2011 – due to high water conditions – thousands of migratory waterfowl and shorebirds flocked to an overflowing Malheur Lake in numbers unseen here in decades (Richard Cockle, The Oregonian; July 30, 2011).
- Ponds and wetlands on the refuge are periodically dried up to expose the substrate to the atmosphere to allow bacteria, fungi and a variety of invertebrates to breakdown accumulated organic matter and release stored nutrients. Many wetlands also become overrun with dense stands of cattails, bulrush and sometimes common carp. When this occurs wetland productivity and wildlife diversity is greatly reduced. Fire and mechanical means (disking and harrowing) are also used to set back succession, release nutrients and expose sediments and dormant seeds to the atmosphere.
- USFWS uses a series of dams, canals, levees, and ditches to ensure the supply of water while birds are rearing their broods. Water levels are manipulated (raised or lowered) to improve marsh soils, stimulate growth of plant, and control carp. Deep flooding drowns unwanted vegetation, creating areas of open water where broods feed and rest, safe from predators.
- A one-acre island is being created by the Corps of Engineers -- located 2,000 feet from shore in deepest and most consistently watered area of the lake and it will be used by Caspian terns and other birds as a nesting location at least nine months of the year. Construction is scheduled to be completed by March 1, 2011 well in advance of the arrival migratory birds which use the lake for resting and nesting. The island and related social attraction measures are aimed at attracting migrating terns to the area instead of the Columbia River estuary – as a salmon protection measure. Corps biologists also expect the terns to provide a local benefit by helping to manage the carp population in Malheur Lake via predation on carp juveniles.

### **Potential Fish & Wildlife Problem – Hypothesis: the re-connected floodplain ecosystem will result in stranded anadromous salmonid juveniles.**

There is no evidence that anadromous salmonid juveniles are physically stranded in any of the emergent wetland reference sites studied in the Columbia River. Juvenile salmon were most abundant in LCREP study sites during April thru June, and generally absent by July when water temperatures reached 20°C at the sites (Catherine Corbett, October 26, 2010 presentation to the Science Work Group). In many of the emergent marsh sloughs temperature reaches the lethal level for juvenile salmonids by August (Figure 11; Jones et al. 2010). The juvenile salmonids migrate out of the slough systems before water levels decrease to the point that stranding would occur.



**Figure 7. Mean water temperature in degrees centigrade by month at each reference site (Jones et al. 2010).**

**Potential Fish & Wildlife Problem – Hypothesis: juvenile salmonids will not utilize seasonal floodplain and associated wetlands; and if anadromous juvenile salmonids enter these floodplain ecosystems they will be lost to predation by birds and piscivorous fish.**

Cyndi Baker (2008) stated:

*“I also found that there were many preconceived notions about fish assemblages in seasonal floodplain wetlands (mostly regarding juvenile salmon) but these notions were based on little, if any, data collected from regional wetlands or similar habitats. Among these assumptions were: 1) It is questionable whether juvenile salmon use seasonal floodplain wetlands. 2) Seasonal floodplain wetlands are havens for introduced fish, and are therefore predatory trap for juvenile salmon.”*

Baker (2008) found that Juvenile salmon were present in all seasonal floodplain wetland study sites (Assumption 1). Relative abundance of juvenile salmon and patterns of seasonal use of floodplain wetlands varied by region and among sites within regions. Distinct patterns of juvenile salmon ingress and egress in UCRE sites demonstrated a more prolonged period of entry in to the wetlands (November through March) and a more contracted period of egress (April and May). Juvenile salmon were present in wetland catch at coastal, Puget Sound and UCRE sites throughout the sampling season.

Based on the low relative abundance of piscivorous fishes in the wetland catch, it did not appear that predation on juvenile salmon by bass or other predatory fishes was an overwhelming risk compared to what may be expected in adjacent riverine habitat (Assumption 2). Most (99.9%) of the catch in wetland sites were small-bodied (<200mm fork length), mostly planktivorous or insectivorous fishes. Native threespine stickleback was the most ubiquitous fish in seasonal floodplain wetlands west of the Cascade Range. Threespine stickleback in wetlands may further ameliorate potential risk of piscivory by juvenile salmon as alternative prey. The high relative abundance of threespine stickleback (Baker 2008), plus their slow swimming speed (Reimchen 1994), make them attractive prey and may decrease the probability of avian or fish predation on juvenile salmon.

#### **Conference Call with Cynthia F. Baker, Ph.D – notes by Steve Vigg, WDFW 12-20-2011**

WDFW Estuary Habitat staff<sup>2</sup> conducted a conference call meeting with Cynthia F. Baker on 12-20-2011 to discuss information on her research on floodplain lakes and associated wetlands – including her Ph.D. Dissertation work. During this discussion WDFW staff described the proposed anadromous fish floodplain wetland Restoration Project at Shillapoo Lake. A functional Columbia River floodplain existed at this site until about 1950, when it was diked-off to create farmland. We included a description of the seasonal frequency and extent of inundation of the re-connected lake basin and adjacent low elevation wetlands and sloughs. The proposed Columbia River connection would be a wide break in the SR 501 highway levee which would be replaced by a bridge or causeway. The channel connecting to the Shillapoo Basin would be relatively wide and short – dimensions yet to be determined – that would provide maximum tidal water exchange and direct flooding of the basin during seasonally high Columbia River stages in winter and spring. We described a permanent 700-acre shallow lake (approximately 3 feet maximum depth) during about 5 months of the year (July-October) that seasonally increased to an annual maximum of 900 to 1,800 acres, dependent on Columbia River stage.. Ground water and artesian flows would enter the basin year-around and Columbia River and Lake River flows would enter the basin when River Stage exceeded about 10-foot elevation. During late fall and winter, river inflow would increase – with a maximum inundation of over 1,800 acres in water surface area occurring during C.R. flood stages exceeding about 19 feet elevation (NAVD88). After winter-spring flood events the depth would fluctuate with tide and river stage changes and subside as the water drained back out of the Columbia River channel, with more extended drainage through Miller Slough and Buckmire Slough out the Lake River.

---

<sup>2</sup> WDFW staff participating on the conference call with Cynthia Baker (12-20-2011) included Steve Vigg, Donna Bighouse, Alex Uber and Dawn Phelps.

Given the above description of the proposed fish habitat restoration project, we asked Dr. Baker how she would describe the potential productivity and fish habitat capacity of the Shillapoo Lake basin and adjacent wetlands and sloughs; and specifically if the entire 700-1,800 acre open water area of the lake basin should be considered highly productive or just the edge of the open water area. Dr. Baker responded that floodplain habitats are “package deal”, i.e., that habitat diversity within the floodplain ecosystem is important for native fishes adapted to seasonal use. Deeper, open water habitats may provide security from stranding for fishes further from the main channel during periods of receding water levels. Aquatic edge habitats with emergent aquatic vegetation that transition to the wet terrestrial habitats provide cover for juvenile fishes and macroinvertebrate productivity (Cyndi Baker, Warm Springs Tribe, Fisheries Research and Monitoring Project Leader, Personal Correspondence, 12-20-2011). Light will penetrate the water column to the bottom of the lake (~3-20 ft maximum depth) during all seasons; therefore, aquatic vascular plants, periphyton and planktonic algae will be present throughout the lake basin throughout the year. This primary production will be the source of the benthic invertebrates (secondary trophic level) that in turn are the food source for juvenile salmonids. Dr. Baker also cited research at gravel-pit ponds along the Willamette River between Albany and Harrisburg that mimicked Oxbow Lakes in floodplains; i.e., these pits provided deep water with relatively cool ground-water seepage that provided thermal refugia -- pockets of cool water that were utilized by juvenile salmonids over summer. High growth rates were observed for Chinook juveniles utilizing these ponds (a mean growth increment of 78mm (172 => 250 mm fork length) or a doubling of weight over 12 months for juvenile Chinook in mid-Willamette River gravel ponds April 2000 to April 2001 (Cyndi Baker, Warm Springs Tribe, Fisheries Research and Monitoring Project Leader, Personal Correspondence, 12-20-2011). Dr. Baker hypothesized that similar cool water pockets might develop within Shillapoo Basin – where groundwater seeps into the lake. We know that groundwater seepage into the Shillapoo Basin is substantial since the water must be continually pumped out during the spring and summer in order to maintain arable moist farm land (Brian Calkins, WDFW Wildlife Manager, Personal Correspondence).

***E. Examples of the importance of floodplain wetlands and shallow lakes -- Summary of findings by Cynthia F. Baker (2008) and Julie Henning (2006).***

**Cyndi Baker (Ph. D. Dissertation 2008)**

Cyndi Baker (2008) has provided some of the best documentation of fish use in floodplain wetlands of the Columbia Basin; including six coastal sites and six sites in the upper-half of the Columbia River estuary (Table 1; Figure 1).

**East Fork Lewis River –LaCenter Bottoms Site**

The LaCenter site was within the tidal zone of the East Fork Lewis River and was heavily utilized by juvenile coho salmon. The LaCenter Bottoms site is a 54-hectare project in which an existing structure intended to drain water from the land was replaced by a structure to retain water and pass fish (Baker 2008). The site was also re-vegetated with native trees and the drainage ditch was re-contoured. This area was cleared of almost all woody vegetation in the 1920's and improved for farming in the 1930's with the addition of drainage ditches and a flood-control dike along the river. The dike had three culverts with screw gates at the outlet of the main ditch draining to the East Fork Lewis River. The screw gates had broken away from the pipes and no longer functioned to keep floodwater out.

Although there are no dams on the East Fork Lewis River, hydrology at LaCenter Bottoms is affected by the Columbia River stage, 5.6 km downstream, which is significantly affected by main stem dam operations. The East Fork Lewis River is under tidal influence at LaCenter and high water typically inundates the entire project area at least annually but usually multiple times during the winter and spring. The area typically inundated and available for fish use is about 6 hectares and includes two ponds, one with a pool-weir-chute wetland restoration structure (with a fish ladder incorporated in the design), and channels connecting the ponds to the East Fork Lewis River.

Table 1. Site description and years sampled.

| Region                  | Wetland site                         | Site area (ha) | Distance (km) from salmon migration route | WCS <sup>3</sup> (year installed) | WY <sup>5</sup> within wetland sampling |
|-------------------------|--------------------------------------|----------------|-------------------------------------------|-----------------------------------|-----------------------------------------|
| Coast (n=6)             | Lewis                                | 52             | 0                                         | PWC (02)                          | 02, 03, 04, 05                          |
|                         | Porter Point                         | 60             | 0                                         | PWC (02)                          | 02, 03, 04, 05                          |
|                         | Greenhead                            | 32             | 5.1                                       | Riser (99)                        | 02, 03                                  |
|                         | Hoxit                                | 7              | 0.8                                       | Riser (97)                        | 02, 03                                  |
|                         | Larson Slough                        | 32             | 0                                         | PWC (02)                          | 04, 05, 06                              |
|                         | Arago                                | 83             | 1.0                                       | Riser (05)                        | 04, 05, 06                              |
| Puget Sound* (n=1)      | Cripple Creek                        | 41             | 1.0                                       | --                                | 04                                      |
| UCRE <sup>1</sup> (n=6) | Ruby Lake                            | 10             | 2.1                                       | Riser (01)                        | 02, 03, 04                              |
|                         | Wigeon Lake                          | 5              | 1.2                                       | Riser (01) <sup>4</sup>           | 02, 03, 04                              |
|                         | Mulnomah North <sup>2</sup>          | 17             | 0                                         | Riser (01) <sup>4</sup>           | 02, 03, 04, 05, 06                      |
|                         | McCarthy Creek                       | 3              | 0                                         | --                                | 03, 04, 05, 06                          |
|                         | Smith-Bybee <sup>2</sup>             | 400            | 4.4                                       | PWC (fall 04)                     | 03, 04, 05, 06                          |
|                         | LaCenter Bottoms <sup>2</sup>        | 54             | 0                                         | PWC (fall 04)                     | 03, 04, 05, 06                          |
| Eastern OR/WA (n=2)     | Satus <sup>2</sup> (eastern WA)      | 98             | 0                                         | Risers (98)                       | 02                                      |
|                         | Ladd Marsh <sup>2</sup> (eastern OR) | 72             | 2.1                                       | PWC (02)                          | 03, 04                                  |

<sup>1</sup>Upper Columbia River Estuary<sup>2</sup>Sites with two sample days per trip<sup>3</sup>Water-control structure (WCS); pool-weir-chute (PWC) and Riser structure types<sup>4</sup>WCS installed in 2001 but riser boards were not installed until 2003 (operated as control for WY02)<sup>5</sup>WY is water-year, which begins October 1 and ends September 30

