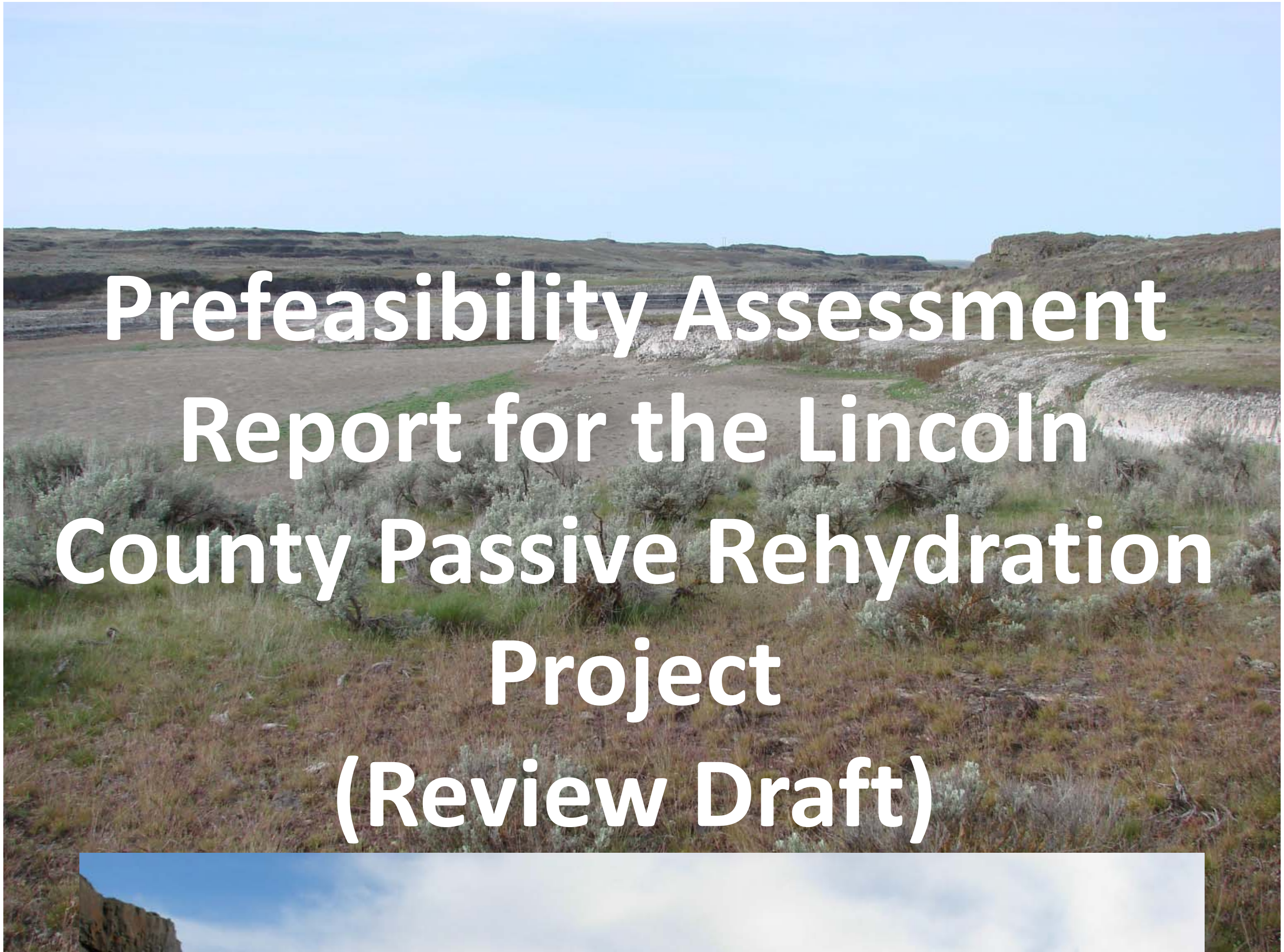
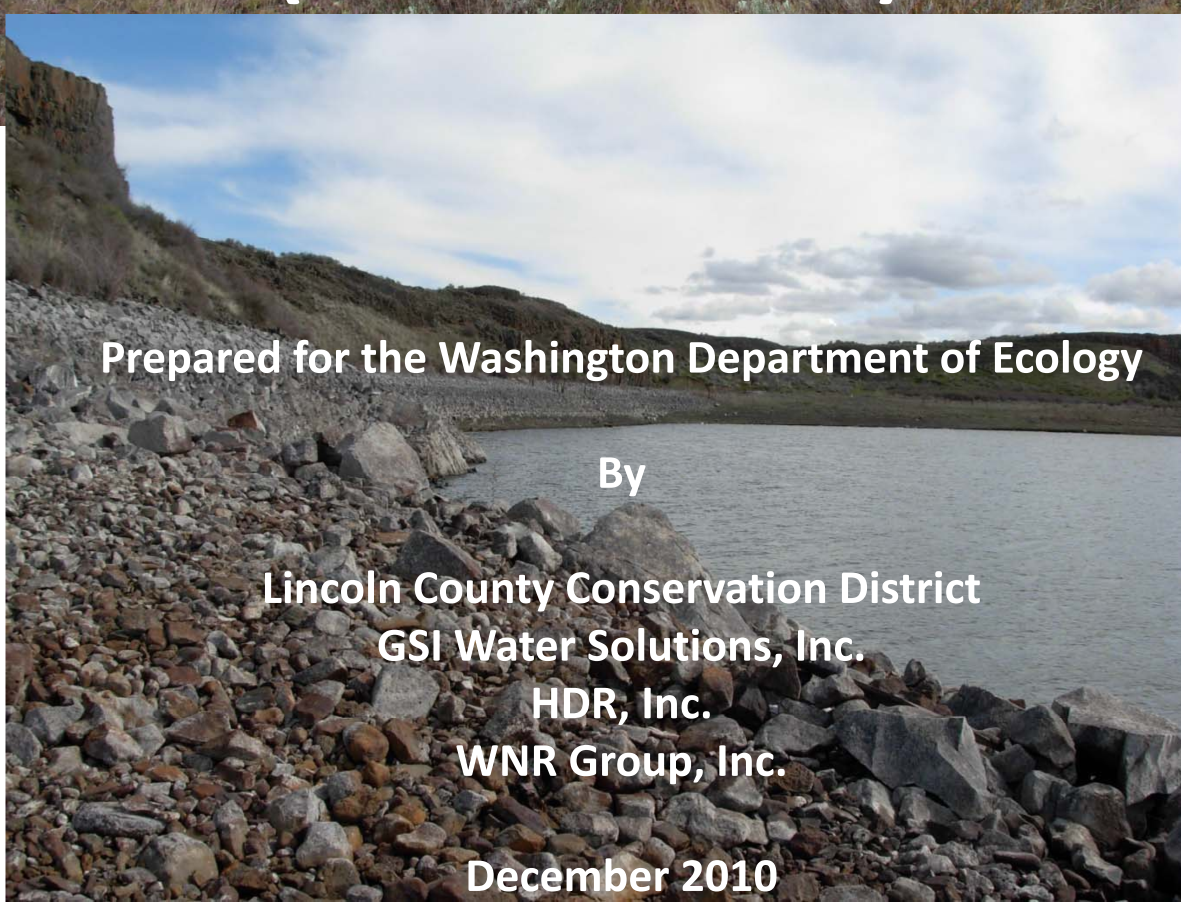


Prefeasibility Assessment Report for the Lincoln County Passive Rehydration Project (Review Draft)



Prepared for the Washington Department of Ecology

By

Lincoln County Conservation District
GSI Water Solutions, Inc.
HDR, Inc.
WNR Group, Inc.

December 2010

Prefeasibility Assessment Report for the Lincoln County Passive Rehydration Project (Review Draft)

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Washington Department of Ecology
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December 2010

Executive Summary

The objective of the Lincoln County Rehydration Project is to deliver water from Lake Roosevelt to the Crab Creek drainage (watershed) within Lincoln County. This report was commissioned by the Lincoln County Conservation District (LCCD) with funds from the Columbia River Basin Management Program to conduct a prefeasibility analysis of this project idea. Using available scientific information, preliminary field reconnaissance, very basic engineering assessments, review of potentially available water rights, interviews with landowners in and around the potentially affected area, and information provided by personnel from various federal and state agencies this prefeasibility assessment for the Lincoln County Conservation District Rehydration Project was done to determine if work should move forward into further defining the scope of a project, securing permits and authorizations to proceed, and planning and implementing a pilot scale project.

Based on the work reported on herein, it is our conclusion that: (1) the goals, objectives, and intent of RCW 90.90 could be met by the rehydration project envisioned by LCCD, (2) there are viable options for securing water rights to be used in supplying water for a proposed pilot scale project, and (3) one or more drainage routes seem to be amenable to a potential project. Coupled with these conclusions this Prefeasibility Study did not identify fatal flaws in the passive rehydration concept with respect to geology, hydrogeology, routing, delivery pathways, regulatory and permitting issues, land ownership, water rights, and environmental concerns that could influence project implementation. While many challenges were identified, none were found to be insurmountable. This Prefeasibility Assessment Report does not include a cost-benefit evaluation.

With respect to RCW 90.90 in which a one-third in-stream, two-thirds out of stream division of water is specified we have found that this may, or may not apply to the pilot study. In particular, it is unclear whether every project must comply exactly with the division of water, and it is not completely clear that instream flow benefits only apply to the mainstem of the Columbia River, or if they could also apply to tributaries such as Crab Creek. It is likely that only the total of all the projects funded under the law (or of a given combination of projects) needs to comply. Nevertheless, a brief description of how a Lincoln County Re-hydration pilot study might meet this requirement is provided in this section.

If this project proceeds water will be pumped out of Lake Roosevelt and delivered into one or more drainages in the Crab Creek watershed; initially in a pilot project and possibly in a larger, subsequent long-term project. This prefeasibility assessment identifies Lake Creek as the best drainage for continued evaluation. Water pumped out of Lake Roosevelt and released into Lake Creek would flow downstream, contributing to instream flows and likely producing gains to riparian habitat and water-based recreation. The extra water flowing down the targeted creek could be diverted for use by irrigation water users along the creek, or it could be allowed to continue flowing downstream to rehydrate the channel and lakes at the bottom of the basin. If allowed to flow undiverted to the confluence of Lake Creek with Crab Creek, a portion of the supplemental water would seep into the ground and, presumably, contribute to the overall groundwater supply in the area, which is currently over-allocated. If allowed to flow into Crab Creek, the water would continue down the stream and enter

Moses Lake and Potholes Reservoir, being incorporated into that water supply in the Columbia Basin Project. In addition, a portion of the water could potentially return, unconsumed, to the Columbia River via the lower Crab Creek drainage. It should be noted that both the water that seeps into the ground and any part of the supplemental water that is diverted would directly contribute to groundwater recharge in the Odessa Subarea and therefore meet the guidelines for RCW 90.90 part (2)(b) "alternatives to groundwater for agricultural users in the Odessa subarea aquifer".

In a review of potential water rights options that might be used for a pilot project: (1) a temporary use authorization, (2) municipal and industrial use water acquired from the BOR, (3) long-term water rights agreements with the BOR under their existing water rights, and (4) use of existing private water rights, and (5) a preliminary permit issued under a reservoir permit application suggests this later approach is the most feasible. A preliminary permit would provide authorization for the use of Lake Roosevelt water for a potential pilot project. If the project is authorized for moving forward into the feasibility phase, a reservoir permit application would be completed and submitted to Ecology at the completion of the feasibility phase if the feasibility work suggests a project is feasible. This application would name the responsible authority that will take on the planning, permitting, construction, and operation of the pilot project.

Governance and land owner issues will need to be addressed in the feasibility study. Governance, or ownership, of the pilot project and a potential subsequent long-term project is important from the point of view that some entity will be responsible for owning and operating the project, holding necessary water rights and permits that will be required for the project to function, and planning and reporting on project activities. While no specific entity has yet been identified for this role, the currently inactive Lincoln PUD and the Lincoln Water Conservancy Board have expressed conditional interest in at least exploring potential roles in the project. Once an ownership, or governance, entity is identified, land owner agreements, NEPA/SEPA, and other activities can be completed.

Various routes were assessed in the Crab Creek watershed, including, from east to west: Rock Creek, upper Crab Creek, Bluestem Creek, Coal Creek, Duck Creek, Lake Creek, Marline Hollow, Canniwai Creek, Sinking Creek, Goose Creek, and Wilson Creek. Basic observations relative to the potential suitability of these drainages for the project are as follows:

- The eastern three drainages (Rock, upper Crab, and Bluestem) were generally found to be poorly suited for the project because of distance from Lake Roosevelt, small channel size, and/or active farming on and immediately adjacent to the channel course. Given this though, Bluestem Creek might be suitable for the project, especially is used in conjunction with creeks to the west.
- The central streams (Coal, Duck, Lake, Marlin, and Canniwai) are tentatively identified as offering more potential opportunities for a project. Lake Creek is the highest ranked, and recommended for further evaluation, because of distance from Lake Roosevelt, well developed channel system, potential for aquifer recharge, and existing potential surface storage in the system. With that though, there are some land access issues that need to be addressed, including: (1) addressing private land owner concerns directed at riparian setbacks and flooding and (2) following permitting and access requirements on federal lands, including preparation of

an Environmental Impact Statement under NEPA. At this time our basic conclusion is that these are solvable issues, and given the potential for passive recharge and rehydration in the Lake Creek drainage and adjacent Marlin Hollow and Duck Creek, these drainages should be targeted for further evaluation in a feasibility study.

- The three western drainages (Sinking, Goose, and Wilson) are favorable from a distance and potential aquifer recharge perspective. However, the history of water use and water rights challenges in these drainages lead us to recommend that these drainages not be evaluated further at this time.

Based on the pipeline routing assessment, the proposed project should move forward with the feasibility analysis, and further review the preferred Lincoln Pipeline Route for delivering water into the Lake Creek drainage. This route is slightly longer than the others, but overall has a more open construction route and would require lower head pumps.

Given the history of stream flow losses and lake depletion in the lower half of the Lake Creek drainage, we conclude that the lower reaches of the creek are likely candidates for potential basalt aquifer recharge. At this time we speculate that shallow basalt aquifer recharge (that staying with 200 to 300 feet of the surface) likely will be mostly local, and at best result in spring discharge into Crab Creek at and downstream of Odessa. If on the otherhand, and as seems likely given the distribution of the Sentinel Bluffs Member of the Grande Ronde Basalt, recharged groundwater water can reach into this unit the project should recharge groundwater systems south of Crab Creek. This is simply because the creek does not incise deeply in the Sentinel Bluffs. If water can get deeper in to the unit it has the potential to move unimpeded beneath the creek and south into the core of the Odessa Subarea.

This prefeasibility assessment was funded by a grant awarded to Lincoln County Conversation District by the Department of Ecology Columbia River Basin Water Management Program. If the results of this prefeasibility assessment are accepted by Ecology, additional funds will be released for the next phase, a feasibility study.

Contents

1.0 INTRODUCTION

1.1 Background

Columbia Basin irrigators currently irrigate an average of 300,000 acres per year using groundwater. This, and other groundwater pumping, has resulted in groundwater levels in many wells declining several feet per year. Declining groundwater levels have been an issue in the central Columbia Basin for several decades, resulting in management programs such as the formation of the Odessa Sub-Area and as outlined in Chapter 173-128A WAC and 173-130A WAC. State and Federal entities have been actively seeking alternatives to mitigate the declining aquifers in the area. Due to the serious declines seen in aquifer storage, it is generally assumed that multiple options may be required to mitigate for these declines.

Although much attention has been directed at declining groundwater levels, a drastic decline in surface water also has occurred. A very prominent example is Pacific Lake (Figure 1), located a few miles north of the town of Odessa (Figure 2). This lake, and several others in the area that have gone dry, are located in coulees cut deep into the Wanapum Basalt and almost to the top of the Grande Ronde Basalt. Pacific Lake has historically seen recreational uses such as fishing, boating and water skiing. It is approximately 130 acres in area, ranges in depths up to 30 feet, and has an approximate static storage volume of 2,400 acre-feet of water (Ecology, 1973). In the mid 1980's Pacific Lake went dry and has only periodically held water since then. It is assumed that surface water declines seen since the early 1980's are coupled with the groundwater withdrawals and accompanying basalt aquifer system water level declines seen in the Columbia River Basalt (CRB) aquifer system to the south (down-dip and down-gradient) of Pacific Lake.

The entire CRB aquifer system covers over 64,000 square miles in the Pacific Northwest. Of immediate concern to this project is the several thousand square miles of the CRB aquifer system in Lincoln County, Grant County to the west, and Adams County to the south. Within this area, the general configuration of the CRB aquifer system suggests that at least some historical recharge areas for the Grande Ronde and Wanapum portions of the system are located in Lincoln County (GWMA, 2009a, 2009b, 2009c, 2009d). Also, within this area, groundwater flow is generally to the south and southwest towards the Odessa Subarea where large groundwater users are primarily withdrawing water from water-bearing zones the Grande Ronde. These aquifers are experiencing declining groundwater levels, indicative of withdrawal rates exceeding recharge to the aquifers.

Part of a proposed solution, as envisioned in this project, to these groundwater declines is to identify viable recharge areas for Wanapum and Grande Ronde portions of the CRB aquifer system and passively infiltrate water diverted from the Columbia River into these recharge areas. Water infiltrated into these parts of the CRB aquifer system will then migrate under natural conditions to down-gradient areas where a portion of this passively recharged groundwater could become available for recovery by groundwater users in portions of the Odessa sub-area. This project concept has wide local support due to known declining groundwater levels in the central Columbia Basin, including the Odessa sub-area. The proposed project comes from local organizations searching for potential options to mitigate for the likely impacts of groundwater pumping on groundwater and surface water while maintaining the local economy. If potential passive rehydration sites can be identified, and programs implemented, benefactors will range from local ecosystems to CRB aquifer system groundwater users.

1.2 The Rehydration Project

The Lincoln County Conservation District (LCCD), with support from the Columbia Basin GWMA, the WRIA 43 Water Resource Management Group, The Columbia Basin Development League, and the Lincoln, Grant, Franklin and Adams County Commissioners, submitted the Lincoln County Passive Rehydration Feasibility Study and Pilot Project (the Feasibility Study-Pilot Project) proposal to the Washington State Department of Ecology (Ecology) for consideration under the 2008 – 2009 grant funding cycle provided by the Columbia River Basin Water Management Program (CRBWMP). Funding for projects accepted by the CRBWMP is provided as specified in the Columbia River Water Supply Act (Chapter 90.90 RCW) passed by the Washington State Legislature in 2006. The project was proposed as part of the solution to mitigate for declining groundwater levels in the CRB aquifer system in Lincoln County and adjacent parts of Grant and Adams County's in the Odessa Subarea (Figure 3). LCCD is the lead agency for the proposed Feasibility Study-Pilot Project.

