Prefeasibility Assessment Report

Lincoln County Passive Rehydration Project

Prepared for the
Washington State Department of Ecology

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

April 2011

Passive Rehydration Project	
Ecology Grant No.	G1000097
Source of Funds:	Columbia River Basin Water Supply Developments Account
Grant Amount:	$350,000
Eligible Project Cost:	$350,000
Department Share:	$350,000
Effective:	August 1, 2009 to June 30, 2011

Ecology Publ;ication Number: 11-12-005

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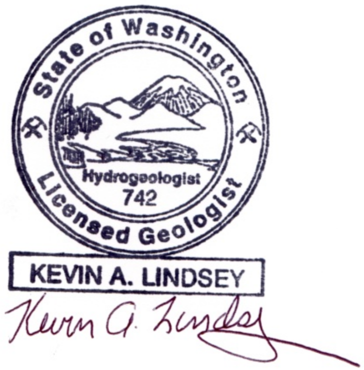

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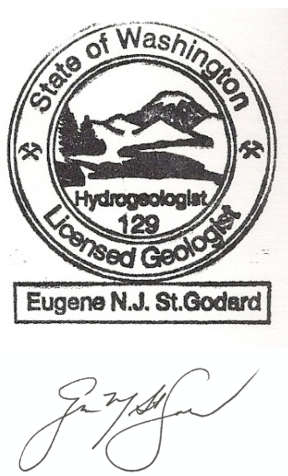

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Table of Contents

List of Tables

List of Figures

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Acronyms and Abbreviations

AMSL	above mean sea level
bgs	below ground surface
Bi-Op	Biological Opinion
BLM	Bureau of Land Management
BPA	Bonneville Power Administration
cfs	cubic feet per second
CRB	Columbia River Basalt
CRBG	Columbia River Basalt Group
CWA	Clean Water Act
DCM&I	domestic-commercial-municipal, and industrial
DNR	Washington State Department of Natural Resources
DTW	depth to water
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
ESA	Endangered Species Act
FCRPS	Federal Columbia River Power System
GIS	geographic information system
GRB	Grande Ronde Basalt
GSI	GSI Water Solutions
GWMA	Columbia Basin Ground Water Management Area
HDR	HDR Engineering, Inc.
LCCD	Lincoln County Conservation District
M&I	Municipal and Industrial
MOU	Memorandum of Understanding

MSL	mean sea level
n.d.	no date
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
OCPI	overriding consideration of public interest
PCHB	Pollution Control Hearings Board
PUD	Public Utility District
RCW	Revised Code of Washington
Reclamation	U.S. Bureau of Reclamation
ROW	right-of-way
SEPA	State Environmental Policy Act
SNOTEL	Snowpack Telemetry System
U.S.C.	U.S. Code
USDOE	U.S. Department of Energy
WAC	Washington Administrative Code
WB	Wanapum Basalt
WDFW	Washington State Department of Fish and Wildlife
WNR	Water and Natural Resources Group
WRCC	Western Regional Climate Center
WRIA	Water Resource Inventory Area

Executive Summary

The Lincoln County Rehydration Project would deliver water from Lake Roosevelt to the Crab Creek watershed within Lincoln County. A portion of the delivered water would rehydrate depleted lakes and streams tributary to Crab Creek. A portion of the delivered water would infiltrate and help replenish the over-drafted groundwater aquifer within the Odessa Subarea. This report describes a prefeasibility analysis of this project idea. Using available scientific information, preliminary field reconnaissance, basic engineering and hydrologic assessments, interviews with landowners in and around the potentially affected area, and information provided by personnel with various federal and state agencies, this prefeasibility assessment for the Lincoln County Conservation District Passive Rehydration Project shows that work should move forward into the feasibility phase: further defining the scope of the project, securing permits and authorizations to proceed, and planning and implementing a pilot scale project.

Based on the work reported on herein, it is the project team's conclusion that (1) the goals, objectives, and intent of RCW 90.90 can 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 potential options identified for assembling a potential water right portfolio for a final project buildout; and (3) one or more routes and drainages seem to be favorable to a potential project. Coupled with these conclusions, this Prefeasibility Study identifies no fatal flaws in the passive rehydration concept with respect to geology, hydrogeology, routing, delivery pathways, regulatory and permitting issues, land ownership, water rights, or environmental concerns. While many challenges were identified, none were found to be insurmountable. The assessments done for this report do not include a cost-benefit evaluation.

RCW 90.90 Compliance. RCW 90.90 specifies that one-third of the water developed by new storage under the Act must contribute to instream flow. The project team finds that this may not apply to the pilot study, since new storage water will likely not be the source of the water used. Also, not every project must exactly comply with the division of water—it is likely that only the total of all of a combination of projects needs to comply. Nevertheless, a brief description of how a Lincoln County rehydration pilot study might meet this requirement is provided in this report.

As shown in the project schematic, this project would pump water out of Lake Roosevelt and deliver it into one or more drainages in the Crab Creek watershed, initially in a pilot project and, if successful, in a larger, 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 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 contribute to the overall groundwater supply in the area, which is currently over-allocated. The portion allowed to flow into Crab Creek would 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 rediverted would directly contribute to RCW 90.90 part (2)(b), which encourages "alternatives to groundwater for agricultural users in the Odessa subarea aquifer."

Water rights review. A review of potential water rights options that might be used for a pilot project identifies the following: (1) a temporary use authorization, (2) municipal and industrial use water acquired from the U.S. Bureau of Reclamation (Reclamation), (3) long-term water rights agreements with Reclamation, (4) a preliminary permit, and (5) lease/ transfer of a private water right. This prefeasibility assessment suggests that approach 5 is the most feasible. The temporary permit would provide authorization for the use of Lake Roosevelt water for a potential pilot project and allow it to be put to beneficial use while the pilot testing program was being conducted. If the project is authorized for moving forward into the feasibility phase, a water right permit application would be completed and submitted to the Washington State Department of Ecology (Ecology) at the completion of a successful feasibility phase. This application would name the responsible authority that would take on the planning, permitting, construction, and operation of the pilot project. Other water right use options other than a new water right permit would be used to compile a water right portfolio to operate the system, inclusive of but not limited to leasing water, purchasing and transferring water rights, and developing an Upper Lake Roosevelt water banking program.

Project governance. Governance and landowner issues would 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 would be responsible for owning and operating the project, holding necessary water rights and permits that would 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 Public Utility District (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, then landowner agreements, National Environmental Policy Act/State Environmental Policy Act (NEPA/SEPA), and other activities can be completed.

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

Drainage recommendation. 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 plausible candidates for potential basalt aquifer recharge. At this time we believe that basalt aquifer recharge will impact a shallow basalt aquifer system and a deeper basalt aquifer system. The shallower basalt aquifer system (that staying within 200 to 300 feet of the surface) is most likely a local system predominantly within the Wanapum Basalt and will result in spring discharge into Crab Creek at and downstream of Odessa. The deeper basalt aquifer system, found predominantly within the upper Grande Ronde Basalt, is more extensive. If recharged groundwater water can reach into this system the project should recharge groundwater systems south of Crab Creek. 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.

Next steps. The prefeasibility assessment was funded by a grant awarded to Lincoln County Conservation District by the Department of Ecology Columbia River Basin Water Management Program (Grant No. 1000097). If the results of the prefeasibility assessment are accepted by Ecology, additional funds will be released for the next phase, a feasibility study.

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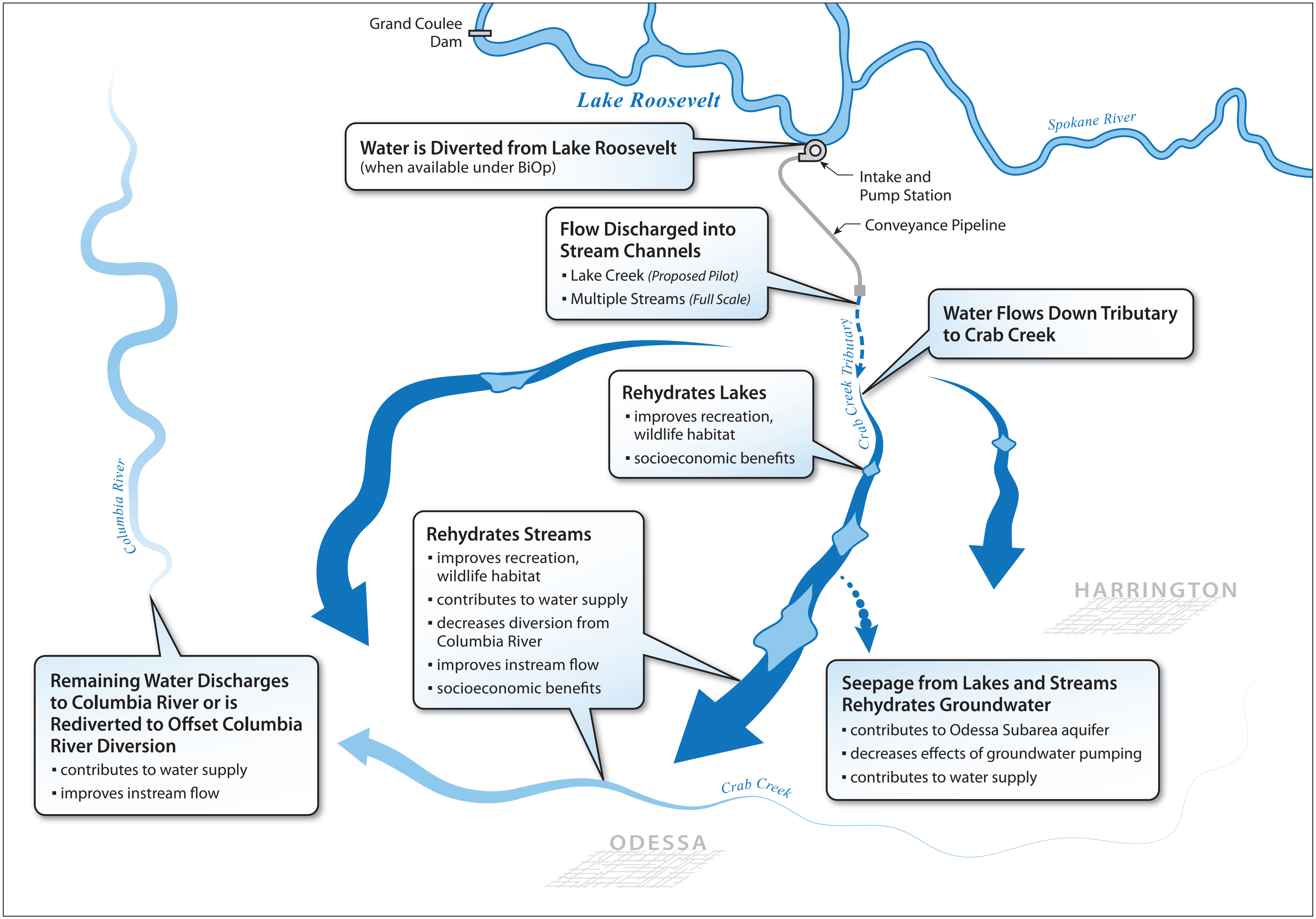

Lincoln County Passive Rehydration Project
Conceptual Schematic Diagram

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Prefeasibility Study Conclusions
Hydrology and Water Rights
Water is likely to be available for diversions from Lake Roosevelt during average and/or wet water years to provide a source for a 10- to 20-cfs pilot project, and a subsequent larger (50 to 100+ cfs) full-scale project.
Water rights for the pilot project could be obtained by multiple means. The most favorable approach appears to be a temporary permit issued under a water right permit application in order to conduct the pilot test.
Water released into a tributary of Crab Creek would increase depleted natural stream flows and help rehydrate dried up lakes, especially in the central portion of Lincoln County.
A portion of water released into a tributary flowing toward Crab Creek (most notably Duck Creek, Lake Creek, Marlin Hollow, and Canniwai Creek) would provide recharge to a local lower Wanapum Basalt groundwater system and a deeper, more regional groundwater system found within the widespread Sentinel Bluffs Member (Grande Ronde Basalt).
Engineering
The Lake Creek drainage is identified as the preferred site for the pilot project.
A preferred pipeline route for delivering water into the Lake Creek drainage has been identified.
Governance
More than one potential organization is available to assume sponsorship and management of the pilot project.
RCW 90.90 Compliance
If water supply is developed under the storage provisions of RCW 90.90, the project could contribute to instream flow.
If successful, the project could provide alternatives to groundwater for the east Odessa area.
Hydrogeology
Recharge of the localized lower Wanapum groundwater system would help recharge depleted springs.
Water added to the more widespread Sentinel Bluffs (upper Grande Ronde) groundwater system would migrate southwest into the core of the Odessa Groundwater Management Subarea.

Critical Questions for the Feasibility Phase of Study
Hydrology and Water Rights
Begin negotiations for a pilot study water supply.
Prepare water right permit application and further define other water right options to create a water portfolio.
Conduct monitoring and further hydrologic analysis; begin establishing hydrologic baseline for assessing pilot project results.
Engineering
Estimate costs for a pilot and full-scale project and compare against project benefits.
Prepare design for pilot project.
Environmental and Permitting
Prepare list of required permits and environmental issues.
Meet with resource agencies to extent of environmental review.
Governance
Further address governance and landowner issues.
Name the responsible authority to take on the planning, permitting, construction, and operation of the pilot project.

Chapter 1: Introduction

1.1 Overview

The proposed Lincoln County Passive Rehydration Project is a multi-phase project that would help recharge aquifer systems, revitalize dry streams, and refill dry lakes using available water pumped from Lake Roosevelt on the Columbia River. The proposed project—located in Lincoln County in eastern Washington (see Figure 1)—addresses the declining availability of groundwater for irrigation purposes and the reduced surface water volumes in streams and lakes that provide wildlife habitat and recreational opportunities. The project would benefit and has the support of agricultural users, local government entities, and local watershed management organizations.

Funding for the initial phase of the project (the "prefeasibility" phase) was provided by the Washington State Department of Ecology (Ecology). Acting on a 2006 directive from the Washington State Legislature (RCW 90.90[1]), Ecology is "aggressively pursuing development of water supplies to benefit both instream and out-of-stream uses" in the Columbia River Basin (Ecology n.d.). The Columbia River Basin includes the Odessa Groundwater Management Subarea (see Figure 2). The Lincoln County Passive Rehydration Project's focus is on the eastern and northern part of this subarea.

What is rehydration?

In eastern Washington and other arid regions, groundwater is heavily relied upon for agricultural, municipal, and other uses. Because of the demand for water, groundwater may be withdrawn from aquifers faster than it is naturally replenished. To help avoid aquifer depletion, hydrogeologists have looked for ways to use excess water to "rehydrate" aquifers. This process can involve diverting water to lakes and streams, allowing it to infiltrate and recharge the aquifer, and storing water in the aquifer for later recovery. Though the process presents technical challenges, its feasibility has been demonstrated under the right circumstances (Scott 2008).

Passive rehydration occurs when water enters an aquifer through natural processes like infiltration from lakes and streams. This contrasts with an active process where water is mechanically pumped into an aquifer.

This report describes the prefeasibility assessment conducted by the Lincoln County Conservation District (LCCD), the lead agency for the project. The report describes the geology, hydrogeology, and climate in the study area; water availability and governance; drainage and routing of water; and land access. Based on the positive results of the prefeasibility assessment, it concludes with a recommendation that the project proceed to the next phase—a feasibility evaluation and design of a pilot project.

[1] http://apps.leg.wa.gov/rcw/default.aspx?cite=90.90

1.2 Background

Odessa Groundwater Management Subarea

The Odessa Groundwater Management Subarea, defined in Chapter 173-128A WAC as "the segment of the Columbia basin groundwater system centered around the community of Odessa"[2] in Lincoln County (see Figure 2), has experienced a steady decline in groundwater levels since 1967[2]. Groundwater is the primary, and commonly the only, source of water for domestic wells, municipal and public water systems, and irrigated agriculture in Lincoln County and adjacent portions of Grant, Adams, and Franklin counties. In addition, groundwater from stock wells and springs is very important to stock raisers throughout this area. Concurrent with declining groundwater levels, surface water systems (lakes and streams) in the same area have been drying up.