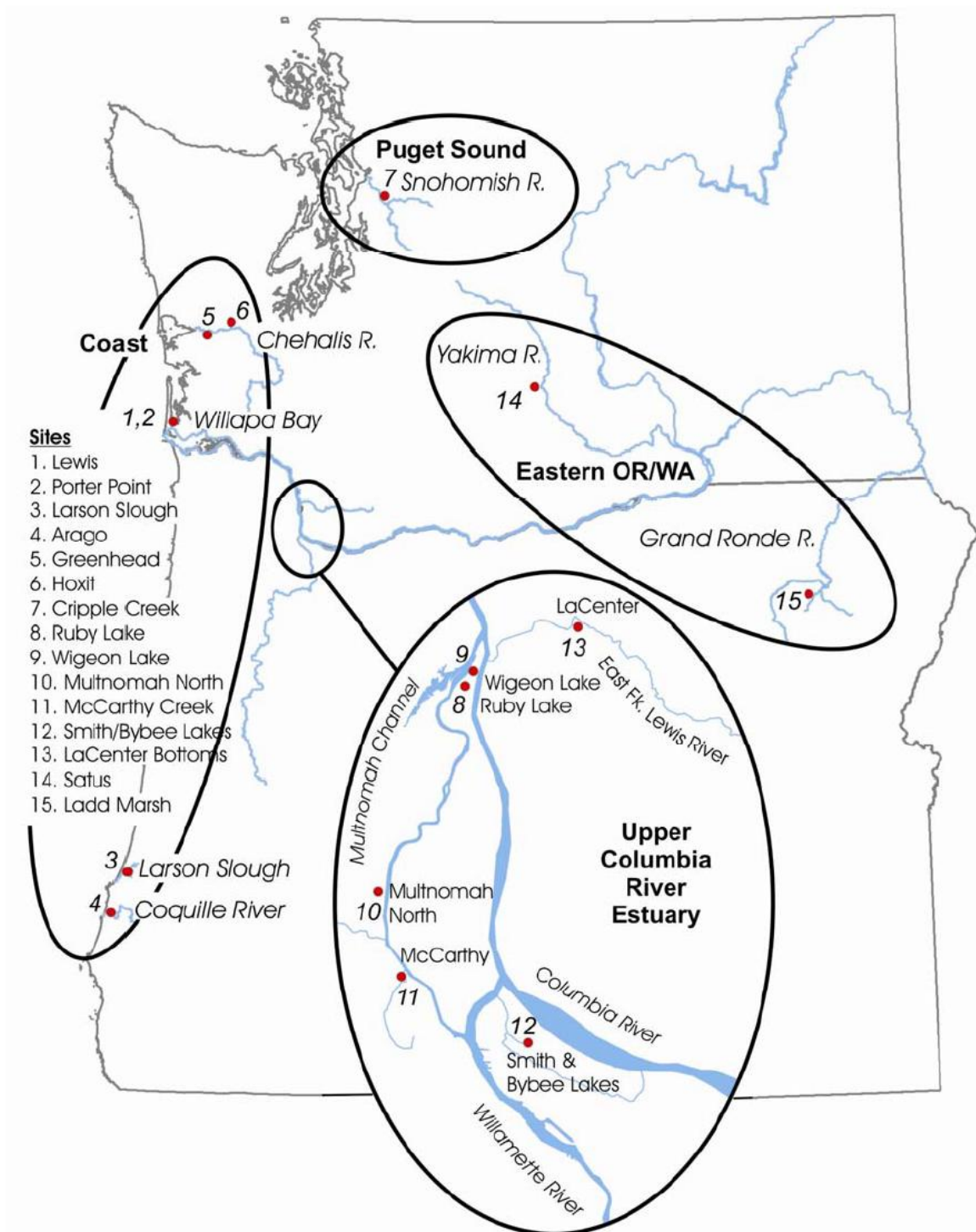


Figure 3. Study sites in Oregon and Washington

Baker (2008) found that Salmonids used the LaCenter freshwater seasonal floodplain wetland represented the greatest total within-wetland catch along the Upper Columbia River Estuary. In 141 trap sets at various times between 2002-2006, Baker caught a total of 965 juvenile coho and 2,654 Chinook. In addition to coho and Chinook, juvenile chum salmon, rainbow trout, cutthroat trout and bull trout were also caught. Juvenile salmon responded to different environmental cues depending on whether they were caught within wetlands or caught entering or leaving wetlands and depending on site. Juvenile coho that entered Lewis and LaCenter wetlands responded to different environmental variables (river water temperature and lunar phase, tide vs. water level), perhaps due to differences in environmental characteristics and/or physiological and behavioral differences from genetic stock. At times it appeared that juvenile salmon entered wetlands from passive entrainment with high water but there was also evidence that they entered wetlands volitionally, as they swam up fish ladders and into ingress traps. Juvenile salmon leaving LaCenter wetland responded to a drop in barometric pressure and a new moon, likely related to seaward migration.

Catch of juvenile coho at coastal sites and juvenile Chinook in UCRE wetlands during within wetland sampling was highest when temperatures were in the range that was optimal for metabolic function. As they moved within wetlands feeding, they were more susceptible to catch with passive trap nets. In UCRE wetlands, juvenile coho resided up to 154 days and juvenile Chinook resided up to 111 days suggesting that habitat conditions in the wetlands were favorable, including water temperature. Water temperatures in wetlands were within the preferred range for juvenile rearing for at least one-and-a-half months. Juvenile salmon leaving the wetlands when water temperatures were above the preferred temperature range appeared unharmed.

Fish integrate a multitude of environmental variables, not just water temperature, which influences their location. Juvenile salmon were caught in the wetland study sites in the late spring and early summer when water temperatures were warmer than what was optimal for growth (Table 4) and had free access to leave and seek other habitat. For example, at Lewis wetland a coho (156mm fork length) and cutthroat (188mm fork length) were caught on July 15, 2002 when the water temperature averaged 19.2C (17.9-20.6C). At Ladd Marsh, two Chinook (66 and 71mm fork length) were caught June 16, 2004 when the water temperature averaged 18.1C (16.4-20.2C). These are just two of many examples from sampling fish in wetlands for five years. Two-way trap data show that the majority of salmonids leave the wetlands during a contracted period earlier in the spring and these examples of salmon leaving in late spring likely represent the stragglers but demonstrate the variability among individuals and the capability of surviving warmer than optimal water temperatures.

*Table 6. Preferred water temperatures for juvenile salmonid rearing.*

| Species         | Water Temperature Range (C) | References                 |
|-----------------|-----------------------------|----------------------------|
| Chinook         | 10 to 15.6                  | (Armour 1991)              |
| Chinook         | 12 to 14                    | (Scott and Crossman 1998)  |
| Chum            | 12 to 14                    | (Scott and Crossman 1998)  |
| Coho            | 12 to 15                    | (Bjornn and Reiser 1991)   |
| Cutthroat trout | 12 to 15                    | (Hickman and Raleigh 1982) |
| Rainbow trout   | 10 to 16                    | (Benke 1992)               |

Several lines of evidence suggest that juvenile salmon successfully emigrated from the floodplain. The deliberate and repeated pattern of increased juvenile salmon catch during spring in egress traps at UCRE sites, modeled response of juvenile salmon leaving LaCenter wetland as environmental and physiological cues signaled their departure in the spring, and emigration of coho at Arago wetland with receding floodwater support this claim. While stranding was not specifically documented in this study, Sommer et. al (2005) found that the majority of young Chinook salmon successfully emigrated from the Sacramento River floodplain and adult ocean recoveries of tagged fish that reared on the floodplain had survival comparable with that of adjacent perennial river channels.

### **Smith and Bybee Wetlands Natural Area**

Smith and Bybee Wetlands Natural Area, located in North Portland, is a 400-hectare site owned and managed by Metro (Figure 64). Historically surrounded by a maze of slough channels and wetlands it now lies among commercial developments, port terminals, warehouses, and also the now closed St. Johns Landfill, a former wetland that was filled and served as Portland's primary garbage disposal site from 1940 to 1991. Smith and Bybee wetland is connected to the Willamette River via the Columbia Slough and North Columbia Slough, a distance of 4.4 km from the Willamette River for migrating salmonids. During fall 2003, a wetland restoration structure that restricted fish passage was replaced with a structure that incorporated a fish ladder

in its design. With the installation of the new structure came a change in management. Previous to the new structure, the wetlands were impounded in response to a suspected avian botulism outbreak in the early 1980s. The impoundment was intended to disperse wintering waterfowl and reduce the spread of future outbreaks. After the installation of the new structure, the wetlands were managed as seasonal floodplain wetlands, their condition prior to development on the floodplain. The change in management of the wetlands was intended to suppress reed canary grass, encourage native vegetation and provide seasonal habitat for rearing juvenile salmon. The vegetation classification for Smith and Bybee wetlands includes 48.7% paulustrine scrub shrub, 28.2% paulustrine emergent, 21.7% lacustrine littoral and 1.4% riverine. Figure 64. Vicinity map of Smith-Bybee Wetlands Natural Area.

**Julie Henning (2006) *North American Journal of Fisheries Management* 26:367–376.**

Juvenile salmon have only recently been documented in floodplain emergent wetlands during the spring (Sommer et al. 2001; Baker and Miranda 2002; Henning 2004), and the significance of this association is unclear. In part, this is related to the perception that floodplain freshwater emergent wetlands are atypical salmonid habitat; they become seasonally anaerobic, have intermittent connections with the river main stem, are shallow, vegetated, and lack woody cover. However, the shallow depths, increased water temperatures, and emergent vegetation support high invertebrate production (Eldridge 1990; Fredrickson and Reid 1998). Such conditions may enhance prey resources, providing opportunities for fish growth and survival that are superior to those found in the main river channel. Thus, during the spring, floodplain emergent wetlands may provide excellent habitat for juvenile salmonids, but these factors can be offset by the risk of stranding as the wetland desiccates and oxygen levels decline. Henning et al. (2006) studied juvenile coho use of enhanced and unenhanced freshwater, emergent floodplain wetlands on the Chehalis River, Washington and found that greater growth rates, survival and emigration of juvenile coho can result from enhancing freshwater wetlands via wetland restoration structures to increase the consistency of habitat during of floodplain inundation during the winter and spring. Little is known of the use of off-channel habitat by juvenile Chinook salmon, although they were documented using off-channel mining dredge ponds in Salmon River (Richards 1992). Sommer et al. (2001a: 2005; 2001b) demonstrated higher growth and survival rates of juvenile Chinook salmon rearing and migrating in the primary floodplain of California's lower Sacramento River than juvenile Chinook that used the main stem Sacramento River. Sommer et al. also found that Chinook that reared in seasonal floodplains as juveniles had adult return rates comparable with those of adjacent perennial river channels (Sommer et al. 2005).

Henning et al. (2006) suggested that declining dissolved oxygen concentrations in the wetlands may trigger a volitional emigration of salmonids from these wetland habitats. Habitat conditions gradually became unsuitable for fishes in individual wetlands as water temperatures increased, dissolved oxygen concentrations decreased and wetland water levels declined. Dissolved oxygen concentrations decreased throughout the sampled months. Additional details of follow.

Water levels decreased more slowly at the enhanced than the unenhanced wetlands, maintaining the wetted area for a longer duration. This may be particularly important for fishes that use the floodplain for spawning and rearing, and can thereby increase fish productivity (Welcomme, 1985). Water temperatures did not reach lethal limits for fishes in the wetlands, although preferred rearing temperatures for some species were exceeded (i.e. salmonids: lethal limit c. 25° C and preferred rearing 12–14° C; Brett, 1952). Dissolved oxygen concentrations were at or near lethal levels for many fishes in June (<1.0 mg l<sup>-1</sup> in emergent wetlands). Low DO was more of a limiting factor for fishes than water temperatures. Prolonged inundation of floodplain habitats often results in low dissolved oxygen levels (i.e. anoxia; Mitsch & Gosselink, 1993; L. J. McKinnon, unpubl. data). Such conditions can limit activity and growth in some fishes (Brett, 1979). For example, the Olympic mudminnow can tolerate dissolved oxygen levels as low as 0.18 mg l<sup>-1</sup> (Meldrim, 1968), but juvenile coho salmon show reduced food consumption. Oxbow habitats connected and recharged by the river provided rearing for coho salmon that differed from the main river channel or seasonal, freshwater wetlands of the floodplain.

Bustard & Narver (1975) found that during winter, juvenile salmonids used side pools or alcoves that were on the channel margin protected by the stream bank. In their study, these habitats were more similar to stream habitat than seasonal emergent wetland habitat because of water recharge, velocity and river connectivity. Higher abundances of yearling coho salmon were in enhanced wetlands compared with unenhanced wetlands where river wetland connectivity was also less. Thus, the degree of connectivity between the river and floodplain, as well as unexplored habitat characteristics, may be key determinants of the fish species and life stages present in a floodplain wetland habitat. The wetland projects provide rearing habitat for numerous fishes, including coho salmon, and provide breeding habitat for amphibians (Henning and Schirato, 2006).

Modifications of the floodplain (i.e. ditching and draining) may have the greatest affect on fishes that depend on wetlands for the majority of their life cycle. Seasonally flooded freshwater wetlands with water control structures allow fishes a greater amount of time for spawning, rearing and emigration as river water levels recede in such modified landscapes. Fish survival is dependent on emigrating from enhanced wetlands before water quality conditions become harmful. Off-channels habitats, oxbows, beaver ponds, emergent wetlands and enhanced

wetland habitats are supporting a diversity of fishes, and floodplain management should focus on maintaining this habitat complexity. Research is just beginning to elucidate the roles that emergent floodplain habitats play in fish community composition and productivity, particularly in regions such as the Pacific Northwest where these habitats have been overlooked generally and reduced substantially by land-use practices.

### ***F. Cultural Resources – Importance of Floodplain Lakes to Native Americans in the Lower Columbia River.***

In 1805-06, Lewis and Clark noted the prosperity of the Indian (Cathlapotle) nation, as well as the abundant wildlife in the lower Columbia River floodplains:

***“Over the millennia, the river’s floodwaters altered the landscape by braiding new channels, refreshing marshes, and depositing sediments which created a mosaic of bottomland forests, meadows, and marshes, teeming with a rich diversity of fish and wildlife. Native people chose this strategic place to sustain a thriving population and trade goods among Indian tribes along the river.”*** (Moulton 1990, 1991)

Based on their analysis of ethno-historic literature, Boyd and Hajda (1987) found that the subsistence economy of the Portland Basin Chinook focused mainly on fish, especially salmon, sturgeon, and eulachon. Remains of various freshwater fish and freshwater shellfish have been recovered from sites in the Portland Basin, including the greater Vancouver Lake area and specifically within the Shillapoo Wildlife Area. Although only a limited amount of archaeological research has been completed in this area, the primary historic occupation occurred along the lowlands adjacent to Vancouver Lake, including Lake River, Buckmire Slough and the Columbia River (Munsell 1973; Boyd and Hajda 1987; and Roulette and Thomas 2011).

### ***G. Shillapoo WLA ‘Open Water Habitat Area’ calculation review (Alex Uber, WDFW)***

Summary: A review of the ERTG Template (revised 4/22/10) and ERTG Meeting Notes from July 30, 2009 to October 15, 2010 found no references to any limits on the potential ‘habitat area’ metric used to estimate the SBU scoring contribution of CRE 10.1, 10.2, or 10.3.

There are references to restoration area size in general however (see reference below)

From p 13 of Attachment 13, Project Evaluation Criteria, ERTG Meeting no. 3, October 21, 2009

#### 4) Adequate Size and Shape (0-5 points)

Size refers to reach length and the size of the potential habitat within a reach. In general, larger size enhances habitat stability, increases the number of salmonid species that can potentially use the site, makes it easier to find by migratory species such as salmonids, and increases within-habitat complexity.

Guidance Questions:

- What is the overall size (acres or stream miles) of the project site?
- What is the state of the current drainage network at the site (i.e., how much of the historic tidal condition is intact versus artificially manipulated?)
- What is the condition of the project site's immediate surrounding habitat?