As originally proposed, the objective of the Feasibility Study-Pilot Project was to evaluate the possibility of diverting excess Columbia River water for stream rehydration and aquifer storage in the CRB aquifer system, and if feasible conduct a pilot scale demonstration project. The original proposal envisioned conveying Columbia River water into several drainages in the Crab Creek watershed to recharge to the CRB aquifer system, and the surface waters of Lincoln, Adams and Grant Counties. After replenishing the streams and lakes in the Crab Creek watershed, water left in stream from the Passive Rehydration project would flow to Moses Lake and become part of the Columbia Basin Project. Fully implemented, the proposed Feasibility Study-Pilot Project would rehydrate streams, provide basalt aquifer recharge, and replenish streams (Crab Creek) that flow into Moses Lake.

In late 2009 the CRBWMP awarded LCCD a Grant for the feasibility portion of the originally proposed Feasibility Study-Pilot Project. The Grant for the Feasibility Study divides that work into two phases, a Prefeasibility Assessment and a Feasibility Study. The Prefeasibility Assessment must address at a minimum several basic issues, including:

1. How the goals, objectives, and intent of the RCW 90.90 could be met by a potential surface water and groundwater rehydration project in Lincoln County.
2. A strategy for securing water rights for an initial, temporary pilot rehydration project and a subsequent full size, or long-term project.
3. What route or routes should be evaluated further in the second, or feasibility, phase of the project?

Coupled with addressing these goals, the Prefeasibility Assessment attempts to identify fatal flaws in the passive rehydration concept, assessing geology, hydrogeology, routing, delivery pathways, regulatory and permitting issues, and land ownership concerns that could influence project implementation. If no fatal flaws are found, the Prefeasibility Assessment will be followed by a work plan for the second phase of the project, a Feasibility Study tentatively scheduled for completion in late 2011/early 2012.

If this project progresses to the Feasibility Study, such a study would potentially: 1) identify one or more potentially viable areas into which Columbia River surface water can be conveyed and infiltrated into basalt interflows which are in direct hydraulic continuity with the basalt aquifers to the south in the Odessa subarea; 2) identify waters potentially available from the Columbia River (during the September though January high flows) and other potential water rights available for acquisition from February through August; 3) prepare a preliminary design of a pilot project, 4) prepare a preliminary cost-benefit analysis for proceeding with implementation of a passive rehydration project; and (5) present a Pilot Project plan.

1.3 The Prefeasibility Assessment Report

This document reports on the results of the Prefeasibility Assessment. It is subdivided into sections describing:

- Prefeasibility Assessment objectives.
- Study area physical setting, including geography, surface soils, surface hydrology, ecology, climate, and geology and hydrogeology.
- Water availability and governance, which includes water rights needed for a pilot project, compliance with RCW 90.90, and governance of a pilot or full scale project.
- An assessment of selected drainages, including surface hydrology and hydrogeology, routing, and other physical conditions as they may relate to the drainages that might be targeted for a pilot project.
- Conclusions and recommendations with respect to fatal flaws and a path forward, including if appropriate an outline of a Feasibility Study work plan.

The project team, lead by Lincoln County Conservation District (LCCD) as the grant recipient and grant manager, included:

- At LCCD, David Lundgren, LCCD grant manager and Elsa Coffman, technical support.
- Kevin Lindsey, LHg, Molly Reid, Jon Travis, Travis Hammond, John Porcello, and Terry Tolan of GSI Water Solutions, Inc. (GSI) working under contract to LCCD to provide hydrogeologic and geologic assessment, evaluate land ownership issues, manage the consulting team working on the project, and coordinate preparation of this report.
- Steve Thurin, P.E., Emily Flanagan, P.E., Brian Bartle, P.E., Rona Spellacy, AICP, and Aaron Meilleur, P.E. at HDR, Inc. worked under contract to GSI to evaluate RCW 90.90 issues, routing and infrastructure needs, surface water drainage and habitat issues, and governance required for a water project.
- Gene St. Godard of Water and Natural Resources Group, Inc. (WNR), also working under contract to GSI, how lead the public outreach effort, evaluated water rights issues, and provided general technical support.

GSI worked under contract to LCCD, dated 22 January 2010. HDR and WNR worked under subcontracts to GSI.

2.0 Prefeasibility Assessment Objectives

As noted previously, the objectives of the Prefeasibility Assessment are to address:

1. How the goals, objectives, and intent of the RCW 90.90 could be meet by a potential surface water and groundwater rehydration project in Lincoln County.
2. A strategy for securing water rights for an initial, temporary pilot rehydration project and a subsequent full size, or long-term project.
3. What route or routes should be evaluated further in the second, or feasibility, phase of the project?

Coupled with addressing these objectives, the Prefeasibility Assessment attempts to identify fatal flaws in the passive rehydration concept by assessing geology, hydrogeology, routing, delivery pathways, regulatory and permitting issues, and land ownership concerns that could influence project implementation. Many of these issues are physical in nature, ranging from infiltration capacity to stream size. Other issues are regulatory or societal in nature, ranging from what rules and regulations would govern a potential project to whether the community (landowners and their representatives) want the project. The assessments done for this Report do not include a cost-benefit evaluation.

The range of physical issues the Prefeasibility Assessment addresses includes: (1) geologic and hydrogeologic conditions that might influence it and (2) routing and delivery constraints, including channel conditions. For example, the geologic and hydrogeologic evaluation looks at available data and information to identify whether or not there was a reasonable potential for surface water to provide a recharge source for portions of the CRB aquifer system. Coupled with this, the Assessment attempted to identify streams that likely would be more or less suitable for aquifer recharge. For streams where recharge seems plausible, the Assessment made an initial, qualitative evaluation of the potential aquifer area influenced by such recharge. With respect to routing and delivery constraints the Assessment attempted to identify extreme physical conditions that in the project teams qualitative judgment argued against a specific route. Such judgments included such things as whether or not it seemed practical to establish a pump station and/or pipeline at a particular location because of physical access, what other types of infrastructure might be present along a particular water transportation route that might require extensive (or excessive) modification, and/or is any single drainage simply too small to accommodate stream flows that would provide viable recharge options.

Physical elements covered in the Prefeasibility Assessment were addressed using predominantly existing information, data, materials, and reports. A limited field reconnaissance was undertaken to become familiar with a number of these physical elements. If the project moves beyond the prefeasibility stage additional fieldwork and data analysis will be needed.

Regulatory and societal issues also are outlined in this report, although the report does not generally propose specific solutions to potential issues that may be encountered if a rehydration project moves forward. Where the project team deems appropriate though, recommendations for possible courses of action are proposed. Regulatory issues that will need to be solved focus on permits needed (both federal and state) to implement a project and regulations (particularly relating to NEPA and clean water) that must be addressed, and resolved. Authorization in the form of a water right to use water from Lake Roosevelt is also discussed. Regulatory issues were identified in an initial review of potentially relevant rules and regulations and/or in the course of interviews and conversations with agencies that may have an interest in the project, or the land the project will be situated one.

When we discuss societal issues in this report we generally focus on whether or not the public supports such a project as it takes shape and people see what it entails, and do landowners along a project route agree with it being implemented on their land, especially if it has the potential to impose limitations on how they might use their property. These societal issues largely were identified from direct conversations with landowners in the drainages being evaluating for the project.

Throughout the Prefeasibility Assessment we have attempted to identify issues that need to be resolved if the project moves forward. To the extent possible we have identified potential solutions to these issues. Some issues are physical and will be resolved through implementing project designs that are specific to that physical element. The regulatory and societal issues will require people working together to address the issues and/or finding alternative actions that allow the project to move forward if the community decides there is a compelling need.

3.0 THE STUDY AREA

This section summarizes the basic physical setting of Lincoln County, including geography and surface hydrology, climate and habitat, and surface soils, geology, and hydrogeology. Much of this information is derived from previous compilation reports, including WRIA 43 and WRIA 53 Phase 1 and Phase 2 assessment reports (Kennedy/Jenks, 2005; WNR, 2008) and Columbia Basin GWMA reports (GWMA, 2009a, 2009b; 2009c, 2009d), Columbia Basin GWMA databases and GIS data, and Lincoln County Planning Department GIS databases.

3.1 Geography

Lincoln County encompasses approximately 1.49 million acres, or approximately 2,335 square miles in north-central Washington. The Columbia River and Spokane River (as Lake Roosevelt) bounds the northern edge of the County, with Grant County, Adams County, and Spokane County bounding Lincoln County to the west, south, and east, respectively. The County's landscape varies from forested uplands and canyons in the north near Lake Roosevelt to irrigated farm lands, dry land farming, range ground, grassland, shrub steppe, and rocky scablands throughout the rest of the County (Figure 4). Less than 1 percent of the county is found in towns and communities. The largest of these include Reardan, Davenport, Lincoln, Creston, Wilbur, Odessa, Harrington, Almira, and Edwall (Figures 2 and 4). In addition, a number of small private housing developments occur in the northern part of the County, near Lake Roosevelt.

Elevation in the County varies from highs of approximately 2,600 feet above mean sea level (MSL) on the drainage divide separating Lake Roosevelt from the Crab Creek watershed to lows of approximately 1,400 feet above MSL in the Crab Creek drainage as it exits the southwestern portion of the County. Within the Crab Creek watershed much of the land surface consists of basalt bedrock scabland. These scablands are characterized by isolated buttes, deep, steep-sided canyons, and locally chaotic drainages and deep potholes (Figure 5). Historically, perennial streams flowed through many of these scabland drainages and lakes were common. Within the scablands stock grazing, small localized irrigated farming, and habitat management activities are the most common land uses.

In the north-central portion of the County these scablands are characterized by a chaotic, very poorly developed drainage system. To the south scablands are more linear and associated with specific drainages. These scabland drainages are separated by rolling, loess hills (Figure 6) similar in appearance to the hill county of the Palouse Slope located to the south in Adams and Whitman Counties. Land uses on these loess hills consist predominantly of dry land farming, irrigated farming, and conservation reserve.

Other landscapes found in Lincoln County consist of the high, partially wooded hills overlooking Lake Roosevelt and the partially isolated, largely unwooded hills such as Creston Butte and those found in the east near the Spokane County line. The hills overlooking Lake Roosevelt delineate where the canyon of the Columbia River was incised into the Columbia Basin where the Columbia River Basalt Group abuts against the igneous and metamorphic rocks of the adjacent Okanagan Highlands. This hilly landscape overlooking the Columbia River (Lake Roosevelt) is devoted largely to woodlands, small scale farming, grazing, and rural residential development. At the base of these hills are predominately irrigated orchard, vineyards, and residential developments. The isolated hills, such as Creston Butte, are devoted largely to grassland habitat and grazing uses.

The feature in the Lincoln County landscape of particular note to this project is Crab Creek and the series of drainages that generally flow to the south and southwest into Crab Creek off the drainage divide adjacent to the Lake Roosevelt valley. Crab Creek, and from east to west its major tributaries Rock Creek, Bluestem Creek, Lords Valley Creek, Coal Creek, Duck Lake Creek, Lake Creek, Marlin Hollow, Canniwai Creek, and Wilson Creek lie in the scabland valleys originally scoured into the Lincoln County landscape by Pleistocene Cataclysmic Flood Waters that spilled over the drainage divide in northern Lincoln County and flowed south into the Columbia Basin. As such, these streams, and in some cases the natural lakes found in these drainages, generally do not completely fill the scoured canyons in which they are found. The most notable exception to this general statement is Lake Creek in which a number of lakes are found, or were present historically, that filled the valley floor.

Lake Creek, and to a lesser extent the other Crab Creek tributaries, host a number of lakes, several of which are now dry. The primary lakes of the Lake Creek tributary, from its upper reaches, downstream, include Hurley, Wall, Twin, Coffee Pot, Deer, Brown's, Tavares, Neves, Pacific, and Bob's Lake (Figure 2). Of these lakes, Wall and Twin have seen little or no decline in stage in recent years. Beginning with Coffee Pot, which generally sees a few feet of decline each summer, and continuing downstream to Tavares Lake, which is almost completely dry, the Lake Creek chain of lakes appear to have experienced progressively greater stage declines in the past decades. Anecdotal information provided by landowners in the lower Lake Creek area, and limited data (LCCD, 2000) suggest the lowest three lakes, Neves, Pacific, and Bob's, largely dried up in the 1980's and have only occasionally contained water since then, most recently in the late 1990's.

Crab Creek, and its tributaries, lie on the floors of these canyons (more commonly referred to as coulees) which in many cases are carved 100 to 300 feet or more into basalt bedrock. The coulees proper usually are less than one mile across, although they commonly are incised into a flood scoured surface (commonly referred to as scabland) associated with each drainage that can be several miles across. In the upper reaches of these drainages channel ways may be poorly developed and the drainage patterns can be somewhat chaotic, with numerous box canyons and deep potholes with no drainage exit.

3.2 Climate and Habitat

Precipitation amounts and patterns, as well as temperature and evapotransportation regimes are strongly influenced by air masses and storms that come from the west, southwest, and north-northeast. Those that come from the west across the Cascade Range bring high moisture content and moderate temperatures, although the majority of the moisture in these air masses is dropped on the Cascade Range as rain and snow. Air masses that come from the southwest more typically are hot and dry. Arctic air from the north and continental influences from the east cause winters to be cold and relatively long. When two or more of these predominant air masses mix, some of the highest precipitation storm events occur.

These different weather patterns, coupled with the topography of Lincoln County, yield climates in the County combining characteristics typical of semi-arid mountain foothill climates with those more typical of a semi-arid grassland and steppe climates. The foothills-like climate is predominate in the northern part of the County, adjacent to Lake Roosevelt, where precipitation is greater than to the south and north facing slopes and canyons offer cooler local microclimates. The grassy steppes and farmlands found south of the highlands bordering Lake Roosevelt lie within the semi-arid climates that dominate the bulk of the County.

Climatic data for the area is found in the Western Regional Climate Center (WRCC) database (WRCC, 2009) and has been previously summarized in reports for WRIA's 43 and 53. The WRCC compiles and maintains climatic data from the National Oceanographic and Atmospheric Administration (NOAA), the Natural Resource Conservation Service Snowpack Telemetry System (SNOTEL), and regional cooperators that operate individual recording stations (WRCC, 2009). Generally these climatic data show annual precipitation varies from approximately 7 to 16 inches per year, with higher amounts prevailing at the higher elevations of northern Lincoln County. July through October generally are the driest months of the year. Except in the coldest months of the year, evapotransportation exceeds precipitation.

Given this climate, the bulk of Lincoln County lies within a semi-arid shrub steppe ecosystem. Major plant types are *shrubs* (such as sagebrush, hopsage, greasewood, and bitterbrush); and *perennial bunchgrasses* (such as bluebunch, needle-and-thread, Idaho fescue and Sandberg's bluegrass). Numerous annual and perennial wildflowers (such as phlox, mariposa lily, fleabanes and locoweeds) thrive in the spaces between shrubs and bunchgrasses. Much of the shrub steppe is also plagued with non-native plant species such as cheat grass and Russian thistle. Animal species populating the area include many mammals such as mule deer, jack rabbits, coyotes, bobcats, and various rodent species. Bird species found within the study area include Horned Larks, Sage Sparrows, Sage Thrashers, Brewer's Sparrows, Sage Grouse, and Vesper Sparrows. In northern Lincoln County, on the highlands and in the canyons along the drainage divide between Lake Roosevelt and the Crab Creek drainage, the semi-arid shrub steppe habitat transitions into a mixed steppe and forest habitat. This transition generally corresponds to areas where annual precipitation exceeds 12 to 14 inches, and temperatures are slightly lower than to the south. This is commonly seen on sheltered north facing slopes and canyons.

3.3 Geology and Hydrogeology

Lincoln County lies on the northern edge of the Columbia River flood basalt province where it pinches out against the metamorphic and crystalline igneous rocks of the Okanagan Highlands. The flood basalt province contains erosion features from Pleistocene cataclysmic flooding. The major geologic units found within Lincoln County include: (1) supra-basalt sediments and continental flood basalt of the Columbia River Basalt Group (CRBG) and (2) the metamorphic and crystalline igneous rocks underlying the CRBG. This section provides basic information about the geology and hydrogeology of Lincoln County as it has the potential to influence the proposed project. The reader is referred to other reports as cited herein for more detailed information about the geology and hydrogeology of the greater Lincoln County area.

3.3.1 Soils

Soil types within Lincoln County range from silt loams to sandy and gravelly soils, to rocky soils directly on bedrock. The silt loams, which dominate the rolling hills between the major drainages, are mostly well drained silt loams. In many areas, layers of calcium carbonate and silica hardpan (caliche/duripan) are present. Much of the active modern farming is done on these soils, and these soils typically have been farmed in the past. Unaltered intact silt loam soils are rare as the area has been used for agriculture and livestock grazing for many decades. The infiltration capacity of these soils would be relatively low. If these soils are found at locations where other factors suggest basalt aquifer recharge potential is high, then it might be necessary to remove them to enhance infiltration capacity.

The sandy and gravelly soils are most common in and around coulees. These soils typically are developed on Pleistocene Cataclysmic flood deposits, including sand and gravel bars deposited in and adjacent to the coulees. One would expect these soils to have a relatively high infiltration capacity, and little or no site modifications would be necessary if these materials are found at a location that is deemed appropriate for recharge for other reasons. These types of substrates are common in coulees where most, if not all, of future potential recharge projects would occur. In such areas, recharge potential for the underlying basalt aquifer system could be high.

Thin rocky soils are present in scablands where a thin veneer of rocky silt and sand has developed directly upon bedrock. Generally basalt aquifer recharge will not be widespread on these thin rocky soils developed over bedrock because the bedrock will typically have extremely low to essentially no infiltration capacity (USDOE, 1988). However, there may be cases where an underlying basalt substrate is dominated by a rubbly and/or brecciated interflow zone. In such cases the infiltration capacity of such soils could be favorable for basalt aquifer recharge. These later examples would be targeted as preferred basalt aquifer recharge areas as they are identified in the field.

3.3.2 Suprabasalt Sediments

Suprabasalt sediments within Lincoln County consist predominantly of Pleistocene to Holocene aged alluvium, Pleistocene Cataclysmic Flood deposits, and Pleistocene loess. Using GWMA's regional mapping (GWMA, 2009a, 2009b) and 1:100,000 scale surface geologic maps published by the State of Washington (Gulick, 1990; Joseph, 1990; Waggoner, 1990a, 19909b) these sediments are sub-divided into two basic units for this report, coarse Quaternary alluvium and fine-grained Quaternary deposits.

The coarse Quaternary alluvium consists of mixed silt, sand, and gravel (Figure 7) deposited predominantly by Pleistocene Cataclysmic Flood waters and to a lesser extent by post-flood stream reworking of flood deposits and colluvial processes on hill slopes. These strata are most commonly found in and adjacent to coulees, stream and river canyons, and steep cliffs cut into bedrock. In some areas these materials may form benches in canyons and coulees. The widespread Pleistocene Cataclysmic Flood deposits can be found almost everywhere flood waters scoured the Lincoln County landscape, from terraces adjacent to Lake Roosevelt to gravel bars along Crab Creek. The other coarse Quaternary deposits are very limited spatially, being found at the base of steep slopes and localized along modern stream channels. According to subsurface geologic maps created by the Columbia Basin

GWMA, the thickness of this unit within the study area ranges from less than 10 feet to as much as 200 feet (GWMA, 2009b).