Ecology and the U.S. Bureau of Reclamation (Reclamation) prepared an environmental impact statement (EIS) that describes alternatives for delivering surface water from the Columbia Basin to irrigated lands in the western portion of the Odessa Groundwater Management Area (Ecology and Reclamation 2010). In this western portion of the Odessa Groundwater Management Area, identified in the EIS as the Special Study Area, irrigated agriculture places the largest demand on the groundwater system, with approximately 102,000 acres of irrigated ground supplied by groundwater pumping. Adding the groundwater-irrigated acres outside the Special Study Area, but within the larger Odessa Groundwater Management Subarea, probably at least doubles the number of groundwater-supplied irrigated acres in the region. At least a quarter (more than 50,000 acres of 200,000-plus acres) of groundwater-supplied irrigated ground is located in the focus area of the Lincoln County Passive Rehydration Project.

Pacific Lake

One prominent example of the drastic declines in stream flows and lake volumes that have occurred in much of Lincoln County and adjacent counties is Pacific Lake (Figure 3), located a few miles north of Odessa. In the mid 1980s, Pacific Lake went dry. It has held water only periodically since that time. Previously, the lake was approximately 130 acres in area, ranged up to 30 feet deep, and had an approximate storage volume of 2,400 acre-feet (Dion et al. 1976). Pacific Lake had historically seen high levels of recreational use including fishing, boating, and water skiing.

Based on conversations with area residents and farmers, wildlife professionals, and field observations, it seems plausible that surface water declines in the region since the 1980s are related to the large groundwater withdrawals and accompanying declines in the Columbia River Basalt (CRB) aquifer system in the surrounding area. Pacific Lake, and several others in the nearby area that have gone dry, are located in coulees cut deep into the CRB.

[2] http://apps.leg.wa.gov/wac/default.aspx?cite=173-128A&full=true

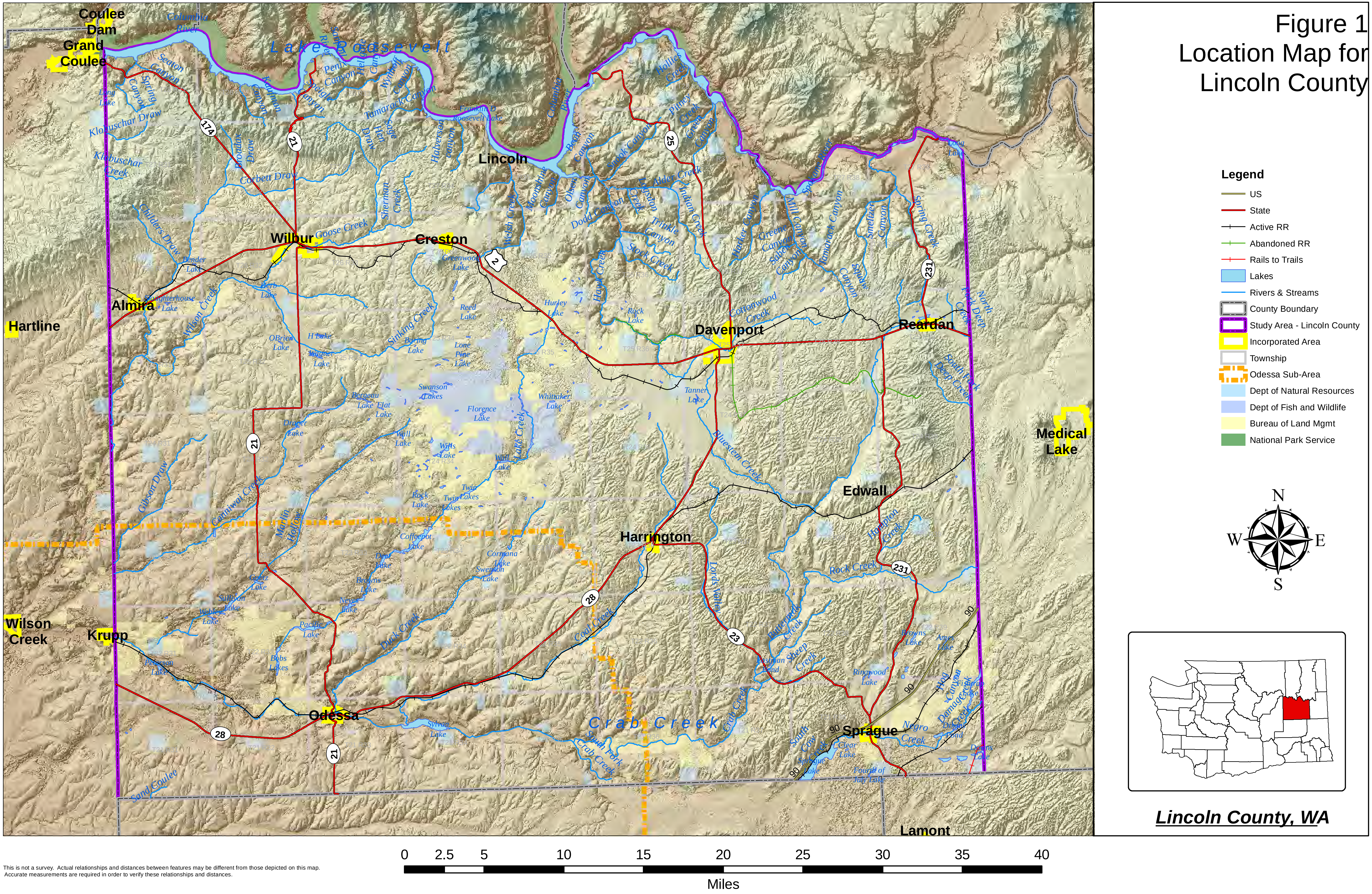

Figure 1
Location Map for
Lincoln County

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map.
Accurate measurements are required in order to verify these relationships and distances.

Lincoln County, WA

Figure 2
Map showing the boundaries of the Odessa Groundwater Management Subarea

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map.
Accurate measurements are required in order to verify these relationships and distances.

Figure 3. Photograph of the Dry Bed of Pacific Lake (lower Lake Creek) at the Allington Bay Boat Launch

1.3 Project Phases and Goals

Overall Project

As noted above, water diverted from Lake Roosevelt would revitalize dry streams, refill dry lakes, and help recharge the underlying aquifer system in the eastern and northern portions of the Odessa Groundwater Management Subarea. The overall goal of the project is to deliver between 50,000 and 100,000 acre-feet of water into multiple streams in the upper Crab Creek watershed (see Figures 1 and 2). One of the few perennial streams in the Columbia Basin, Crab Creek and its tributaries, some of which are now dry, flow generally south and southwest and drain most of Lincoln County.

Because this project requires careful consideration of feasibility issues—ranging from water sources, to stream capacity, to aquifer recharge potential—implementation is planned in phases or steps. The goals and objectives of each phase are contingent on the results of the previous phase, including whether or not to move the project from one phase to the next. The project phases are planned as follows:

- Phase 1 – Prefeasibility Assessment (the subject of this report)
- Phase 2 – Feasibility Evaluation and Design of a 10- to 20-cfs Pilot Project
- Phase 3 – Environmental Evaluation and Implementation of a 10- to 20-cfs Pilot Project Supplying a Single Drainage
- Phase 4 – Implementation of 5- to 20-cfs Pilot Projects Supplying Multiple Drainages
- Phase 5 – Construction of a Full-Scale, 50- to 250-cfs Rehydration Project in Multiple Drainages

The objectives of Phase 1, the Prefeasibility Assessment are summarized below. For additional details on the potential scope of Phases 2 through 5, see Chapter 6.

Phase 1 – Prefeasibility Assessment Goals

When the project was first proposed in 2008/2009, project proponents envisioned moving directly to construction of a pilot project that would test project concepts, operations, and impacts by operating a small project that delivered water into a target drainage and included observing the impacts of this water on streams, lakes, and groundwater. However, after consulting with Ecology staff, Phase 1 of the project was scaled-back to a prefeasibility assessment having the following goals:

- Determine if water is available from Lake Roosevelt for a rehydration project, both a single stream pilot-scale rehydration project and a potential full-scale rehydration project.
- Propose how much water is needed for each phase of a rehydration project.
- Identify drainages where water might be applied in a subsequent pilot-scale and larger rehydration project.
- Propose primary and secondary streams for a pilot-scale rehydration project.
- Describe the flow capacities of target drainages.
- Describe potential governance structures for the management, operation, permitting, and funding of a rehydration project.

In addition to addressing these goals, Phase 1 also addresses preliminary engineering, hydrologic, hydrogeologic, and land access issues. Based on the results of the Prefeasibility Assessment, a decision will be made about whether or not to proceed to Phase 2.

1.4 Elements Addressed in the Report

During the prefeasibility phase, the project team evaluated potential “fatal flaws” in the passive rehydration concept. Fatal flaws can involve conditions that are physical in nature (e.g., geology, hydrogeology, water routing and delivery pathways, and channel conditions), or regulatory or societal in nature (e.g., rules and regulations that would govern a project, or whether or not the community wants the project). The prefeasibility phase did not include a cost–benefit evaluation.

Physical Elements

The prefeasibility assessment addressed whether or not there is a reasonable potential for surface water to provide a recharge source for portions of the CRB aquifer system. The project team identified streams that would be more or less suitable for aquifer recharge, and for streams where recharge seems plausible, made an initial, qualitative evaluation of the potential aquifer area influenced by such recharge.

With respect to constraints on routing and delivery of the water, the prefeasibility assessment identified extreme physical conditions that, in the project team's qualitative judgment, argued against a specific route. Qualitative judgments included such things as whether or not it is 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 too small to accommodate stream flows that would provide viable recharge options.

The project team obtained information on physical elements from studies, reports, plans, maps, and other materials. A limited field reconnaissance was undertaken to become familiar with these physical elements. If the project moves beyond the prefeasibility phase, additional fieldwork and data analysis will be needed.

Regulatory and Societal Elements

This report outlines regulatory and societal issues that may be encountered if a rehydration project moves forward. As part of the prefeasibility phase, the project team has not proposed specific solutions to potential issues, but does make recommendations about possible courses of action.

Regulatory issues that will need to be resolved relate to federal and state permits required to implement a project, and to regulations, particularly those set forth in the National Environmental Policy Act (NEPA), State Environmental Policy Act (SEPA), and the Clean Water Act (CWA).

Chapter 3 includes a discussion of authorization in the form of a water right to use water from Lake Roosevelt. 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 would be situated on.

The societal issues discussed in this report focus on whether or not the public would support a rehydration project, and whether or not landowners along a project route would agree to implementing a project on their land, especially if it had the potential to impose limitations on how they might use their property. These societal issues were largely identified from direct conversations with landowners in the drainages evaluated for the project.

1.5 Report Structure

This chapter of the report (Chapter 1) provides general information about the project including its intent, goals, location, funding source, phases, and background, and identifies the individuals and firms that contributed to completion of Phase 1. Chapters 2 through 4 provide in-depth technical information specific to Phase 1. Chapter 5 discusses the conclusions and recommendations resulting from the prefeasibility analysis, and Chapter 6 describes potential next steps (future phases) of the project. Chapter 7 lists the references cited in the text.

1.6 Project Team

LCCD, as the lead agency, grant recipient, and grant manager, led the project team. Table 1 identifies the project team members.

Table 1. Prefeasibility Assessment Team Members

Affiliation	Team Members	Role
LCCD	David Lundgren Elsa Coffman	Grant management, technical support.
GSI Water Solutions (GSI)	Kevin Lindsey, L.Hg Molly Reid Jon Travis Travis Hammond John Porcello Terry Tolan	Worked 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.
HDR Engineering, Inc. (HDR)	Steve Thurin, P.E. Emily Flanagan, P.E. Brian Bartle, P.E. Rona Spellecacy, AICP Aaron Meilleur, P.E. Barb Whiton	Worked under contract to GSI to evaluate RCW 90.90 issues, routing and infrastructure needs, surface water drainage and habitat issues, governance required for the project, and report editing and formatting.
Water and Natural Resources Group (WNR)	Gene St. Godard, P.G., L.Hg	Worked under contract to GSI; he led the public outreach effort, evaluated water rights issues, and provided general technical support.
Lincoln County Planning Department	Courtney Thompson	Worked under contract to LCCD to provide GIS support.

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Chapter 2: Study Area Description

This chapter summarizes the physical setting of Lincoln County, including its geography and surface hydrology, climate and habitat, and geology and hydrogeology. Much of this information was derived from previous reports, including Water Resource Inventory Area (WRIA) 43 and WRIA 53 Phase 1 and Phase 2 assessment reports (Kennedy/Jenks 2005) and Columbia Basin Ground Water Management Area (GWMA) reports (GWMA 2009a, 2009b, 2009c, 2009d), Columbia Basin GWMA databases and geographic information system (GIS) data, and Lincoln County Planning Department GIS databases.

The study area for the Lincoln County Passive Rehydration Project is the eastern and northern part of the Odessa Groundwater Management Subarea (see Figure 2).

2.1 Geography and Surface Hydrology

Geography

Lincoln County encompasses approximately 1.49 million acres, or approximately 2,335 square miles in eastern Washington (see Figure 1). The Columbia River and Spokane River (as Lake Roosevelt) mark the northern boundary of the county. Grant County, Adams County, and Spokane County border Lincoln County to the west, south, and east, respectively.

Lincoln County's landscape varies from forested uplands and canyons in the north near Lake Roosevelt to irrigated farmlands, dryland farms, range ground, grasslands, shrub steppes, and rocky scablands (see Figure 4). Less than 1% 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 1 and 4). In addition, a number of small private housing developments occur in the northern part of the County, near Lake Roosevelt.

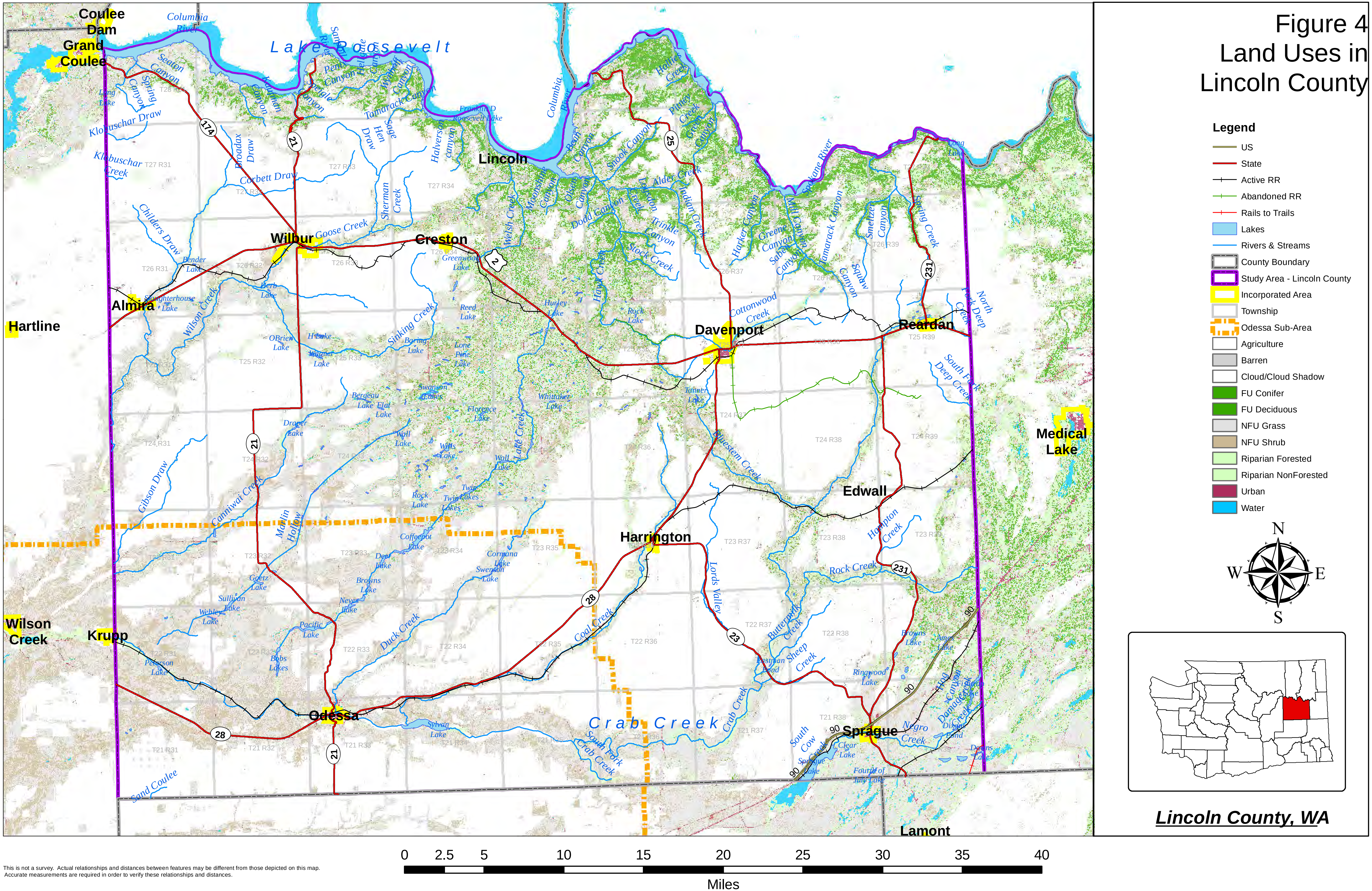
The upland areas of northern and northwestern Lincoln County generally consist of high, partially wooded hills overlooking Lake Roosevelt, and isolated, largely unwooded hills such as Creston Butte and those found in the east near the Spokane County line. The hills overlooking Lake Roosevelt delineate where the Columbia River canyon was incised into the Columbia Basin, and where the CRB abuts against the igneous and metamorphic rocks of the adjacent Okanagan Highlands. This hilly landscape overlooking the Columbia River (Lake Roosevelt) is characterized largely by woodlands, small-scale farming, grazing, and rural residential development. At the base of these hills, adjacent to the Columbia River, many terraces and benches are devoted to irrigated orchards and vineyards, and to residential developments. The isolated hills, such as Creston Butte, are devoted largely to grassland habitat and grazing uses. Elevations across the northern tier of the County range from highs of 2,400 to 2,600 feet above mean sea level (MSL) to lows of approximately 1,270 feet MSL adjacent to Lake Roosevelt.