From p.5 April 22, 2010 ERTG Meeting Notes:

- possible:
- One value of large sites is that they could maximize natural processes and functions; however, the ecological evidence for this is not there yet.
  - The BPA is funding a habitat classification system for the LCRF. Reach 5 is the restoration

From p. 2 May 24, 2010 ERTG Meeting Notes:

- Project size may not be well-covered in this method. The ERTG will need to keep this in mind and think about possible refinements to the Calculator.
  - Large projects are probably better than small ones because the former would be expected to be more resilient to impacts. Also, the more connections to quality adjacent habitats, the better. In general, the less stressed the surrounding landscape is, the better the project's chances to be self-maintaining and meet its goals.
  - Furthermore, project context is important. Context is the surrounding area or landscape. The ultimate functionality of a project will likely be dependent on the project's context. Don't rule out the value of small projects within large sites with good condition. Note, however, that the scientific basis for the value of "context" is not well established.
- 

These discussions indicate that large restoration sites may have greater value as salmonid habitat than smaller ones. I found no discussion of lesser importance of large open water areas or floodplain lakes vs. channels, or other fluvial features.

Regarding Shillapoo specifically, aquatic habitat will be ‘established’ vs. improved, since the lake basin and surrounding lands are currently (and have been since the 1950’s) diked, drained and used for dry land crops. Essentially the baseline as fish habitat is zero, unlike other floodplain lake restoration sites (ie Vancouver Lake, lakes on Sauvies Island, etc).

---

**Management Action CRE-10:**

Breach or lower dikes and levees to establish or improve access to off-channel habitats.

| Project                                                                                                                                                                                                                 | Unit                                     | Cost         | Schedule    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|--------------|-------------|
| 1. Breach or lower the elevation of dikes and levees; create and/or restore tidal marshes, shallow-water habitats, and tide channels.                                                                                   | 5,000 acres <sup>1</sup> @ \$10,000/acre | \$50 million | 2006 - 2031 |
| 2. Remove tide gates to improve the hydrology between wetlands and the channel and to provide juveniles with physical access to off-channel habitat; use a habitat connectivity index to prioritize projects.           | 2,000 acres <sup>1</sup> @ \$10,000/acre | \$20 million | 2006 - 2031 |
| 3. Upgrade tide gates or perched culverts where (1) no other options exist, (2) upgraded structures can provide appropriate access for juveniles, and (3) ecosystem function would be improved over current conditions. | 1,000 acres <sup>1</sup> @ \$5,000/acre  | \$5 million  | 2006 - 2031 |

It is the intention of WDFW to re-establish a surface water connection with the Columbia River via an open channel, in a levee breach location. Ideally, a large-span bridge would be placed over this opening to convey traffic and maintain access. This approach would justify using CRE 10.1 to score the ‘restored area’ metric required in the SBU calculation.

From ERTG Template, Revised 4/22/10.

---

|                                          |    |   |                                                                                                                                                                                                                      |
|------------------------------------------|----|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CRE-10. Breach or lower dikes and levees | 15 | 6 | CRE-10.1: Breach or lower the elevation of dikes and levees; create and/or restore tidal marshes, shallow-water habitats, and tide channels.                                                                         |
|                                          |    |   | CRE-10.2: Remove tide gates to improve the hydrology between wetlands and the channel and to provide juveniles with physical access to off-channel habitat; use a habitat connectivity index to prioritize projects. |
|                                          |    |   | CRE-10.3: Upgrade tide gates where (1) no other options exist, (2) upgraded structures can provide appropriate access for juveniles, and (3) ecosystem function would be improved over current conditions.           |

---

Below is a summary of ERTG discussion of the Shillapoo project specifically, following a presentation of project concepts by WDFW in June 2010. There are no references to, or discussion of, a limitation on the 'restored area' metric which would be used to with CRE 10.1 for the project. Further scoping completed by WDFW since this date has answered some of the critical questions raised regarding elevation of the site, potential for reconnection etc.

From June 3-4 2010 ERTG Meeting Notes:

Shillapoo

- This is a potential Washington MOA Project. Alex Uber (WDFW) answered questions about the project. The ERTG's role was to provide preliminary feedback and discussions on the project; no scoring.

Prepared by G. Johnson

June 15, 2010

- Comment: The hydrology of reconnecting this area is unclear. For example, there's water being pumped from the Col. R. into the area which is a complex of ditches, sloughs, and lakes. It's hard to identify methods to restore connections to the mainstem. This could require extensive analysis of Lidar data to identify areas for reconnection. Reply: WDFW is starting to analyze Lidar data for the area. Plus, they're collecting water surface elevation data. And, there's river stage data at from the Vancouver gauge.
- Q: Will it be possible to naturally maintain an entrance point for a reconnection? A: Not likely without lowering the invert of the channel. Q: If the reconnection is at the location where the pump is, how much inundation would there be? A: Don't know exactly. One needs to keep in mind the elevations inside the study area.
- Comment: The area with the swales might be something to look at restoring. It's relatively close to the Col. R. The swale area might be preferred to areas downstream where the Fazio property is. Reply: Good point. It might be possible to reconnect the swales and Shillapoo Lake through WDFW property.
- Comment: The point is to restore broader ecosystem function, areas used historically by juvenile salmon, and natural habitat forming processes. "Engineered" solutions are a red flag. In the case of the swales, though, deepening them might permit enough tidal energy to keep them open. This should be modeled using computational fluid dynamics. Need to be careful that deepening the swales doesn't cause draining of the surrounding wetlands.
- Comment: There seems to be potential for connections to larger projects in the vicinity. In restoration theory, bigger is better because the habitats will typically be more diverse and resilient than at smaller sites. Also, there should be some cost efficiencies for a larger project.
- Comment: It's going to be tough to restore the entire lake system because you'll have to establish a new hydrologic regime. The potential for successful restoration of the connection at the location of the pump station between the mainstem and the lake would be low. However, examination of a smaller, limited area along with some elevation analysis might be fruitful. Be careful about designing too small of an entrance cross-section; don't neck it down.
- Comment: Seems like a high risk project because there are serious concerns about the certainty of success. It might be useful to do some in-depth modeling and baseline monitoring. This type of project especially will require adaptive management to manage the risks.
- Comment: The Estuary Partnership's Tier 3 prioritization process will help provide the landscape perspective for the project, as should the Trask/Simenstad strategy. Habitat connectivity methods from the Corps' Salmon Benefit project should also be consulted.

**Notes – EPTC Breakfast Session**

---

## References

- Baker, C.F. 2008. Seasonal Floodplain Wetlands as Fish Habitat in Oregon and Washington. Dissertation for the Degree of Doctor of Philosophy in Fisheries Science. March 17, 2008. Oregon State University. Corvallis, Oregon. 306 pages.
- Baker, C. F., and R. S. Miranda. 2003. Floodplain wetland restoration and Pacific salmon, 2002 annual report to NOAA Fisheries. Ducks Unlimited, Vancouver, WA.
- Bayley, P. B. 1995. Understanding large river-floodplain ecosystems. *BioScience* 45(3):153-158.
- Bonar, S. A., B. D. Bolding, M. Divens, and W. Meyer. 2005. Effects of introduced fishes on wild juvenile coho salmon in three shallow Pacific Northwest lakes. *Transactions of the American Fisheries Society* 134:641- 652.
- Boyd, Robert T., and Yvonne P. Hajda. 1987. Seasonal Population Movement Along the Lower Columbia River: the Social and Ecological Context. *American Ethnologist* 14(2):309-326.
- Brown, T. G. 2002. Floodplains, flooding, and salmon rearing habitats in British Columbia: A review. Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, B.C.
- Bottom, D.L., C.A. Simenstad, A.M. Baptista, D.A. Jay, J. Burke, K.K. Jones, E. Casillas, and M.H. Schiewe. 2001. Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. U.S. National Marine Fisheries Service. Seattle, Washington.
- Brett, J.R. 1952 Temperature tolerances in young Pacific Salmon, genus *Oncorhynchus*. *Journal of the Fisheries Research Board of Canada* 9:265-323.
- Briner, W. 2011. Post Office Lake and Shillapoo Lake Sediment Quality Evaluation Report. (Technical review by Mark Siipola). July 2011. Portland District, Corps of Engineers -- §536 funding. 19 Pages.
- Burns, T. 2003. Shillapoo Wildlife Area Fish Passage Barrier Assessment Report, TAPPS 2003. WDFW <http://wdfw.wa.gov/publications/pub.php?id=00594>
- Caromile, S.J., W.R. Meyer, & C.S. Jackson. 2000. The 1998 Warmwater Fish Survey of Vancouver Lake, Clark County. Washington Dept. of Fish and Wildlife.
- Christy, J. A. and J. A. Putera. 1993. Lower Columbia River natural area inventory 1992. Report to the Nature Conservancy, WA Field Office, Seattle. February 3, 1993.

- Diefenderfer, H. L. 2007. Channel morphology and restoration of Sitka spruce (*Picea sitchensis*) tidal forested wetlands, Columbia River, U.S.A. Ph.D. dissertation, Univ. Wash., Seattle, WA. 103 pp + illust.
- Dunne, K. P., Rodrigo, A. M., Samanns, E. (1998). "Engineering Specification Guidelines for Wetland Plant Establishment and Subgrade Preparation," Technical Report WRP-RE-19, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Haskell, C.A., R.C. Koch, K.F. Tiffan, and D.W. Rondorf. 2004. Crims Island Habitat Restoration in the Columbia River Estuary-Fisheries Monitoring and Evaluation, 2003, Draft Report of Research Submitted to U.S. Army Corps of Engineers, Portland District
- Haskell, C.A., K.F. Tiffan, and J.O. Olson. 2007. Crims Island habitat restoration in the Columbia River estuary - fisheries monitoring and evaluation, 2006. U.S. Army Corps of Engineers, Portland, OR. Contract No. W66QKZ60441176.
- Henning, J. A. 2005. Floodplain emergent wetlands as rearing habitat for fishes and the implications for wetland enhancement. Master's thesis. Oregon State University, Corvallis.
- Henning, J. A. 2004. An evaluation of fish and amphibian use of restored and natural floodplain wetlands. Washington Department of Fish and Wildlife, EPA Grant CD-97024901-1, Final Report, Olympia.
- Henning, J. A., R. E. Gresswell, and I. A. Fleming. 2006. Juvenile salmonid use of freshwater emergent wetlands in the floodplain and its implications for conservation management. *North American Journal of Fisheries Management* 26:367-376.
- Hudson, J.M., S.M. Castle, J.R. Cook, B.P. Silver, S. Lohr, and T.A. Whitesel. 2010. Pre-restoration Monitoring at Bandon Marsh National Wildlife Refuge 2007-2010. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, Washington. (pdf 1.5mb)
- Johnson, G.E., R.M. Thom, A.H. Whiting, G.B. Sutherland, T. Berquam, B.D. Ebberts, N.M. Ricci, J.A. Southard, and J.D. Wilcox. 2003. An ecosystem-based approach to habitat restoration projects with emphasis on salmonids in the Columbia River estuary. PNNL-14412. Prepared by Pacific Northwest National Laboratory.
- Johnson, J., J. Poirier, R. Horal, and T.A. Whitesel. 2007a. Lower Columbia River Channel Improvement: Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands. 2006 Project Report

- Johnson J., J. Poirier, and T.A. Whitesel. 2007b. Lower Columbia River Channel Improvement: Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands. 2007 Project Report.
- Johnson J., S. Ennis, J. Poirier, and T.A. Whitesel. 2009a. Lower Columbia River Channel Improvement: Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands. 2008 Project Report.
- Johnson J., J. Poirier, S. Ennis, and T.A. Whitesel. 2009b. Julia Butler Hansen National Wildlife Refuge: Assessment of Fishes, Habitats, and Tide gates in sloughs on the Mainland. 2007, 2008 Progress Report.
- Jones, K.K., C.A. Simenstad, D.L. Higley, and D.L. Bottom. 1990. Community structure, distribution, and standing stock of benthos, epibenthos, and plankton in the Columbia River estuary. *Progress in Oceanography*. 25(1-4):211-241.
- Jones, K. L., K. E. Marcoe, C. A. Simenstad, M. F. Ramirez, J. L. Burke, J. E. O'Connor, T. D. Counihan, I. R. Waite, A. B. Borde, S. A. Zimmerman, N. K. Sather, R. M. Thom, J. L. Morace, L. L. Johnson, P.M. Chittaro, K. H. Macneale, O. P. Olson, S. Y. Sol, D. J. Teal, G. M. Ylitalo, and L. K. Johnson. 2009. Lower Columbia River Ecosystem Monitoring Project Annual Report for Year 5 (September 2008 to August 2009). Prepared by the Lower Columbia River Estuary Partnership for the Bonneville Power Administration.
- Jones, K. L., J.C. Leary, J. L. Morace, K. McCarthy, C. A. Simenstad, J. L. Burke, T. D. Counihan, I. R. Waite, K.L. Sobocinski, A. B. Borde, L. L. Johnson, P.M. Chittaro, K. H. Macneale, O. P. Olson, K. Peck, S. Y. Sol, and G. M. Ylitalo. 2007. Lower Columbia River Ecosystem Monitoring Project Annual Report for Year 3b (September 1, 2006 to August 31, 2007). Prepared by the Lower Columbia River Estuary Partnership for the Bonneville Power Administration.
- Jones, K. L., K. E. Marcoe, C. A. Simenstad, M. F. Ramirez, J. L. Burke, J. E. O'Connor, T. D. Counihan, I. R. Waite, A. B. Borde, S. A. Zimmerman, N. K. Sather, R. M. Thom, J. L. Morace, L. L. Johnson, P.M. Chittaro, K. H. Macneale, O. P. Olson, S. Y. Sol, D. J. Teal, G. M. Ylitalo, and L. K. Johnson. 2009. Lower Columbia River Ecosystem Monitoring Project Annual Report for Year 5 (September 2008 to August 2009). Prepared by the Lower Columbia River Estuary Partnership for the Bonneville Power Administration.
- Jones, K. L., J.C. Leary, J. L. Morace, K. McCarthy, C. A. Simenstad, J. L. Burke, T. D. Counihan, I. R. Waite, K.L. Sobocinski, A. B. Borde, L. L. Johnson, P.M. Chittaro, K. H. Macneale, O. P. Olson, K. Peck, S. Y. Sol, and G. M. Ylitalo. 2007. Lower Columbia River Ecosystem Monitoring Project Annual Report for Year 3b (September 1, 2006 to

August 31, 2007). Prepared by the Lower Columbia River Estuary Partnership for the Bonneville Power Administration.