The other primary suprabasalt geologic unit in the project area is the fine-grained Quaternary deposits. These consist predominantly of loess – silt, silty sand, and very fine sand, (Figure 8) and form the rolling hill topography between the major drainage valleys that cross-cut Lincoln County. This unit is largely absent within coulees and drainages that are possible sites for passive recharge. GWMA's subsurface geologic maps show the unit varying from less than 10 feet to as much as 200 feet thick in Lincoln County (GWMA, 2009b). Its distribution largely is controlled by the depth of cataclysmic flood erosion that formed the scabland coulees that cross-cut the area.

Vadose zone conditions in the suprabasalt sediments are marked by stratigraphic and sedimentologic heterogeneities within the range of coarse to fine strata comprising these sedimentary strata. These heterogeneities result in complex flow paths marked by downward percolation, upward diffusion, and lateral movement of soil and vadose zone moisture. Local perched aquifers may exist where discrete areas or lenses of fine grained materials exist and act as barriers to downward percolation.

Where the suprabasalt sediment strata are saturated, the base of the suprabasalt aquifer is defined as the top of the upper-most CRBG flow. The lateral extent of the suprabasalt aquifer in Lincoln County appears to be controlled by surface CRB outcrops and areas of quaternary sediment deposition within coulees and canyons. As a result, the suprabasalt sediment aquifer is a very discontinuous system, and hydrologic continuity between different areas of saturated sediment will be extremely limited. Generally, the fine-grained Quaternary strata do not host significant accumulations of groundwater. Estimated suprabasalt sediment aquifer thicknesses within the County range from less than 10 feet up to as much as 100 feet, generally depending on the thickness of valley fill in any given reach of a coulee.

Where a suprabasalt sediment aquifer is present, depth to water (DTW) is relatively shallow and ranges from less than 10 feet up to 60 feet. Estimated water table elevations in the system range from approximately 1200 to 1300 feet AMSL in the southwestern part of the County and from 2200 to 2300 feet AMSL in the northern part of the County. However, because the suprabasalt aquifer system is localized by basalt bedrock topography, a single, countywide suprabasalt sediment aquifer is not present.

Because average annual precipitation is low, less than 16 inches, and the summer season is hot and dry, natural surface recharge for the suprabasalt sediment aquifer from precipitation (rain and snowmelt) is most likely small (in the north and northwest) to essentially absent in the south and southwest. Where irrigation occurs on these sediments some artificial recharge is likely. Surface discharge from the suprabasalt sediment aquifer in the study area is most likely into streams, lakes, and ponds where they are present in coulees. The degree of hydrologic continuity with the underlying basalt aquifer system will be explored later in this report. Where it occurs in Lincoln County, the suprabasalt sediment aquifer system typically is unconfined. Elsewhere in the region, measured hydraulic conductivity for coarse strata analogous to the Quaternary coarse unit range from 2,000 to 25,000 feet/day with effective porosity greater than 10 percent (USDOE, 1988). Within the Quaternary fine unit hydraulic conductivities will be several orders of magnitude lower.

3.3.3 Columbia River Basalt Group (CRBG)

The CRBG is a thick sequence of more than 300 continental tholeiitic flood basalt flows that cover an area of more than 59,000 mi^2 (164,000 km^2) in Washington, Oregon, and western Idaho (Tolan et al., 1989; Camp et al., 2003; Camp and Ross, 2004) with a maximum thickness of over 10,000 feet. Numerous reports have been written about a variety of CRBG topics, ranging from petrology, to stratigraphy, to emplacement, to tectonics, to hydrology. Several of the more recent compilations of CRBG geology and hydrogeology are found in PNNL (2002), GWMA (2009a, 2009b, 2009d), and Tolan et al. (2009).

The CRBG has been divided into a host of regionally mappable units (Figure 9) based on variations in physical, chemical, paleomagnetic properties, and stratigraphic position between flows and packets of flows (Swanson et al., 1979a; Beeson et al., 1985; Reidel et al., 1989b; Bailey, 1989). The CRBG in the Columbia Basin region is subdivided into four formations. These formations are, from youngest to oldest, the Saddle Mountains Basalt, Wanapum Basalt, Grande Ronde Basalt, and Imnaha Basalt (Swanson et al., 1979a, 1979b). These formations have been further subdivided into members defined, as are the formations, on the basis of a combination of unique physical, geochemical, and paleomagnetic characteristics. These members can be, and often are, further subdivided into flow units (e.g., Beeson et al., 1985).

Vertical exposures through CRBG flows reveal that they generally exhibit the same basic three-part internal arrangement of intraflow structures. These features, which originated either during the emplacement of the flow or during the cooling and solidification of the lava after it ceased flowing, are referred to as the flow top, flow interior, and flow bottom (Figure 10). The flow top is the crust that formed on the top of a molten lava flow. Flow tops commonly consist of glassy to very fine-grained basalt that is riddled with countless spherical and elongate vesicles (Figure 11). Flow interiors are dense, non-vesicular, glassy to crystalline basalt that contains numerous contraction joints (termed cooling joints) that formed when the lava solidified. Joints are organized regularly and form perpendicular to cooling surfaces (Figure 12). With alteration, cooling joints are filled in with precipitated minerals, resulting in greatly diminished permeability. The character of the flow bottom largely is dependent on the environmental conditions the molten lava encountered as it was emplaced. They can be thin, vesicular, and glassy if the flow encountered dry ground. Pillow complexes (Figure 13) formed if the lava flowed into a body of water.

Interflow zones are the intervals between successive lava flows that can contain various combinations of flow top (from the underlying flow) and flow bottom (from the overlying flow) features. Interflow zones are hydrogeologically important in that they host aquifers and, where they outcrop, can serve as basalt aquifer recharge and/or discharge sites. If a sediment interbed is present between the two flows, it would also be part of the interflow zone. The physical characteristics of basalt flow structures are important as they exert fundamental controls on groundwater occurrence and movement within the CRBG.

The Wanapum Basalt and Grande Ronde Basalt are the two CRBG units that underlie the study area. Table 1, based on GWMA mapping (GWMA, 2009b), lists the CRBG units and their thickness ranges beneath the immediate study area. The Wanapum Basalt ranges between <100 and 400 feet thick and the Grande Ronde Basalt ranges between 1000 and over 3400 feet thick. Total CRBG thickness, beneath the study area, ranges between 1100 and 3900 feet.

3.3.3.1 CRBG Stratigraphy- Wanapum Basalt

The Priest Rapids Member (the uppermost widespread CRBG unit in the County), Roza Member, and the Frenchman Springs Member of the Wanapum Basalt are found in Lincoln County. In addition to these units, dikes and associated vent systems for the Roza and the Priest Rapids are known to occur within the County.

The top of the Priest Rapids Member, although modified by erosion in many areas, generally dips to the south-southwest across much of the County (Figure 14). In the northernmost part of the County it does locally dip to the north. Because this is the uppermost CRBG unit in the County its distribution has been influenced by post-emplacement incision. It is absent from many of the larger coulees seen in the County, including long reaches of Sinking Creek, Lake Creek, Coal Creek, and Crab Creek. In addition, the unit appears to be absent from a large portion of the southwestern corner of the County. Where present, the unit ranges in thickness from less than 50 feet to over 200 feet. Priest Rapids Member dikes are inferred to be present in the eastern and north-central portions of the County. Their inferred presence, shown on Figure 14, is based on the projections of known dikes from the southeast into the County, and the presence of near vent tephra and related materials along this projection that can only be present because of the proximity of dikes.

Like the overlying Priest Rapids Member, the top of the Roza Member generally dips to the south-southwest where the unit is present (Figure 15). The Roza Member also is absent from many of the larger coulees where it has been completely incised through. However, unlike the Priest Rapids Member, the Roza Member is present across much of the southwestern corner of the County and absent from the eastern and northeastern part of the County. Where present, the thickness of the member varies from less than 100 to 300 feet. Roza Member dikes are inferred to be present in the southern to central portions of the County. Their inferred presence, shown on Figure 15, is based on the projections of known dikes from the south-southeast into the County, the presence of near vent tephra and related materials along this projection that can only be present because of the proximity of dikes, and a dike found in Lake Creek at Tavares Lake (Figure 16).

The Frenchman Springs Member is the least extensive of the Wanapum units in Lincoln County, being largely restricted to the southern and southwestern portion of the County. Of the six Frenchman Springs Member sub-units mapped south of Lincoln County (GWMA, 2009b), only two are present to any extent in Lincoln County, the basalt of Sentinel Gap (Figure 17) and the basalt of Sand Hollow (Figure 18). The basalt of Ginkgo is only in the extreme southwestern corner of the County. Like the other Wanapum units, the tops of the Frenchman Springs Member units generally dip to the south-southwest where they are present, and they commonly are completely eroded through (especially in lower Crab Creek). Total Frenchman Springs Member thickness, where it is present, ranges from less than 50 feet to as much as 400 feet. Dikes for Frenchman Springs units have not been identified in Lincoln County.

Catastrophic Pleistocene flood scouring exposed numerous ring structures in the surface of the CRBG. These structures are quasi-circular in plain view and usually have rims raised above their centers. It has been suggested that ring dikes were formed when lava flowed over water resulting in steam explosions which caused radial jointing and fracturing of the rock (Jaeger et al., 2003). Ring dikes, occurring within the area proposed for the LCCD passive rehydration project, are associated with the Rosa Member of the Wanapum Basalt Formation.

The greatest concentration of known ring dikes lie in the Lake Creek drainage extending from where it empties into the Crab Creek drainage to the northeast just above Wall Lake (Figure 19). A high concentration of ring dikes also exists in Crab Creek drainage around the town of Odessa and near the eastern end of Sylvan Lake (east of Odessa). In general, the surface exposure pattern of ring dikes within the study area follows the trends of the respective drainages in which the ring dikes occur. However, it is likely that many unexposed ring dikes associated with Roza Member exist within the study area. These unexposed dikes could be covered by loess, alluvium, and/or the Priest Rapids Member of the Wanapum Basalt in many areas. The influence of ring dikes on groundwater recharge, occurrence, and movement is not currently understood.

3.3.3.2 CRBG Stratigraphy - Grande Ronde Basalt

Subsurface mapping by the Columbia Basin GWMA (GWMA, 2009b) shows the known and inferred extent of five major upper Grande Ronde Basalt units beneath Lincoln County. These units are the Sentinel Bluffs Member, Umtanum Member, Ortley Member, Grouse Creek Member, and Wapshilla Ridge Member. Several of these members, as mapped by GWMA, are composites of multiple Grande Ronde units with those of lesser extent being included within the units mapped by GWMA. Units below the Wapshilla Ridge Member are not mapped because they likely only occur deep beneath the southernmost portion of the County. The presence of Grande Ronde dikes have never been reported in Lincoln County, although it would not be surprising if dikes for one or more of the units mapped for this effort are present. The occurrence and distribution of the Grande Ronde Basalt members mapped beneath the area are as follows:

- The Sentinel Bluffs Member (Figure 20) underlies almost all of Lincoln County with its top generally dipping to the south-southwest, except near Lake Roosevelt where it commonly dips to the north. Where present, the unit ranges from 200 to over 700 feet thick, and likely contains up to 7 interflow zones. The Sentinel Bluffs Member is exposed at, or present within 200 feet of, the top of basalt throughout much of the Crab Creek drainage, including tributaries, and in the northern portion of Lincoln County on and near the highlands bordering Lake Roosevelt.
- The Umtanum Member (Figure 21) and the underlying Ortley Member (Figure 22) are only present beneath the central to southern portions of Lincoln County, pinching out beneath the Sentinel Bluffs Member. Based on this distribution these units are not exposed at in Lincoln County, and because of the thickness of the Sentinel Bluffs Member these units are generally some hundreds of feet below ground surface. Given the thickness of the Umtanum,

approximately 200 to 500 feet thick, and the Ortley, approximately 100 to 300 feet thick, they likely contain several interflow zones. The tops of both units dip south-southwest.

- The Grouse Creek Member (Figure 23) is more widespread than the overlying Umtanum and Ortley Members, being found along at least portions of the highlands above Lake Roosevelt in north-central Lincoln County. Throughout most of its extent the top of the unit dips to the south-southwest, except near Lake Roosevelt where it may dip, at least locally, to the north. The thickness of the unit ranges from approximately 200 feet to 800 feet.
- The Wapshilla Ridge Member (Figure 24) is the deepest individual Grande Ronde unit mapped by GWMA (2009) in the Lincoln County area. It also is almost as widespread as the Sentinel Bluffs Member and is found at, or near, the top of basalt throughout much of its northernmost extent near Lake Roosevelt. Like other Grande Ronde units, it appears to generally dip to the south-southwest, and it ranges in thickness for approximately 100 feet, to as much as 1000 feet to the south. As the unit thickens, the number of interflow zones it contains likely increase.

3.3.4 Pre-Basalt Basement

Field reconnaissance and existing geologic maps (Joseph, 1990; Waggoner, 1990a) show that the CRBG overlies a variety of older crystalline intrusive and metamorphic rocks. This pre-basalt Basement consists predominantly of granite and related felsic crystalline rocks and low to medium grade metamorphic rocks, especially quartzites and phyllites. These rocks crop out along most of the southern shore of Lake Roosevelt, in steptoe buttes found across the area, in the canyon bottoms along the middle reaches of Hawk Creek, and in the highlands to the north and east of the study area. Fracture and shear zones, including faults, are known to cross-cut these rocks. The pre-basalt basement within the study area dips to the south from highs near Lake Roosevelt (>3200 feet elevation) to 1200 feet below ground surface (Figure 25). As mentioned earlier, local upward extrusions of basement (Steptoe buttes) through the CRBG exist within the study area such as Creston Butte.

3.3.5 Structural Geology

Most of Lincoln County lies on the northern and eastern edge of the Palouse Slope structural subprovince. This subprovince comprises much of the eastern half of the Columbia Plateau and is characterized by a regional dip slope (<1 to 2 degrees) extending from highs of 3,000 feet in western most Idaho and north-central Washington to lows of 500 to 600 feet in south-central Washington (Myers and Price, 1979; USDOE, 1988). Deformation on the Palouse Slope is primarily characterized by north to northwest trending and several east-west trending folds with little or no apparent topographic expression (Swanson et al., 1980; Tolan and Reidel, 1989). Dips on these folds typically are less than 5 degrees.

Large offset faults are essentially absent in the CRBG in the region, although some large faults have been mapped in the basement underlying the CRBG (Derkey and Hamilton, 2009). The single largest fold found in the region generally corresponds to the surface water and topographic divide that separates the Crab creek drainage from the Lake Roosevelt-Columbia River drainage to the north and the valley occupied by Banks Lake to the west. This anticline folds the CRBG such that northern oriented dips are found along the northern periphery of the County. In its eastern extension, along Hawk Creek and to the east, this anticline merges with faults and hills that bring sub-basalt basement rocks to the surface.

Creston Butte is the westernmost of these hills, also known as steptoes. Generally the CRBG beneath the Crab Creek drainage dips southwards, southeastwards, and southwestwards off of this anticline and Steptoe system, towards adjacent portions of Grant County and Adams County.

Small folds are known to occur across the Lincoln County area. These folds generally have east-west to northwest-southeast orientations. GWMA's subsurface geologic mapping suggests a low amplitude fold system is present along and south of Crab Creek in the general area of Odessa.

3.3.6 CRBG Hydrogeology

Groundwater in the CRBG regionally, and beneath the study area, occurs as a series of confined water-bearing intervals hosted in CRBG interflow zones and the Ellensburg Formation sediments (Gephart and others, 1979; Hansen and others, 1994; Packard and others, 1996; Sabol and Downey, 1997; USDOE, 1988). Groundwater occurs within the interflow zones and interbeds and in joints, vesicles, fractures, and other local features that create permeable zones and in intergranular pores in sediment interbeds. Folds and faults are inferred to impede lateral flow and act as vertical flow pathways, depending on the physical characteristics of specific features.

Table 2 summarizes basic hydrologic properties of CRBG interflow structures and sedimentary interbeds of the Ellensburg Formation. Hydraulic conductivity of CRBG flow tops ranges from 1×10^{-6} to 1,000 feet per day (feet/day) and averages 0.1 feet/day with flow tops serving as the primary conduit for lateral groundwater flow (USDOE, 1988). Ellensburg formation interbeds were determined to have horizontal hydraulic conductivities ranging from 1×10^{-6} to 1 feet/day, averaging 0.01 to 0.1 feet/day for various interbeds (USDOE, 1988).

Given the nature of the CRBG aquifer system, which is a series of planar-tabular water-bearing zones (interflow zones) separated by extremely low permeability basalt flow interiors, construction of a single water level map for this aquifer system is not warranted. Unfortunately, current available data does not provide enough insight into groundwater conditions within the study area for the preparation of water level maps for individual or groups of water-bearing zones, and the identification of average water levels is a relatively meaningless exercise. Within these constraints, available depth to water data suggests the following:

- Depending on which water bearing zones(s) an individual well is open to, depth to water throughout the region varies from approximately 20 to as deep as 800 feet below ground surface (bgs). Generally, these shallower depths will likely be associated with low yield zones in the Wanapum Basalt especially where lateral continuity is disrupted by incised coulees. Deeper water levels will more commonly be associated with Grande Ronde zones, especially in the areas of deep well irrigation in the central to southern portion of the project area.
- These depths to water generally correspond to water level elevations ranging from approximately 1295 to 2350 feet AMSL.
- It is interesting to note that in the upper reaches of the streams being considered in this study, reported depth to water in the basalt aquifer system is relatively shallower in the north

(between approximately 25 and 73 feet bgs) than in the south where it can be many hundreds of feet deep. .

- The general deepening of significant groundwater zones also occurs from east to west across the County.

Granitic basement highlands to the north of the study area boundary represent the divide for groundwater flow between Lake Roosevelt to the north and the Columbia Basin to the south. This most likely is the main influence on the general groundwater flow direction within basalt aquifers (NE to SW) through the study area.

Based on past studies, direct recharge to shallow CRBG aquifers results from infiltration of precipitation, runoff, and irrigation within (and along the margins of) the Columbia Basin (Newcomb 1969; U.S. Department of Energy 1988; Hansen and others, 1994). Infiltration has been variously interpreted to be vertically downward along faults, past the ends of flow pinchouts, where CRBG flows are breached by erosional windows, on highlands within and bordering the Columbia Basin, and through dense flow interiors. Recharge of the deeper Wanapum and Grande Ronde aquifers is inferred to occur largely from interbasin groundwater movement originating around the edge of the Columbia Basin in areas where exposures of these deeper units occur (Gephart et al., 1979; USDOE, 1988; Hansen et al., 1994) and downward through overlying CRBG flows (Hansen et al., 1994; Bauer and Hansen, 2000). However, based on the physical geology of the CRBG summarized herein, it seems likely that vertical leakage through multiple, dense, CRBG basalt flow interiors is greatly restricted and that the primary source of natural recharge into the CRBG aquifer system is through erosionally thinned units, around erosional and emplacement pinchouts, through open faults and tectonic fractures, and in up-dip areas where units thin and pinchout. All of these features allow successive interflow zones to come into contact, forming a direct hydraulic connection with each other. GWMA's recent work (GWMA, 2009) suggests the depth of effective infiltration through planar-tabular dense interiors probably does not exceed 2 or 3 interflow zones, or approximately 200 to 300 feet.