South of the uplands adjacent to Lake Roosevelt, the landscape slopes generally downward to the south and southwest in the Crab Creek watershed, reaching elevations of approximately 1,400 to 1,660 feet MSL where Crab Creek exits the County. The Crab Creek watershed encompasses the bulk of the county. Within the Crab Creek watershed the land surface generally consists of basalt bedrock scablands separated by rolling hills. The scablands are characterized by isolated buttes, deep, steep-sided canyons, and locally chaotic drainages and deep potholes (Figure 5). The nature of the scablands generally changes from the north (up-slope) to the southwest (down-slope). In the north-central portion of the county, the scablands are characterized by a chaotic, very poorly developed drainage system. To the south, scablands are more linear and associated with specific drainages. Where these drainages become more defined, they form canyons (more commonly referred to as coulees), which in many cases are carved 100 to 300 feet or more into basalt bedrock. These coulees and associated scablands range from less than 1 mile to several miles across.

Within the scablands, stock grazing, small localized irrigated farming, and habitat management activities are the most common land uses. The hills found between the scablands generally consist of wind-deposited silts and fine sands (loess), which commonly are subjected to dryland agriculture, grazing, and habitat uses. These loess hills (Figure 6) are similar in appearance to the hill county of the Palouse Slope located to the south in Adams and Whitman counties.

Surface Hydrology

Historically, perennial streams flowed through many of these scabland drainages, and lakes were common. The feature in Lincoln County's 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 Creek, Lake Creek, Marlin Hollow, Canniwai Creek, and Wilson Creek (Figures 1 and 4)—lies in the scabland valleys originally scoured into the Lincoln County landscape by the Pleistocene Missoula flood waters that spilled over the drainage divide in northern Lincoln County and flowed south into the Columbia Basin. Lake Creek, and to a lesser extent the other Crab Creek tributaries, host a number of lakes, several of which are now dry.



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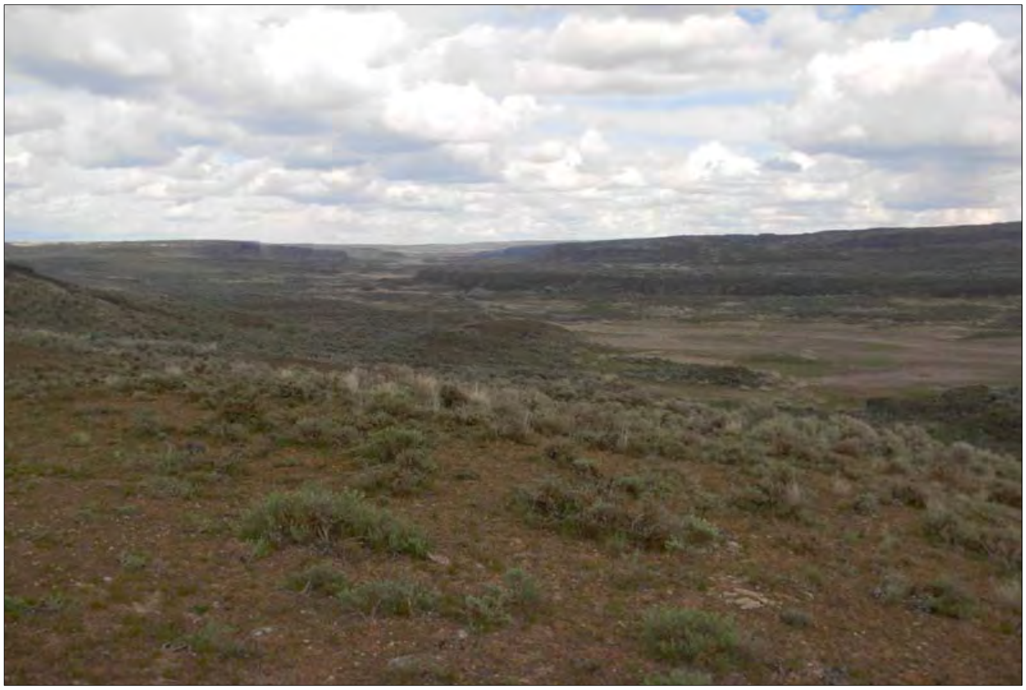


Figure 5. Photograph of the Lake Creek Coulee between Deer Lake and Taveres Lake

The topography seen in the photograph is typical of the area where the stream drainages are located in scabland coulees.

Figure 6. A Typical Landscape in the Northern Part of the Columbia Basin and Lincoln County

In the foreground is a rocky scabland tract, while the hills in the background are loess-covered hills.

2.2 Climate and Habitat

Climate

Precipitation amounts and patterns, as well as temperature and evapotranspiration 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 are more typically 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, result in climates in the County that combine characteristics typical of semi-arid mountain foothill climates with those more typical of semi-arid grassland and steppe climates. The foothills-like climate predominates in the northern part of the county adjacent to Lake Roosevelt, where precipitation is greater. 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 and is summarized in reports for WRIAs 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 that annual precipitation varies from approximately 7 to 16 inches per year, with higher amounts prevailing at the higher elevations of northern Lincoln County. The period from July through October is generally the driest time of the year. Except in the coldest months, evapotranspiration exceeds precipitation.

Habitat

Given the climate described above, the bulk of Lincoln County lies within a semi-arid shrub steppe ecosystem. Major plant types in this ecosystem 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.

Fisheries

Fisheries in the project area consist of those found in Lake Roosevelt and those found in the Crab Creek drainage. The Lake Roosevelt fishery is a dynamic system influenced by large reservoir fluctuations, limited habitat, and abundant non-native fish species (BPA 1999). Extreme reservoir level fluctuations, especially drawdown, likely result in high levels of entrainment of fish from Lake Roosevelt. BPA (1999) reports 20 species from 8 families being collected in its survey of the fishery. The most abundant species captured was rainbow trout, followed by walleye, lake whitefish, largescale suckers, and Kokanee salmon. Other species surveyed are white sturgeon, carp, northern pikeminnow, tench, longnose sucker, bridgelip sucker, Chinook salmon, mountain whitefish, brown trout, eastern brook trout, burbot, sculpin, smallmouth bass, black crappie, and yellow perch. The BPA survey indicated a healthy population of brown trout, and reductions in largescale suckers, walleye, and rainbow trout. The hatchery Kokanee population has been stable. Closure of the Spokane Arm to fishing during the walleye spawning season has protected the walleye from over-harvest. Interactions between native and non-native species add complexity to the system when these species compete and habitat utilization when non-native fish prey on native fish.

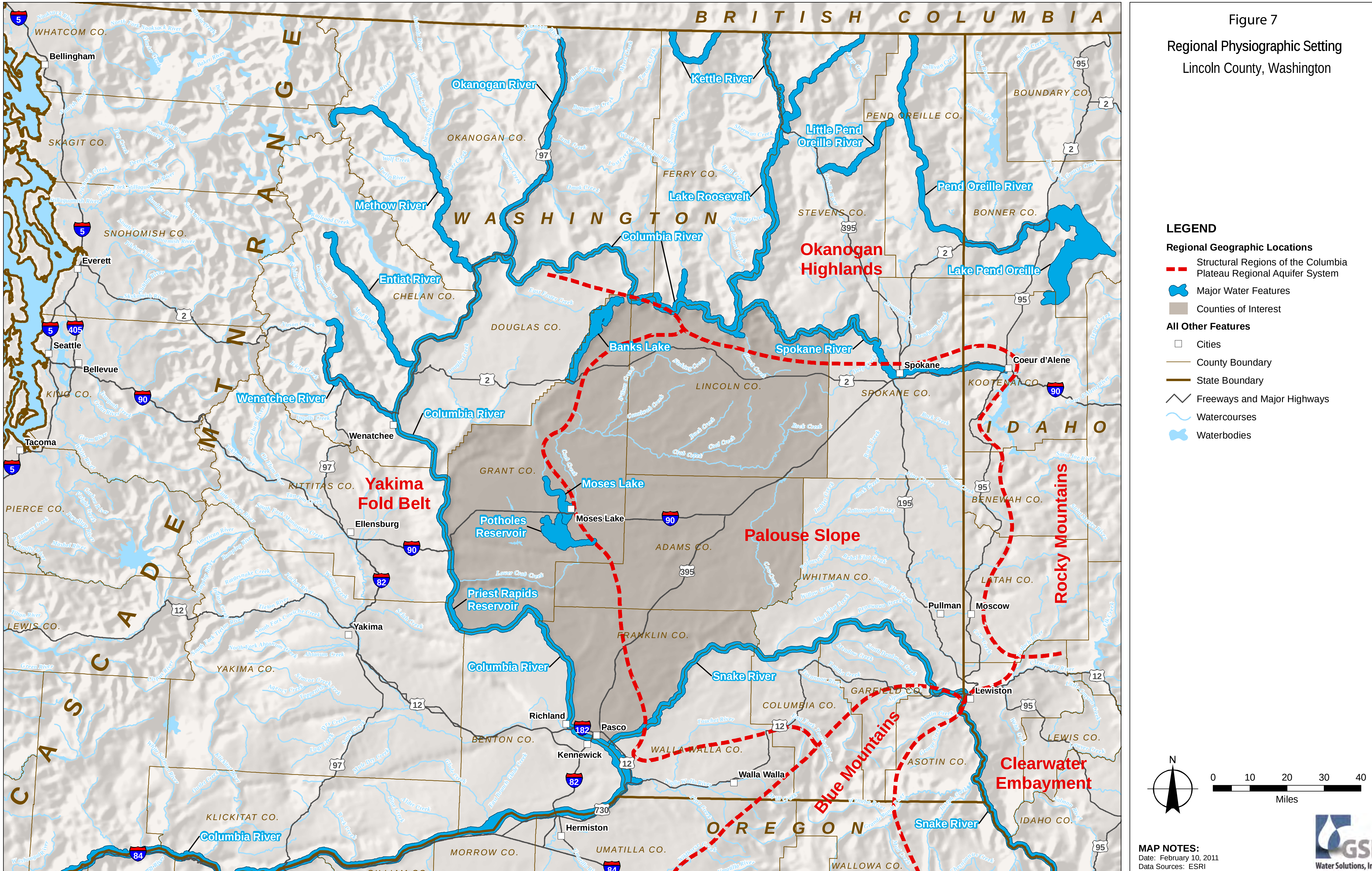
Information on fish species in the Crab Creek drainage appears to be limited, and a systematic examination of this fishery was not found. The upper Crab Creek watershed assessment (Kennedy/Jenks 2005) indicates that the system historically contained trout; however, presence of the species is uncertain. Anecdotal reports suggest that westslope cutthroat trout, hatchery rainbow trout, brook trout, brown trout, and Kokanee were introduced to the watershed in the early 1900s. Between 2001 and 2003, Eastern Washington University collected data at various locations within the Crab Creek Watershed that indicate interior redband rainbow trout may exist in the Crab Creek drainage along with hatchery-origin rainbow trout (Kennedy/Jenks 2005). Non-native salmonids (brook trout and brown trout) have historically been stocked in the watershed and have contributed to the fishery resource of the watershed. Anecdotal evidence suggests that portions of the watershed support a robust and self-sustaining population of the fish species listed above.

Lakes in the Crab Creek drainage, at least those that still contain water, contain a mix of cold water and warm water fish. In June 2003, the Washington Department of Fish and Wildlife Warmwater Enhancement Program conducted fisheries surveys on Upper and Lower Twin Lakes in the Lake Creek Drainage (WDFW 2005). Six fish species were collected from Upper and Lower Twin Lakes: largemouth bass, pumpkinseed sunfish, rainbow trout, brown bullhead, yellow perch, and black crappie. Current management strategies were recommended for Upper Twin Lake, while an increase in predator abundance was recommended for Lower Twin Lake. Coffeepot Lake, part of the Lake Creek system, is reported to sustain rainbow trout, largemouth bass, and smallmouth bass.

2.3 Geology and Hydrogeology

The geology and hydrogeology of the project area will have a profound impact on one of the two primary goals of the project: recharging a portion of the CRB aquifer system that has been overdrafted by groundwater pumping in the Odessa Groundwater Management Subarea. The proposed rehydration project will need to be implemented in areas where rehydrated lakes and streams can recharge the underlying CRB aquifer system, and once recharged, that water will need to be able to migrate southward into the Subarea. Section 2.3 summarizes the geologic and hydrogeologic conditions present in the project area that will eventually influence the ability of a possible project to recharge the CRB aquifer system.

Lincoln County lies on the northern edge of the Columbia River flood basalt province where the CRB pinches out against the metamorphic and crystalline igneous rocks of the Okanagan Highlands (Figure 7). 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 summarizes basic information about the geology and hydrogeology of Lincoln County as it relates to the potential to influence the proposed project. The reader is referred to other reports cited in this document for more detailed information about the geology and hydrogeology of the greater Lincoln County area.



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2.3.1 Soils

Soil types in 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. 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 because the area has been used for agriculture and livestock grazing for many decades. Nevertheless, the infiltration capacity of these soils is relatively low. If these soils are found at rehydrated locations where other factors suggest that basalt aquifer recharge potential is high, then it might be necessary to improve permeability to enhance infiltration capacity.

The sandy and gravelly soils are most common in and around coulees. These soils typically are developed on Pleistocene Missoula flood deposits, including sand and gravel bars deposited in and adjacent to the coulees. These soils 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, future potential recharge projects would occur. In such areas, recharge potential for the underlying basalt aquifer system would 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 would not be widespread on these thin, rocky soils developed over bedrock because the bedrock typically has 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 were identified in the field.

2.3.2 Suprabasalt Sediments

Suprabasalt sediments (the sediments overlying the top of basalt) in Lincoln County consist predominantly of Pleistocene- to Holocene-aged alluvium, Pleistocene Missoula 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; Gulick and Korosec 1990; Joseph 1990; Waggoner, 1990a, 1990b), these sediments were subdivided into two basic units—coarse Quaternary alluvium and fine-grained Quaternary deposits—for the purposes of this report.

Coarse Quaternary alluvium. Coarse Quaternary alluvium consists of mixed silt, sand, and gravel (Figure 8) deposited predominantly by Pleistocene Missoula 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. Pleistocene Missoula 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, and are 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 in the study area ranges from less than 10 feet to as much as 100 feet (GWMA 2009b).