- Klingeman, P.C. 1987. Environmental Assessment for Sturgeon Lake Restoration Project. Water Resources Research Institute. Oregon State University. Corvallis, Oregon.
- Leary, J.C., J. L. Morace, C. A. Simenstad, J. L. Burke, T. D. Counihan, J. R. Hatten, I. R. Waite, K. L. Sobocinski, J. Dietrich, F. Loge, B. Anulacion, J. Spromberg, M. Arkoosh, and L. L. Johnson. 2005. Lower Columbia River Ecosystem Monitoring Project Annual Report for Year 2 (September 2004 to August 2005). Prepared by the Lower Columbia River Estuary Partnership with funding from the Bonneville Power Administration.
- Leary, JC, Jennifer L. Morace, Charles A. Simenstad, Jennifer L. Burke, Timothy D. Counihan, James R. Hatten, Ian R. Waite, Kathryn L. Sobocinski, Joseph Dietrich, Julann Spromberg, Lyndal Johnson, Gina Ylitalo. 2006. Lower Columbia River Ecosystem Monitoring Project -- Annual Report for Year 3 (September 2005 to August 2006). Prepared by the Lower Columbia River Estuary Partnership with funding from the Bonneville Power Administration and the Lower Columbia River Estuary Partnership.
- Lower Columbia River Estuary Partnership (LCREP). 2007. Lower Columbia River Estuary ecosystem monitoring: water quality and salmon sampling report. Prepared by the Lower Columbia River Estuary Partnership, Portland, OR.
- Lower Columbia River Estuary Partnership (LCREP). 2004. Columbia River estuary habitat monitoring plan: Portland, OR, prepared by the Lower Columbia River Estuary Partnership with funding from the Bonneville Power Administration and technical support from the Pacific Northwest National Laboratory, the University of Washington, and the U.S. Geological Survey.
- Munsell, David A. 1973. An archaeological survey of the Clark County Park at Vancouver Lake, Vancouver, Clark County, Washington. Clark County Parks and Recreation Commission.
- Northwest Hydraulic Consultants (nhc). 1998. Columbia River Ecosystem Restoration at Shillapoo Lake: Hydrologic and Hydraulic Analysis'. nhc, Inc.
- Poirier J., R. Horal, R. Sollee, S. Gainer, S. Lohr and T.A. Whitesel. 2006. Lower Columbia River Channel Improvement: Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands. 2005 Project Report.
- Poirier J., S. Lohr, T.A. Whitesel, and J. Johnson. 2009. Assessment of Fishes, Habitats, and Fish Passage at Tide gates on Deer Island Slough and lower Tide Creek. Project Report.

- Poirier J., J. Johnson, J. Jolley, G. Silver, M. Hudson, S. Lohr, and T. A. Whitesel. 2010. Presence, distribution and movement of select aquatic species in tide Creek, Merrill Creek and Deer Island Slough, Columbia County, Oregon. 2009 Progress Report.
- Richter, A., and S.A. Kolmes. 2005. Maximum temperature limits for Chinook, Coho, and Chum salmon, and steelhead trout in the Pacific Northwest. *Reviews in Fisheries Science*. 13:23-49.
- Roulette, Bill R., M.A., RPA, and Becker, Thomas E., M.A., RPA. 2011. Shillapoo Wildlife Area Historic Properties Management Plan Phase 1: Literature Review and Assessment, Clark County, Washington.. 12/12/2011.
- Sommer, T. R., W. C. Harrell, and M. L. Nobriga. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. *North American Journal of Fisheries Management* 25:1493–1504.
- Schroeder, R. L. (1996). "Wildlife community habitat evaluation using a modified species-area relationship," Technical Report WRP-DE-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A314 513.
- Shafer, D. J., and Yozzo, D. J. (1998). "National Guidebook for Application of Hydrogeomorphic Assessment of Tidal Fringe Wetlands," Technical Report WRP-DE-16, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Thom, R.M., R. Zeigler, A.B. Borde. 2002. Floristic development patterns in a restored Elk River estuarine marsh, Grays River, Washington. *Restoration Ecology* 10(3):487-496.
- Thom, R.M., A.B. Borde, N.R. Evans, C.W. May, G.E. Johnson, J.A. Ward. 2004. A Conceptual Model for the Lower Columbia River Estuary Prepared by Pacific Northwest National Laboratory for the U.S. Army Corps of Engineers, Portland District.
- Uber, A. and S. Vigg. 2011. Shillapoo Floodplain – Habitat Restoration Scoping Report. Prepared for Bonneville Power Administration, Contract #49040. Prepared by Washington Department of Fish & Wildlife, Vancouver, Washington. 37 pages.
- Ward, D.L., and T.A. Rien. 1992. Relative Abundance of Juvenile Salmonids in Sturgeon Lake Before and After Completion of the dairy Creek Bypass Channel. Information Reports Number 92-4. (Fish) Oregon Department of Fish and Wildlife Portland.
- Weitkamp, L.A. 1994. A review of the effects of dams on the Columbia River estuarine environment, with special reference to salmonids.

## Attachment 1. Vancouver Lake -- Annotated Bibliography (Source StreamNet).

Scheduled for Digitization

Available in digital format

### ***Books and Technical Reports:***

\_\_\_\_\_. 197?. Combined technical report—water quantity and quality studies of Vancouver Lake, Washington.

\_\_\_\_\_. 1984?. Vancouver Lake maintenance and operations handbook and project summary. Vancouver, WA: Port of Vancouver.

[<http://www.fishlib.org/bibliographies/vlwp/documents/summarymo.html>]

With the completion of the flushing channel and dredging of the lake, the restoration project moved into the maintenance of the conditions of the lake. This handbook is designed to provide guidance to the Port of Vancouver on future maintenance and operations of the flushing channel and provides timelines for future dredging requirements.

AGI Technologies. 1999. Geotechnical soils evaluation: Vancouver Lake lowlands, Vancouver, Washington. Vancouver, WA: Port of Vancouver.

[<http://www.fishlib.org/bibliographies/vlwp/documents/agi1999.html>]

While the title suggests the entire lowlands, the report is about a specific 80 acre parcel on the southeastern shore of Vancouver Lake. The area was used as a dredge spoil site that the Parks and Recreation Department would like to excavate to restore wetlands.

Addy, C. 1991. 1990 annual water quality report for Burnt Bridge Creek—Clark County, Washington: draft report.

Ames, K.C., D.B. Hawkins. 1997. Statistical analysis and areal trends of background concentrations of metals in soils of Clark County, Washington. U.S. Geological Survey (Water-resources investigations report 96-4252).

Arvid Grant & Associates. 1976. Clark County-wide water supply development program: project status review. Vancouver, WA: Regional Planning Council of Clark County.

Arvid Grant & Associates. 1977. Clark County-wide water supply development plan: phases I and II: final report. Vancouver, WA: Regional Planning Council of Clark County.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/arvid1977.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/arvid1977.html)

“Comprehensive documentation of the significant groundwater systems in Clark County and their responses to given sets of projected recharge and discharge conditions.” The data is based on differential equations which are figured using information from Clark County’s hydrologic character.

Beecher, H. & C. Dugger. 1991. Salmon Creek (Clark County) Instream flow report, technical memorandum to K. Sinclair and B. Caldwell, Dept. of Wildlife, Dec. 16.

Beeman, O. & G. Hartman. 1980. Dredge planning for lake reclamation: a case study. Vancouver, BC, Canada: Ninth World Dredging Conference.

Beeson, M.H., T.L. Tolan. 1987. *Columbia River Gorge—the geologic evolution of the Columbia River in northwestern Oregon and southwestern Washington*. IN Hill, M.L. ed. Cordilleran section of the Geological Society of American: Geological Society of American DNAG Centennial Field Guide 1, p.321-326. [Not digitized due to copyright restrictions]

Beeson, M.H., T.L. Tolan, I.P. Madin. 1991. Geologic map of the Portland quadrangle, Multnomah and Washington Counties, Oregon and Clark County, Washington. Olympia, WA: Oregon Dept. of Geology and Mineral Industries. (GMS-75).

Bhagat, S.K. & W.H. Funk. 1968. Hydroclimatic studies of Vancouver Lake. Pullman, WA: Washington State University, Technical Extension Service. (WSU College of Engineering. Research Division. (Bulletin 301). [\[http://www.fishlib.org/bibliographies/vlwp/documents/bhagat1968.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/bhagat1968.html)

“The study reported on in this publication deals with the problems of water pollution. Since the development plan of the area includes recreation as a significant use of the system, provision and maintenance of good water quality is essential for healthy recreational activity and as such is an important consideration in the overall planning of the area.”

Bhagat, S.K., J.F. Orsborn. 1971. Summary report on water quantity and quality studies of Vancouver Lake, Washington. Pullman, WA: WSU college of Engineering Research Division.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/bhagat1971.html>]

Background and history of Vancouver Lake followed by a summary of the various studies performed by the faculty at Washington State University at the request of the Port of Vancouver to establish conditions in Vancouver Lake.

Bhagat, S.K., W.H. Funk, D.L. Johnstone. 1972. Correlated studies of Vancouver Lake-water quality prediction study. Washington, D.C.: U.S. EPA.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/correlatedwq.html>]

As part of the larger study by faculty at Washington State University, the Water Quality Prediction Study was designed to show how the lake would be affected by proposed changes as well as to establish a baseline for future monitoring after completion of the rehabilitation projects.

Bonneville Power Administration. 1995. Vancouver lowlands Columbia River wildlife mitigation project: preliminary environmental assessment and management plan. Portland, OR: BPA. (DOE/EA-0964) [<http://www.fishlib.org/bibliographies/vlwp/documents/bpa1995ea.html>]

Bonneville Power Administration proposes acquiring land and operating wildlife preserves as mitigation for the effects of construction of Bonneville and The Dalles Dams.

Bonneville Power Administration. 1996. For Your Involvement (FYI): Vancouver lowlands Columbia River wildlife mitigation project (March & June). Portland, OR: BPA.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/bpa1996fyi.html>]

Public information documents to inform the citizens of Vancouver, and especially those most directly affected in the lowlands, about the intentions of the BPA and Washington Dept. of Fish and Wildlife to develop and improve wildlife habitat in the region.

Bortleson, G.C. N.P. Dion, and J.B. McConnell. 1976. Reconnaissance data on lakes in Washington, v.4, Clark, Grays Harbor, Lewis, Pacific, Skamania, and Thurston counties. Olympia, WA: Washington State Dept. of Ecology. (Water-supply bulletin 43, v.4)

Bottman, B. to S. O'Brien. 1977. Metals and pesticide levels found in fish taken from Vancouver Lake [memo; May 19]. Olympia, WA: Washington Dept. of Ecology.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/bottman1977.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/bottman1977.html)

After the Pilot Dredge Study (Dames & Moore 1978a), the levels of metals and certain pesticides were at significant concentrations. A one time study was done to establish if these concentrations were affecting fish populations.

Buell, J.W. n.d. Anadromous salmonid fishery problems, possible solutions and other considerations relating to the proposed flushing channel for Lake Vancouver, Washington.

Burnt Bridge Creek Drainage Utility. 1982-1991. Annual water quality monitoring report for Burnt Bridge Creek. Vancouver, WA: Southwest Washington Health District Laboratory.

Burnt Bridge Creek Interim Management Board. 1979. Report. Vancouver, WA: the Board.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/bbcimb1979.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/bbcimb1979.html)

The City of Vancouver and Clark County governments agreed to jointly manage the Burnt Bridge Creek watershed. The Interim Management Board was created to help direct the plans until the 'Storm and Surface Water Utility' could be formalized.

Caldwell, B. (to G. Hanson). 1992. Salmon Creek Instream flow [letter; January 8]. Washington State Dept. of Ecology.

Caldwell, B. (to G. Hanson). 1992. Salmon Creek Instream flow mitigation [letter; December 29]. Olympia, WA: Washington State Dept. of Ecology.

Calkins, B.M. 1996. Evaluation of future habitat values and mitigation crediting within the BPA Vancouver Lowlands project area. Vancouver, WA: Washington Dept. of Wildlife.

Caromile, S.J., C.S. Jackson, W. Meyer. 2000. 1998 warmwater fish survey of Vancouver Lake, Clark County. Olympia, WA: Washington Dept. of Fish and Wildlife.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/caromile2000.html>]

Inventories the fish species found in the lake and discusses habitat requirements for each.

CH2M-Hill. 1974. Water quality management plan: technical report, WRIA 27 and 28, Clark, Cowlitz, and Skamania Counties, Washington. Bellevue, WA: CH2M-Hill.

CH2M-Hill. 1995. Salmon Creek wastewater treatment plant expansion program: final environmental impact statement: phase III expansion, phase IV expansion, ultimate buildout expansion(s). Vancouver, WA: Clark County Dept. of Public Works.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/ch2mhill1995.html>]

As the development in the Salmon Creek watershed has grown, the need for sanitary sewers has increased so that Salmon Creek will not experience the same problems as Burnt Bridge Creek with septic system leakage. The Salmon Creek Wastewater treatment plant needs to expand to meet this growing need for more capacity.

City of Vancouver (Wash.). 1994. Visions for the Vancouver urban area, growth management plan.

City of Vancouver (Wash.). 1997. Shoreline management master program. Vancouver, WA: the City.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/shoreline1997.html>]

This plan manages 'shorelines-of-the-state' which include "those portions of the Columbia River, Vancouver Lake, Lake River, Salmon Creek, Mill Creek, Burnt Bridge Creek (from I-205 to its mouth), and Glenwood (aka Curtin) Creek (south to approximately the alignment of 111<sup>th</sup> Street) within the stated boundaries. The Columbia River and Vancouver Lake are further classified as shorelines-of-statewide-significance owing to their size, flow rates, and importance to the state." All development within the shoreline jurisdiction areas is governed by this management plan.

City of Vancouver (Wash.), Parks and Recreation Dept. 1985. City of Vancouver parks and recreation master plan.

Clark County (Wash.). 1981b. Master program for shoreline management. Prepared by Clark County Citizen Advisory Committee for Shoreline Management with Clark County. Clark County Board of Commissioners.

Clark County (Wash.). 1994a. Clark County park, recreation, and open space plan. Vancouver, WA: the County.

Clark County (Wash.); Clark Public Utilities. 1997. Lakeshore & Salmon Creek watershed areas business plan. Vancouver, WA: the County; CPU.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/lsc1997bp.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/lsc1997bp.html)

An implementation plan for the Legacy—Salmon Creek Watershed Management Plan, this business plan is “to employ an ecosystem approach to achieve fishable and swimmable conditions in the Lakeshore and Salmon Creek watershed areas.”

Clark County (Wash.). 1994b. Clark County comprehensive growth management plan.

Clark County (Wash.), Parks and Recreation Dept. 1981a. Clark County comprehensive park and recreation plan. Vancouver, WA: the Dept.