Beneath the study area, groundwater flow directions in CRBG aquifers generally are toward the south-southwest (Drost and Whiteman, 1986; U.S. Department of Energy, 1988, Hansen and others, 1994). Potential discharge areas for the deeper aquifers (i.e., Wanapum and Grande Ronde Aquifers) are uncertain, but groundwater flow is inferred to be generally southwestward with discharge speculated to occur south of the Pasco Basin (USDOE, 1988) where folds and faults bring Wanapum and Grande Ronde flows closer to the surface. Hansen et al. (1994) and Bauer and Hansen (2000) have also speculated that discharge from deep CRBG aquifers may be directly upward through multiple dense basalt flow interiors into major rivers like the Columbia and Snake. However, it is difficult to envision this given the physical properties of CRBG basalt flows in this stratiform aquifer system. If movement of groundwater through multiple dense CRBG flow interiors does occur, it must be extremely slow, being measured in extremely long geologic terms, not human terms.

Potential basalt aquifer recharge areas within the study area include basalt unit interflow zones exposed at the surface, especially in coulees, and along contacts with pre-basalt basement in the north and exposed pinchouts, interflow zones, and interbeds within flood scoured coulees. Recharge of deeper

Grande Ronde units is extremely slow and follows tortuous pathways. Uncased wells penetrating water bearing units of both the Wanapum and Grande Ronde formations allow for passive dewatering of the Wanapum aquifers by down-hole flow and in turn artificially recharge Grande Ronde aquifers in some areas.

The Priest Rapids and Roza Members of the Wanapum Basalts are exposed in many coulees within the study area and hence recharge could occur at exposed interflow zones. The Frenchman Springs member of the Wanapum Basalt is present only in the SW portion of the study area. Therefore, the potential for recharge at exposed interflow zones and interbeds of the Frenchman Springs Member exists in those areas (Figures 8 and 9). Members of the Grande Ronde Basalts have minimal surface exposure within the study area and therefore the potential for direct passive recharge of these units is small. However, at least in the Sentinel Bluffs, indirect recharge of Grande Ronde units could occur through erosionally thinned Wanapum units where they are deeply scoured by coulees.

Basalt aquifer discharge areas are present in many of the same areas in which recharge occurs. Discharge to lakes, streams, and surface springs occur within coulees in the study area. Historically, recharge to these surface water bodies was considerable, but it has likely diminished in recent decades due to factors such as increased groundwater pumping from basalt aquifers. Water-bearing interflow zones within the area which lie below the depth of incision of the deepest coulees likely do not discharge to the surface in Lincoln County. Instead, this groundwater exits the county, moving down gradient into adjacent Grant and Adams County.

4.0 WATER AVAILABILITY AND GOVERNANCE

The purpose of this section is to review several programmatic and regulatory issues potentially associated with the project. These include:

- Water rights needed to conduct a pilot rehydration project. This discussion does not address water rights needed to run a longer term, permanent project. These will be addressed if a pilot project is conducted and its results indicate a longer term project has merit.
- A discussion of how this project could comply with the requirements of RCW 90.90.
- An evaluation of possible governance structures that could be used if a pilot or subsequent longer term permanent project is put in place.

These topics are reviewed in an effort to identify issues that may need to be addressed for both a pilot project and a subsequent potential full sized project. This was done with the expectation that paths forward may be defined here, or with subsequent work, to address these issues.

4.1 Water Rights

Washington State water codes RCW 90.03 and RCW 90.44 require any water put to a beneficial use to be subject to a water right under the Prior Appropriation Doctrine (first in time, first in right). Under these statutes, the proposed project would be required to maintain a water right for: 1) conducting a pilot test program in which there will be a short term (1 to 3 years) use of water; and 2) a permanent water right(s) for the long term operation of the project. The pathways for the water rights for the Pilot Test Program and the Long Term Operation differ, and as such will be discussed separately.

In the near-term, for the potential Pilot Project, the priority is to seek 10 to 20 cfs from the Columbia River (Lake Roosevelt). In the long-term, the goal of the Lincoln County Passive Rehydration Project is to recharge a minimum of 50,000 acre-feet. This would require the diversion of approximately 100 cfs of water from the Columbia River on an annual basis.

Defined water rights for the Long Term Project are not addressed at this time based on: 1) long term operational requirements for instantaneous and annual quantities are not known at this time; 2) water quantities for final operation of the project will be defined in the subsequent Pilot Test; 3) exact points of diversion for the final project will be defined in the Feasibility Project; 4) more detailed negotiations with existing water right holders and water operators were requested after a defined project quantity was known; and 5) further discussions with Ecology and BOR will be required to determine if the “new” water delivered via the project can be credited under other water rights, and will be further defined in the Feasibility Project.

The conveyance of Columbia River water will be to several drainages for the final project operation, in order to maximize the recharge to the basalt aquifers, and the surface waters of Lincoln, Adams and Grant Counties. Although the goal is 200,000 acre-feet per year, the Feasibility Study and Pilot Project will attempt to develop a proposed solution for the maximum amount of conveyed and recharged water that has the maximum beneficial use to the water users in the basin. Potential projections of recharge water would be to the aquifers in the Odessa area by using multiple infiltration sites and water courses such as Lake Creek drainage, Sinking Creek, and the headwaters of Crab Creek. After replenishing the streams and lakes in the Crab Creek watershed, water left in stream from the Passive Rehydration project would flow to Moses Lake and become part of the Columbia Basin Project. Therefore the goal of the Lincoln County Passive Rehydration Project is twofold, to directly recharge the basalt aquifers that are a water source for multiple water users throughout the basin, and to indirectly replenish the surface water that eventually supplies water to the Columbia Basin Project, which would result in a net gain to the Columbia Basin Project and potentially reduce quantities that they would need to divert from Banks Lake for the Basin irrigation conveyance system. In order to determine a final build out water quantity, the Pilot Project must be completed.

4.1.1 Pilot Test Water Rights Options

For the Prefeasibility Assessment several options for acquiring water rights to operate the proposed Pilot Testing program were evaluated. For this, the Pilot Testing program will seek a proposed diversion of 10 to 20 cfs. Therefore, potential options to acquire this quantity of water were evaluated. Water rights evaluated in a potential hydration pilot test project included:

1. **A *temporary use authorization*** issued by the Ecology. Temporary water rights are issued under the authority of RCW 90.03.250. As described in Ecology Policy 1035, a Temporary Permit authorizes water use during the pendency of an application review. The project proposal would be required to submit an application for a project, and then request a Temporary Permit. This authorization typically would be conditioned to such things as minimum flow requirements and habitat needs, and it would be junior to all other water rights in the source water body. In addition, this is a one year authorization, and it would need to be renewed annually. Ecology guidelines state that a Temporary Permit should only be issued when it is confident that a permit will be approved in a reasonable time. Due to the requirements of the Pilot Test program, and the quantities sought, Ecology informed the project team that issuance of a temporary permit for the Pilot Project is not a feasible alternative.
2. ***USBOR Municipal and Industrial (M&I)*** *use water* can be acquired from the Bureau of Reclamation (BOR) under certain conditions. The project team met with the USBOR to discuss the potential option of using this program to develop water for the Pilot Project. The project is setup to provide water to municipal and industrial users under existing BOR water rights. This type of authorization is capped at 13 cfs and based on our discussions with BOR staff; the availability of this type of water for the proposed project will be limited to unavailable based on the recent Bi-Op. Therefore, this option was determined to not be a feasible option.
3. The project team also approached the USBOR to determine if there were opportunities to utilize an ***existing USBOR water right*** for the Pilot Project, under a lease or cooperative agreement. The USBOR currently maintains numerous "irrigation" rights and "hydropower" rights as presented on Table 3. Discussions with the USBOR determined that due to the multi-beneficial use of the proposed Pilot Project, existing rights may not be available to for use under the proposed Pilot Project. Therefore, this option was determined to not be a feasible approach to obtain water for the proposed Pilot Project, but may be an option for the long term Passive Rehydration Project.

4. ***Private water rights*** were also evaluated as a potential source to conduct the Pilot Project. These water rights are held by private property owners and could be utilized for a pilot project if they could be successfully transferred either to the project directly or under a temporary change authorization. Under the quantities sought for the Pilot Project, it is assumed that numerous (estimated at 10 to 15) water rights would need to be identified, agreements reached, and extent and validity analyses completed in order to verify transferable quantities. For the purpose of a short-term pilot project such an approach is cumbersome, expensive, and likely not an effective way to secure water for a short duration (few years long) pilot project.
5. The final approach, and the one we recommend, is to submit a ***reservoir permit*** to Ecology asking for issuance of a ***preliminary permit*** that authorizes withdrawal of water from Lake Roosevelt for the pilot project. A preliminary permit can be issued under RCW 90.03.290 and in accordance with Ecology Policy 1030. These preliminary permits are issued to retain a priority date and establish a formal timeline and data collection plan when additional information is needed to make permit decisions. The preliminary permit requires the applicant to make surveys, investigations, or conduct studies to satisfy the information needs of the Department of Ecology (Policy 1030). However, a preliminary permit does not authorize the beneficial use of water. The proposed approach to obtain approval of water for the Pilot Project is presented below.

The purpose of the preliminary permit would be to provide authorization for the use of Lake Roosevelt water for a potential pilot project. An application for Lake Roosevelt water will be made in accordance with RCW 90.03.290 prior to requesting a Preliminary Permit. Reservoir permits will be filed in accordance with RCW 90.03.370. With this water approved under the Reservoir/Preliminary Permit, a pilot project would test the operational feasibility of a project that moves water from Lake Roosevelt into one or more drainages in Lincoln County. The pilot project also would examine management and operations in the targeted drainages. Finally, the pilot project using water supplied under the preliminary permit would provide a field scale test of aquifer recharge potential in the project area, the ability of these aquifers to transmit water, and the baseline data needed to assess the feasibility of a much larger project to have a positive benefit to aquifer recharge and habitat needs.

If the project is authorized for moving forward into the feasibility phase, a reservoir permit application would be completed and submitted to Ecology at the completion of the feasibility phase if the feasibility work suggests a project is potentially viable. The reservoir permit application, which will request issuance of a preliminary permit will be accompanied by a project plan that likely includes monitoring requirements (which would include Quality Assurance Project Plan(s) – QAPP), operations plans, and related documents describing how the project would operate, how achieving project goals would be evaluated to measure project success, and describing what the project would physically look like. These documents also would name the authorities/entities responsible for management and operations.

4.1.2 Potential Long-Term Water Right Options

The project investigated several final build out water right options to determine if any fatal flaws were identified for long range operation of the Lincoln County Passive Rehydration Project. As stated previously, at this time, an estimated total quantity of water needed to successfully complete the Passive Rehydration project has not been determined. After completion of the Pilot Testing program, a proposed quantity will be recommended. Preliminary estimates of stream capacity for conveyance of Lake Roosevelt water is estimated to be at least 50,000 acre-feet annually. Several potential water right options appeared feasible for the long range operation of the project. These include:

1. ***USBOR Existing Water Rights:*** As stated previously, the USBOR maintains numerous water rights. Upon implementation of the Lincoln County Passive Rehydration Project, water from the project will have some influence on the USBOR Project operations, primarily by water introduced to the Upper Crab Creek tributaries that does not infiltrate into the basalt aquifers, will eventually return to USBOR operations as it flows to Moses Lake and the Potholes Reservoir, thus reducing potential quantities the USBOR will need to divert from their diversions on the Columbia River for their project area. In addition, water that is infiltrated into the aquifers in the eastern portions of the Odessa Area may reduce potential needs within the defined irrigable acreage area of the USBOR Project. During discussions with USBOR representatives, they informed the project team that upon development of a known water quantity for the Passive Rehydration build out, discussions could be initiated for potential agreements with USBOR existing water rights. It should be noted that at this time, no definitive arrangements or agreements have been developed, only that discussions should be held in the future for evaluating if potential arrangements are available.
2. ***New Water Rights:*** If the project moves into the implementation phase, new water right applications will be submitted for any available waters from the Columbia River. Available waters may only be appropriated from those times outside the Bi-Op. This would result in available waters only in the winter months. A further evaluation of potentially available surface water will be conducted in the Feasibility phase of the project. A summary of available water above Priest Rapids is presented in Section 4.1.3 of this report.
3. ***Private Water Rights:*** Private water rights may be an alternative for long term operation of the Project. The project team attempted to compile an estimate of papered surface water rights within the main stem Columbia River above Grand Coulee Dam and within the Spokane, Kettle, and Pend Oreille Rivers within Washington State. However, Ecology's water rights GIS database was not operating and is not expected to be operational until early 2011. A further evaluation of private water rights will be conducted during the Feasibility phase of the project. It should be noted that available private water rights may be costly, and may only constitute a small portion of future project water. In addition, these waters would primarily be sought for water rights outside the potential time limitations of new appropriated water rights.
4. ***Legislative Options:*** A preliminary evaluation was conducted into potential legislative options for fining water for the long term operation of the Passive Rehydration Project. One option may be the development and operation of a potential water trust/bank. This scenario would allow private water holders who currently withdraw water upstream of Grand Coulee Dam to place their water rights into the Passive Rehydration Trust Banking Account. The water would then be used to operate the Project. Water rights entered into the trust bank would be protected from relinquishment. A contractual agreement will need to be developed for landowners placing

water into the bank. The bank could also be developed to accept donated water rights for operation of the Project. A more detailed evaluation as to the legislative development of a "Passive Rehydration Trust Bank" will be conducted in the Feasibility phase of the Project.

5. ***Water Portfolio:*** It is the general conclusion of the project team that in order to operate the Passive Rehydration project on a long term basis, a water right portfolio will most likely be the feasible option. The water right portfolio will consist of a mixture of all the options listed above, and potentially other feasible alternatives when identified. Holding and maintaining new water rights, purchased water rights, leased water rights, and a water trust bank will be required. Instituting a water portfolio will require a more detailed management program of the water rights. It is inferred that the operational entity developed for the Project, will manage the water rights. A more detailed analysis of the potential structure of a water right portfolio will be developed in the Feasibility portion of the project.

4.1.3 Longer Term Water Availability in the Columbia River System

As part of the water rights analysis, the potential for long-term water availability within the entire Columbia River system also was reviewed. After consultation with representatives from Ecology, it was determined that water availability projections could be used from previous regional documents completed by Ecology and the USBOR. The "Appraisal Evaluation of the Columbia River Mainstem Off-Channel Storage Options" report completed in May 2007 by Ecology and USBOR was determined to be the best reference for determining water availability in the Columbia River. Although the data presented in Section 3 of the Off-Storage Appraisal report is representative of determining the availability to divert water just downstream of the Priest Rapids Reservoir, we feel it is still representative of potential water availability upstream of the Grand Coulee Dam. Major tributary contributions to the water budget between the Grand Coulee Dam and below Priest Rapids Reservoir consists of the Okanogan, Methow, Entiat and Wenatchee Rivers, Lower Crab Creek, as well as numerous other creeks and streams along the approximately 200 mile river course.

The water availability estimates are based on a computer model developed by the Bonneville Power Administration (BPA) in 1992 that models the operations on the Columbia River for a 50-year period of simulation from 1929 through 1978. From this model, an average monthly Columbia River water volume that is available for diversion in excess of downstream flow objectives under current operations was developed. Estimates of water volumes available for diversion from the Columbia River are often more than 20 million acre-feet annually (Ecology, May 2007). The available volumes for diversion are presented in Table 3-2.1 of the report and are summarized in Table 4.

The current estimate for total annual demands are approximately 3,368,000 acre-feet and include agricultural, DCM&I, and flow augmentation. Largest demand for water is agriculture, which accounts for approximately 75 percent of the total diversions. The largest of these is the Columbia Basin Project, whose demand is 1,364, 800 acre-feet, followed by the Yakima Project (662,046-810,410 acre-feet), and additional agricultural users (330,000 acre-feet). DCM&I water accounts for 109,100 acre-feet of the demand, and 754,000 acre-feet for flow augmentation.

At this time we do not know what the potential authorization needs of a final, longer term project would be. Based on this prefeasibility assessment though, we suspect that a long-term, large scale project likely would involve the delivery of 100 cfs or more into multiple drainages. Total water quantities delivered in such a project could exceed 50,000 acre-feet. If such a project is undertaken it would not operate under a preliminary permit, although a reservoir permit likely would be used. These issues will not be addressed further in this report.

4.2 RCW 90.90 Compliance

The Columbia River Basin Water Management Law (RCW 90.90) establishes a Columbia River Basin water supply development account in the state treasury for funding water resources development projects in the basin. Section RCW 90.90.020 of the law (shown below) requires that two-thirds of the new water supply developed under the program be available for out of stream uses, and that one-third of the developed supply be available for in-stream uses. RCW 90.90 may be the source of the funding of a Lincoln County re-hydration pilot project. Also, Section 90.90.020 applies directly to “water supplies secured through the development of new storage facilities”, which may, or may not be the source of the water used in a Lincoln County Re-hydration pilot study.

The one-third in-stream, two-thirds out of stream division of water that is specified in RCW 90.90 may, or may not apply to the pilot study. A final interpretation by the Department of Ecology of how the RCW 90.90 provision for division of water may actually work on various types of projects is pending. In particular, it is not clear that every project must exactly comply with the division of water, and it is not completely clear that in stream flow benefits only apply to the main stem of the Columbia River. It is likely that only the total of all the projects funded under the law (or of a given combination of projects) needs to comply. Nevertheless, a brief description of how a Lincoln County Re-hydration pilot study might meet this requirement is provided in this section.

Water pumped out of Lake Roosevelt and released into the Crab Creek system would flow downstream, contributing to in stream flows and likely producing gains to riparian habitat and water-based recreation. The extra water flowing down the creek could be diverted for use (as new supply) by irrigation water users along the Creek, or it could be allowed to continue flowing downstream to rehydrate the channel and lakes at the bottom of the basin. If allowed to flow undiverted to the confluence of Lake Creek with Crab Creek, a portion of the supplemental water would seep into the ground and, presumably, contribute new supply to the overall groundwater supply in the area, which is currently over-allocated. If allowed to flow into Crab Creek, the water would continue down the water course and enter Moses Lake, enhancing the existing USBOR project. In addition, a portion of the water would presumably return, unconsumed, to the Columbia River via the lower Crab Creek drainage.

Using the water balance model described below, a 10 cfs rehydration pilot project is estimated to produce an average outflow from Lake Creek of 8.3 cfs. This is contrasted with the existing estimated outflow volume of 2.3 cfs, to show a net gain to in-stream flow at the outlet of Lake Creek of 6.0 cfs. This estimate indicates that 4.0 cfs, or 40% of the water released into the stream seeps into the groundwater or is evaporated. While it is flowing down Lake Creek, the entire 10 cfs is contributing to in-stream flow. After it leaves Lake Creek, the remaining supplemented flow would continue to contribute to stream flow and aquatic resources in Crab Creek. Further losses to groundwater seepage and/or supply water users are also likely, although they have not been estimated in this analysis.