Fine-grained Quaternary deposits. Fine-grained Quaternary deposits consist predominantly of silt, silty sand, and very fine sand loess (Figure 9) 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 120 feet thick in Lincoln County (GWMA 2009b). Its distribution is largely controlled by the depth of cataclysmic flood erosion that formed the scabland coulees that cross-cut the area and dissect the hills where these strata are found.

Figure 8. Photograph of a 30- to 50-Foot Thick Sequence of Pebble to Boulder Gravel Deposited by the Pleistocene Missoula Floods

Typical of the Pleistocene Missoula flood deposits commonly seen in coulees and scabland tracts throughout the region.

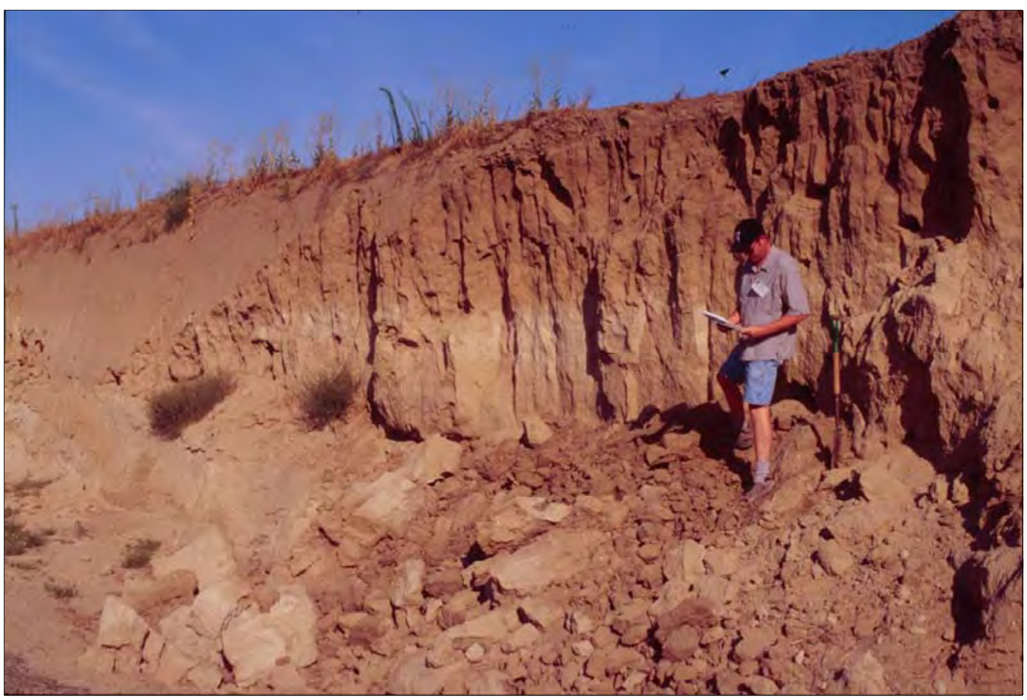

Figure 9. Photograph of a Typical Loess Embankment Exposed in a Road Cut

Suprabasalt Sediment Hydrology. Vadose zone conditions, and consequently infiltration capacity, in the suprabasalt sediments are controlled by physical heterogeneities within these coarse to fine strata. These heterogeneities would result in complex flow paths that include downward percolation, upward diffusion, and lateral movement of vadose zone moisture. For example, local perched aquifers could exist where discrete areas or lenses of fine-grained materials exist and act as barriers to downward percolation. Clearly, a potential future recharge area would have better infiltration capacity and aquifer recharge potential if it is underlain by coarse suprabasalt sediments rather than fine sediments.

Saturated suprabasalt sediments, and the suprabasalt sediment aquifer system, more commonly occur in coarse Quaternary sediments found within scabland tracts, than in the fine-grained Quaternary sediments found covering the hills bordering the scablands. As with the vadose zone, where saturated suprabasalt sediments are present in a potential recharge area, coarse-grained strata generally will be more conducive to recharge than fine sediments. The base of the suprabasalt aquifer is defined as the top of the CRBG. The lateral extent of the suprabasalt aquifer in Lincoln County is controlled by surface CRB outcrops and areas of Quaternary sediment deposition within coulees and canyons. These physical features result in a suprabasalt sediment aquifer that is very discontinuous, with hydraulic continuity between different areas of saturated sediment being extremely limited. The limited continuity between occurrences of the suprabasalt aquifer suggests that recharge areas targeting these strata will be localized at specific locations up and down any targeted stream drainage.

Estimated suprabasalt sediment aquifer thicknesses in 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 are approximately 1,200 to 1,300 feet above mean sea level (AMSL) in the southwestern part of the county, and 2,200 to 2,300 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.

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 ranges from 2,000 to 25,000 feet/day with effective porosity greater than 10% (USDOE 1988). Within the Quaternary fine-grained unit, hydraulic conductivities will be several orders of magnitude lower.

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) most likely is small. In addition, because the majority of precipitation that falls in the area occurs in the winter and spring, the small amount of natural recharge that occurs takes place primarily in the winter and spring. In addition, given the local climatic conditions found across the county, natural recharge decreases to the southwest across the county as elevations and precipitation decrease.

Bauer and Vaccaro (1987, 1990) and Vaccaro (2007) describe methodologies for estimating aquifer recharge from natural precipitation. Generally, natural recharge will be 10% or less of natural precipitation. However, where irrigation occurs, some artificial recharge is likely because the amount of water available on the surface and in shallow soils can periodically exceed evapotranspiration.

Surface discharge from the suprabasalt sediment aquifer system in the study area is most likely into streams, lakes, and ponds where they are present in coulees. The degree of hydraulic continuity with the underlying basalt aquifer system is discussed in Section 2.3.6.

2.3.3 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 square miles in Washington, Oregon, and western Idaho (Tolan and Reidel 1989, Camp et al. 2003, Camp and Ross 2004) with a maximum thickness of over 10,000 feet. Numerous reports describe 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), Kahle et al. (2009), and Tolan et al. (2009).

The CRBG has been divided into a host of regionally mappable units (Figure 10) based on variations in physical, chemical, and 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).

Series		Group		Formation	Member	Isotopic Age (m.y)	Magnetic Polarity
Miocene	Upper	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	**Lower Monumental Member**	6	N
					Ice-Harbor Member	8.5	
					Basalt of Goose Island		N
					Basalt of Martindale		R
					Basalt of Basin City		N
					Buford Member		R
					Elephant Mountain Member	10.5	N, T
	Middle				**Pomona Member**	12	R
					Esquatzel Member	N	
					Weissenfels Ridge Member		
					Basalt of Slippery Creek		N
					Basalt of Tenmile Creek		N
					Basalt of Lewiston Orchards		N
					Basalt of Cloverland		N
					Asotin Member	13	
					Basalt of Huntzinger		N
					Wilbur Creek Member		
					Basalt of Lapwai		N
					Basalt of Wahluke		N
					Umatilla Member		
					Basalt of Sillusi		N
					Basalt of Umatilla		N
				Wanapum Basalt	**Priest Rapids Member**	14.5	
					Basalt of Lolo		R
					Basalt of Rosalia		R
					Roza Member		T, R
					Shumaker Creek Member		N
					Frenchman Springs Member		
					Basalt of Lyons Ferry		N
					Basalt of Sentinel Gap		N
					Basalt of Sand Hollow	15.3	N
					Basalt of Silver Falls		N, E
					Basalt of Ginkgo	15.6	E
					Basalt of Palouse Falls		E
					Eckler Mountain Member		
					Basalt of Dodge		N
					Basalt of Robinette Mountain		N
					Vantage Horizon		
				Grande Ronde Basalt	**Member of Sentinel Bluffs**	15.6	N_2
					Member of Slack Canyon		
					Member of Fields Spring		
					Member of Winter Water		
					Member of Umtanum		
					Member of Ortley		
					Member of Armstrong Canyon		
	Lower			Prineville Basalt	**Member of Meyer Ridge**		R_2
					Member of Grouse Creek		
					Member of Wapshilla Ridge		
					Member of Mt. Horrible		
					Member of China Creek		N_1
					Member of Downy Gulch		
				Picture Gorge Basalt	**Member of Center Creek**		R_1
					Member of Rogersburg		
					Teepee Butte Member		
					Member of Buckhorn Springs	16.5	
				Imnaha Basalt			R_1
							T
							N_0
						17.5	R_0

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Figure 10. Stratigraphic Nomenclature of the CRBG

From Tolan et al. (1989) and Reidel et al. (1989a).

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 11).

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, and contains variable amounts of basalt rubble (Figure 12). Flow interiors are dense, non-vesicular, glassy to crystalline basalt that contains numerous contraction joints (termed cooling joints) that formed when the lava solidified (Figure 13). Joints are organized regularly and form perpendicular to cooling surfaces (Figure 13). 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 14) 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 (and important to this project) 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 because they exert fundamental influences on groundwater occurrence and movement within the CRBG.

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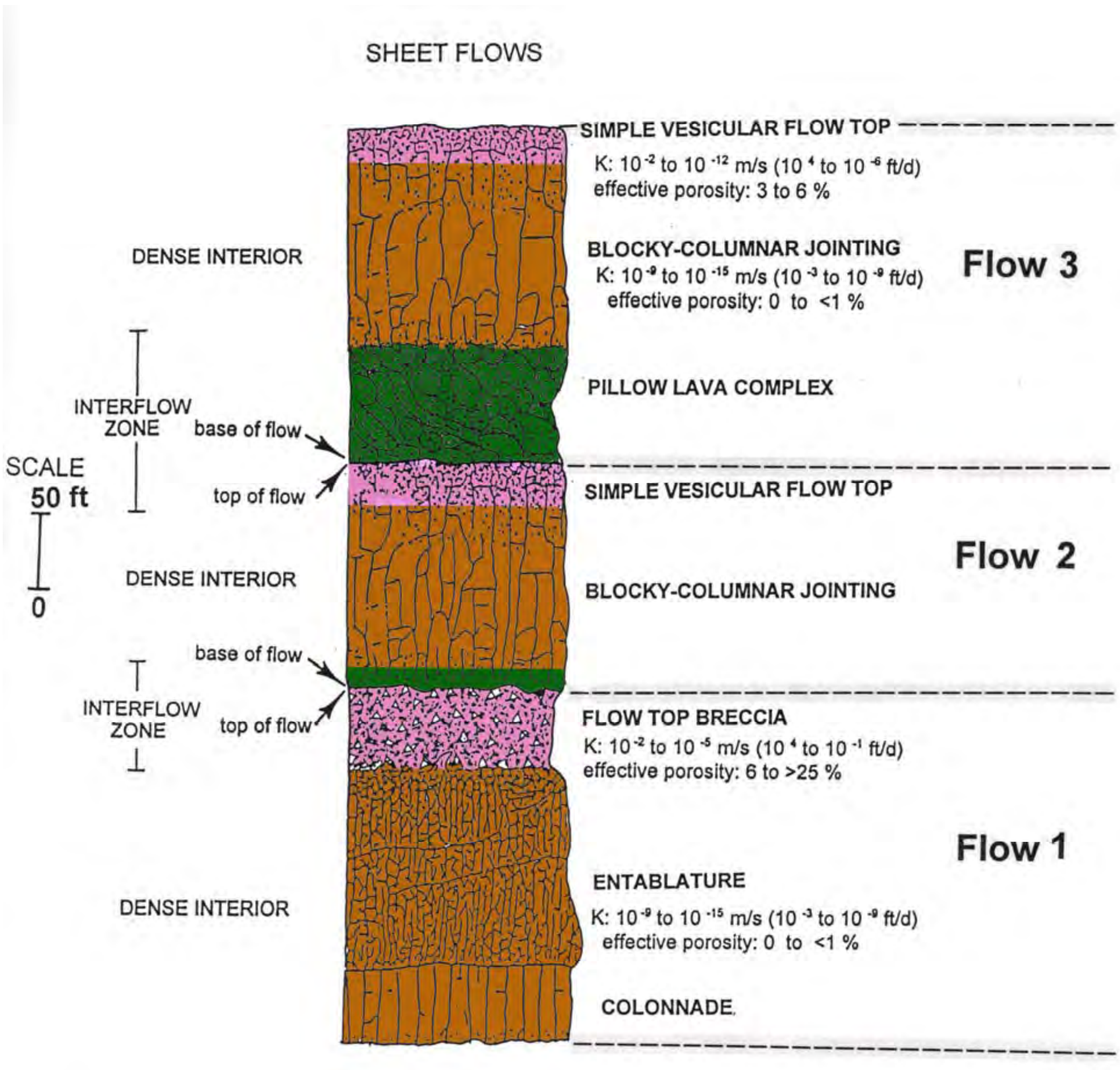

Figure 11. Internal Structure of CRBG Flows

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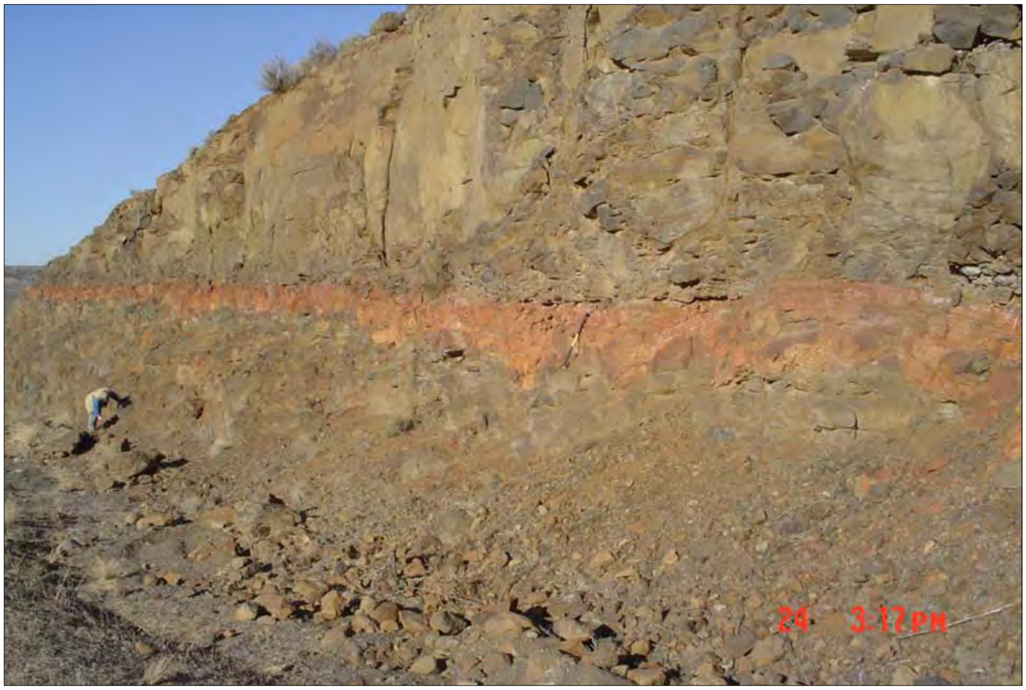


Figure 12. Photograph of a Simple Flow Top in the CRBG

The flow top is marked by the red banded interval in the middle of the outcrop.

Figure 13. Photograph of Entablature–Collonade of a Typical Dense Flow Interior

Entablature (above); colonnade (below).

Figure 14. Photograph of a Pillow Lava Complex at the Base of a CRBG Flow

The Wanapum Basalt and Grande Ronde Basalt are the two CRBG units that underlie the study area. Table 2, based on GWMA mapping (GWMA 2009b), lists the primary suprabasalt sediment and CRBG units and their thickness ranges beneath the immediate study area. The Wanapum Basalt ranges from less than 100 to 400 feet thick and the Grande Ronde Basalt ranges from 1,000 to over 3,400 feet thick.