Clark County (Wash.), Planning Dept. 1968. Vancouver Lake complex, staff analysis of the study completed by Stevens, Thompson, and Runyan. Vancouver, WA: the Dept.

Clark County (Wash.), Public Works Dept. 1984. Burnt Bridge Creek Drainage Basin flood control study: environmental impact statement. Vancouver, WA: the Dept.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/CCPW1984.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/CCPW1984.html)

Written as a supplement to the Burnt Bridge Creek Drainage Management Plan EIS, "This supplement will address only the recommended changes to the capital improvement program for flood control ..."

Clark County (Wash.), Public Works Dept. 1988. Burnt Bridge Creek basin progress report 1988. Vancouver, WA: the Dept.

[<http://www.fishlib.org/bibliographies/vlwp/documents/bbcbpr1988.html>]

Updates the various activities mandated by previous reports and outlines future actions to develop more plans.

Clark County (Wash.), Public Works Dept. 2004. Clark County stream health. Vancouver, WA: Clean Water program.

Clark County (Wash.), Water Quality Division. 1995. Burnt Bridge Creek watershed plan: Clark County watershed protection program. Vancouver, WA: the Division.

[<http://www.fishlib.org/bibliographies/vlwp/documents/bbc1995wp.html>]

Blamed for pollution levels in Vancouver Lake, Burnt Bridge Creek has been studied and plans written to lower pollution levels draining into the lake. Clean up and protection plans are outlined to improve water quality and control flooding.

Clark County (Wash.), Water Resources Division. 1997. Lakeshore & Salmon Creek watershed areas plan: Clark County watershed protection program. Vancouver, WA: the Division.

[<http://www.fishlib.org/bibliographies/vlwp/documents/lsc1997wp.html>]

"The overall watershed program goal is to prevent localized flooding, minimize streambank erosion and protect water resources at a minimal monetary cost to the local community."

Education and outreach to the public is a primary part of the plan. The County also hopes to accomplish the goals of the plan with minimal costs to the public.

Clark County Ground Water Advisory Committee. 1992. Ground Water management plan: executive summary. Vancouver, WA: Clark County Dept. of Community Development, Water Quality Division. [<http://www.fishlib.org/bibliographies/vlwp/documents/groundwater1992.html>]

Primary water supplies in Clark County are from ground water. Protecting this resource requires plans for preventing pollution from entering the aquifers. There are several toxic sites that affect aquifers in Clark County, and these are closely monitored. Groundwater recharge is from rainfall and the Columbia River which also serves as outfall.

Clark County-Vancouver Regional Planning Commission. 1960. Inventory of water and sewer (Utilities inventory of southwest Clark County). Vancouver, WA: the Commission.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/ccvrpc1960.html>]

Preliminary discussion of municipal water supplies and how the aquifers are currently being used. The second part discusses the sanitary sewer systems and how they are necessary to help protect the municipal water supplies from contamination.

Clark County-Vancouver Regional Planning Commission. 1961. An inventory of parks in Southwest Clark County, Washington. Vancouver, WA: the Commission.

Clark County-Vancouver Regional Planning Commission. 1962. Tomorrow's neighborhood and community park needs: a dialogue and a proposed plan with supporting evidence. Vancouver, WA: the Commission.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/ccvrpc1962.html>]

"In recognition of the problem of standards for future parks and recreation the Portland Metropolitan Planning Commission set up a technical advisory committee of local specialists in the fields of recreation and planning. The pages immediately following summarize the recommendations of that committee with respect to neighborhood and community parks, and illustrate future recreation area needs in the urban part of Clark County based on alternative standards or levels of service. Available figures are also presented for a comparison of present park and recreation acreages in selected Washington and Oregon cities."

Clark County-Vancouver Regional Planning Commission. 1963. A planning report on the Columbia River lowlands stretching between Vancouver and the Lewis River. Vancouver, WA: the Commission.

Clark/Vancouver Television. 2004. Burnt Bridge Creek greenway restoration celebration [VIDEO]. Vancouver, WA: CVTV.

Cogentrix Energy, Inc. 1995. Final environmental impact statement River Road generating project.  
Vancouver, WA: Public Utility District #1 of Clark County.

[<http://www.fishlib.org/bibliographies/vlwp/documents/riverroad1995.html>]

The River Road Generating Plant is built in the Vancouver lowlands. The EIS found no significant impacts from the construction and operation of the plant. While the plant may have no further impacts on the environment, the area around the plant was already highly disturbed by human activities.

Collins, C.A. & T.A. Broad. 1993. Estimated average annual ground-water pumpage in the Portland Basin, Oregon and Washington 1987-88. Portland, OR: U.S. Geological Survey. (Report 91-4018).

Cooper & Associates. 1980. Report to Port of Vancouver on cultural resources affected by the Vancouver Lake rehabilitation project, Clark County, Washington. Portland, OR: Cooper & Assoc.

[<http://www.fishlib.org/bibliographies/vlwp/documents/cooper1980.html>]

"The scope of the research to date has included: resurveying of selected areas, reconnaissance of areas not previously surveyed, synthesizing site specific information from previous surveys, eligibility, determining direct and indirect effects, developing possible mitigative measures, integrating archaeological data and research needs into the project design, developing an initial framework for a 'life of the project' cultural resource management plan as a possible mitigative combination alternative. Future work needed for compliance with cultural resource law will be discussed within a phased framework."

Cooper & Associates. 1981a. Vancouver Lake restoration project: progress report #1-7. Vancouver, WA: Port of Vancouver.

[<http://www.fishlib.org/bibliographies/vlwp/documents/progressreports.html>]

Monthly updates on the progress of the project to restore Vancouver Lake and create the flushing channel. Includes engineering reports, monthly costs, and updates for schedules.

Cooper & Associates. 1984a. Report for Vancouver Lake post-project water quality monitoring, October 1983-January 1984 [memo; Feb 7]. Vancouver, WA: Port of Vancouver.

[<http://www.fishlib.org/bibliographies/vlwp/documents/cooper1984memo.html>]

Quarterly report to summarize the water quality monitoring for the time period.

Cooper Consultants, Inc. 1983. Program description: Vancouver Lake post construction monitoring: draft. Vancouver, WA: Port of Vancouver.

[<http://www.fishlib.org/bibliographies/vlwp/documents/cooper1983.html>]

“The post construction monitoring program at Vancouver Lake is intended to determine and document the flushing, fishery, water quality and related effects of the lake restoration project. A small work element involving the establishment of wetland vegetation suitable for wildlife habitat is also included in the program.”

Cooper Consultants, Inc. 1985. Water quality effects of dredging and flushing at Vancouver Lake: draft report. Vancouver, WA: Port of Vancouver.

[<http://www.fishlib.org/bibliographies/vlwp/documents/cooper1985.html>]

Water quality monitoring during the restoration project was required to verify that required standards were being met during construction. “During construction, the monitoring program was expanded to attempt to assess the overall water quality changes in the lake subsequent to completion of dredging and operation of the flushing channel. This report details the findings of the expanded water quality monitoring program.”

Dames & Moore. 1977a. Master plan rehabilitation of Vancouver Lake, Vancouver, Washington. Seattle, WA: Dames & Moore.

[<http://www.fishlib.org/bibliographies/vlwp/documents/damesmaster1977.html>]

Developed as part of the 208 Water Quality Management Plan (*Regional Planning Council of Clark County, 1978a*), the Master Plan outlines in detail the steps to rehabilitate Vancouver Lake.

Dames & Moore. 1977b. Bathymetric survey map, Vancouver Lake, Vancouver, Washington. Vancouver, WA: Regional Planning Council of Clark County.

Dames & Moore. 1978a. Pilot dredge program—Vancouver Lake (and follow-up report of 3/10/78). Seattle, WA: Dames & Moore.

[<http://www.fishlib.org/bibliographies/vlwp/documents/damespilot1978.html>]

The rehabilitation of Vancouver Lake hinged on the dredging portion of the project. A pilot study was conducted to determine the best type of dredging as well as the effects dredging would have on the water quality of the lake. It was determined that water quality would be negatively affected during the dredging process, but quality would improve rapidly at the conclusion of dredging as the flushing channel and new hydraulics of the lake took over the system.

Dames & Moore. 1978b. Geotechnical investigation: proposed flushing channel, Vancouver, Washington. Vancouver, WA: Regional Planning Council of Clark County.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/dames1978b.html>]

Soil and groundwater conditions for the site of the flushing channel were evaluated to ascertain the appropriateness of the site and to determine any engineering requirements that might need to be changed due to variances in soil conditions or groundwater levels.

Dames & Moore. 1979a. Proposal: Vancouver Lake reclamation operations plan. Vancouver, WA: Port of Vancouver. [<http://www.fishlib.org/bibliographies/vlwp/documents/dames1979.html>]

Proposal written to begin work on the Operations Plan (Dames & Moore 1980). Outlines the conditions set forth by the Environmental Protection Agency in the Final Environmental Impact Statement as well as the conditions of the Port of Vancouver to accept the funding for the Clean Lakes Program grant applied for in 1976 (Port of Vancouver 1976).

Dames & Moore [to R.F. Gorini]. 1979b. Fisheries—Vancouver Lake operations plan [memo; July 12]. Vancouver, WA: Port of Vancouver.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/dames1979memo.html>]

Explains the concerns and addresses how these concerns will be mitigated during operation of the flushing channel into Vancouver Lake. The fisheries of concern include the now endangered Chinook salmon and other salmon species wandering into the lake through the flushing channel or Lake River.

Dames & Moore. 1980. Operations plan: Rehabilitation of Vancouver Lake. Seattle, WA: Dames & Moore. [<http://www.fishlib.org/bibliographies/vlwp/documents/dames1980.html>]

“The purpose of this operations plan is to provide specific criteria and recommendations for implementing the measures and actions presented in the 1977 Master Plan for the Rehabilitation of Vancouver Lake.”

Davis, T. 1983. Vancouver Lake post construction monitoring files: monthly summary report 5/1/83-5/31/83 [memo; 6/17]. Vancouver, WA: Cooper & Associates, Inc.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/memo19830617.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/memo19830617.html)

With completion of the flushing channel, other aspects of the Vancouver Lake Restoration Project as well as monitoring efforts to ensure the stability of the water quality are outlined with schedules for completion.

DeBoni & Associates. 1986a. Vancouver Lake lowlands land use plan analysis: a proposal. Vancouver, WA: DeBoni & Assoc.

DeBoni & Associates. 1986b. Questions and answers regarding the Clark County Planning Commission's recommendations for the Vancouver Lake lowlands. Vancouver, WA: Port of Vancouver, Alcoa.

DeBoni & Associates. 1986c. Vancouver Lake lowlands conservation and development plan. Vancouver, WA: Port of Vancouver, Aluminum Co. of America (Alcoa).

Dion, N.P., G.C. Bortleson, J.B. McConnell, J.K. Innes. 1976. Data on selected lakes in Washington: pt. 5. Olympia, WA: Washington Dept. of Ecology. (Water-supply bulletin 42, pt.5).

Ebbert, J.C., K.L. Payne. 1985. The quality of water in the principal aquifers of southwestern Washington. U.S. Geological Survey. (Water-resources investigations report 84-4093).

Eddy, P.A. 1971a. Geology and ground water resources in vicinity of the Columbia River and Interstate 5, Clark County, Washington, no.3. Olympia, WA: Washington Dept. of Ecology. (Technical Report 71-10).

Eddy, P.A. 1971b. Geology and ground water resources in vicinity of the Columbia River and Interstate 5, Clark County, Washington, no.2. Olympia, WA: Washington Dept. of Ecology. (Technical Report 71-9).

Eddy, P.A. 1971c. Geology and ground water resources in vicinity of the Columbia River and Interstate 5, Clark County, Washington, no.4. Olympia, WA: Washington Dept. of Ecology. (Technical Report 71-11).

EnviroData Solutions, Inc. 1998. Burnt Bridge Creek water quality data trend analysis. Vancouver, WA: City of Vancouver, Public Works.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/envirodata1998.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/envirodata1998.html)

Pulls together data that has been gathered since the early 1970's to summarize the conditions of the creek and provides recommendations for continued monitoring and further improvements in water quality.

Envirosphere Co. 1983-1985. Vancouver Lake fisheries catch data report for ... [1982-1984]. Bellevue, WA: Envirosphere.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/envirospherecatchdata.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/envirospherecatchdata.html)

Annual reports to analyze catch data for fisheries in Vancouver Lake. Each provides a summary of the species found in the lake according to the methods set out in the monitoring and evaluation program of the Vancouver Lake Restoration Project.

Envirosphere Co. [to Cooper Consultants, Inc.]. 1983-1984. Report for Vancouver Lake restoration fish sampling[memo]. Vancouver, WA: Port of Vancouver.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/envirospheresamplingmemo.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/envirospheresamplingmemo.html)

Quarterly report to summarize fish sampling data for the time period.

Envirosphere Co. 1986. Habitat inventory and evaluation of the Vancouver Lake/Columbia River lowlands for Port of Vancouver USA. Bellevue, WA: Envirosphere.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/envirosphere1986.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/envirosphere1986.html)

Written to provide a baseline for future planning and development in the lowlands.

Fies, T.T. 1971. Survey of some sloughs of the lower Columbia River. Salem, OR: Oregon State Game Commission.

Fishman Environmental Services, LLC. 2002. Vancouver Lake flushing channel phase 1 investigations: summary of results. Vancouver, WA: Port of Vancouver.

[<http://www.fishlib.org/bibliographies/vlwp/documents/fishman2002.html>]

Preliminary effort to determine current conditions of Vancouver Lake and to determine if there is enough data to establish answers to questions about salmonid habitat.

Gaddis, P. 1994a. Burnt Bridge Creek biological monitoring program: benthic invertebrates and water quality, 1991-1992.

Gaddis, P. 1994b. Burnt Bridge Creek—water quality monitoring report, 1991-1993. Vancouver, WA: Clark County Water Quality Division.

[<http://www.fishlib.org/bibliographies/vlwp/documents/gaddis1994>]

Continuously monitored, Burnt Bridge Creek water quality was report annually until 1990, then summarized for 1991 to 1993 in this report. Water quality continues to be poor in the creek which has adversely affected water quality in Vancouver Lake.

Gannett, M.W., R.R. Caldwell. 1998. Geologic framework of the Willamette Lowland aquifer system, Oregon and Washington. U.S. Geological Survey. (Professional Paper 1424-A).