To achieve an exact division of water equal to one-third in-stream, two-thirds out of stream would require either that another 2.7 cfs of the 10 cfs be allowed to seep into groundwater from Crab Creek, or that the same volume be directly diverted from Crab Creek or Lake Creek for out of stream use. Given the extremely high water needs in this area, use of a portion of the supplemental water for water supply would not be a problem. It should be noted that both the water that seeps into the ground and any part of the supplemental water that is directly diverted would directly contribute to RCW 90.90 part (2) (b) below, "alternatives to groundwater for agricultural users in the Odessa subarea aquifer".

The Lincoln County Passive Rehydration Project is different from most of the water supply development projects being proposed under the Columbia Basin Program. The additional water supply developed under this project would be stored in the groundwater aquifer, and not be controllable, as is the case with surface water storage projects. The water would contribute new supply to water users in need, and unconsumed water would return to the Columbia River or would offset diversions from it, and thereby contribute to in stream flow. However, because of the lack of control over timing, the project is not able to make releases to the Columbia River that are targeted to meet specific windows of in stream flow need. However, the project could be very beneficial to the water supply in the Odessa sub area, since it could provide necessary supplies to offset over-pumping that other proposed projects do not. To the extent that in stream flow benefits called for under RCW 90.90 must occur in the main stem of the Columbia River, this project might need to be combined with another project that is specifically formulated to do that.

4.3 Potential Governance Structures

This section provides information and options for organizational structures that could be used to manage the Lincoln County passive rehydration project. Regardless of which governance structure is selected, owning and managing this project will involve tasks that are similar to running a utility. Governance of the rehydration project will require technical, financial, and managerial skills and attributes. For example, the organization would need the capacity to hire and/or manage contracts for technical staff; plan, design, construct, operate, and maintain facilities; maintain insurance; and manage funding for the project.

Key aspects of governance will include:

- Ownership
- Operation and maintenance
- Technical support

Given the need for cost effective and efficient services over a large geographical area, the project might be best managed by an entity that has the organization in place to carry out the necessary functions throughout the rehydration area. These activities will likely be most efficiently provided by only one jurisdiction serving a broader coalition. It is also possible that the management of the rehydration project could be shared by several organizations. Any combination of shared responsibility which falls under the legal authority of a partner can be assigned through an intergovernmental agreement.

A brief summary of several governance options and their legal authorization is provided below.

- **Interlocal Cooperation Act (RCW 39.34)** – This statute serves as the basis for many Intergovernmental Agreements in the state and provides broad authority to share infrastructure, government services or activity. In 39.34.080, RCW, it states: "Any one or more public agencies may contract with any one or more other public agencies to perform any governmental service, activity or undertaking which each public agency entering into the contract is authorized by law to perform..."
- **Public Utility Districts (RCW 54)** – Public utility districts (PUDs) have county-wide authority to provide utility services. RCW 54.16.090, RCW 54.16.180, and RCW 54.16.230 allow the PUD to contract with other entities, engage in services. The later statute specifies that the PUD's actions be consistent with the County Comprehensive Plan and formation or expansion of service will require a majority vote of its customers. In this case, the PUD would not be serving "customers" and thus would rely on other funding sources such as grants, taxes, etc. Because the Lincoln County PUD is already in existence, governance of the project by the PUD presents the simplest option for implementation.
- **Counties (RCW 36) –** RCW 36.94.140 establishes the authority and mechanism for county management of water systems, including financing and setting of rates and charges. RCW 36.94.220 authorizes counties to establish local improvement districts and associated special assessments to improve utilities that benefit an area within the county. RCW 36.94.490 authorizes counties to participate in cooperative watershed management activities as part of maintaining a water or sewer system.
- **Cities and Towns (RCW 35 and 35A)** – This legislation covers all authorized responsibilities and actions of city and towns. RCW 35.67.300 and RCW 35.67.331 allow cities to contract with other cities or water-sewer districts, but must have a vote of the people if indebtedness is incurred. Of particular note is RCW 35.67.380, which authorizes participation on cooperative watershed management actions for water supply, water quality, and water resource and habitat protection and management.
- **Water-Sewer Districts (RCW 57)** – Formation of a water-sewer district could occur for the purpose of regional water/wastewater treatment, disposal, collection, or any combination thereof, if formed in accordance with RCW 57.02.040. The formation process requires compliance with comprehensive plans as well as approval by the County Boundary Review Board, unless the BRB takes no action in which case the finding of the County Commissioners is final. A District would have similar powers as cities, counties, and PUDs for funding its activities.
- **Corporations and Associations (RCW 24)** – Under RCW 24.03, Washington Nonprofit Corporation Act, and RCW 39.34, Interlocal Cooperation Act, local governments may form a 501(c)3, non-profit corporation to function as a water/wastewater treatment and resource management organization for the planning, financing, operation, maintenance, and governance of a water/wastewater utility and its facilities. The functions of the organization are governed

by its Articles of Incorporation and a set of By-laws. Membership may be composed of local governments.

- **Conservation Districts (Chapter 98.08 RCW)** – Conservations districts are authorized to engage in practices and programs for furthering agricultural and nonagricultural phases of conservation, development, utilization, and disposal of water, for the purposes of preserving natural resources. The individual districts function as an extension of the State Conservation Commission. Districts may employ technical experts, administer programs, and enter into agreements with other local or state entities to manage joint programs. Districts are typically funded by the State Conservation Commission and do not have the authority to levy taxes or issue bonds; however, RCW 89.08.400 authorizes special assessments for the purposes of natural resource conservation, to be imposed by the county legislative authority. Conservation districts have the option of utilizing a streamlined permitting process for watershed restoration projects (RCW 89.08.450-510).

The Lincoln County Public Utility District (PUD) is an in-active public utility district authorized in Lincoln County. If re-activated, it could provide the governance structure needed for the rehydration project. Because the PUD already exists, it presents the simplest option for implementation of the project, although re-activation would require a vote of Lincoln County residents. In addition, PUDs have broad powers that would accommodate governance of this type of project. The key provisions from the Revised Code of Washington (RCW) Chapter 54.16 relating to the powers of public utility districts are provided below.

- **RCW 54.16.030 Water and irrigation works.** A district may construct, purchase, condemn and purchase, acquire, add to, maintain, conduct, and operate water works and irrigation plants and systems, within or without its limits, for the purpose of furnishing the district, and the inhabitants thereof, and of the county in which the district is located, and any other persons including public and private corporations within or without the limits of the district or the county, with an ample supply of water for all purposes, public and private, including water power, domestic use, and irrigation, with full and exclusive authority to sell and regulate and control the use, distribution, and price thereof.
- **RCW 54.16.035 Provision of water service beyond district subject to review by boundary review board.** The provision of water service beyond the boundaries of a public utility district may be subject to potential review by a boundary review board under chapter 36.93 RCW.
- **RCW 54.16.050 Water rights.** A district may take, condemn and purchase, purchase and acquire any public and private property, franchises and property rights, including state, county, and school lands, and property and littoral and water rights, for any of the purposes aforesaid, and for railroads, tunnels, pipe lines, aqueducts, transmission lines, and all other facilities necessary or convenient, and, in connection with the construction, maintenance, or operation of any such utilities, may acquire by purchase or condemnation and purchase the right to divert, take, retain, and impound and use water from or in any lake or watercourse, public or private, navigable or nonnavigable, or held, owned, or used by the state, or any subdivision thereof, or by any person for any public or private use, or any under flowing water within the state; and the

district may erect, within or without its limits, dams or other works across any river or watercourse, or across or at the outlet of any lake, up to and above high water mark; and, for the purpose of constructing or laying aqueducts or pipelines, dams, or waterworks or other necessary structures in storing, retaining, and distributing water, or for any other purpose authorized hereunder, the district may occupy and use the beds and shores up to the high water mark of any such lake, river, or watercourse, and acquire by purchase or by condemnation and purchase, or otherwise, any water, water rights, easements, or privileges named herein or necessary for any of such purposes, and a district may acquire by purchase, or condemnation and purchase, or otherwise, any lands, property, or privileges necessary to protect the water supply of the district from pollution: PROVIDED, That should private property be necessary for any of its purposes, or for storing water above high water mark, the district may condemn and purchase, or purchase and acquire such private property.

- **RCW 54.16.070 District may borrow money, contract indebtedness, issue bonds or obligations -- Guaranty fund.** (1) A district may contract indebtedness or borrow money for any corporate purpose on its credit or on the revenues of its public utilities, and to evidence such indebtedness may issue general obligation bonds or revenue obligations; may issue and sell local utility district bonds of districts created by the commission, and may purchase with surplus funds such local utility district bonds, and may create a guaranty fund to insure prompt payment of all local utility district bonds. The general obligation bonds shall be issued and sold in accordance with chapter 39.46 RCW. A district is authorized to establish lines of credit or make other prearranged agreements, or both, to borrow money with any financial institution. (2) Notwithstanding subsection (1) of this section, such revenue obligations and local utility district bonds may be issued and sold in accordance with chapter 39.46 RCW.
- **RCW 54.16.080 Levy and collection of taxes -- Tax anticipation warrants.** A district may raise revenue by the levy of an annual tax on all taxable property within the district, not exceeding forty-five cents per thousand dollars of assessed value in any one year, exclusive of interest and redemption for general obligation bonds. The commission shall prepare a proposed budget of the contemplated financial transactions for the ensuing year and file it in its records, on or before the first Monday in September. Notice of the filing of the proposed budget and the date and place of hearing thereon shall be published for at least two consecutive weeks in a newspaper printed and of general circulation in the county. On the first Monday in October, the commission shall hold a public hearing on the proposed budget at which any taxpayer may appear and be heard against the whole or any part thereof. Upon the conclusion of the hearing, the commission shall, by resolution, adopt the budget as finally determined, and fix the final amount of expenditures for the ensuing year. Taxes levied by the commission shall be certified to and collected by the proper officer of the county in which the district is located in the same manner as provided for the certification and collection of port district taxes. The commission may, prior to the receipt of taxes raised by levy, borrow money or issue warrants of the district in anticipation of the revenue to be derived from the levy or taxes for district purposes, and the warrants shall be redeemed from the first money available from such taxes. The warrants shall not exceed the anticipated revenue of one year, and shall bear interest at a rate determined by the commission.

- **RCW 54.16.360 Cooperative watershed management.** In addition to the authority provided in RCW 54.16.030 relating to water supply, a public utility district may participate in and expend revenue on cooperative watershed management actions, including watershed management partnerships under RCW 39.34.210 and other intergovernmental agreements, for purposes of water supply, water quality, and water resource and habitat protection and management.

Some measures that could be used to incorporate stakeholder involvement into the governance structure for the project are briefly described below:

- **Initial Memorandum of Understanding (MOU)** – Crafting a MOU early in development of a regional partnership which outlines the key principles of the partnership that are universally agreed to and will serve as the foundation for developing a detailed intergovernmental agreement.
- **Voting Arrangements** – Establishing a voting protocol that reflects some percentage or share allocation based on a combination of capacity purchased, committed customers served, infrastructure value contributed to the regional system, or other factors. Frequently, there are varying categories of decisions that may be decided by simple majority voting. However, for more significant decisions, particularly those authorizing significant financing or changes in governance or organizational structure, a super majority or weighted vote is required such as a two thirds or three quarters majority decision.
- **Integrated Committees** – Having representation of all regional partners on committees regarding operations, maintenance, budget, etc, will provide a voice in decision making that may balance any perception of lost ownership or control. These activities may focus on routine or seasonal determinations and decisions are made by consensus or simple majority unless the issue is subject to one of the special voting arrangements.
- **Clear Cost Allocation Procedures** – Establishing cost allocation procedures on the principle of cost follows benefit. Capital costs may be assigned based on initial or expanded capacity commitments. Monthly rates should be based on cost of service procedures generally accepted in the industry that include a prorates share of O&M, taxes, debt and other costs, assigned based on measured flow or strength characteristics. Decisions must also be made regarding whether single or multiple jurisdictions would be involved in wholesale versus retail rate setting.
- **Intergovernmental Agreement** – Under RCW 39.34, Interlocal Cooperation Act, local governments can contract with each other for services that each are legally authorized to provide. Joint development and legal review of an Intergovernmental Agreement in a clear and fair manner is essential to a sustained and effective working relationship.

As the initial steps for preparation of governance for the pilot program are being implemented, it is recommended that a workshop be conducted with representatives of applicable jurisdictions and stakeholders to explore the opportunities and obstacles associated with implementation and operation of the rehydration project. Each of these entities would be asked to provide input on key policies and issues that might prove critical to the interests of their local government. Regardless of the above evaluation, there are definite advantages to shared operational staff and management strategies. The regional partners should explore these options.

5.0 DRAINAGE AND ROUTING ASSESSMENT

The purpose of this chapter is to describe the results of our assessment of the drainages selected for evaluation in this project. These reviews assess the surface hydrology and physical location of ten streams in the Crab Creek drainage to a greater or lesser degree. In the selected drainages, this assessment reviews:

1. Available information.
2. Drainage physiography, topography, and characteristics, including the size of each drainage area and some of the basic physical features within them.
3. Land use and conveyance issues, including distances for a possible delivery route by which water might be delivered from Lake Roosevelt to the drainage, usually along an existing county road or other right-of-way.
4. Groundwater and hydrogeologic conditions.
5. Specific water right issues that may play a role in determining a drainages general appropriateness for further evaluation.
6. Potential habitat and recreation benefits.
7. Potential suitability for a pilot project.

Following these reviews of the basic characteristics of these systems, the selected drainages are ranked in order of preference for further evaluation. Additional discussion of the potential fate of water, both on the surface and as recharged groundwater, delivered to the highest ranked drainage is provided. This is a very preliminary assessment of conditions within these drainages. The observations and interpretations provided here are preliminary and should be confirmed and verified through further study and monitoring. These preliminary results are not suitable for design-level evaluation and no express or implied warranty is provided. Significant additional hydrologic analysis and measurement is recommended at the feasibility level of study. The rest of this discussion focuses on the drainages in three major sub-regions of the County: (1) upper Crab Creek and its tributaries in eastern Lincoln County, (2) the tributaries draining out of central Lincoln County into Crab Creek, and (3) the Wilson Creek drainage in northwestern Lincoln County.

5.1 Eastern Lincoln County

This portion of Lincoln County is drained by upper Crab Creek and two major tributaries, Bluestem Creek and Rock Creek (Figure 27). Surface conditions in these drainages are explored individually. Basic groundwater conditions are explored in a single assessment for the eastern Lincoln County area. This assessment is based largely on anecdotal information, interviews with area residents, and field reconnaissance in 2010.

5.1.1 Upper Crab Creek

For this study upper Crab Creek is defined as that portion of the stream that flows generally north-south from the area near Reardan to the area west of Sprague, also known locally as Horseshoe Bend. Crab Creek is the trunk stream into which almost all surface drainages in Lincoln County flow. Upper Crab Creek rises near Highway 2, west of Reardan. A potential rehydration system delivery location is northwest of Reardan, at the head of Squaw Creek. This is 30 miles from a possible intake at the confluence of Hawk Creek and Lake Roosevelt, although it is much closer to the upper end of the Spokane Arm of Lake Roosevelt at Porcupine Creek or Squaw Creek in Mill Canyon (less than 15 miles).

The Crab Creek channel generally is well-defined where it crosses Highway 2. For several miles downstream of Highway 2 the stream generally occupies a broad, relatively flat valley floor where it commonly is restricted to an artificial channel. Anecdotal evidence suggests there are reaches of the stream where it flows in the subsurface, probably through Pleistocene Cataclysmic Flood deposits, and surface flows only occur during high water. Because of this pattern, much of this channel is actively farmed. Below the mouth of Bluestem Creek more reaches of the stream are dominated by narrower, bedrock bottomed coulees become more frequent.

Above the mouth of Bluestem Creek much of the valley floor is devoted to grazing and varying degrees of crop growing. Near Horseshoe Bend bottomland cropping on the valley floor also is common. From its headwaters near Reardan to the Horseshow Bend area approximately 12 road crossings are present, including those of Highway 23 and Highway 2. If water is delivered to Crab Creek as part of a future project, some of these stream crossings, especially those associated with graveled county roads may require improvements.

The presence of farmed fields and leveled channels intermittently along upper Crab Creek will need to be considered if water is delivered to the stream as part of a future project. Given this, landowner acceptance of a stream flow augmentation project will be important on this stream.

5.1.2 Bluestem Creek

Bluestem Creek rises just south of the City of Davenport, and flows southeast into Crab Creek west of Edwall. It has a drainage area of approximately 70 square miles, and the stream is approximately 15 miles long. The headwaters of Bluestem Creek are approximately 20 miles from a likely water intake location on Lake Roosevelt near the mouth of Hawk Creek.

The upper portion of the stream, from its headwaters to several miles below the Highway 28 crossing, generally occupies a broad, generally flat valley. The channel generally is less than a few feet across and a few feet deep. Below the Highway 28 crossing, the valley generally narrows and steepens, being incised into a basalt scabland coulee. There are several very small lakes along its length, generally no more than a few acres in size. Anecdotal observations suggest water generally flows in the stream most of the year.

Along most of its length land uses are devoted primarily to grazing. In addition to the Highway 28 crossing, there are five additional stream crossings on the creek, generally associated with graveled county roads. Improvements may be necessary on one or more of these if a recharge project delivers additional quantities of water to the stream.

No readily identified fatal flaw issues were identified, although the generally small size of the stream lead us to devote only a small effort to assessing the drainage.

5.1.3 Rock Creek

Rock Creek is located on the eastern side of the study area and rises in Tucker and Malloy Prairies, just southwest of the City of Medical Lake in Spokane County. Clear Lake and West Medical Lake are two of the larger water bodies in the upper basin. Rock Creek drains an area of 115 square miles and flows for 25 miles in a southwestern direction before entering Crab Creek south of Edwall. Any likely delivery location on the Rock Creek in Lincoln County is over 40 miles from the confluence of Hawk Creek and Lake Roosevelt. Given this distance Rock Creek is not assessed further for this prefeasibility study.

5.1.4 Eastern Lincoln County Hydrogeology

The Priest Rapids Member and Roza Member are both present at, or near the top of basalt in the eastern Lincoln County area (Figures 14 and 15). However, the Priest Rapids is completely absent in most down dip areas. Given unit distribution, if water is introduced into these units in their upper stream reaches, much of it will discharge into the canyons to the southwest through which the units are partially or fully incised.

The only Frenchman Springs unit with any significant presence in this group of drainages is the Sentinel Gap. The Sentinel Gap is found in the lower reaches of these drainages and if groundwater could be introduced into Sentinel Gap interflow zones, groundwater could move beneath Crab Creek and southwest into northern Adams County, assuming it could get past the Roza Dike system which would cut through the Sentinel Gap.

The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member does underlie almost the entire County. Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of all the drainages north of Crab Creek (Figure 20). If recharged, strike and dip of the unit suggests the predominant interflow orientation, and groundwater movement within such zones will be to the southwest. GWMA maps show the top of the Sentinel Bluffs exposed in Crab Creek near and east of Odessa in down dip areas. Given that, one could expect some discharge from the Sentinel Bluffs into the Crab Creek drainage. In addition, given the depth of incision into the top of the Sentinel Bluffs (which is only the uppermost 100 feet or so of this several hundred feet thick unit), and its regional dip to the south-southwest, one should expect the multiple interflow zones present within it to carry recharged water in that direction, assuming other barriers do not exist. The most notable of these barriers would be the Roza dike system. It is not known if this dike system would pose a significant barrier to groundwater movement further southwest into Lincoln County.