Table 2. Summary of the Main Geologic Units Underlying the Project Area

Geologic unit	Thickness range (feet)	Comments
Coarse Quaternary alluvium	0-100	Localized in and near coulees and scablands
Quaternary fine-grained unit	0-120	Predominantly loess
Priest Rapids Member (WB)	0-400	Absent in southwest corner of county
Roza Member (WB)	0-300	Absent from western 1/3 of county
Sentinel Gap, Frenchman Springs Mbr (WB)	0-150	Absent from northern and eastern part of county
Sand Hollow, Frenchman Springs Mbr (WB)	0-120	Only present in south-central and southwestern part of county
Ginkgo, Frenchman Springs Mbr (WB)	0-50	Only present in southwestern most corner of county
Sentinel Bluffs Member (GRB)	0-800	Underlies almost all of county
Umtanum Member (GRB)	0-300	Absent beneath northern half of county
Ortley Member (GRB)	0-600	Absent beneath northern half of county
Grouse Creek Member (GRB)	0-400	Absent in northeastern and northwestern corners of county
Wapshilla Ridge Member (GRB)	0-500	Underlies most of county
Undifferentiated Grande Ronde Basalt	0->2,000	Only beneath southern half of county
Pre-basalt basement	>20,000	Underlies all of county

WB – Wanapum Basalt; GRB – Grande Ronde Basalt

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, dikes and associated vent systems for the Roza and the Priest Rapids Members were identified in the County during reconnaissance work for this project and during the course of GWMA field investigations.

Priest Rapids Member. 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 15). In the northernmost part of the County it locally dips 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 part of the county. Where present, the unit ranges in thickness from less than 50 feet to over 400 feet.

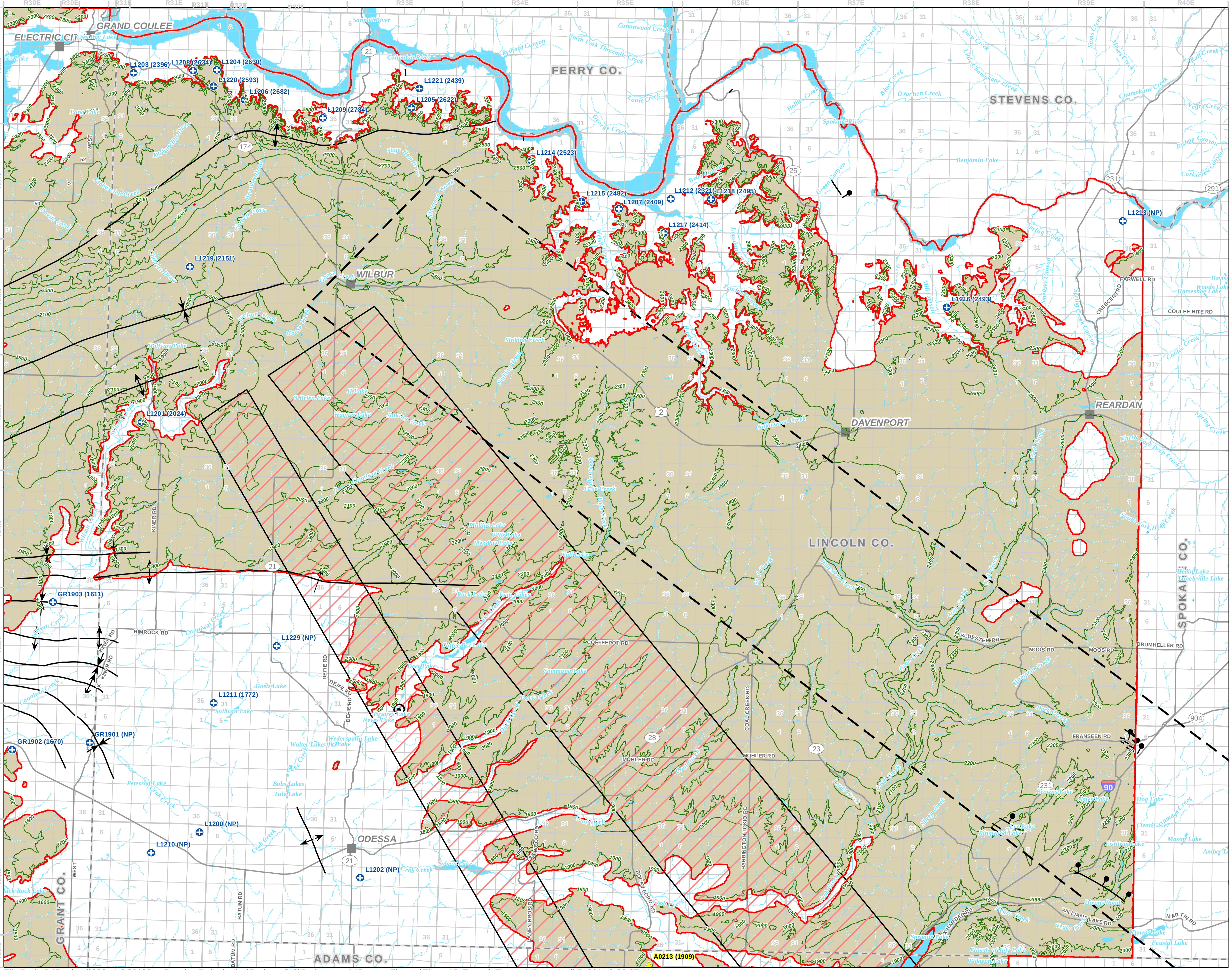
Priest Rapids Member dikes are inferred to be present in the eastern and north-central portions of the county for two basic reasons. One is the presence of the unit in northern Lincoln County, high on the paleoslope inferred to have been present during emplacement in the Miocene (Fecht et al. 1987, Tolan et al. 1989, Smith et al. 1989), which would require eruptive vents to have extended well north into the area now occupied by the county (Tolan et al. 2009). The other is that this area lies on the northwestern projection of feeder dikes that are known to occur to the south. Reconnaissance done for this study, and GWMA field investigations, provide some confirmation of the extent of the Priest Rapids dike system with the discovery of Priest Rapids near vent facies in a road cut on Duke Lake Road north of Odessa, Washington, in Sections 5 and 6, Township 22 North, Range 34 East. The general inferred extent of this dike system is shown in Figure 15, which shows the mapped extent of the Priest Rapids Member in the study area.

Roza Member. Like the overlying Priest Rapids Member, the top of the Roza Member generally dips to the south-southwest where the unit is present (Figure 16). 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 is 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.

FIGURE 15

Structure Contour Map of the Top of the Priest Rapids Member (Tpr) of the Wanapum Basalt

Lincoln County, Washington



LEGEND

- Areas Where Top of Tpr is Within 200 feet of the Top of Basalt
- Tpr Pinchouts
- Top of Tpr - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perennial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5
Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

GSI Water Solutions, Inc.

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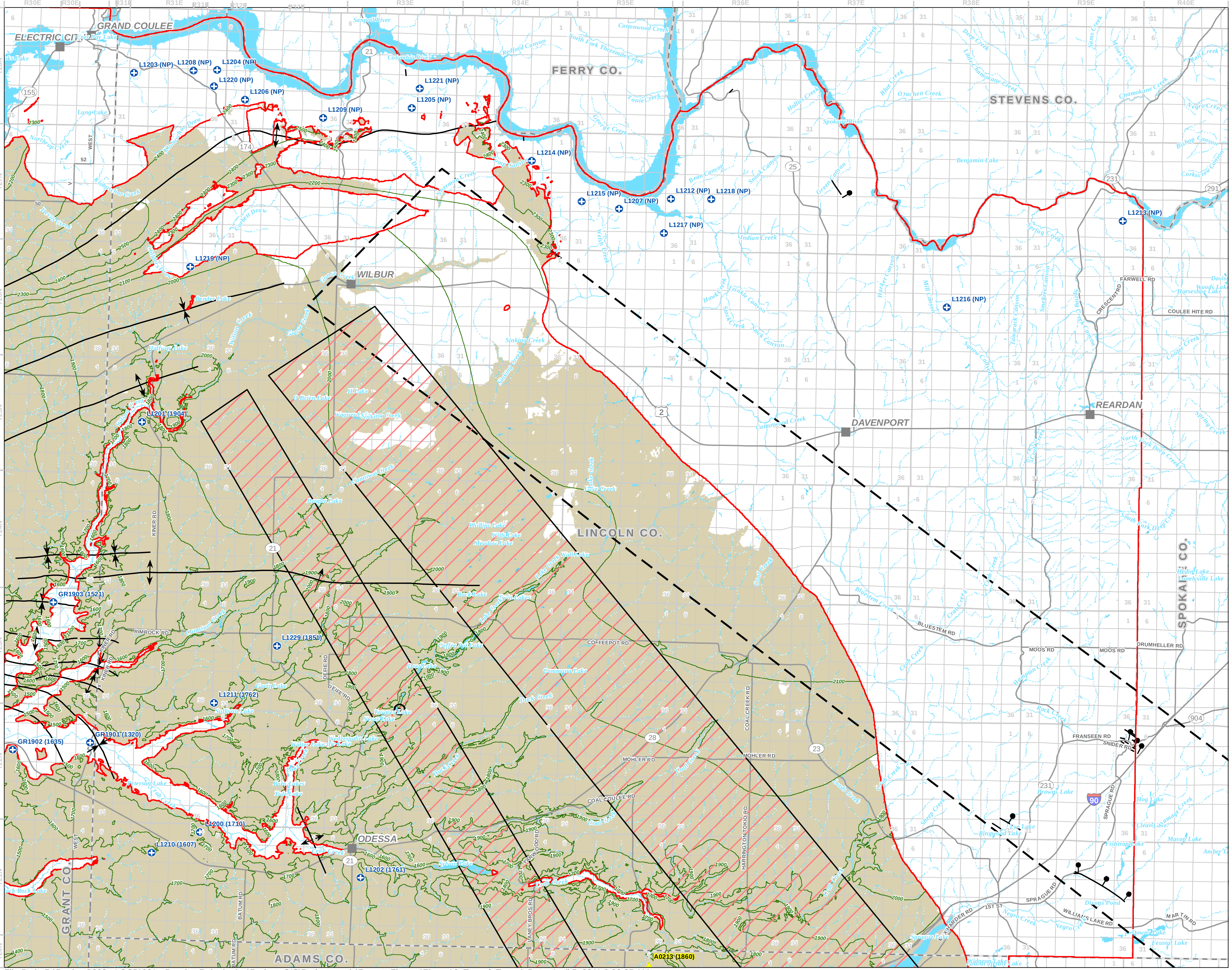

FIGURE 16

Structure Contour Map of the Top of the Roza Member (Tr) of the Wanapum Basalt

Lincoln County, Washington

LEGEND

- Areas Where Top of Tr is Within 200 feet of the Top of Basalt
- Tr Pinchouts
- Top of Tr - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perennial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5

Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

GSI Water Solutions, Inc.

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Roza Member dikes are inferred to be present in the eastern and north-central portions of the county for two basic reasons. One is the presence of the unit in northern Lincoln County, high on the paleoslope inferred to have been present during emplacement in the Miocene (Fecht et al. 1987, Tolan et al. 1989, Smith et al. 1989), which would require eruptive vents to have extended well north into the area now occupied by the county (Tolan et al. 2009). The other is that this area lies on the northwestern projection of feeder dikes and associated near vent rocks that are known to occur to the south. Reconnaissance done for this study, and GWMA field investigations, provide some confirmation of the extent of the Roza Member dike system with the discovery of near vent facies rocks (Figure 17) in a road cut on Downs Road in the Crab Creek coulee approximately 5 miles east of Sylvan Lake Duke Lake Road north of Odessa, Washington, in Sections 5 and 6, Township 22 North, Range 34 East, and the presence of a pair of dikes found in Lake Creek at Tavares Lake (Figure 18). The inferred extent of this dike system is shown on Figure 16, which shows the mapped extent of the Roza Member in the study area.

Figure 17. Platy, Rubbly Strata Typical of Near Vent Facies in the CRBG

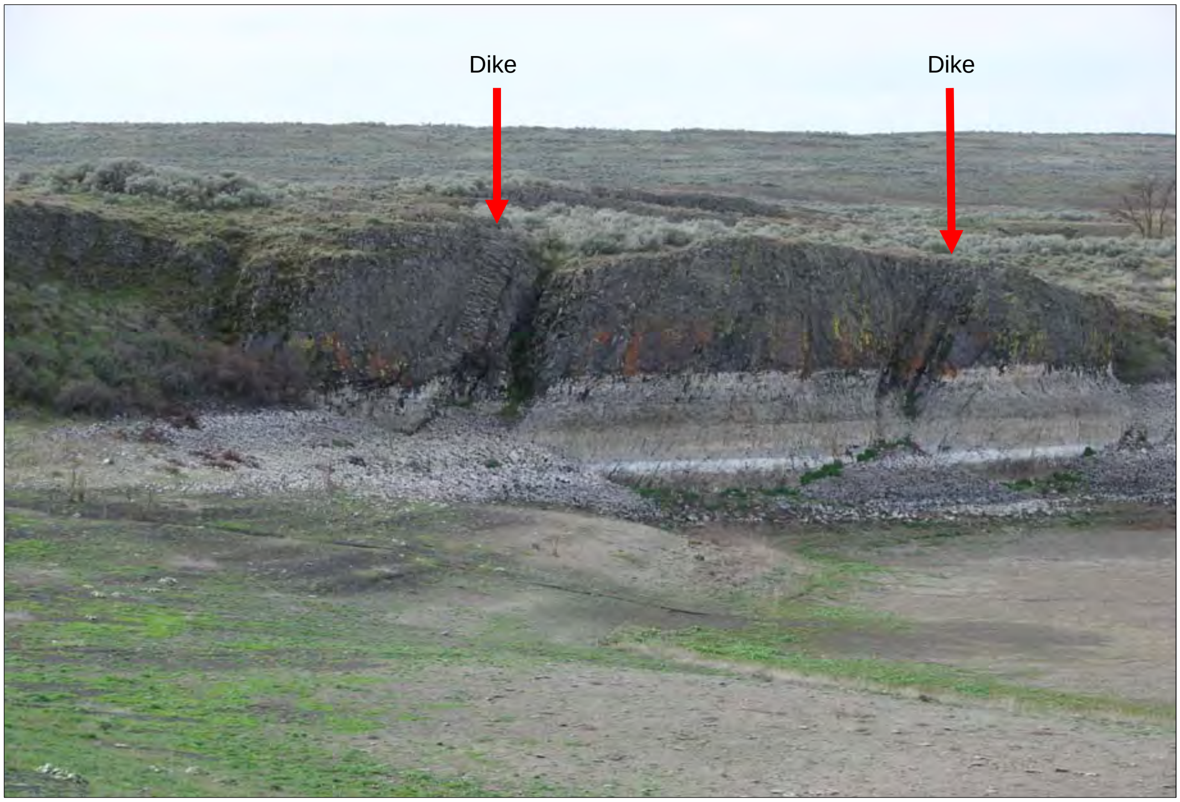

Figure 18. Two Subvertical Dikes of the Roza Member at Taveres Lake

Frenchman Springs Member. The Frenchman Springs Member is the least extensive of the Wanapum units in Lincoln County, being largely restricted to the southern and southwestern portions 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 19), and the basalt of Sand Hollow (Figure 20). The basalt of Ginkgo is only in the extreme southwestern corner of the county. Like the other Wanapum units, the tops of 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 320 feet.

Dikes for Frenchman Springs units have not been identified in Lincoln County, although the mapped extent of the units, compared to the inferred paleoslope at the time of emplacement, suggests they might be present beneath the southwestern portion of the county.