Gorini, R.F. 1987. *Lake restoration by dredging*. IN Management of bottom sediments containing toxic substances: proceedings of the U.S./Japan experts meeting (13<sup>th</sup>) held in Baltimore, Maryland on 3-5 November 1987. [<http://www.fishlib.org/bibliographies/vlwp/documents/gorini1987.html>]

Summarizes the Vancouver Lake Restoration Project and specifically addresses the dredging portions of the plan. All aspects of the dredging process are described as well as the benefits derived from the contouring of the lake bottom.

Gorini, R.F. [to B.H. Hanke]. 1988. IRC grant request to monitor Vancouver Lake [memo; 3/24]. Vancouver, WA: Port of Vancouver.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/memo19880324.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/memo19880324.html)

Outlines the need for periodic monitoring of lake conditions and what maintenance might also be required to keep the lake above state water quality standards.

Graham, N. (to P. Hildebrandt). 1972. Scoping for water quality survey on Salmon and Burnt Bridge Creeks, Clark County, Washington [memo; 11/1].

[\[http://www.fishlib.org/bibliographies/vlwp/documents/memo19721101.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/memo19721101.html)

As primary tributaries in the Vancouver Lake watershed, Salmon Creek and Burnt Bridge Creek water quality significantly impacts the water quality in the lake. Determination of water quality in the creeks helps to understand the water quality dynamics of the lake.

Gray & Osborne. 1996. Water system comprehensive plan. Vancouver, WA: City of Vancouver Water Utility.

Griffin, W.C. F.A. Watkins, Jr., & H.A. Swenson. 1956. Water resources of the Portland, Oregon and Vancouver, Washington, Area. Washington, D.C.: U.S. Geological Survey. (Circular 372).

HDR Engineering, Inc. 2002. Salmon Creek limiting factor analysis. Portland, OR: U.S. Army Corps of Engineers ; Vancouver, WA: Clark Public Utilities.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/hdr2002.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/hdr2002.html)

Evaluates the Salmon Creek basin for biological and habitat constraints that limit salmonid survival in all freshwater life stages. Identifies those areas that most need improvement and makes recommendations to remedy those problems with the highest mortality.

Habitek Consortium. 1986. Vancouver Lake lowlands comprehensive plan review and revision. Vancouver, WA: Clark County Board of Commissioners, Clark County Planning Commission.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/habitek1986.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/habitek1986.html)

“to provide a major review and updating of the Clark County Comprehensive Plan affecting over 13,000 acres in the Vancouver Lake Lowlands area.” Proposes various changes to previous plans for the area as well as strategies for implementation.

Harvester & Willie. 1989. An adult and juvenile salmonids population estimate and habitat evaluation in the Salmon Creek Basin. Olympia, WA: Washington Dept. of Ecology.

Hibbs, C.H. & L. Ross. 1972. Archaeological reconnaissance of the southern shore of Vancouver Lake, Clark County, Washington. Vancouver, WA: National Park Service, Ft Vancouver National Historic Site. [<http://www.fishlib.org/bibliographies/vlwp/documents/hibbs1972.html>]

To perform a survey of the areas where levees were to be constructed along the southern shore of the lake. Several sites were found and a more extensive survey/inventory was scheduled.

Houghton, S.A. [to K. Robbins, D. Gorini]. 1979. Evaluation of potential salmonids losses at Vancouver Lake [memo; Oct 16]. Vancouver, WA: Port of Vancouver.

J.R. Carr & Associates. 1985. Ground water management and development plan. Prepared for Clark County Public Utility District.

[<http://www.fishlib.org/bibliographies/vlwp/documents/groundwater1992.html>]

Jeane, G.S. (to D. Burkhalter). 1973. Water quality survey of Burnt Bridge and Salmon Creeks, Clark County, Washington [memo; 2/1]. Olympia, WA: Washington State Dept. of Ecology.

[<http://www.fishlib.org/bibliographies/vlwp/documents/memo19730201.html>]

Salmon Creek and Burnt Bridge Creek sampled the two creeks to determine water quality. Aquatic insects richness and evenness were analyzed as well as basic water quality standards such as temperature, pH, turbidity, dissolved oxygen, and nutrients.

Kent, R.J. 1982. Cultural resources research design for the Vancouver Lake restoration project: a proposal for completion of cultural resource survey, data recovery, laboratory analysis, reports and curation. Portland, OR: Cooper & Assoc.

[<http://www.fishlib.org/bibliographies/vlwp/documents/kent1982.html>]

Proposal to continue the archaeological record on the Columbia River lowlands to help complete the record on settlement patterns in the lowlands and around Vancouver Lake. This project was proposed as a result of the discovery of significant sites in areas affected by the Vancouver Lake Restoration Project.

Kincheloe, J.W. [to D. Gorini]. 1977. Summary of the Fish and Wildlife Service's gill net survey in Vancouver Lake [memo; March 4]. Portland, OR: U.S. Fish and Wildlife Service.

Knutzen, J.A. & R.D. Cardwell. 1984. Fisheries monitoring program: Vancouver Lake restoration project (revised). Bellevue, WA: Envirosphere Co.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/knutzen1984.html>]

Reservations about the Vancouver Lake Restoration Project included concerns that the flushing channel might divert migrating salmonids into the lake which would affect their upstream migration as the flushing channel is designed as a one-way system. Resident fish would also be affected by the introduction of Columbia River water which was predicted to have a major affect on the lake's system. Monitoring and evaluation were proposed to ensure the survival of resident fish as well as the affects on migratory paths of salmonids.

Kranz, R.D. & B. MacWhinney, M.E. Boule, T. Miller. 1987. Wetland delineation, functional value assessment, and protection mechanisms on the Vancouver Lake lowlands (prepared for Clark County Planning Dept.). Seattle, WA: Shapiro & Assoc.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/shapiro1987.html>]

This study was written to provide better detail of the lowlands' wetland habitats and to further divide the various ecosystems found in the lowlands for more precise zoning for protection and development.

Lin, C., S.K. Bhagat, J.F. Orsborn. 1972. Simulation of water quality enhancement in a polluted lake: a case study of Vancouver Lake, Washington. Pullman, WA: WSU Engineering Extension Service. (WSU College of Engineering. Research Division. Bulletin 324).  
[<http://www.fishlib.org/bibliographies/vlwp/documents/lin1972.html>]

"This study emphasizes the analysis of flow regime and water quality conditions in the lake before and after the dredging of the lake, and the construction of the conduit are

accomplished.” The authors developed a mathematical model that can be applied to other lake systems using Vancouver Lake as a test case.

Lincoln, J.H. & R.F. Foster. Report on investigation of pollution in the lower Columbia River. Olympia, WA: Washington State Pollution Commission; Salem, OR: Oregon State Sanitary Authority.

Lower Columbia Fish Recovery Board. 2004. Lake River Tributaries (Lower Columbia Tributaries). Longview, WA: the Board.

[<http://www.lcfrb.gen.wa.us/2004%20Strategy/App%20IV%20WS/Lake%20River%20WS.pdf>]

Brief survey of the habitat available for salmonids in the Lake River watershed, including Salmon Creek and Vancouver Lake. Tables consist of fish distribution and habitat types.

Mabey, M.A., I.P. Madin and S.P. Palmer. 1994. Relative earthquake hazard map for the Vancouver, Washington, urban region. Olympia, WA: Washington Division of Geology & Earth Resources.

Manson, C.J. 1999. Bibliography and index of the geology of Clark County, Washington. Olympia, WA: Washington Dept. of Natural Resources, Div. of Geology and Earth Resources.

[<http://www.evergreen.edu/library/govdocs/pdf/wadnr/biblio/clark/08nov99.pdf>]

Bibliography of all geologic reports and maps for Clark County, includes information resources on ground water.

Matrix Management Group. 1985. Lowlands industrial area infrastructure conceptual engineering report. Prepared for the Port of Vancouver, Washington.

McFarland, W.D. & D.S. Morgan. 1996. Description of the ground-water flow system in the Portland Basin, Oregon and Washington. Portland, OR: U.S. Geological Survey. (Water-supply paper 2470-A).

McGinn, M. 2004. Cyanobacteria (blue-green algae) monitoring plan for Vancouver Lake. Vancouver, WA: City of Vancouver; Clark County.

[<http://www.fishlib.org/bibliographies/vlwp/documents/mcginn2004.html>]

Recent droughts have slowed the water turnover in Vancouver Lake and silting of the flushing channel has slowed the amount water washing in from the Columbia River. As a eutrophic (rich in nutrients) lake, Vancouver Lake easily supports algal blooms. In particular, blue-green algae can be toxic and sampling bi-weekly over the summer months can help the Clark County Health Dept. determine when the lake is unsafe for contact.

Meigs, G.R. [to D. Tilson, P. Gregory]. 1973. Supplemental questions relative to Vancouver Lake reclamation [memo; April 20]. Vancouver, WA: Stevens, Thompson & Runyan.

Miller, Karen. 1977. Wetland habitat evaluation: Vancouver Lake, Washington. Sacramento, CA: Jones & Stokes Assoc. [<http://www.fishlib.org/bibliographies/vlwp/documents/miller1977.html>]

"This report identifies and describes wetland and lowland wildlife habitats surrounding Vancouver Lake and estimates the value of these habitats to the dominant faunal species. An attempt is made to rank habitat types in order of their value to wildlife." Aquatic habitats are not evaluated or delineated.

Morgan, D.S. & W.D. McFarland. 1994. Numerical model analysis of the ground-water flow system in the Portland Basin, Oregon and Washington. U.S. Geological Survey. (Water-resources investigations report 92-4089).

Morgan, D.S. & W.D. McFarland. 1996. Simulation of the ground-water flow system in the Portland Basin, Oregon and Washington. Portland, OR: U.S. Geological Survey. (Water-supply paper 2470-B).

Mundorff, M.J. 1959. Geology and ground water resources of Clark County, Washington. Washington, D.C.: U.S. Geological Survey. [Unable to obtain complete copy of document; <http://www.fishlib.org/bibliographies/vlwp/documents/mundorff1959.html>]

Complete, technical descriptions of the geology, surface water and ground water resources of Clark County. Includes discussion of efficiency of wells for irrigation, municipal water supply, and industrial uses.

Mundorff, M.J. 1964. Geology and ground-water conditions of Clark County, Washington, with a description of a major alluvial aquifer along the Columbia River. Portland, OR: U.S. Geological Survey. (Water-supply paper 1600).

[\[http://www.fishlib.org/bibliographies/vlwp/documents/mundorff1964.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/mundorff1964.html)

Munsell, D.A. 1973. An archaeological survey of the Clark County Park at Vancouver Lake, Vancouver, Clark County, Washington. Vancouver, WA: Clark County Parks & Recreation Commission.

O'Brien, S. [to J. Watne]. 1979. Status and inter-relationships of 208 and related programs. Vancouver, WA: Clark County, Clean Water Program.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/obrien1979.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/obrien1979.html)

"A summary of the status of the 208 Program since its beginnings in 1975 as well as the status of other water programs that are closely related to the 208."

Oetting, R.A. & R. Minor. 1989. Cultural resource survey of the southeastern shoreline of Vancouver Lake, Clark County, Washington. Eugene, OR: Heritage Research Associates.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/oetting1989.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/oetting1989.html)

A survey to determine if any sites of historical significance were located in the construction site for a levee for an industrial development in the lowlands.

Ogden, Beeman & Associates. 1985. Appendix report on sedimentation and flushing system characteristics--Vancouver Lake reclamation project.

Orsborn, J.F. 1971a. Hydrographic study of Vancouver Lake. College of Engineering, Research Div., Washington State University.

Orsborn, J.F. 1971b. Hydrologic study of Vancouver Lake. College of Engineering, Research Div., Washington State University.

Orsborn, J.F. 1972. Correlated studies of Vancouver Lake-hydraulic model study. Washington D.C.: U.S. Environmental Protection Agency.

[<http://www.fishlib.org/bibliographies/vlwp/documents/correlatedhms.html>]

A model of the lake was constructed to predict how planned changes in the hydraulic structure of the lake would affect the system's environment. Other options for lake rehabilitation were also tested.

Pacific Groundwater Group (PGG). 1997. Salmon Creek basin monitoring and management implementation plan annual report 1996. Prepared for Clark Public Utilities, Vancouver, Washington.

Pacific Groundwater Group (PGG). 1999. Salmon Creek basin monitoring and management implementation plan annual report.

Pacific Groundwater Group (PGG). 2000. Salmon Creek basin monitoring and annual report 1999. Prepared for Clark Public Utilities, Vancouver, Washington.

Pacific Groundwater Group (PGG). 2002. Salmon Creek watershed assessment.

Pacific Northwest River Basins Commission. 1970. Water resources, Appendix V, Columbia-North Pacific Region comprehensive framework study, v.2, subregions 7-12. Vancouver, WA: PNRBC.

Parente, W.D. and J.G. Smith. 1981. Columbia River backwater study: phase two. Vancouver, WA: U.S. Fish & Wildlife Service, Fisheries Assistance Office.

PBS Engineering and Environmental. 2004. Quality assurance project plan: Burnt Bridge Creek water quality monitoring. Vancouver, WA: City of Vancouver, Surface Water Management.  
[<http://www.fishlib.org/bibliography/vlwp/documents/pbs2004.html>]

This monitoring plan is limited to just the area between NE 18<sup>th</sup> St and I-205.

Perron Partnership. 1973. Vancouver Lake Park, a master plan study prepared for Clark County Parks and Recreation Dept. Olympia, WA: Arvid Grant & Associates.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/perron1973.html>]

“to formulate a development program that will be: responsive to recreation user needs, feasible and appropriate for the park site, and cognizant of the opportunities and limitations presented by anticipated future developments for the lake and the surrounding lowland basin.”

Petersen, R.R. & L. Carter. 1977. Water quality assessment: Vancouver Lake, Lake River, Burnt Bridge Creek, Columbia River. Prepared for Wilsey & Ham.

Phillips, W.M. 1987 (rev.). Geologic map of the Vancouver quadrangle, Washington and Oregon. Olympia, WA: Washington Div. of Geology and Earth Resources. (Open-file report 87-10). 1:100,000 scale map. Includes descriptions of geochemical data, sedimentary deposits, and elevations.

Port of Vancouver. n.d. Proposed Columbia River lowlands/Vancouver Lake FAIR study: flood control, agriculture, industry, recreation. Vancouver, WA: the Port.

Port of Vancouver. 1965a. Columbia River lowlands/Vancouver Lake: outdoor recreation and open space plan. [F.A.I.R. Study].

Port of Vancouver. 1965b. Columbia River lowlands/Vancouver Lake F.A.I.R. study (flood, agriculture, industry, recreation).