The deeper Grande Ronde units present in Lincoln County, the Grouse Creek Member and Wapshilla Ridge Member are only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. Given these mapped distributions, it seems likely that recharge pathways into these deeper units may be torturous and that recharge timing is slow. The most likely pathways for recharging water would be along the up-dip edges of sub-units, where water moving down dip along an interflow zone splits as a new unit intervenes. If water can get into these units as a result of recharge along the upper reaches of this drainage, it would move generally to the south-southwest.

Groundwater is reported in water wells that penetrate to the top of pre-basalt basement in eastern Lincoln County and adjacent portions of Spokane County. Generally, this groundwater seems to be associated with paleodrainages incised into the pre-basalt rock prior to the emplacement of the CRBG. We do not know if such features are present beneath this drainage system. However, given that the top of basement generally lies hundreds, if not several thousand feet beneath the surface in much of the area, it is unlikely if significant volumes of recharge water would reach it as it would have to migrate into, through, and between multiple CRBG interflow zones in the Grande Ronde to reach the top of the pre-basalt basement.

5.2 Central Lincoln County

Central Lincoln County is occupied by a series of essentially parallel northeast to southwest flowing stream drainages that merge into Crab Creek near and west of Odessa. The headwaters of all of these drainages lie near and just south of Highway 2. Fairly chaotic topography with poorly developed stream channels is common in the upper reaches of many of these streams. These streams are, from east to west, Coal Creek, Duck Creek, Lake Creek, Marlin Hollow, and Canniwai Creek (Figure 28). This assessment is based largely on anecdotal information, interviews with area residents, and field reconnaissance in 2010.

5.2.1 Coal Creek

Coal Creek rises in chaotic scabland topography southwest of the headwaters of Bluestem Creek and north of Harrington. The 35 mile long channel flows into Crab Creek five miles east of Odessa, at Sylvan Lake. There are only a few very small lakes on Coal Creek. The drainage area is 105 square miles. A likely rehydration project delivery location is two miles south of Highway 2, near Old Kuch Road. This location is approximately 27 miles from Lake Roosevelt.

Within a few miles of its headwaters Coal Creek takes on a recognizable channel as it flows down a fairly wide, gently sloped valley to and beyond Harrington. Where it flows through Harrington it occupies a channelized course that is several tens of feet wide and approximately 10 feet deep. Below Harrington, Coal Creek flows down a valley that is narrower than above, but not generally as deeply incised or bedrock floored like many of the streams in the Crab Creek system. Throughout much of this reach of the stream, the creek is channelized. The stream does not appear to have a significant history of depleted flow or losses.

Above Harrington land use along the creek is dominated by grazing. This continues below the town as well. The lower reach of the stream includes some cropping in its last few miles. There appear to be 10 stream crossings along the creek from its headwaters above Harrington to its mouth at Sylvan Lake on Crab Creek. Many of these, especially at and below Harrington are relatively large and may not require significant improvement. Unlike other streams assessed in this study, Coal Creek does flow through a town.

Land ownership issues could be difficult for getting water to the delivery point, given that it is on private property in an area lacking a defined drainage course. In addition, enhanced flows through Harrington may present challenges. If stream flow is augmented as part of a rehydration project, project managers will need to evaluate operations to prevent flooding in the town as a result of increased flows associated with rain events, snow melt events, or ice damming events. Potential issues with this stream are related to conveyance of water to the headwaters over open ground (similar to Bluestem and Canniwai). It has positive issues related to channel conveyance, recreation, and habitat.

5.2.2 Duck Creek

Duck Creek is bounded by Lake Creek to the west and Coal Creek to the east. The creek drains 115 square miles and is 21 miles in length. Duck Creek joins Crab Creek in the town of Odessa. A likely rehydration project delivery point is the creek crossing at Coffee Pot Road E. However, this location is approximately 38 miles from Lake Roosevelt near the town of Lincoln.

The upper drainage is a fairly broad, flat valley which contains a series of lakes, with Cormana and Swenson Lakes being the largest. The drainage is poorly developed above Cormona Lake, being a broad rather chaotic scabland topography, especially north of Haines Road. Downstream from Cormona Lake to the Duck Lake Road crossing the stream generally has a well developed channel and commonly occupies a small, bedrock canyon or coulee. Land uses in this reach focus primarily on stock grazing. From near the Duck Lake Road crossing to the stream's confluence with Crab Creek the valley floor is relatively flat, the stream flows through a number of channelized reaches, and cropping is common on the valley floor.

The bulk of the land along this creek is privately owned and the creek and lakes in the valley have experienced flow declines over the years. Given the distance to its headwaters, and the lack of a well defined drainage in its upper valley, Duck Creek is not evaluated further in this prefeasibility assessment.

5.2.3 Lake Creek

In addition to reconnaissance done for this project, a fair amount of previously collected information relative to other drainages in the area is available for Lake Creek (LCCD, 2000). This summary is based on that report, and field reconnaissance conducted in the spring and summer of 2010.

The Lake Creek drainage area is approximately 175 square miles and numerous lakes are located along the creek. Lake Creek is about 40 miles in length and enters Crab Creek about four miles west of Odessa. The headwaters of Lake Creek lie on either side of Highway 2 between Creston and Davenport. Most maps show that the headwaters of Lake Creek lie at a feature known as Hurley Lake, located approximately 1 mile north of Highway 2. In recent years Hurley Lake has been dry, or at best, a wetland. A likely delivery location is in the upper basin at Hurley Lake, or just south of nearby Highway 2, approximately 12 miles from Lake Roosevelt near the town of Lincoln.

The upper reaches of Lake Creek are a rocky scabland within which a poorly to moderately developed drainage exists. North of Seven Springs Dairy Road the channel is broken up in to a series of artificial ponds built to enhance wetlands and related habitat. South of this road, to the area below Delzer Falls, the stream, when it is flowing, occupies a fairly well developed channel incised into bedrock and connecting the numerous lakes in the drainage. From upstream to its confluence with Crab Creek these lakes include Wall, Twin, Coffee Pot, Deer, Browns, Tavares, Neves, Pacific, and Bobs. In addition, when water is present numerous un-named lakes, wetlands, and ponds are present along the full length of Lake Creek.

Land uses along most of its length are devoted to habitat conservation and grazing. Much of the habitat conservation ground is located in the upper drainage above Coffee Pot Lake, where significant reaches of the stream valley are owned by the Washington Department of Fish and Wildlife (WDFW) and the U.S. Bureau of Land Management (BLM). The only significant areas devoted to cropping occur locally in the upper reaches, where stock growers raise hay, and in the lower part of the drainage below Delzer Falls, where the bottomlands along the creek are partially cropped and the stream is channelized for flood control. In addition to Highway 2, the stream is crossed by seven roads of various sizes and several flow control structures have recently been built on the BLM ground. Depending on the size of a pilot test, and later full size operations, some of these structures may require reconstruction.

All indices evaluated suggest Lake Creek is favorable for further evaluation, although as is discussed in the land ownership section, local land owner concerns will need to be addressed.

5.2.4 Marlin Hollow

The headwaters of Marlin Hollow lie in the area between Willow Lake and Swanson Lakes. The drainage area is approximately 130 square miles and 25 miles in length. Marlin Hollow enters Crab Creek about two miles southeast of Krupp/Marlin. A likely rehydration project delivery location is in the upper hollow at the Swanson Lakes, about 20 miles from Lake Roosevelt.

In the upper half of the drainage, essentially above Eagle Springs Lake, there generally is no well defined channel. Marlin Hollow includes numerous lakes throughout its lower reaches, including from upstream down, Eagle Spring Lake, Little Tule Lake, Goetz Lake, Sullivan Lake, Little Sullivan Lake, and Webley Lake. Generally a moderately to well defined channel in a bedrock scabland coulee connects these lakes. In 2009, and again in 2010, most of these lakes were observed to be dry, or significantly below historical high water levels suggested by observable high water lines seen in the lakes (Figure 28). Throughout the investigation the Hollow was generally devoid of flowing water.

Land uses along the majority of the Hollow are devoted to grazing with most of the stream valley privately owned. Public lands, owned and/or administered by WDFW are found in the valley in its upper reaches around Swanson Lake. The long distance from Lake Roosevelt to the headwaters and the lack of a well developed channel in the upper Hollow presents challenges to a potential rehydration project.

5.2.5 Canniwai Creek

Canniwai Creek has its headwaters in the chaotic terrain south of Creston and Highway 2 and west of the headwaters of Marlin Hollow. Bergeau Lakes seems to generally occupy this headwaters area. The stream flows into Crab Creek between the towns of Krupp and Wilson Creek. The drainage area is about 135 square miles and its length is 30 miles. A likely rehydration project delivery location is above Flat Lake or Bergeau Lake, just south of where Sinking Creek also rises. This is 26 miles from a likely water intake location on Lake Roosevelt, with much of the conveyance route over open ground, rather than along roadways (a potentially adverse issue).

Land uses in the lower portion of the drainage, below Draper Lake, alternate between areas of cropping and pasturage and those dominated by bedrock scabland and associated grazing. This drainage generally has more defined cropping activity than the other streams considered. Most of the land along the stream is privately owned. There are six or seven road crossings along the creek, most of which appear to be in need of some improvement if water were to be introduced to the drainage. Canniwai Creek has a history of lost stream flow.

Land ownership issues could be difficult for getting water to the delivery point. The distance from Lake Roosevelt to its headwaters and the lack of a well developed upper drainage channel also present challenges to a future project. It has positive issues related to hydrogeology and water rights, recreation, and habitat.

5.2.6 Central Lincoln County Hydrogeology

The Priest Rapids and Roza both are present at, or very close to top of basalt in the upper reaches of the central County drainages (Figures 14 and 15). However, these units are completely eroded through in the middle to lower reaches the central Lincoln County drainages, and in the case of the Priest Rapids, completely absent. Based on northwest-southeast strike and southwest dip, water moving through these interflow zones will move predominantly to the southwest. Given unit distribution, if water is introduced into these units in their upper stream reaches, much of it will discharge into the canyons to the southwest where the units are fully incised through, including Crab Creek.

Two Frenchman Springs units, the Sentinel Gap and Sand Hollow, are present but do not extend far into these drainages. Sentinel Gap and Sand Hollow are only present approximately half way to two-thirds of the way up these drainages (to northwest). To recharge these units water would have to come far down these drainages. If that were to occur, any recharged groundwater would predominantly flow southwest until the units are truncated in the Crab Creek coulee around and west of Odessa. Therefore, if these were successfully recharged, they would likely discharge into Crab Creek valley. The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member, does underlie almost the entire area (Figure 20). Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of all the drainages in central Lincoln County. This system includes reaches as far northeast as Highway 21 on Cannawai Creek, above Highway 21 on Marlin Hollow, and upstream of Twin Lakes on Lake Creek. If recharged, strike and dip of the unit suggests the predominant interflow orientation, and groundwater movement within it will be to the southwest. However, the presence of at least one Roza Dike between Deer Lake (which still contains water) and Pacific Lake (dry) may restrict this flow path. If this dike system is a significant barrier to groundwater movement, the best recharge opportunities for the Sentinel Bluffs would be southwest of it. In Lake Creek that would be the area downstream of Deer Lake.

GWMA maps show the top of the Sentinel Bluffs exposed in Crab Creek near and west of Odessa in down dip areas. Given that, one could expect some discharge from the Sentinel Bluffs into the Crab Creek drainage. In addition, given the depth of incision into the top of the Sentinel Bluffs (generally less than 100 feet), and its regional dip to the south-southwest, one should expect the multiple interflow zones present within it to carry recharged water in that direction, assuming other barriers do not exist.

If these were to occur, groundwater movement would be to the southwest in eastern Grant County and the northwest corner of Adams County.

The deeper Grande Ronde units present in Lincoln County, the Grouse Creek Member and Wapshilla Ridge Member, are only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. Given these mapped distributions, it seems likely that recharge pathways into these deeper units will be torturous and recharge timing slow. The most likely pathways for such water would be along the up-dip edges of sub-units, where water moving down dip along an interflow zone splits as a new unit intervenes. If water can get into these units as a result of recharge along the upper reaches of this drainage, it would move generally to southwest

Groundwater is reported in water wells that penetrate to the top of pre-basalt basement in eastern Lincoln County and adjacent portions of Spokane County. Generally, this groundwater seems to be associated with paleodrainages incised into the pre-basalt rock prior to the emplacement of the CRBG. We do not know if such features are present beneath this drainage system. However, given the basement gets progressively deeper from north (at the surface to a few hundred feet) to the south where it is several thousand feet deep, it is unlikely if significant volumes of recharge water would reach it as it would have to migrate into, through, and between multiple CRBG interflow zones in the Grande Ronde to reach to top of the pre-basalt basement.

5.3 Western Lincoln County

This portion of the County is drained by Wilson Creek and its two main tributaries, Goose Creek and Sinking Creek (Figure 30). This summary is generally shorter than the preceding sections because the Wilson Creek drainage has been the focus of several contentious water rights challenges since the late 1980's and early 1990's. These challenges coupled with some less advantageous hydrogeologic observations suggest the drainages in western Lincoln County are not the best selections for the subsequent feasibility phase of this project.

5.3.1 Goose Creek

Goose Creek is an upper tributary to Wilson Creek and rises about 5 miles to the northwest of Creston. The contributing drainage area is 90 square miles. Goose Creek is about 18.5 miles in length and passes through the town of Wilbur before converging with Sinking Creek to form Wilson Creek. A likely rehydration project delivery location is located at the head of Halverson Canyon, which is 12 miles from Lake Roosevelt. An alternate delivery location at the head of Sherman Creek, a tributary of Goose Creek, and reached via Jump Canyon is only approximately 2 miles from Lake Roosevelt. However, an extremely steep grade and evidence of flash flooding in Jump Canyon lead us to defer further prefeasibility phase consideration of this route. Goose Creek generally flows year round and usually has large crossings and culverts. Goose Creek may be too far to the west to have a significant hydrogeologic connection or provide benefit to the middle Crab Creek reach.

5.3.2 Sinking Creek

Sinking Creek is an upper tributary to Wilson Creek and rises just south of the town of Creston. This headwater area is approximately 11 miles from a potential intake on Lake Roosevelt near the town of

Lincoln. Sinking Creek drains an 81 square mile area and flows for a length of 21 miles before converging with Goose Creek to form Wilson Creek. Sinking Creek experiences significant dewatering and would be a good location for recharging flows. However, similar to Goose Creek, Sinking Creek may be too far to the west to have a significant hydrogeologic connection to the middle Crab Creek reach.

5.3.3 Wilson Creek

Wilson Creek begins at the confluence of Sinking and Goose Creeks and travels in a southwest direction for 38 miles before entering Crab Creek at the town of Wilson Creek. The drainage area encompasses 440 square miles and it is the westernmost stream considered in the Prefeasibility Assessment. A likely rehydration project delivery location would be about a mile south of Highway 2 on Gavon Road at the creek crossing. This location is approximately 26 miles from Lake Roosevelt near the town of Lincoln. Similar to Goose and Sinking Creeks, Wilson Creek may be too far to the west to have a significant hydrogeologic connection to the middle Crab Creek reach.

5.3.4 Western Lincoln County Hydrogeology

The Priest Rapids Member and Roza Member are both present at, or very close to, the top of basalt in the upper reaches of this drainage area (Figures 14 and 15). However, below the confluence of Goose Creek and Sinking Creek, they are absent. Based on northwest-southeast strike and southwest dip, water moving through interflow zones in these units will move predominantly to the southwest. Given unit distribution, if water is introduced into these units in their upper stream reaches, much of it will discharge into the canyons to the southwest where these units are deeply incised.

The Sentinel Gap, Sand Hollow, and Ginkgo, Frenchman Springs units, do not extend far into these drainages. The Sentinel Gap and Sand Hollow only are present where Wilson Creek is leaving Lincoln County, so to recharge these units water would have to come far down these drainages. If that were to occur, any recharged groundwater would move out of the County to the south-southwest. GWMA's maps in northeastern Grant County show these units are dissected by the Crab Creek coulee. Therefore, if these units are successfully recharged, they would likely discharge into Crab Creek valley.

The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member, is found within 200 feet of the bottoms of large reaches of all the drainages in the Wilson Creek system. If the Sentinel Bluffs is successfully recharged, strike and dip suggests the predominant interflow orientation, and groundwater movement within such zones will be to the south-southwest. GWMA maps show the top of the Sentinel Bluffs exposed in Crab Creek in Grant County near and west of Marlin. Given that, one should expect some discharge from the Sentinel Bluffs into the Crab Creek drainage. In addition, given the depth of incision into the top of the Sentinel Bluffs, and its regional dip to the south-southwest, one should expect the multiple interflow zones present within it to carry a significant proportion of potential recharge water in that direction, below Crab Creek, assuming other barriers do not exist.

The deeper Grande Ronde units present in Lincoln County, the Grouse Creek Member and Wapshilla Ridge Member are only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. Given these mapped distributions, it seems likely that recharge pathways into these deeper units will be torturous, if present at all, and recharge timing will be slow. If water can get into these units as a result of recharge along the upper reaches of this drainage, it would move generally to the south-southwest.

Groundwater is reported in water wells that penetrate to the top of pre-basalt basement in eastern Lincoln County and adjacent portions of Spokane County, and northernmost Lincoln County. Generally, this groundwater seems to be associated with paleodrainages incised into the pre-basalt rock prior to the emplacement of the CRBG. We do not know if such features are present beneath the western drainage system, although they seem likely. However, given that basement is many hundreds to several thousand feet deep in most of the western County it is unlikely if significant volumes of recharge water would reach it as it would have to migrate into, through, and between multiple CRBG interflow zones in the Grande Ronde to reach to top of the pre-basalt basement.

5.4 Land Ownership Issues

A potential rehydration project would move water in a pipeline uphill from Lake Roosevelt, over the drainage divide south of the Lake, and down the generally southerly flowing drainages targeted in Lincoln County. Such a route will cross ground owned by both public entities and private individuals. These owners will have different issues and concerns that will need to be addressed in order to gain access to a proposed route. The purpose of this section is to summarize the range of issues identified during the prefeasibility assessment that need to be addressed for a rehydration project. To prepare this list of issues, GSI staff met with landowners and government entity stakeholders to describe the proposed project and learn what their issues and concerns might be concerning potential routes across their ground. A current list of interviewed landowners and stakeholders was compiled and a list of comments and concerns was prepared.