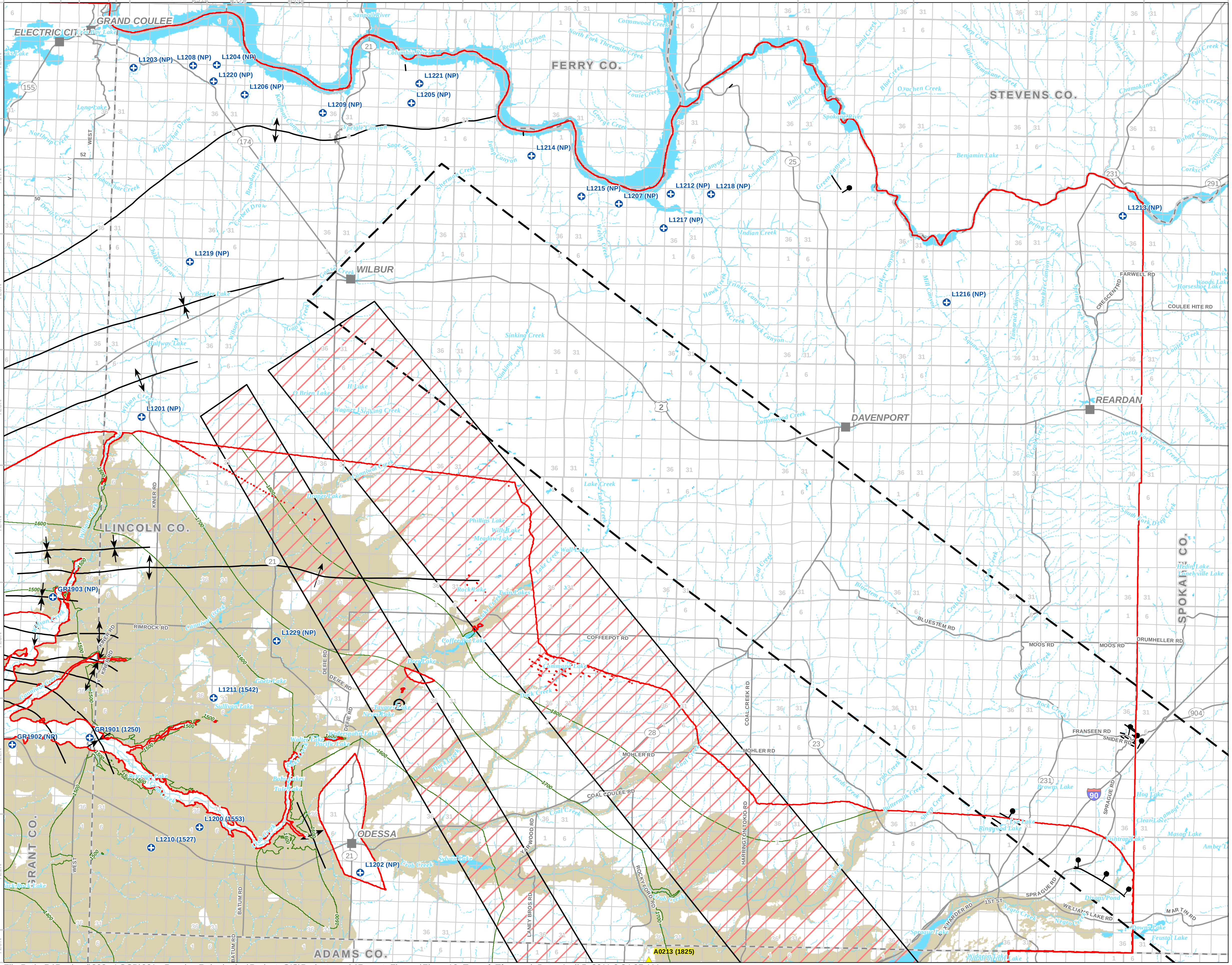

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FIGURE 19

Structure Contour Map of the Top of the Sentinel Gap Unit (Tfsg) of the Frenchman Springs Member of the Wanapum Basalt

Lincoln County, Washington

LEGEND

- Areas Where Top of Tfsg is Within 200 feet of the Top of Basalt
- Tfsg Pinchouts
- Top of Tfsg - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perrenial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5

Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

GSI Water Solutions, Inc.

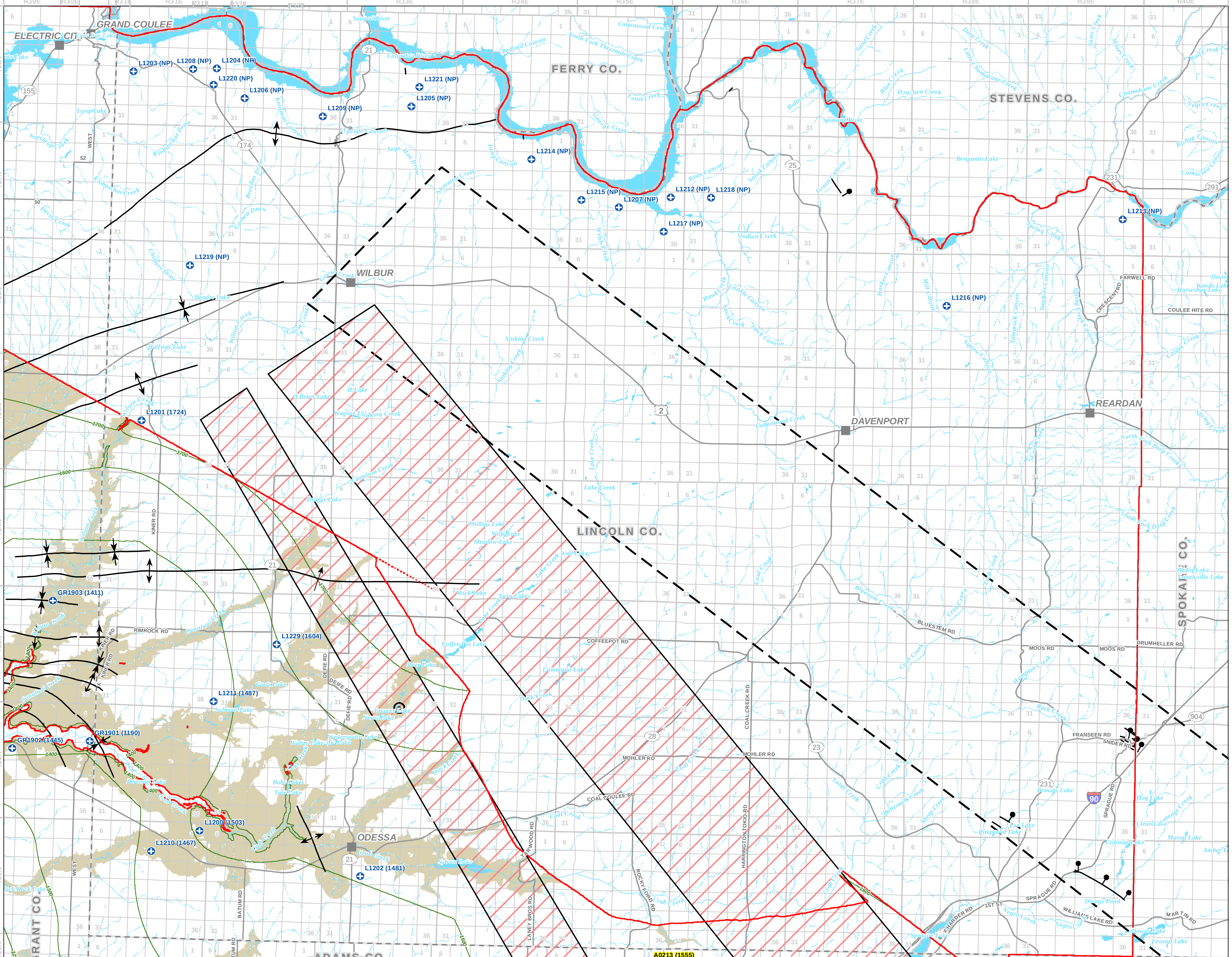

FIGURE 20

Structure Contour Map of the Top of the Sand Hollow Unit (Tfsh) of the Frenchman Springs Member of the Wanapum Basalt

Lincoln County, Washington

LEGEND

- Areas Where Top of Tfsh is Within 200 feet of the Top of Basalt
- Tfsh Pinchouts
- Top of Tfsh - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perrenial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5
Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

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Ring Dikes. Pleistocene Missoula flood scours expose numerous ring structures in the surface of the CRBG. These structures are quasi-circular in plan 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 that caused radial jointing and fracturing of the rock (Jaeger et al. 2003).

Ring dikes, occurring within the area proposed for the rehydration project, are associated with the Roza Member, and less commonly the Priest Rapids Member, of the Wanapum Basalt. The greatest concentration of known ring dikes lies in the Lake Creek drainage, extending from where it empties into the Crab Creek drainage to the northeast just above Wall Lake (Figure 21). A high concentration of ring dikes also exists in the 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 in 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 in 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.

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 included within the units mapped by GWMA. Units below the Wapshilla Ridge Member are not mapped by GWMA because it is likely that they occur only deep beneath the southernmost portion of the county. The presence of Grande Ronde dikes has not 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 because of unit extent and inferred paleoslope at the time of emplacement. The occurrence and distribution of the Grande Ronde Basalt members mapped beneath the area by GWMA are described below.

Sentinel Bluffs Member. The Sentinel Bluffs Member (Figure 22) 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 800 feet thick, and likely contains up to seven 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 many of the tributaries being considered for this project, and in the northern portion of Lincoln County on and near the highlands bordering Lake Roosevelt.

Umtanum Member. The Umtanum Member (Figure 23) and the underlying Ortley Member (Figure 24) 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 in Lincoln County, and because of the thickness of the Sentinel Bluffs Member these units are generally some hundreds of feet below the ground surface. Given the likely maximum thicknesses of the Umtanum, approximately 300 feet thick, and the Ortley, approximately 600 feet thick, they likely contain several interflow zones. The tops of both units dip south-southwest.

Grouse Creek Member. The Grouse Creek Member (Figure 25) is more widespread than the overlying Umtanum and Ortley Members, and is 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, where present, ranges from approximately 200 feet to 400 feet.

Wapshilla Ridge Member. The Wapshilla Ridge Member (Figure 26) is the deepest individual Grande Ronde unit mapped by GWMA (2009b) 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 the CRBG's northernmost extent near Lake Roosevelt. Like other Grande Ronde units, it appears to generally dip to the south-southwest, and it ranges in thickness from approximately 100 feet to over 500 feet to the south. As the unit thickens, the number of interflow zones it contains likely increase.

Beneath southernmost Lincoln County, Grande Ronde units underlying the Wapshilla Ridge Member are present (Reidel et al. 1989b, GWMA 2009b). However, the lack of deep geologic control wells makes identification of specific units difficult. For that reason, GWMA only maps an undifferentiated Grande Ronde unit beneath the southern portion of Lincoln County. Beneath the southern edge of Lincoln County these undifferentiated Grande Ronde strata may exceed 2,000 feet in thickness.

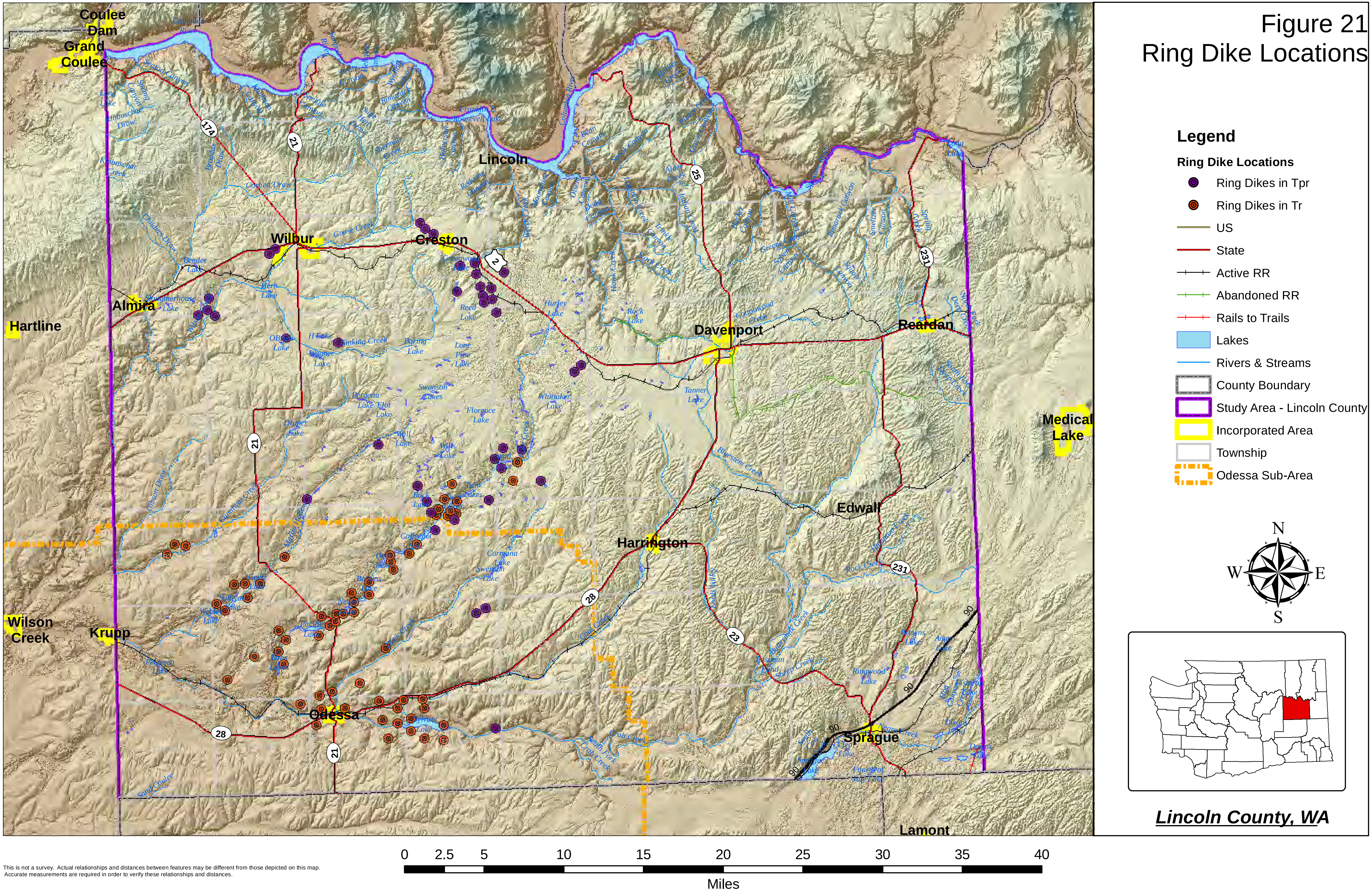

Figure 21
Ring Dike Locations

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

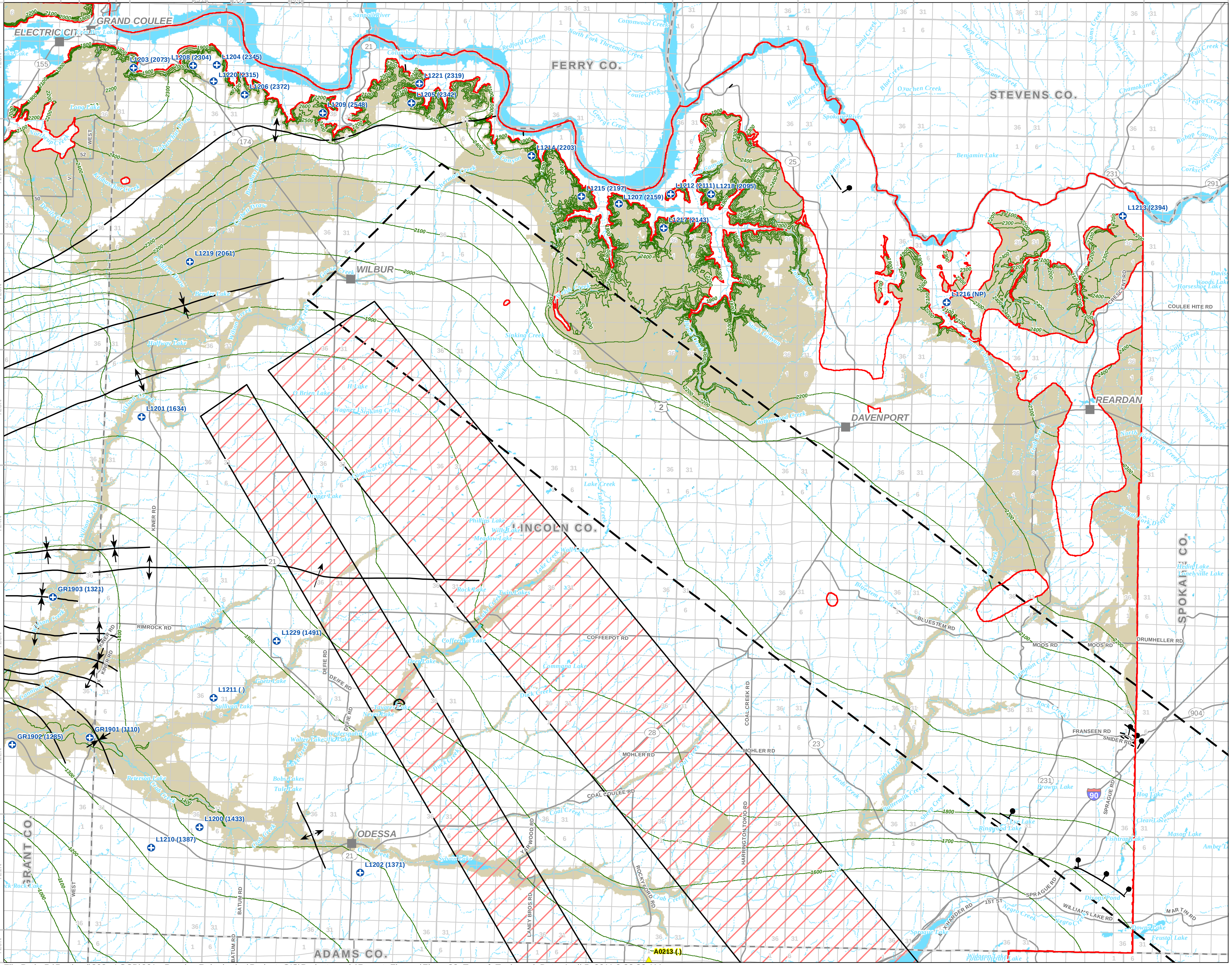

FIGURE 22

Structure Contour Map of the Top of the Sentinel Bluffs Member (Tgsb) of the Grande Ronde Basalt

Lincoln County, Washington

LEGEND

- Areas Where Top of Tgsb is Within 200 feet of the Top of Basalt
- Tgsb Pinchouts
- Top of Tgsb - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perrenial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5
Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

GSI Water Solutions, Inc.