Port of Vancouver. 1971?. Time to plan [FILM].

Port of Vancouver. 1973a. Status report on the Vancouver Lake area project. Vancouver, WA: the Port.

Port of Vancouver. 1973b. Rebirth of a Lake [FILM].

Port of Vancouver. 1976. Vancouver Lake reclamation [EPA grant application]. Vancouver, WA: the Port.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/pov1976.html>]

Grant application for the Clean Lakes Program for the Environmental Protection Agency to assist with the massive rehabilitation effort to restore acceptable water quality to Vancouver Lake and its tributaries.

Port of Vancouver. 1979a?. Outline summary: the Vancouver Lake reclamation program. Vancouver, WA: the Port. [<http://www.fishlib.org/bibliographies/vlwp/documents/pov1979a.html>]

Outlines the background and history as well as funding and grant application status for the reclamation program. Discusses the requirements to continue with the grants from EPA and WDOE. Attached is an outline of the Operations Plan (Dames & Moore 1980).

Port of Vancouver. 1979b?. Operations plan [summary]. Vancouver, WA: the Port.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/pov1979b.html>]

Summary of the Operations Plan (Dames & Moore 1980). Includes comments, contribution analysis, and implementation recommendations for the project.

Port of Vancouver. 1985?. Vancouver Lake. Vancouver, WA: the Port.

Port of Vancouver. 1986. Vancouver Lake reclamation project. Vancouver, WA: the Port.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/pov1986.html>]

Summary of the efforts of the Port to restore Vancouver Lake, most likely a press release on the project.

Port of Vancouver?. 1988?. Development of a proposal to reassess the status of Vancouver Lake restoration 205(j) concept paper. Vancouver, WA: the Port.

[<http://www.fishlib.org/bibliographies/vlwp/documents/pov1988concept.html>]

Even after the extensive rehabilitation project in the early 1980's, the lake remains on the lower side of the water quality scale. This paper is a proposal to develop a new project to reassess the conditions of the lake and create a new baseline to proceed with restoring water quality.

R2 Resource Consultants, Inc. 2004. Kalama, Washougal and Lewis River habitat assessments: chapter 5, the Salmon Creek basin. Longview, WA: Lower Columbia Fish Recovery Board.

[[http://www.lcfrb.gen.wa.us/Watershed%20Assessments%20Report%20Chps/LCFRB\\_Chapter5\\_SalmonBasin\\_FINAL\\_12.31.04.PDF](http://www.lcfrb.gen.wa.us/Watershed%20Assessments%20Report%20Chps/LCFRB_Chapter5_SalmonBasin_FINAL_12.31.04.PDF)]

This assessment was written in order to provide better detail for the Subbasin planning process as outlined by the Northwest Power and Conservation Council.

Raymond, R.B. & F.C. Cooper. 1983a. *Vancouver Lake: pre-restoration status and restoration progress report*. IN Lake Restoration, Protection & Management, Taggart, J. & Moore, L. (eds.)

[<http://www.fishlib.org/bibliographies/vlwp/documents/raymond1983a.html>]

Summarizes the conditions of the lake and how progress in the restoration process has affected water quality in the lake. Also discusses briefly how improved water quality affects recreational uses of the lake.

Raymond, R.B. & F.C. Cooper. 1983b. *Vancouver Lake: dredge material disposal and return flow management in a large lake dredging project*. IN Lake and Reservoir Management, Proceedings of the Third Annual Conference. Knoxville, TN: North American Lake Management Society, October 18-20, 1983, p.580-585.

[<http://www.fishlib.org/bibliographies/vlwp/documents/raymond1983b.html>]

Provides specific details about the environmental aspects of dredging the lake as well as specifics about how to handle dredging in a large shallow lake.

Regional Planning Council of Clark County. 1970. Environmental design sketch plan. Vancouver, WA: the Council. [<http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1970.html>]

Meant to create dialogue in the community about protecting the environment and developing plans to preserve natural resources.

Regional Planning Council of Clark County. 1973. Parks and recreation element of the comprehensive plan. Vancouver, WA: the Council.

Regional Planning Council of Clark County. 1974a. Vancouver land use inventory. Vancouver, WA: the Council. [<http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1974a.html>]

Documents existing land use patterns in the city limits of Vancouver (at the time) and the environmental impacts of those patterns. This inventory is part of the data gathering stage to develop an informed growth management plan.

Regional Planning Council of Clark County. 1974b. Clark County land use inventory. Vancouver, WA: the Council. [<http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1974b.html>]

Documents existing land use patterns in the unincorporated county and the environmental impacts of those patterns. This inventory is part of the data gathering stage to develop an informed growth management plan.

Regional Planning Council of Clark County. 1974c. Vancouver Lake task force report: a recommended land use concept and policies. INCLUDES Subsurface investigations. Vancouver, WA: the Council. [<http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1974c.html>]

The Task Force recommended multiple land uses. The area was divided into zones so each area could be considered with the best data for that land type rather than trying to make decisions for the entire lowlands areas as a whole.

Regional Planning Council of Clark County. 1975a. Final environmental impact statement Vancouver Lake Task Force report: recommended land use concept and policies. Vancouver, WA: the Council. [<http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1975a.html>]

"The anticipated action involves the eventual adoption of a recommended land use concept that would become an amendment to the County Comprehensive Plan. The land use concept

through the application of the goal, objectives and policies would provide a framework for rational land uses within the constraints of the lowlands natural environment.”

Regional Planning Council of Clark County. 1975b. Project control program, areawide waste treatment management planning (Section 208, Federal Water Pollution Control Act). Vancouver, WA: the Council.

Regional Planning Council of Clark County. 1975c. Burnt Bridge Creek drainage management study—preliminary master plan: phase one. Vancouver, WA: Kramer, Chin & Mayo-Water Resources Engineers, Inc.

Regional Planning Council of Clark County. 1976a. Burnt Bridge Creek drainage management study: water quality summary. Vancouver, WA: Kramer, Chin & Mayo-Water Resources Engineers, Inc. [<http://fishlib.org/bibliographies/vlwp/documents/kcm1976wq.html>]

Assesses the impacts of increased urbanization on Burnt Bridge Creek and evaluates future ramifications this urbanization on water quality in the creek and its tributaries.

Regional Planning Council of Clark County. 1976b. Burnt Bridge Creek drainage management study (alternative plans summary report (product I) including initial draft outline of final report (product K). Vancouver, WA: Kramer, Chin & Mayo-Water Resources Engineers, Inc. [<http://www.fishlib.org/bibliographies/vlwp/documents/kcm1976ap.html>]

Presents alternative plans for dealing with surface runoff in the Burnt Bridge Creek basin. Each of these plans includes contingencies for dealing with 100-year floods to prevent stream erosion.

Regional Planning Council of Clark County. 1976c. Computer simulation report, Task 6.4 (preliminary draft). Vancouver, WA: Kramer, Chin & Mayo-Water Resources Engineers, Inc.

Regional Planning Council of Clark County. 1976d. Burnt Bridge Creek drainage management study: review draft of recommended plan and appendix B water quality, summary report. Vancouver, WA: Regional Planning Council of Clark County.

Regional Planning Council of Clark County. 1977. Recommended plan: Clark County Clean Water Program, Burnt Bridge Creek element. Vancouver, WA: Kramer, Chin & Mayo, Inc.-Water Resources Engineers, Inc.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1977.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1977.html)

The primary objective of this plan is to achieve a 'steady state' for water quality in Burnt Bridge Creek. Further objectives hope to begin restoring water quality to meet federal and state standards for water quality in similarly classified streams.

Regional Planning Council of Clark County. 1978a. Water quality management plan [208 water quality management plan]. Vancouver, WA: the Council.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/208report.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/208report.html)

The plan covers the southern half of Clark County, including the Vancouver Lake watershed and the Washougal River watershed. The data shows that all water bodies in the study are impacted heavily by non-point source pollution. The plan would like aggressive action to repair the damage and prevent future pollution, but recognizes that monetary and practical considerations mean that pollution may only be reduced, not eliminated.

Regional Planning Council of Clark County. 1978b. Final environmental impact statement for Burnt Bridge Park, a residential-commercial development in Clark County, Washington. Wilson Design, Clark County Commissioners.

Regional Planning Council of Clark County. 1979. County comprehensive plan: final environmental impact statement. Vancouver, WA: the Council.

Regional Planning Council of Clark County. 1980a. Vancouver historic survey. Vancouver, WA: the Council.

Regional Planning Council of Clark County. 1980c. Salmon Creek Pollution Control Plan. Vancouver, WA: the Council. [\[http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1980c.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/rpccc1980c.html)

Part of the 208 planning process, the pollution control plan for Salmon Creek is an expansion of the Water Quality Management Plan (Regional Planning Council of Clark County 1978a) for this watershed.

Regional Planning Council of Clark County. 1981a. Comprehensive plan, city of Vancouver, Washington. Vancouver, WA: the Council.

Regional Planning Council of Clark County. 1981b. Clark County comprehensive plan [updated]. Vancouver, WA: the Council.

Regional Planning Council of Clark County. 1982. Clark County coordinated water system plan. Economic & Engineering Services, Inc.

Regional Planning Council of Clark County. 1983. Comprehensive plan. Vancouver, WA: the Council.

Regional Planning Council of Clark County. 1984a. Vancouver Lake lowlands industrial development plan: proposed scope of work and budget (prepared for the Port of Vancouver USA). Vancouver, WA: the Council.

Regional Planning Council of Clark County. 1984b. Vancouver Lake lowlands planning study [incomplete].

Robert E. Meyer Consultants, Inc. 1981. Salmon Creek Basin sewer master plan. Vancouver, WA: Clark County Board of Commissioners.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/meyer1981.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/meyer1981.html)

Plans for the next 20 years of growth in the northern portion of Clark County. "Without a master plan, sewerage facilities could be provided that would not allow for orderly development of residential and business properties in the basin without violating Federal and State requirements. Adverse environmental situations and/or health hazards could also result without a sewer master plan."

Robinson, Noble, & Carr, Inc. 1980. City of Vancouver ground-water source and use study. Vancouver, WA: RNC.

Rosholt, J.E. [to N. Smith]. 1974. Water quality of streams in Clark County [memo; Sept 4]. Vancouver, WA: Clark County Water Quality Division.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/rosholt1974.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/rosholt1974.html)

Part of the technical document required for the 208 management plan, this report summarizes surface water quality in Clark County.

Samadpour, M. & C. Addy. 1998. Burnt Bridge Creek microbial source tracking: identification of sources of microbial pollution in Burnt Bridge Creek watershed. Vancouver, WA: Burnt Bridge Creek Drainage Utility. [\[http://www.fishlib.org/bibliographies/vlwp/documents/samadpour1999.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/samadpour1999.html)

Microbial pollution of Burnt Bridge Creek can be traced to several sources, with at least one quarter of the load traced directly to human impacts. Septic systems account for the majority of E. coli found in the stream and can be eliminated by removing the systems and hooking buildings up to the sanitary sewer system.

Schnabel, J. 2004. Salmon Creek watershed: summer 2003 stream temperature. Vancouver, WA: Clark County Public Works, Water Resources Section.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/schnabel2004.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/schnabel2004.html)

Temperature data was collected and assessed to determine if stream temperatures exceeded Washington State water quality criteria as well as aquatic life, especially salmonid, requirements. The report also tested for correlations between riparian canopy, groundwater influences, and ponding and stream temperatures.

Scofield, D.H., J.D. Martin. 1997. Examples of groundwater/surface water interactions along lower Columbia River, Oregon/ Washington [abstract]. Association of Engineering Geologists, 40<sup>th</sup> Annual Meeting, program with abstracts, p. 146-147.

Shannon & Wilson, Inc. 1972. Subsurface investigation Vancouver Lake urban planning project, Port of Vancouver, Washington. Portland, OR: Stevens, Thompson & Runyan.

[<http://www.fishlib.org/bibliographies/vlwp/documents/shannonwilson1972a.html>]

“The investigation described in this report considers only the dredging of the Lake and spoil placement aspects of the overall project, with the understanding that recreational, agricultural and possibly industrial development would be desirable over the hydraulically placed dredge spoil.

Sheely, Terry W. 2002. Washington State fishing guide. 8th ed. Black Diamond, WA: TNScommunications.

Contains complete descriptions of water bodies throughout the state of Washington with information on fish species found within each.

Skolnick, A. 1979. Cultural resources investigation in the Vancouver Lake Project Area, Washington. Seattle, WA: U.S. Army Corps of Engineers.

[<http://www.fishlib.org/bibliographies/vlwp/documents/skolnick1979.html>]

“A total of fifty-eight prehistoric sites and fourteen historic sites were located, surveyed, inventoried and evaluated. In addition, the culture history of the area was thoroughly investigated.” The area was found to be seasonally occupied and an important area for Native American activities, especially along the shores of the Columbia River.

Snyder, D.T., D.S. Morgan, & T.S. McGrath. 1994. Estimation of ground-water recharge from precipitation, runoff into drywells, and on-site waste-disposal systems within the Portland Basin, Oregon and Washington. Portland, OR: U.S. Geological Survey. (Water-resources investigation report 92-4010).

Stevens & Thompson, Inc. 1965. Master plan sewerage study for Vancouver, Washington. Portland, OR: Stevens & Thompson.

Stevens, Thompson & Runyan. 1967a. Preliminary report: Vancouver Lake alternative land use development plans. Vancouver, WA: STR.

Stevens, Thompson & Runyan. 1967b. Vancouver Lake complex development plan: prepared for Port of Vancouver and Clark County-Vancouver Regional Planning Commission. Portland, OR: Stevens, Thompson & Runyan. [<http://www.fishlib.org/bibliographies/vlwp/documents/str1967.html>]

The area surrounding Vancouver Lake was studied and a plan developed to create a 'complex' of industrial, agricultural and recreational uses. The Regional Planning Commission appointed a steering committee to meet with the planning consultant. Industry was planned as the major use of the area with channels from the Columbia River to provide access to Vancouver Lake for shipping.

Stevens, Thompson & Runyan. 1970. Clark County sewerage and drainage master plan. Vancouver, WA: Regional Planning Council of Clark County. [<http://www.fishlib.org/bibliographies/vlwp/documents/str1970.html>]

"The primary objective of this study is to develop long range plans for sanitary sewerage and surface drainage in the study area and to coordinate existing and projected land use development plans with these considerations." The study concentrates on urbanized areas, which make up slightly less than one half of the county.