5.4.1 Private Landowners

Among the private landowners interviewed there were a variety of interests represented: stock raising, irrigated and dry land farming, and recreation. The most common concerns raised with the reintroduction of water to the area and re-establishment of flowing streams focused on questions regarding the physical transmission of the water. These concerns included:

1. The need for repairing roads and stream crossing. If flows are increased in these streams there are a number of stream crossing that will need to be upgraded to handle these increased flows without erosion damage.
2. Rebuilding fences and regulating riparian corridors. The question of whether or not fencing off of creek/water bodies was of concern to landowners who run cattle/livestock on their lands. If fencing is required, some landowners raised questions of property value should their livestock not be able to navigate property that may be essentially cut into halves should a creek return to flowing. If riparian areas are to be fenced off will more regulations from state and federal entities follow?
3. Loss of usable pasture/tillable ground. With some uncertainty of where recharge water is likely to go, some landowners are concerned about the potential for loss of pasture and hay ground due to flooding and high water. Water

4. Dam rebuilds. There are a number of small dams along many of these streams associated with past irrigation practices. Will any of these be rebuilt, and if so, how will they be operated and regulated.
5. Increased traffic with public access. Several landowners are concerned about increased traffic through their properties if the presence of water attracts waterfowl, fish and wildlife.
6. Water quality. With the objective of recharging groundwater comes a concern about the quality of recharged water. Many local residents expressed a concern for making sure that local groundwater quality is not degraded by a rehydration project.

In addition to these issues, there was an often repeated concern about the involvement of the Department of Ecology. For example, would the Department of Ecology allow the transfer of water rights from some areas that may become flooded or wet year round to areas that had previously not been covered by a water right? Also, would Ecology allow the use of surface water rights previously idled due to lack of source; and would DOE issue new water rights from renewed surface water sources?

The full list of issues we heard in the course of our interviews with private landowners and other interested parties is as follow:

- Cattle fences – will fencing off of a stream course or water body to protect water quality become an issue.
- Losing pasture/hay ground due to flooding and high water.
- Road rebuilds.
- Dam rebuilds.
- Increase in bad/noxious plants/weeds.
- Increased public access followed by abuse of private property, littering, tearing up the land.
- Piping water through or around hay/pasture ground.
- Fencing off riparian areas – do not want to invite more reasons to regulate or give Ecology any extra help in getting their foot in the door.
- Lake Creek system – landowners in favor of water returning to the lakes. Irrigation wells have decreased capacity – related to the decrease of water in the lakes.
- Cattle owners don’t want to see their access to water cut off.
- Could the project provide the potential for damming water and generating power?
- Can the project recoup some of the initial pumping costs out of Lake Roosevelt?
- What is the potential for job enhancement should the project move forward?
- Will landowners near Lake Roosevelt cooperate?
- Will the tribes cooperate? Have issues with the tribes concerning withdrawals from Lake Roosevelt been resolved?
- Would the project help move fertile soil to higher ground in favor of lower ground for submersion?
- How will project be paid for if water continues to be pumped?
- One landowner reported he felt the passive rehydration would help increase cattle supporting capacity of the land.

- Is there an existing RCW that allows public access to lakes that have a public road nearby? If water comes back, will the landowner have to allow public access to his land?
- Can landowners who have existing surface water rights drill a shallow/hydraulically connected well near stream to remove existing point of withdrawal from the stream?
- Has injecting water into the basalt system been discussed as part of this project, or an extension of this project?

As the feasibility of a specific drainage is targeted for future work, issues specific to it, including some or all of those listed above, will need to be resolved.

5.4.2 Public Entities

The primary public land managers in the drainages being assessed are the U.S. Bureau of Reclamation (BLM) and the Washington Department of Fish and Wildlife (WDFW). The WDFW field representatives we talked to about the project expressed little major concern about the prospect of revitalized stream flows in the area.

In a June 2010 meeting with the Bureau of Land Management to discuss and provide comments for their RMP, BLM indicated they are in favor of the passive rehydration project but reported that there will be NEPA requirements that have to be met before the project could proceed on BLM ground. At a minimum, a right-of-way grant will have to be obtained (see BLM ROW program – Title 43 of the Code of Federal Regulations, Parts 2800 and 2880). A ROW authorization would come from the local BLM office whose jurisdiction includes the project area. A pre-application meeting with BLM will provide an opportunity to discuss the project in detail and allow both BLM and the applicant to go over the processing requirements, as well as to address any questions or concerns regarding the project, and the fees involved. A processing fee is required for a ROW application. BLM also charges a monitoring fee and rent. However, it is possible that this project may fall under an exemption, waiver, or reduction in the processing and monitoring fees as the project is part of a state and local agency (DOE funded and LCCD managed) where the land will be used for governmental purposes and the land resources will continue to serve the public interest.

Other federal agencies such as the U.S. Park Service will also need to provide input on the project. In discussions with individuals from the Washington Department of Fish and Wildlife, they responded very positively to the idea of water being returned to the Lake Creek system if that was to be a main target area.

5.5 Drainage Rankings

The ten streams were evaluated according to the five criteria shown below within a qualitative matrix.

- Available Information: Relatively more is known about the stream based on the number of field visits and availability of prior studies.
- Conveyance Distance /Issues: Distance from Lake Roosevelt I shorter and/or it is easier to convey water to head of stream along public rights of way. (<15 miles is Positive, > 25 miles is Negative).

- Land Owners /Stream Channel Issues: Lower likelihood of adverse issues associated with land owners along the stream and number of anticipated culvert issues along the re-watered channel.
- Hydrogeology Benefits / Water Rights Issues: Higher likelihood of hydrologic benefit to the underlying aquifer and relative lack of issues concerning water rights or water use.
- Recreation and Habitat Benefits: Higher likelihood of recreational and /or habitat benefits from routing water down the channel. Related to presence or absence of de-watered lakes, etc.

The matrix (Table 5) shows how well each stream meets the respective criteria. In the matrix, Green indicates relatively higher positive characteristics. Yellow indicates neutral or a mix of positive and negative characteristics. Red indicates relatively lower or negative characteristics or issues that may count as fatal flaws for the purposes of this selection process. Because significant information is missing for many streams and criteria, the matrix is highly subjective and qualitative.   Additional information and research may alter preliminary ratings.

The qualitative evaluation based on the five criteria described above, the groundwater review, land ownership, routing, and infrastructure shows that at this time no negative issues were only found on two streams: Bluestem Creek and Lake Creek. In addition, Lake Creek had four positive ratings (the most of any stream), while Bluestem had none. After further consideration, Bluestem Creek is dropped from the candidate list at this time because of the conveyance distance and the small size of the stream.

The rankings showed the three creeks of western Lincoln County with negative water rights issues. These are related to past water rights challenges in these areas, and they are dropped from further consideration at this time.

Two creeks, Marlin Hollow and Duck Creek have several positive rankings, but one negative ranking each, channel characteristics and conveyance distance, respectively. The adverse channel characteristics of Marlin Hollow center on the lack of a well defined channel in the upper drainage, especially in its headwaters area. Within Duck Creek, the conveyance distance is high, especially for a channel that is fairly small and highly developed in its lower end.

This qualitative review would suggest that currently, based on what we know right now, Lake Creek is the best choice for a possible Pilot Study.   Based on that, the following sections make a very preliminary assessment of the pipeline infrastructure requirements and the potential fate of water delivered to the Lake Creek system as part of a pilot project. It cannot be over emphasized that this is a rough, concept-level estimate of potential Lake Creek water balance. The hydrologic estimates included in the model are preliminary and should be confirmed and verified through further study. These preliminary results are not suitable for design-level evaluation and no express or implied warranty is provided. Significant additional hydrologic analysis and measurement are recommended at the feasibility level of study.

5.6 Pipeline Infrastructure Assessment – Lake Creek

This section addresses potential infrastructure needs for the pipeline that could delivery water to the Lincoln County Rehydration Project using the Lake Creek drainage. The assumptions made in this section are preliminary in nature and should be verified as further information is available during the feasibility study and design phase. A potential future fully built out system may deliver water to the Lake Creek system, as well as to other drainage systems in Lincoln County.

The proposed system outlined here consists of a pump station sited along the shore of Lake Roosevelt in Lincoln, WA. The pump station and pipeline would convey flow approximately 14.5 miles up and out of Redwine Canyon to a location south of State Route 2. The pilot study would provide approximately 10 to 20 cubic feet per second (cfs) to the Lake Creek system with the anticipated full project providing 100 cfs to be divided between multiple drainages in the area. The preliminary pipeline route is shown on Figure 31, and a preliminary pump station layout is shown on Figure 32. For the purpose of scoping a potential feasibility evaluation, this section reviews pump station and pipeline system hydraulics, pipeline route, and a preliminary discussion on the pipeline design.

5.6.1 Pipeline – System Hydraulics, Pipeline Route, and Pipeline Design

For a 10 CFS pilot study, a 24-inch-diameter pipeline is proposed. The pilot study could be expanded to the full 100 CFS future flow by adding a 48-inch-diameter pipeline parallel to the pilot study pipeline. Conversely, depending on the project funding, a single 60-inch-diameter pipeline could be built which would handle the full build out flows and the pilot study flows (100 CFS). There are three proposed pipeline routes shown on Figure 31: Moonshine Canyon Pipeline Route, Hawk Creek Pipeline Route, and Lincoln Pipeline Route. Each route and the hydraulics will be discussed further below. A summary table of pipeline headloss is presented after the route discussion in Table 6.

The Moonshine Canyon Pipeline Route is approximately 62,000 feet (11.75 miles) long. The static elevation difference between Lake Roosevelt and the highest point is 1,160 feet. The route generally follows existing roads (Copenhaver Road, Miles Creston Road, Telford Road), which may be either gravel or pavement, depending on the location. This route is the shortest and has the lowest total dynamic head of the three routes considered. However, as shown in Figure 33 the route is through a very steep canyon with minimal clearances for construction. This route should be further reviewed during the feasibility study, but is not currently the preferred route.

The Hawk Creek Pipeline Route is approximately 74,000 feet (14 miles) long. The static elevation difference between Lake Roosevelt and the highest point is 1,260 feet. The route generally follows existing roads (Hawk Creek Road N, Miles Creston Road, Telford Road), which may be either gravel or pavement, depending on the location. This route is the second shortest, but has the highest total dynamic head of the three routes considered. The pipeline route appears feasible from the aerial photography available. However, this appears to be a shallow portion of Lake Roosevelt, with the Hawk Creek Campground website indicating that water access and usage is seasonal here. With the high head and potential for water access issues, this is not the preferred location and is not recommended for further study.

The Lincoln Pipeline Route from Lake Roosevelt to the Lake Creek system is approximately 14.5 miles long and has approximately 1,160-feet of elevation change. In general, the route follows existing roads (Redwine Canyon Road, Welch Creek Road, Miles Creston Road, Telford Road), which may be either gravel or pavement, depending on the location. This route has a more gradual elevation climb, and a wider access area for construction, as shown in Figure 34. There is a substantial culvert crossing along

Redwine Canyon Road, shown in Figure 35. While this pipeline route is the longest, it is only slightly higher in total dynamic head, and is the preferred route in this prefeasibility report.

Table 6 summarizes the hydraulic conditions used to evaluate alternative routes. Hydraulic considerations should be further reviewed during the feasibility phase. The 24-inch pipeline for the 10-20 cfs pilot project would have a velocity of approximately 3.2 feet per second regardless of the alternative. Adding the 48-inch pipeline for the full build out of 1oo cfs would give an equivalent pipe diameter of 57 inches, and a velocity of 5.6 feet per second. As discussed above, a 60-inch pipeline could be built to handle both the pilot and future flows. The velocity in this larger diameter line during the pilot study would be 0.51 feet per second; at final build out, the velocity would be 5.1 feet per second.

The Lake Creek system technically begins on the north side of State Route 2; however, based on field reconnaissance, there does not appear to be a culvert or other crossing of State Route 2. Therefore, all proposed routes assume a trenchless crossing of the highway, and nearby railroad tracks, and discharge on the south side of the highway, as shown in Figure 31.

As shown in Figure 31, the Lincoln Pipeline Route grade is steep for the first seven miles; it then flattens out for the remainder of the route. With the approximate 1,160-feet of static head and approximately 100-feet of dynamic head loss, the pipeline pressure is close to 565 psi in the first section of pipe. This pressure will require the use of steel pipe. The second half has a much more moderate 200’ grade change resulting in a pipe pressure less than 100 psi. For this second segment, any pipe material (steel, ductile iron, PVC, or HDPE) could be used. For the purpose of this TM, the entire pipeline route is assumed to be steel. The steel pipe thicknesses used are presented in Table 7.

5.6.2 Pump Station

There are several components to the proposed pump station addressed here, including site, layout, and the intake structure.

Pump Station Location

During field reconnaissance several proposed pump station sites were reviewed. At this time, the preferred location for a pump station is at, or near, an abandoned lumber mill site in Lincoln, Washington. The mill structures have been mostly been demolished and removed from the site, except for the burner structure and some foundation fragments, as seen in Figure 36.

A significant consideration for the pump station siting is available power. During the field visit, three phase power lines were observed all the way to Lincoln. However, the availability, quantity, and quality of this line are not known at this time and should be investigated further in the feasibility and design phases.

Pump Station Layout

A proposed pump station site needs to accommodate both the pilot study size facilities and the future full build out condition. A preliminary plan and section of the pump station is included in Figure 32. This figure shows both the pilot study pump station and future growth plan for the pump station at a later date.

For the pilot study, two 10 cfs pumps are assumed. These pumps would provide redundancy during the pilot study, and also could be run in parallel in the future to increase flows to 15-17 cfs. For the full build out phase, four 20 cfs pumps would be added to increase the total pump station to 100 cfs capacity. Between the different sized pumps, any flow rate between 10 and 100 cfs could be achieved (in 10 cfs increments). This allows the future operators the flexibility to provide different flow rates at different seasons and/or to different creek systems. Redundant pumps and backup power are not included for the facility as it is likely not critical that the pump station provide 100 cfs at all times.

During the feasibility study, further review of the pump station should include determining if portions of the pump station should be built at the full-build out size during the pilot study. For some features, such as the wet well, it may be more cost effective to construct in one project than trying to accommodate future expansion.

Other appurtenances for the pump station, such as meters, valving, surge tanks are not shown at this time and need to be further reviewed during the feasibility study.

Intake Structure and Fish Screen

A challenging aspect of the project will be the pump station intake located in Lake Roosevelt. The water level in Lake Roosevelt varies by season from a low of 1,217-feet to a high of 1,290-feet. As the project progresses, further discussions are needed to determine if the intake structure needs to accommodate the full 80-feet of lake variation or if the pump station would only operate during a portion of the year. The wide variation may require a deep tunnel into the reservoir for the intake. Two options to be considered in the feasibility phase are a lake tap and microtunnelling into the reservoir. Each have benefits and drawbacks which must be examined. For the purpose of this prefeasibility TM, microtunnelling is the preferred option and included in the Opinion of Cost.

The Columbia River and Lake Roosevelt are known fishing habitats and recreation areas. Also, there is a fish farm near the potential intake site in Lincoln in Welsh Creek Cove. A fish screen will be required on the pump station intake, and is shown on Figure 2; however more detailed analysis and design are required. While most portions of the project can be scaled down for the pilot study, the intake structure and fish screen probably should be built to the full-build out condition. Mobilizing a contractor for a lake tap or microtunnel is costly, and the work is quite difficult. There would likely be a cost savings by constructing one intake at a larger size rather than two smaller projects.

5.7 Fate of Water – Surface Hydrology: The Lake Creek Drainage

This section presents a preliminary analysis of the possible fate of water delivered to the Lake Creek system, the drainage currently ranked as the most favorable one for a potential pilot rehydration project. We have selected Lake Creek for this preliminary analysis because the information collected to-date places it at the top of our recommended list of target drainages for a potential pilot project. The preliminary assessment looks at both potential surface water conditions and groundwater conditions that might result from a future pilot rehydration pilot project.

The primary purpose for this water balance analysis is to provide a rough idea of the potential effect of the pilot study on Lake Creek flows and water levels. In addition, it can inform future decision makers regarding characterization and background data collection needs, monitoring design, and implementation of a potential pilot project. If the pilot project is implemented this model will be refined, or more likely upgraded, using characterization, monitoring, and operations data so it can be used to support project management and operations decisions. The analysis provides an indication that the addition of water to the upstream end of Lake Creek may result in additional water in the lakes near the downstream end of the basin.

5.7.1. Available Flow Data and Weather Data

There is no continuous stream gage data available on or near Lake Creek. Spot data was gathered at eleven locations throughout the basin, every other month and once a quarter, from August 1998 to July 1999. This data was collected and presented by Lincoln County Conservation District (LCCD) for a water reuse feasibility study (LCCD, 2000). The Washington Department of Ecology also collected spot data at a single location just upstream of Coffeepot Lake, once a month, from January 1996 to July 1996. The available flow data used in this analysis are summarized in Table 8.

Besides the two sets of spot gage data, there is an anecdotal account of water levels and flows during spring 1996 until present. A local resident reported that in the spring of 1996 Pacific Lake filled for the last time and that by the end of 1997 it was dry. The anecdotal data also says that the stream above Coffee Pot Lake usually has less than 1 to 5 cfs of flow in it most of the year, but below Coffee Pot Lake the creek is ephemeral.

There is a long-term record of precipitation and evaporation-transpiration from the Reclamation Agrimet site at Odessa, Washington, which is near the downstream end of the watershed. This record has daily data from 1984 to present.

5.7.2 Basin Areas and Lake Geometry

The Lake Creek drainage basin was sub-divided into four sub-basins (Figure 37), and the drainage area for each sub-basin was found using USGS quad maps in GIS and the USGS's Watershed Boundary Database. The surface area for lakes along Lake Creek was found using the Water Bodies layer of USGS's National Hydrography Database (NHD). The estimated depth for each major lake was obtained from the text of the water reuse feasibility study performed by LCCD. Additional information on lakes was obtained from (Dion et al., 1976).

In order to have enough, complete data to develop a water balance and estimate runoff losses and seepage, the spot data reported in Table 8 was assumed to be the average flow for that month, and flows were interpolated for the missing months from August 1998 to July 1999. Estimated flows are shown highlighted in Table 9.

Examination of the measured and estimated flow in Table 9, in combination with the anecdotal data, allows a few generalizations about the basin.

- Lake Creek, as it leaves the most upstream sub-basin above Upper Twin Lakes, has flow year round.
- Flow is seen to increase earlier in the year in the upstream reaches compared with downstream reaches.
- Seepage or another similar process depletes Lake Creek flow to zero in the downstream reaches for parts of the year.

5.7.3 Development of Water Balance

Using the limited available and estimated data to predict the possible effects of adding water to Lake Creek was a three step process, as follows:

1. Estimate runoff loss coefficient in the basin.
2. Estimate the average seepage rate for each sub-basin. Use the available data with the calculated runoff loss and seepage rates to create a water balance model to predict how the basin functions long-term. Adjust the seepage estimates so the long-term model agrees with historically measured/observed function of the basin.
3. Use the model to estimate the effects of adding pilot program flows to Lake Creek.

5.7.3.1 Runoff Losses

The runoff loss was calculated for the sub-basin above Upper Twin Lake.

$$R_{loss} = (PxA)+Q_{in}-Q_{out}-S$$

Where:

R_{loss} is runoff loss

P is precipitation

A is sub-basin area

Q_{in} is inflow from upstream (assumed to be zero, because upper Twin Lakes sub-basin is the most upstream in the Lake Creek basin

Q_{out} is outflow into Upper Twin Lake (estimated from Table 9)

S is seepage

The seepage in the Upper Twin Sub-Basin is assumed to be negative, indicating that base flow discharges into the creek, as opposed to seepage from the creek into the underlying groundwater, which would be positive. Anecdotal reports suggest that there is usually flow in the creek upstream from Coffeepot Lake and the smallest spot measurement was 0.5 cfs. Therefore, the seepage in the runoff loss equation, for Upper Twin Sub-Basin, is held at a constant flow of -0.5 cfs.