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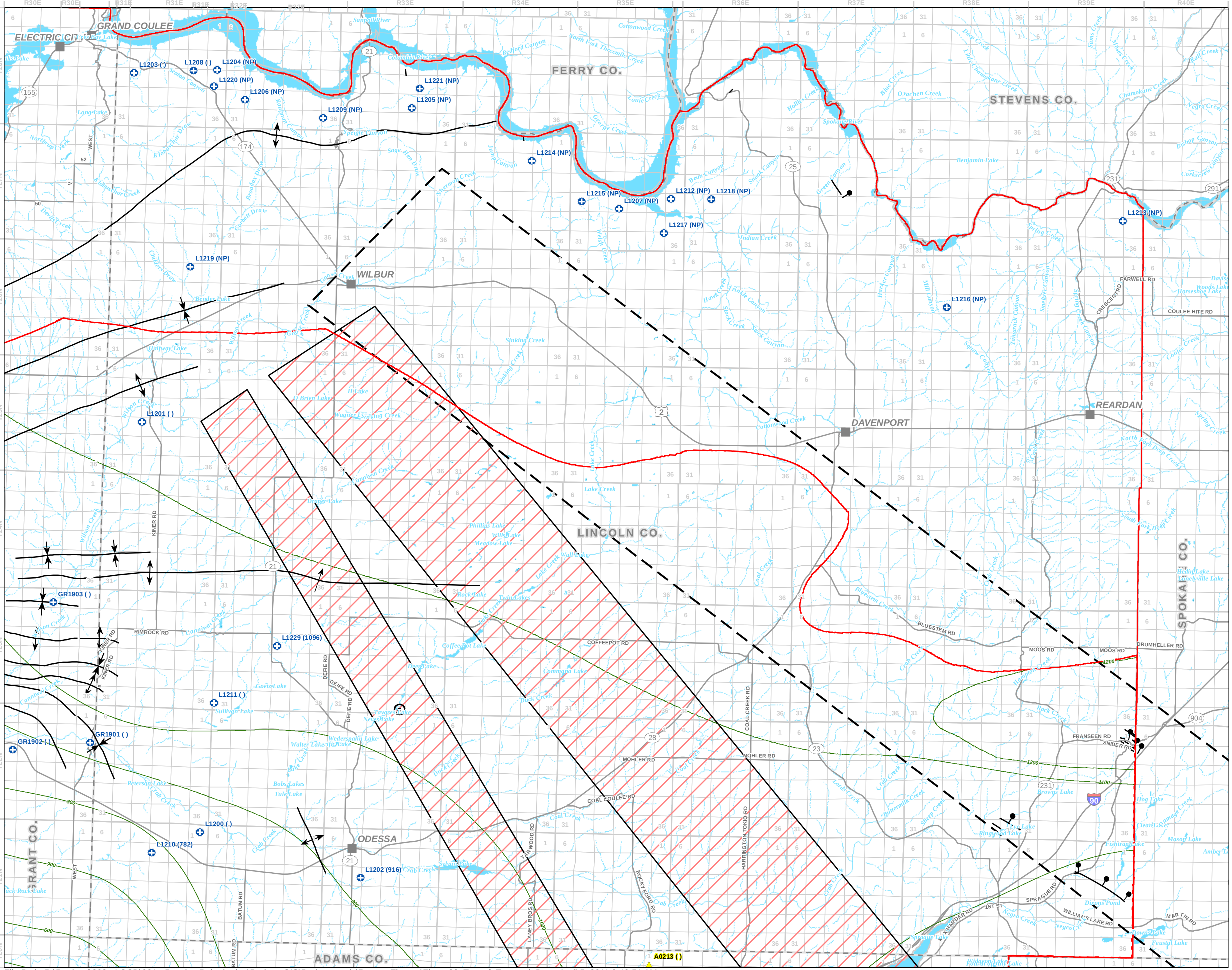

FIGURE 23

Structure Contour Map of the Top of the Umtanum Member (Tgu) of the Grande Ronde Basalt

Lincoln County, Washington

LEGEND

- Areas Where Top of Tgu is Within 200 feet of the Top of Basalt
- Tgu Pinchouts
- Top of Tgu - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perennial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5 Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

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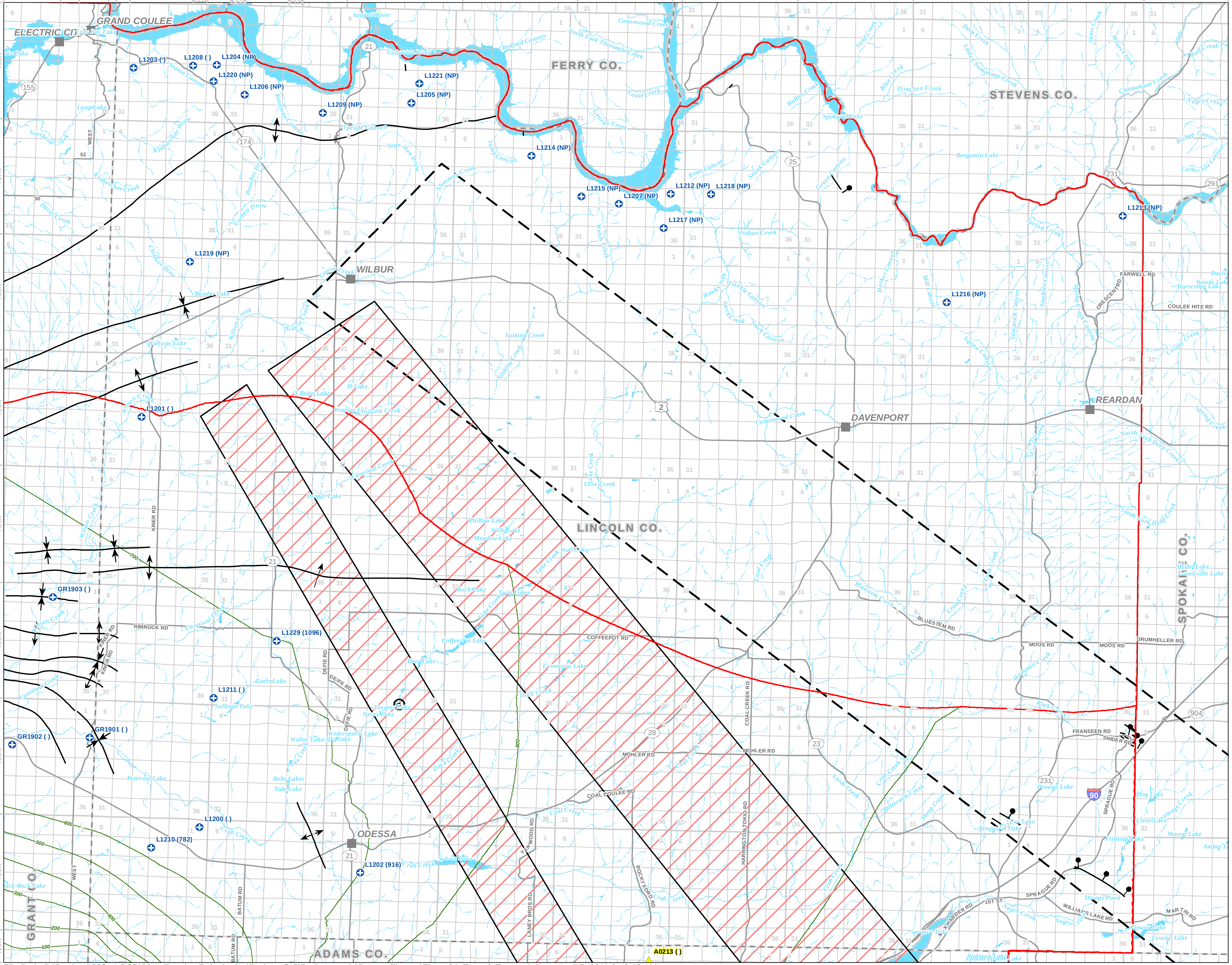

FIGURE 24

Structure Contour Map of the Top of the Ortley Member (Tgo) of the Grande Ronde Basalt

Lincoln County, Washington

LEGEND

- Areas Where Top of Tgo is Within 200 feet of the Top of Basalt
- Tgo Pinchouts
- Top of Tgo - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perrenial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5
Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

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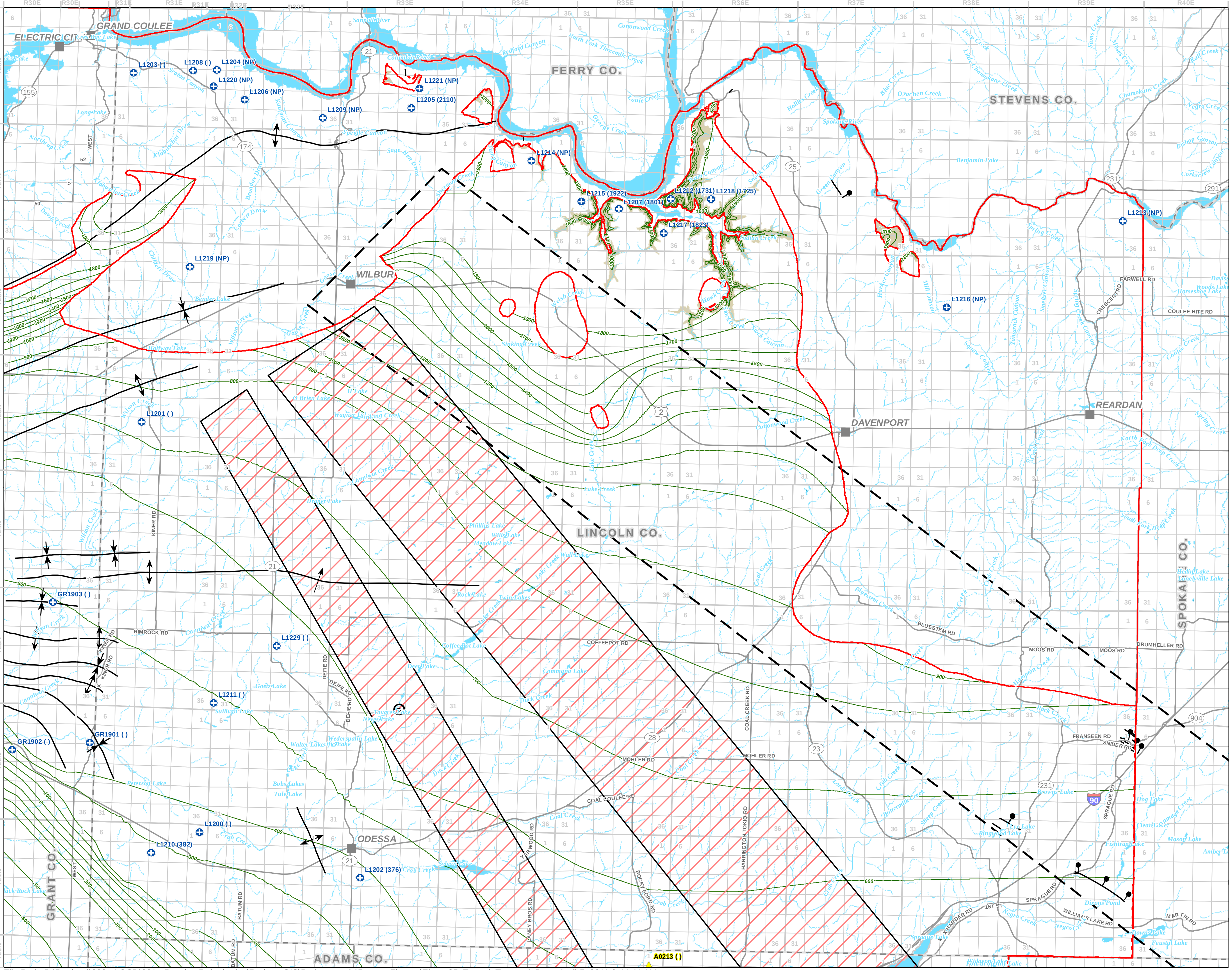

FIGURE 25

Structure Contour Map of the Top of the Grouse Creek Member (Tgg) of the Grande Ronde Basalt

Lincoln County, Washington

LEGEND

- Areas Where Top of Tgg is Within 200 feet of the Top of Basalt
- Tgg Pinchouts
- Top of Tgg - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perennial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5

Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

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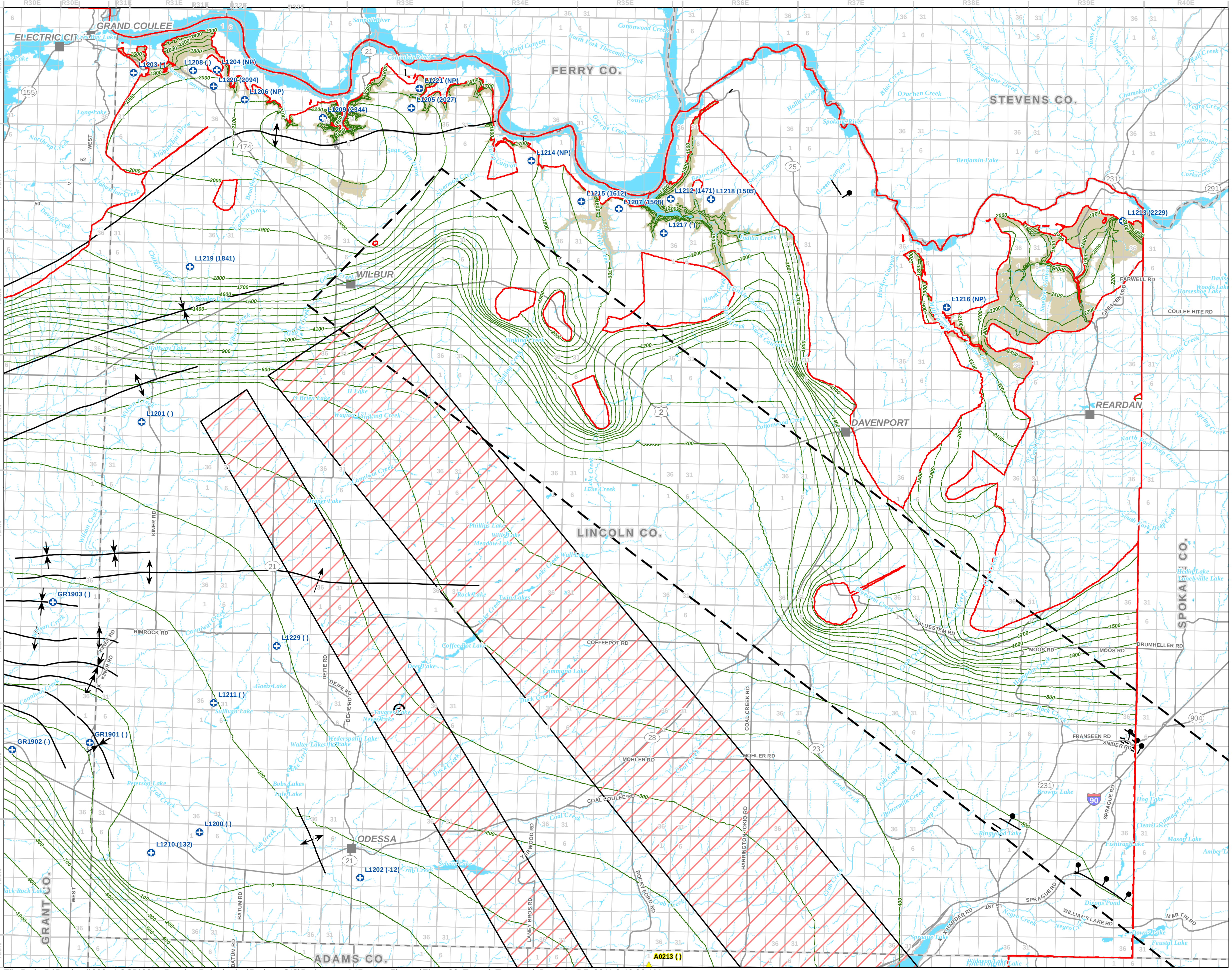