Stevens, Thompson & Runyan. 1973. Vancouver Lake reclamation: lake dredging and Columbia River channel. Vancouver, WA: Port of Vancouver. [<http://www.fishlib.org/bibliographies/vlwp/documents/pov1973.html>]

This study specifically looks at options for uses of the lake, location and possibilities for uses of the flushing channel, engineering and cost considerations for each of the alternatives. This study reached the decision over where the flushing channel would be located as well as disposition sites for dredge spoils.

Swanson, R.D., W.D. McFarland, J.B. Gonthier, & J.W. Wilkinson. 1993. A description of hydrogeologic units in the Portland Basin, Oregon and Washington. Portland, OR: U.S. Geological Survey. (Water-resources investigation report 90-4196).

Swanson, R.D. 1994. Growth management act critical recharge area designation for Clark County, Washington. Vancouver, WA: Clark County Dept. of Community Development, Water Quality Division.

Swanson, R.D. & C. McCarley. 1995. Southwest Clark County generalized water table altitude and depth to groundwater mapping.

Treasher, R.C. 1942a. Geologic history of the Portland area. Portland, OR: Oregon Dept. Geology & Mining Industry. (Short paper 7).

Treasher, R.C. 1942b. Geologic map of the Portland area. Portland, OR: Oregon Dept. Geology & Mining Industry. (Map 7).

Trimble, D.E. 1963. Geology of Portland, Oregon, and adjacent areas. Portland, OR: U.S. Geological Survey. (Bulletin 1119).

Turney, G.L. 1990. Quality of ground water in Clark County, Washington 1988. U.S. Geological Survey (Water-resources investigation report 90-4149).

U.S. Army Corps of Engineers, Portland District. 1958. Lake River, Washington: snagging. (lk-1-11).  
1"=2000'

U.S. Army Corps of Engineers, Portland District. 1968. Checkpoint 1 report: Vancouver Lake, Washington flood control and navigation study.

U.S. Army Corps of Engineers, Portland District. 1971. Vancouver Lake area, proposed improvements, flood protection [stereoplot from aerial photos: Apr/May/June 1971]

U.S. Army Corps of Engineers, Portland District. 1972a. Special flood hazard information: Burnt Bridge Creek in the vicinity of Vancouver, Washington. Portland, OR: the District.  
[<http://www.fishlib.org/bibliographies/vlwp/documents/usace1972a.html>]

Because of the heavy urban development in the Burnt Bridge Creek watershed, the County requested a report to show the 100-year flood plain to help plan for future land use. The report was meant to help prevent substantial losses in the event of flooding in the creek.

U.S. Army Corps of Engineers, Portland District. 1972b. Draft environmental impact statement-improvement of Vancouver Lake area, Washington for flood control.

U.S. Army Corps of Engineers, Portland District. 1972c. Transcript of public meeting on improvement of Vancouver Lake area in the interest of flood control held in the Rotunda Auditorium of the Ft Vancouver High School, Vancouver, Washington, 31 August 1972. Portland, OR: the District. [\[http://www.fishlib.org/bibliographies/vlwp/documents/usace1972c.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/usace1972c.html)

“This meeting tonight is not concerned whether a project should be authorized for Vancouver Lake area. It is concerned with the location and extent of the proposed flood protection works, area to be protected, and the impacts of those works on existing and future development of the area.”

U.S. Army Corps of Engineers, Portland District. 1972d. Improvement of Vancouver Lake area, Washington, for flood control. Portland, OR: the District.

U.S. Army Corps of Engineers, Portland District. 1976. Inventory of riparian habitats and associated wildlife along Columbia and Snake Rivers. V.IIA-B Lower Columbia River. Portland, OR: the District. [\[http://www.fishlib.org/bibliographies/vlwp/documents/usace1976.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/usace1976.html)

The Federal Hydroelectric projects on the Columbia and Snake Rivers proposed a change to a power peaking system rather than steady production to better include thermal electricity production. This study was undertaken to better understand how power peaking would affect fish and wildlife in various sections of the Columbia and Snake Rivers.

U.S. Army Corps of Engineers. Portland District. 1990. Vancouver Lake, Washington, flood control: interim feasibility report. Portland, OR: the District. [\[http://www.fishlib.org/bibliographies/vlwp/documents/usace1990.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/usace1990.html)

“The primary purpose of this study was to determine the feasibility of, and potential Federal interest in, developing flood control improvements for the protection of existing commercial,

industrial and agricultural areas and proposed (zoned) light industrial development lands which are located in the flood plain adjacent to Vancouver Lake, Washington.”

U.S. Coast and Geodetic Survey. 1946. Columbia River, Lake Vancouver, Washington sounding chart.

U.S. Dept. of Health, Education and Welfare. 1958. Action program to control pollution: lower Columbia River between Bonneville dam and Cathlamet, Washington. Portland, OR: USDHEW.

U.S. Environmental Protection Agency. 1977. Draft environmental impact statement for Vancouver Lake reclamation study, Port of Vancouver, Clark County, Washington. (with technical assistance by Wilsey and Ham). Seattle, WA: Region X, U.S. EPA.

U.S. Environmental Protection Agency. 1978. Final environmental impact statement for Vancouver Lake reclamation study, Port of Vancouver, Clark County, Washington.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/feisvlrs1978.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/feisvlrs1978.html)

Prepared in response to the 1976 grant application to have the Environmental Protection Agency fund the majority of the Vancouver Lake Rehabilitation Project. The FEIS includes the EPA’s conditions for approving funding through the Clean Lakes Program.

U.S. Environmental Protection Agency. 1979?. Notice of proposed approval action: Clark County areawide water quality management plan (208 approval). Seattle, WA: EPA, Region X.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/208npaa1979.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/208npaa1979.html)

Conditional approval of the 208 Water Quality Management Plan (*Regional Planning Council of Clark County, 1978a*). Conditions include the removal of septic systems in favor of sanitary sewer, and controls for urban runoff and agricultural wastes. The Vancouver Lake Rehabilitation Plan was also conditionally approved upon “resolution of the fishery problems associated with the diversion from the Columbia River into the lake.”

U.S. Federal Emergency Management Agency. 1981. Flood insurance study: City of Vancouver, Washington, Clark County. Washington, D.C.: FEMA.

U.S. Federal Emergency Management Agency. 1987. Flood insurance study: Clark County, Washington, unincorporated areas. (Revised). Washington, D.C.: FEMA.

U.S. Fish and Wildlife Service. 1975. National wetland inventory map: Vancouver, Wash.—Oreg. NW/4 Portland 15' quad.: N4537.5-W13327.5/7.5

U.S. Fish and Wildlife Service. 1978a. Planning aid letter on fish and wildlife associated with the Vancouver Lake flood control project. Prepared for Corps of Engineers, Portland District, Division of Ecological Services.

U.S. Fish and Wildlife Service. 1978b. Vancouver Lake reconnaissance report. Prepared in response to proposed Corps' Vancouver Lake Flood Control Project.

U.S. Fish and Wildlife Service. 1980. Columbia River backwater study. Vancouver, WA: USFWS.

U.S. Soil Conservation Service. 1979. Areawide resource maps: Clark County Washington. Vancouver, WA: Regional Planning Council of Clark County. [Not digitized due to size limitations of equipment]

Includes 13 maps for various aspects of Clark County, including recreation, vegetation, wildlife, land slopes, and geologic hazards. Most of these maps are in color.

University of Washington. Dept. of Anthropology. 1973? Archaeological survey of the Vancouver Lake—Lake River area, Clark County, Washington. Seattle, WA: Univ. of Wash., Dept. of Anthropology. [<http://www.fishlib.org/bibliographies/vlwp/documents/archvllr.html>]

As a result of a flood protection plan for the Columbia River lowlands around Vancouver Lake, the U.S. Army Corps of Engineers and University of Washington undertook this survey to provide an inventory and evaluation of archaeological resources in the project area.

Valley, D.R. 1976. An archaeological survey of the proposed dredge spoil locations for the pilot dredge program, Vancouver Lake, Vancouver, Washington. Vancouver, WA: Washington Archaeological

Research Center; Port of Vancouver.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/valley1976.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/valley1976.html)

While several sites were near the proposed dredge spoil sites for the pilot dredge program, no sites were directly affected by the program.

Van Arsdol, T. 2001. Habitek: planning showdown in the lowlands. Vancouver, WA: Port of Vancouver.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/vanarsdol2001.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/vanarsdol2001.html)

Summarizes the history and purpose of the HABITEK consortium which was charged with planning for the development of the Vancouver lowlands.

Walsh, T.J., M.A. Korosec, W.M. Phillips, R.L. Logan, H.W. Schasse. 1987. Geologic map of Washington—southwest quadrangle. Olympia, WA: Washington Division of Geology and Earth Resources. (GM-34).

Walters, H.A. 1971. Vancouver, Washington parks and recreation study.

Washington State Conservation Commission. 2001. Salmon and steelhead habitat limiting factors for water resources inventory area 28.

Washington State. Dept. of Ecology. 1972. Water resources of southwest Washington: the hydrology and natural environment technical appendix to the Southwest Washington River Basins Study (review draft). Olympia, WA: the Dept.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/wdoe1972.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/wdoe1972.html)

Only includes the portion of the report for the Water Resources of Salmon-Washougal area, WRIA 28.

Washington State. Dept. of Ecology. 1980. *Shoreline Management Act—streams and rivers, and lakes constituting shorelines of the state; designations of associated with shorelines of the state*. Washington Administrative Code Chapter 173-22 WAC.

Washington State. Dept. of Ecology. 1996. Salmon Creek basin water resources management plan. Prepared for Washington State DOE, Washington State Dept. of Health, Clark Public Utilities, Clark County.

Washington State Pollution Control Commission. 1958. Columbia River Study, 1956-1958, progress report: joint study. The Commission and Crown Zellerbach Corp.

Washington State University hydrographs. 1970. Strip charts from Vancouver Lake. Pullman, WA: WSU.

Wessen, G.C. 1983. Archaeological investigations at Vancouver Lake, Washington. Olympia, WA: Western Heritage; Cooper & Associates.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/westernheritage1983.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/westernheritage1983.html)

Another piece of the 1980's Vancouver Lake Restoration Project, the investigations were undertaken to record and interpret any cultural resources located within the project boundaries and dredge spoil sites.

White, A.C. & S.W. McKenzie. 1979. Benthic invertebrates, periphyton, and bottom material and their trace-metal concentrations in Salmon Creek basin, Clark County, Washington. Portland, OR: U.S. Geological Survey. (Open-file report 79-978).

Wildrick, L., T. Culhane, D. Davidson, and K. Sinclair. 1998. Watershed assessment, water resource inventory area 28, Salmon-Washougal. Washington State Dept. of Ecology (Open-file report 98-02).

Wille, S.A. 1990. Wetland resources of the Salmon Creek basin, Clark County, Washington. Olympia, WA: Washington State Dept. of Ecology; Vancouver, WA: Clark County Public Services.

[\[http://www.fishlib.org/bibliographies/vlwp/documents/wille1990.html\]](http://www.fishlib.org/bibliographies/vlwp/documents/wille1990.html)

Establishes "a baseline of known wetland resources within the basin, and thereby provide information necessary to develop and implement a comprehensive water quality management plan."

Wille, S.A. & R.B. Raymond. 1983. Water quality effects of the restoration of Vancouver Lake. Portland, OR: Cooper Consultants, Inc. (Presentation to the Pacific Northwest Pollution Control Association). [<http://www.fishlib.org/bibliographies/vlwp/documents/wille1983.html>]

Due to increased depth and perceived improvements in water quality, Vancouver Lake is being used more for recreational opportunities. Algal growth during the first few years after construction has definitely been much less than previous years.

Woodward, J.R. 1998. Burnt Bridge Creek water quality data trend analysis. Vancouver, WA: City of Vancouver Public Works.

Zenier & Jackson. 1964. Clark County sewerage and drainage survey: a report for the Clark County-Vancouver Regional Planning Commission, Vancouver, Washington on the feasibility of establishing a central authority for provision of sewerage facilities. Vancouver, WA: the Commission. [<http://www.fishlib.org/bibliographies/vlwp/documents/zenier1964.html>]

“The purpose of this study was to determine what practical, workable method of providing sewerage service to the greatest possible number of residents of the county was available. Further, a service area was to be determined and defined.” All this due to the increasing numbers of failing septic systems throughout the county.

### ***Journal Articles:***

\_\_\_\_\_. 1979. *Vancouver Lake restoration*. IN Waterline (Office of Ecology, Office of Water Programs), Nov 1979.

\_\_\_\_\_. 1987. *Lowlands plan adopted*. IN Business Magazine, Feb/Mar 1987.

\_\_\_\_\_. 1990. *1989 year-end recap: enhancing the community*. IN Portlines, Winter 1990, v.6, iss.1.

\_\_\_\_\_. 2002. *Clark Public Utilities honored for Salmon Creek restoration efforts*. IN Business Wire, 5/30/2002.

Dodge, Robert O. 1971. *Design of Columbia River pile dikes*. IN Journal of the Waterways, Harbors and Coastal Engineering, v.97, no.ww2, p. 323-340.

Hanke, B. 1986. *Vancouver Lake—then and now*. IN Business Magazine, Oct/Nov 1986

Hodge, E.T. 1938. *Geology of the lower Columbia River*. IN Geological Society of America Bulletin, v.49, p. 831-930.

Kienlen, T.W. 1981. *Waterway cleanup: Columbia River diversion will flush polluted lake*. IN Christian Science Monitor, 8/13/1981, v.73, p.8.

Koreny, J.S. & T.T. Fisk. 2000. *Hydraulic continuity of the Portland Basin deep aquifer system*. IN Environmental and Engineering Geoscience, v.6, no.3: 279-292. [Unable to obtain copyright permission for reproduction in digital archive]

Discusses the aquifers that are currently used for municipal water supplies by both Portland, Oregon and Vancouver, Washington. Also describes how the deep aquifers relate to the Columbia River paleo-channel and how this affects surface waters of the region.

Larsen, D.W. 1996. *Curing the incurable?* IN American Scientist, 1/96, v.84, iss.1

Messer, B. 1985. *Project HABITEK: looking to the future*. IN Business Magazine, Apr/May 1985.

Pettigrew, R. 1981. *A prehistoric culture sequence in the Portland Basin of the lower Columbia valley*. IN University of Oregon Anthropological Papers, no.22. Eugene, OR: University of Oregon.

Simpson, G. 1985. *A “new” park is discovered by Clark County residents*. IN Business Magazine, Apr/May 1985.

## **Websites:**

See listing of Links on website: <http://www.fishlib>