The runoff loss was calculated on a monthly basis for August 1998 to July 1999. The total loss for the year is divided by the total annual inflow, and subtracted from one, to get the runoff loss coefficient (C_{loss}) of 85 percent.

$$\underline{\Sigma\, R_{loss}}$$
$$C_{loss} = 1$$
$$\sum P\ xA$$

5.7.3.2 Calculating Seepage Rates

The runoff loss calculated for Upper Twin Lakes Sub-Basin was applied to the drainage areas of the other three sub-basins. The sub-basin equation for each of these basins was then solved for seepage.

$$S = c_{loss}(P \times A) + Q_{in} - Q_{out}$$

Where:
S is seepage (+ infiltration, -discharge)
P is precipitation
A is sub-basin area
Q_{in} is inflow from the sub-basin upstream, Table 9
Q_{out} is outflow into the sub-basin downstream, Table 9
C_{loss} is runoff loss coefficient (initially 0.85)

The seepage is calculated on a monthly basis for each sub-basin from August 1998 to July 1999. The seepage is allowed to be positive or negative. These monthly values were summed for an average annual seepage rate.

5.7.3.3 Water Balance Model

A simple water balance model was developed using the four sub-basins and three lakes. A map of the area with the sub-basins and lakes used in the water balance model is provided in Figure 37. The order that the water balance calculates water flow through the basin is shown in Figure 38.

Because of the scarcity of data available for the basin, several assumptions were made to complete the water balance analysis.

- Runoff loss coefficient is the percent of the precipitation falling on the basin, which results in flow into the creek. This percentage is constant throughout the entire basin and throughout the duration of the water balance model.
- Each sub-basin has a seepage rate that is constant throughout the duration of the model.
- For the water balance, water can only flow out of a lake if the lake is near its maximum volume.

The water balance model was run on a monthly time step from January 1985 through August 2010. The water balance model applies the runoff loss coefficient to the sub-basins and the seepage rates to the lakes. This is discussed in greater detail below.

5.7.4 Sub-Basin Analysis

The equation used for flow through the sub-basins is:

$$= Q_{in} + c_{loss}(P \times A)$$

Q_{out}

The maximum volume for each lake was found by using the surface area found in USGS Water Bodies NHD and the depth provided in the LCCD's reuse feasibility study. The water balance first calculates a change in storage within the lake using weather data, seepage rate, and inflow, see Figure 39. The outflow from the lake to the next sub-basin is not used in this equation.

The change in lake volume is then compared to the existing lake volume and the maximum lake volume using the logic diagramed in Figure 40. This logic sequence decides the volume of the lake and the flow out of the lake for each time step. The flow out of the lake is then used as inflow to the next downstream sub-basin. This step helps approximate the process of the lakes filling during wet periods and draining during dry periods.

5.7.4.1 Long-Term Modeling Results - Runoff Loss Coefficient Results

The long-term modeling results for the prefeasibility estimate yielded the following:

- Runoff Loss Coefficient: The best runoff loss coefficient found using the Upper Twin sub-basin data was 0.896. That means that only about 10.4% of the precipitation falling on the basin on an annual basis results in runoff. The other 89.6% accounts for things like ET, sublimation of snow, and deep infiltration.
- Seepage Loss Results: The seepage rates found using the spot gage data are summarized in Table 10. The calculation resulted in a net baseflow into the creek upstream of Coffeepot Lake and a net loss to groundwater downstream of Coffeepot Lake. This result is supported by the anecdotal reports that the creek above Coffeepot Lake always has some flow in it, and that below Coffeepot Lake the creek is ephemeral.
- Water Balance Seepage Loss: The water balance model used the initial runoff loss and seepage rates calculated from the 1998-1999 spot data. The model was run with the precipitation and evaporation data for the period 1985 through 2010. The water balance model was calibrated to agree with the anecdotal information that Pacific Lake has not filled since 1999. The resulting estimated seepage losses are shown in Table 11. This is approximately a 27% increase in seepage in the downstream reaches, compared with the originally estimated seepage losses from the spot data.
- Predictive Results: Using these long term seepage losses, the outflow from the Lake Creek sub-basin into Crab Creek is estimated as shown in Figure 41. The estimated storage in each modeled lake is shown in Figures 42 through 44.

5.7.5 Water Balance Conclusions

The Lake Creek water balance model suggests that the Lake Creek basin loses approximately 19 cfs to seepage, when there is water available. The average inflow to the basin from precipitation runoff is estimated to be about 14 cfs. Although based on a very small amount of measured data, if the assumptions are close to being correct, these numbers suggest that the water balance of Lake Creek could be altered from being a net losing stream (with losses greater than gains and frequent zero outflow), to a flowing stream, with the addition of as little as 5 to 10 cfs of supply.

The Lake Creek water balance model provides the foundation of a predictive method to estimate the effect on Lake Creek water balance of a proposed rehydration project. By adjusting the inflow to the Upper Twin sub-basin, the model can predict the water levels in the lakes and the flow out of the basin into Crab Creek. A summary of the number of years Pacific Lake is predicted to fill during the water balance simulation and the average additional seepage and flow in Lake Creek at the confluence with Crab Creek is summarized in Table 12. The predicted effect on Pacific Lake of adding as little as 10 cfs of additional water to the stream has the potential of causing a dramatic impact to lake storage. The predictive model indicates that Pacific Lake could fill in nearly every year with an added 10 to 15 cfs of inflow and that this would also produce significant increases in the volume of water entering the groundwater basin contributing to Crab Creek. The model-predicted storage in Pacific Lake, assuming a constant 10 cfs of supplementation, is compared with the existing conditions model-predicted Pacific Lake contents in Figure 45.

5.8 Conceptual Groundwater Model

As is suggested in the previous section, there appears to be capacity for stream losses into the aquifer system underlying the Lake Creek drainage. This certainly is suggested by the anecdotal history of the drainage, especially below Coffee Pot Lake. The purpose of this section of the prefeasibility report is to present a conceptual groundwater flow model that explores the potential fate of that water once it enters the basalt aquifer system underlying the Lake Creek drainage. If the proposed project moves forward this conceptual model will provide a basis for proposing a groundwater monitoring program for the project, and as this data is collected it will be refined to such time as it can be used as the basis for a numerical model that will have utility in predicting future project performance.

Basic assumptions made in this conceptual groundwater model are as follows:

- Within the Lake Creek drainage we assume that vertical leakage into and through the basalt is effective to depths of 200 to 300 feet. Below those depths vertical leakage is assumed to be negligible and all groundwater flow is parallel to bedding dip.
- Regional groundwater flow direction is from north-northeast to the south-southwest, down dip.
- Vertical leakage into the basalt aquifer system is negligible above Coffee Pot Lake, and indicated by normal long-term water levels in Twin Lakes in the upper reach of the drainage.
- Seepage losses become progressively greater below Coffee Pot Lake, as evidenced by each lake downstream appearing to be dryer. Deer Lake has lost approximately 1/3 of its volume, Browns Lake approximately ½, Taveres Lake over 9/10, and lakes below there from Neves Lake to Bob's Lake, including Pacific Lake, are completely dry.
- The fold mapped at the narrows on Coffee Pot Lake and the Roza Dike identified at Taveres Lake are interpreted to contribute to these observed hydrologic conditions with them impeding vertical leakage and lateral flow away from the upper portion of the drainage system.

Groundwater systems within the shallowest units, those completely eroded through in the middle to lower reaches of these drainages, would be fairly localized. Based on northwest-southeast strike and southwest dip, water moving through these interflow zones will move predominantly to southwest. Given unit distribution, if water is introduced into these units in their upper stream reaches, much of it will discharge into the canyons to the southwest where the units are fully incised through, including Crab Creek. Generally, these shallowest units would correspond to the Wanapum Basalt.

The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member, does underlie almost the entire area (Figure 20). Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of all the drainages in central Lincoln County. This system includes reaches as far northeast as Highway 21 on Cannawai Creek, above Highway 21 on Marlin Hollow, and upstream of Twin Lakes on Lake Creek. If recharged, strike and dip of the unit suggests the predominant interflow orientation, and groundwater movement within it will be to the southwest. However, the presence of at least one Roza Dike between Deer Lake (still contains water) and Pacific Lake (dry) may influence this flow path. If this dike system is a significant barrier to groundwater movement, the best recharge opportunities for the Sentinel Bluffs would be southwest of it. In Lake Creek that would be the area downstream of Deer Lake.

GWMA maps show the top of the Sentinel Bluffs exposed in Crab Creek near and west of Odessa in down dip areas. Given that, one could expect some discharge from the Sentinel Bluffs into the Crab Creek drainage. In addition though, given the depth of incision into the top of the Sentinel Bluffs (generally less than 100 feet), and its regional dip to the south-southwest, one should expect the multiple interflow zones present within it to carry recharged water in that direction, assuming other barriers do not exist. If these were to occur, groundwater movement would be to the southwest in eastern Grant County and the northwest corner of Adams County.

The deeper Grande Ronde units present in Lincoln County, the Grouse Creek Member and Wapshilla Ridge Member, are only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. Given these mapped distributions, it seems likely that recharge pathways into these deeper units will be torturous and recharge timing slow. The most likely pathways for such water would be along the up-dip edges of sub-units, where water moving down dip along an interflow zone splits as a new unit intervenes. If water can get into these units as a result of recharge along the upper reaches of this drainage, it would move generally to the south-southwest.

6.0 Conclusions and Recommendations

The ultimate goal of the Lincoln County Rehydration Project is to deliver water from Lake Roosevelt to the Crab Creek drainage (watershed) within Lincoln County. This report summarizes the results of the Prefeasibility Assessment of this project idea. Using available scientific information, preliminary field reconnaissance, very basic engineering assessments, interviews with landowners in and around the potentially affected area, review of water rights availability, and information provided by personnel with various federal and state agencies, this Prefeasibility Assessment for the Lincoln County Conservation District Rehydration Project was done to determine if work should move forward into a feasibility phase. The feasibility phase would further define the scope of a project and potentially start the permit and authorization process, eventually resulting in the planning and implementing of a pilot scale project.

6.1 Conclusions

Based on this Prefeasibility Assessment reported on herein, it is our conclusion that the rehydration project envisioned by LCCD meets the goals, objectives, and intent of RCW 90.90 could be met by the rehydration project envisioned by LCCD. Viable options for securing water rights to be used in supplying water for a proposed pilot scale project have been identified, and one or more delivery routes appear to be amenable to a potential project. Coupled with these conclusions this Prefeasibility Assessment does not identify fatal flaws in the passive rehydration concept with respect to geology, hydrogeology, routing, delivery pathways, regulatory and permitting issues, land ownership, water rights, and environmental concerns that could influence project implementation. While many challenges to this project were identified, none were found to be insurmountable.

With respect to the intent of RCW 90.90 (the one-third in-stream, two-thirds out of stream division of water) we have found that this may, or may not apply to the pilot study. Specifically, it is not clear that every project identified under RCW 90.90 must precisely comply with the division of water, and it is not completely clear that any in stream flow benefits only apply to the main stem of the Columbia River. It is likely that only the total of all the projects funded under the law (or of a given combination of projects) needs to comply. Nevertheless, a brief description of how a Lincoln County Re-hydration pilot study might meet this requirement is provided in this section.

Water pumped out of Lake Roosevelt and released into Lake Creek would flow downstream, contributing to in stream flows and likely producing gains to riparian habitat and water-based recreation. The extra water flowing down the creek could be diverted for use by irrigation water users along the creek, or it could be allowed to continue flowing downstream to rehydrate the channel and lakes at the bottom of the basin. If allowed to flow undiverted to the confluence of Lake Creek with Crab Creek, a portion of the supplemental water would seep into the ground and, presumably, contribute to the overall groundwater supply in the area, which is currently over-allocated. If allowed to flow into Crab Creek, a portion of the water would presumably return, unconsumed, to the Columbia River. It should be noted that both the water that seeps into the ground and any part of the supplemental water that is diverted would directly contribute aquifer recharge in the Odessa Subarea as identified in RCW 90.90 part (2)(b), “alternatives to groundwater for agricultural users in the Odessa subarea aquifer”.

Based on our review of potential water rights options that might be used for a pilot project we have found that a preliminary permit issued under a reservoir permit application would be the most feasible approach to obtaining the use of water for the pilot project. Other options reviewed include: (1) a temporary use authorization, (2) municipal and industrial use water acquired from the BOR, and (3) long-term water rights agreements with the BOR. The preliminary permit would provide authorization for the use of Lake Roosevelt water for a potential pilot project. If the project is authorized to move forward into the feasibility phase, and the feasibility work suggests a pilot project is potentially doable, a reservoir permit application would be completed and submitted to Ecology at the completion of the feasibility phase. This application would name the responsible authority that will take on the planning, permitting, construction, and operation of the pilot project.

Governance and land owner issues will need to be addressed in the feasibility study. Governance, or ownership, of the pilot project and a potential subsequent long-term project is important from the point of view that some entity will be responsible for owning and operating the project, holding necessary water rights and permits that will be required for the project to function, and planning and reporting on project activities. While no specific entity has yet been identified for this role, the currently inactive Lincoln PUD and the Lincoln Water Conservancy Board have expressed conditional interest in at least exploring potential roles in the project. Once an ownership, or governance, entity is identified, land owner agreements, NEPA/SEPA, and other activities can be completed.

A preferred Lincoln Pipeline Route for delivering water into the Lake Creek drainage has been identified in this Prefeasibility Assessment. This route is slightly longer than other potential routes, but overall has a more open construction route and would require lower head pumps.

Given the recorded history of stream flow losses and lake depletion in the lower half of the Lake Creek drainage we conclude that the lower reaches of the Creek are likely candidates for potential basalt aquifer recharge. At this time we believe that shallow basalt aquifer recharge (that staying with 200 to 300 feet of the surface) will most likely be local, and at best result in spring discharge into Crab Creek at and downstream of Odessa. On the other hand, and as seems likely given the distribution of the Sentinel Bluffs Member of the Grande Ronde Basalt, we interpret a high degree of recharge potential for the Sentinel Bluffs Member. Successfully recharging groundwater in this unit will result in down-dip/down-gradient recharge of the upper Grande Ronde aquifer systems south of Crab Creek. Movement of recharged groundwater in this unit to the south of Crab Creek will occur because the creek does not incise deeply in the Sentinel Bluffs; therefore if water can get deeper in to the unit it has the potential to move unimpeded beneath Crab Creek and south into the core of the Odessa Subarea.

6.2 Recommendations

Based on the results of this effort we recommend that the project move forward to the feasibility phase in order to further define how RCW 90.90 would benefit from the project, begin securing the necessary water rights and project authorizations for a pilot scale project, and select a pilot project route and an accompanying preliminary project engineering and routing design and monitoring and operations plan. In addition, the feasibility effort should focus on better defining one or more routes, securing the cooperation of an owning/operating entity, gaining permission to access one or more proposed routes (including identifying potential mitigation actions that might be needed to secure some portions of the route), and writing a project plan that can be used to move the project forward.

Specific recommended actions for the feasibility portion of the project include the following:

1. Gain the active participation of potential governing/ownership entities in the project. While such an entity may not need to be fully in place and operating at the end of the feasibility phase, it should be actively preparing for project participation as it will of necessity be holding water rights associated with the pilot project and executing land access agreements with private and public entities. In addition, this entity will have an important role in submitting and acquiring permit applications (including SEPA and NEPA documentation), soliciting funding for project construction, planning and conducting project construction efforts, and implementing characterization, background monitoring, mitigation, and related investigative efforts prior to the delivery of water.
2. Identify land access requirements for the primary preferred route across private ground, prepare documentation (to the extent possible given available funding) and /or identify documentation needs for access to public lands, and prepare planning documents as needed to describe construction, mitigation, and routing needs for effected public and private entities.
3. Conduct more detailed routing/engineering evaluations such as:
    - A field survey of the pipeline route and potentially other routes.
    - Bathymetric survey in the vicinity of the proposed lake intake.
    - A fish study and determine the intake fish screen structure required.
    - Review the permitting and environmental constraints associated with the project.
    - Perform geotechnical exploration at the pump station location and along the pipeline route.
    - Determine whether a pilot study is desired, or whether the project should proceed to the full build-out condition.
    - Perform a power requirement and availability analysis.
    - Perform more detailed design and analysis for the preferred option.
    - Determine availability of land, both at the pump station site and along the pipeline route. Potentially acquire easements.
    - Determine security requirements, such as fencing and alarms.
    - Determine operation and maintenance costs for the facilities.
    - Perform surge analysis on the pipeline. Determine size and location of surge protection devices, such as surge tanks and air valves.
4. Prepare a monitoring plan to include surface and subsurface monitoring. Surface monitoring would look at such things as: (a) gauging the effects of flow on stream channel stability and

erosion, (b) improvement and/or degradation of habitat, (c) riparian conditions, (d) water quality, and (e) impacts to human structures, including culverts, farm ground, grazing ground, and homes. Subsurface monitoring would focus on two primary efforts. One would be documenting changing conditions from the perspective of non-degradation of existing groundwater resources. The other would be to see if the project even has a measurable impact on groundwater resources, e.g., is recharge occurring. Of necessity, both monitoring efforts would start with a characterization effort to define pre-project background conditions. Data gathering efforts for this endeavor would be guided by Ecology approved QAPP's.

5. While the preparation of a reservoir permit may not be completed during the feasibility portion of the project (because a governing/owning entity may not have yet be formalized), feasibility work should result in the collection and documentation of all information needed to support a reservoir permit requesting a preliminary permit, once that entity is in place.

6.2.1 Feasibility Study Work Plan

A feasibility study work plan will need to be developed prior to the initiation of the study. Most of the elements of that plan are introduced in the recommendations. If the conclusions and recommendations provided herein are accepted, they will be converted to a work plan for guiding the feasibility phase.

6.2.2 Pilot Project

As noted in different sections of this report, the pilot project envisions the delivery of approximately 10 to 20 cfs of water to the upper reaches of one or more drainages in Lincoln County. At this time we recommend that this drainage be Lake Creek. The source of rehydration water will be the Columbia River (Lake Roosevelt).

Generally, the pilot project will pump water up to and over the drainage divide separating Lake Roosevelt from the Crab Creek watershed. This water will be delivered via a pipeline. The pipeline will convey water into a targeted drainage and it will then be allowed to flow under normal conditions down-stream. Channel modifications will be made as are necessary to meet private and public access requirements, mitigate against erosion, siltation, and other unwanted impacts, promote through flow in specific reaches, and if desired facilitate infiltration and groundwater recharge. Monitoring points for both surface and subsurface conditions will be established throughout the project area to alert project operators of the presence of potentially adverse impacts and to allow operators to track project performance especially with respect to groundwater recharge, enhanced water resource supplies, and habitat improvements.

If the feasibility effort is authorized, it will describe the proposed pilot project that could result from the feasibility effort, if it is determined by responsible authorities that such a project is desirable.

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