FIGURE 26

Structure Contour Map of the Top of the Wapshilla Ridge Member (Tgwr) of the Grande Ronde Basalt

Lincoln County, Washington

LEGEND

- Areas Where Top of Tgwr is Within 200 feet of the Top of Basalt
- Tgwr Pinchouts
- Top of Tgwr - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Roza Dike Outline
- Fracture Zone
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perrenial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2.5 5 7.5
Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

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2.3.4 Pre-Basalt Rocks

Field reconnaissance and existing geologic maps (Joseph 1990, Waggoner 1990a) show that the CRBG overlies a variety of older crystalline intrusive and metamorphic rocks. These pre-basalt rocks are reported to consist 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 bottom along the middle reaches of Hawk Creek, and in the highlands to the north and east of the study area. Fracture zones 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 (greater than 3,200 feet elevation) to 1,200 feet below ground surface (Figure 27). Local exposures of the pre-basalt rocks forming hills (such as Creston Butte) that project upward and through the CRBG are known as steptoe buttes, or steptoes. Steptoes and similar but buried pre-basalt rock highs lying beneath the top of the CRBG are generally thought to be part of the pre-CRBG topography buried, or mostly buried, as the CRBG was emplaced.

2.3.5 Structural Geology

Most of Lincoln County, and essentially all of the proposed project area, lie on the northeastern part of the Palouse Slope structural subprovince (Figure 7). 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 westernmost Idaho and east-central Washington to lows of less than 300 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.

In Lincoln County, major mapped structures consist predominantly of folds (Figures 15, 16, 19, 20, 22, 23, 24, 25, and 26). Faults do not seem to be common, at least as portrayed on the available 1:100,000 geologic maps. Major mapped structures in Lincoln County, generally from north to south, include the following:

- A generally east–west trending anticline that follows the crest of the highlands above Lake Roosevelt in the northwestern portion of the County (Waggoner 1990a). As this anticline extends west into Grant County its mapped orientation changes to northeast–southwest and it generally parallels Banks Lake (Gulick and Korosec 1990).
- East of this structure, generally along Lake Roosevelt, several faults are mapped in the pre-basalt rocks, including recently mapped faults in the Hawk Creek drainage that appear to bound the pre-basalt rock high exposed in the Hawk Creek Canyon (Derkey and Hamilton 2009).

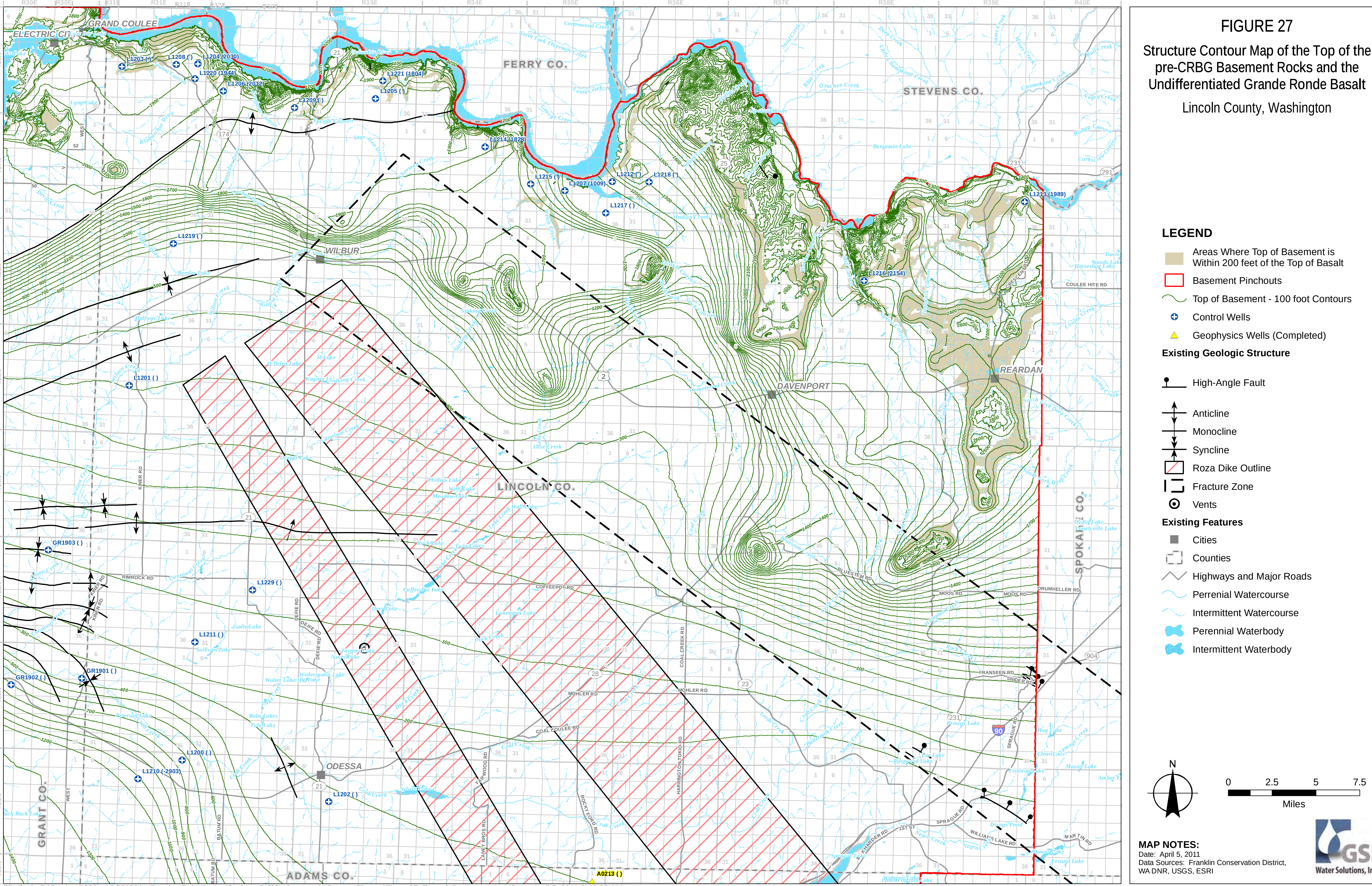
- South of the east–west anticline noted above in the first bullet a series of generally east–west, parallel low-amplitude anticlines and synclines are mapped (Waggoner 1990a). With the exception of two of them, these folds extend eastwards only a few miles into Lincoln County.
- The two folds noted as exceptions in the previous bullet above both extend over 8 miles eastward into Lincoln County. The northern of these two folds is a syncline that lies north of Wilson Creek and extends eastward from the county line almost to Wilbur. The southern of these two folds is an anticline that becomes a north-dipping monocline as it extends eastward across the middle reaches of Canniwai Creek and Marlin Hollow.
- West of Odessa, Washington, Gulick (1990) shows a few northwest–southeast oriented folds crossing Crab Creek. South of Crab Creek along the Lincoln County–Adams County line, and south, no structures (folds or faults) are mapped (Gulick 1990).

Reconnaissance done for this project and by GWMA found evidence for additional low-amplitude folds in the study area. North of Odessa, Washington, at Coffee Pot Lake, an anticline has been incised into by the Lake Creek coulee (Figure 28). This anticline lies a few miles southeast of the monocline noted in the preceding bullets. East of Sylvan Lake the Crab Creek coulee also has incised through at least one anticline. Based on the reconnaissance done to-date, these low-amplitude folds appear to have northwest–southeast orientations.

FIGURE 27

Structure Contour Map of the Top of the pre-CRBG Basement Rocks and the Undifferentiated Grande Ronde Basalt

Lincoln County, Washington



MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

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Figure 28. Photograph of a Low-Amplitude Anticline Exposed at the Narrows on Coffee Pot Lake

Basalt outcrops in the center foreground are dipping to the right at several degrees. The line shows the approximate shape of the fold on the opposite side of Coffee Pot Lake.

2.3.6 CRBG Hydrogeology

Groundwater in the CRBG regionally, and beneath the study area, generally is confined, occurring in water-bearing intervals hosted by interflow zones that may or may not include interbedded Ellensburg Formation sediments (Gephart et al. 1979, Hansen et al. 1994, Packard et al. 1996, Sabol and Downey 1997, USDOE 1988). Groundwater occurring within interflow zones is found in joints, vesicles, fractures, intergranular pores in basalt breccias and sediment interbeds, and other features that create permeable strata at the tops and bottoms of individual CRBG layers.

Physical Hydraulic Properties. Table 3 summarizes basic hydrologic properties of CRBG interflow structures and sedimentary interbeds of the Ellensburg Formation. Horizontal hydraulic conductivity of CRBG flow tops and bottoms ranges from 1 x 10^{-6} to 1,000 feet per day (feet/day) and averages 0.1 feet/day. The most hydraulically productive interflow zones will be at the high end of this range of hydraulic conductivities. Assuming a physical pathway for water movement is present through crystalline-glassy dense basalt flow interiors, vertical and horizontal hydraulic conductivity in dense flow interiors is 3 to 6 orders of magnitude less than those seen in flow tops and bottoms (USDOE 1988). Given this large difference in hydraulic conductivity, and the general lack of interconnected pore space in dense basalt flow interiors, CRB flow tops and bottoms serve as the primary conduit for lateral groundwater flow in the CRBG.

Ellensburg Formation interbeds 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). Obviously those interbeds dominated by coarse clastic sediment will have the highest hydraulic conductivities.

Table 3. Summary of Hydraulic Conductivity Values Typical for CRBG Interflow Structures and Sedimentary Interbeds

Feature		Hydraulic Conductivity Ranges		Reference	Comments
		ft/day	m/day (approx. conversion)		
Flow Tops	Kh	1×10^{-6} to 1,000	3×10^{-7} to 3×10^{2}	USDOE 1988	Average = 0.1 ft/day
Flow Tops	Kv	3×10^{-9} to 3×10^{-3}	9×10^{-10} to 9×10^{-4}	USDOE 1988	
Flow Tops	Kv	1×10^{-5} to 1×10^{-1}	3×10^{-6} to 3×10^{-2}	Sabol and Downey 1997	Measured near Lind, Washington
Flow Interiors	Kh	1×10^{-9} to 1×10^{-3}	3×10^{-10} to 3×10^{-4}	USDOE 1988	Approximately 5 orders of magnitude less than flow tops
Flow Interiors	Kv	3×10^{-9} to 3×10^{-3}	9×10^{-10} to 9×10^{-4}	USDOE 1988	
Flow Interiors	Kv	1×10^{-5} to 1×10^{-1}	3×10^{-6} to 3×10^{-2}	Sabol and Downey 1997	Measured near Lind, Washington
Flow Tops	Kh	7×10^{-3} to 1,892	2×10^{-3} to 6×10^{2}	Whiteman et al. 1994	Vertically averaged for Saddle Mountains Basalt
Flow Tops	Kh	7×10^{-3} to 5,244	2×10^{-3} to 2×10^{3}	Whiteman et al. 1994	Vertically averaged for Wanapum Basalt
Flow Tops	Kh	5×10^{-3} to 2,522	5×10^{-3} to 6×10^{2}	Whiteman et al. 1994	Vertically averaged for Grande Ronde Basalt
Ellensburg Formation Interbeds	Kh	1×10^{-6} to 1	3×10^{-7} to 3×10^{-1}	USDOE, 1988	Average for various interbeds = 0.01 to 0.1 feet/day
Ellensburg Formation Interbeds	Kh	1×10^{-6} to 100 feet/day	3×10^{-7} to 3×10^{1}	Sabol and Downey 1997	Measured for interbeds in Pasco Basin

Kh = horizontal hydraulic conductivity
Kv = vertical hydraulic conductivity

Given the planar-tabular nature of the CRBG, the occurrence and distribution of water-bearing interflow zones within it also display a planar-tabular character (USDOE 1988, PNNL 2002, GWMA 2009, Tolan et al. 2009). With this planar-tabular host rock fabric, one would surmise that the predominant groundwater flow directions within this aquifer system are parallel to, and down-dip, in it. Hydrographs from nested piezometers available to monitor water levels in the CRBG system (Figure 29) and reconstructed wells (Figure 30) suggest a degree of hydrologic separation within the CRBG aquifer system imparted by the layered, planar-tabular nature of the host rocks. This separation, interpreted to reflect stratigraphic controls on groundwater occurrence and hydraulic connection, is plainly seen on the two example hydrographs. Figure 29 shows at least two separate water level trends over time, indicating limited hydraulic connection between the water-bearing intervals being monitored. Figure 30, on the other hand, shows what happens when a single well is reconstructed to monitor multiple water-bearing intervals. The water levels diverge, have different long-term trends, and the deepest of the three levels being monitored has the highest water levels.

Water Levels. Within this planar-tabular rock and aquifer system, and given the multiple water levels commonly observed within it at a given location, construction of a single water level map for it is problematic. Nevertheless, some basic observations with respect to water levels within this aquifer system beneath Lincoln County are as follows:

- 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 study area.
- These depths to water generally correspond to water level elevations ranging from approximately 1,295 to 2,350 feet AMSL.
- This decrease in water level with depth is a criterion used by some entities to differentiate between a shallower water level Wanapum groundwater system and a deeper water level Grande Ronde groundwater system. However, such a criterion should be used with caution because historically some Grande Ronde wells displayed water levels significantly higher than those found in overlying Wanapum portions of the aquifer system (see Figure 30).
- **CRB Aquifer System Recharge.** Pre-basalt basement rock highlands beneath the northern portion of Lincoln County likely form a hydrologic barrier separating the CRBG aquifer system from Lake Roosevelt. This hydrologic barrier prevents recharge of the CRBG system by Lake Roosevelt.

- In the absence of recharge from Lake Roosevelt, direct recharge to shallow CRBG aquifers results from infiltration of precipitation, runoff, and irrigation within (and along the margins of) the Columbia Basin (Newcomb 1959; USDOE 1988; Hansen et al. 1994; GWMA 2009a, 2009d). Infiltration has been variously interpreted to be (a) vertically downward along faults, (b) past the ends of flow pinch-outs, (c) where CRBG flows are breached by erosional windows, (d) on highlands within and bordering the Columbia Basin, and (e) 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).

- GWMA's recent work (GWMA 2009) suggests that the depth of effective infiltration and recharge through planar-tabular dense interiors probably does not exceed 2 or 3 interflow zones, or approximately 200 to 300 feet. Work by Farley et al. (2006) also shows that such connections to surface water will be greatly hindered if sediments overlying the top of basalt are fine-grained. Within the Lincoln County project area, fine-grained sediments are rare in the coulees that would likely be targeted in a potential future rehydration project.

- Regardless of the source of recharge to the CRBG aquifer system, groundwater age dating by GWMA (GWMA 2009c) suggests that the rate of recharge to deep into the CRB aquifer system is slow because groundwater more than a few hundred feet deep in the CRBG aquifer system usually is thousands, to several tens of thousands of years old. Based on GWMA's groundwater geochemical data, much of the water in the CRBG aquifer system was introduced into the system in the Pleistocene. Areas where younger groundwater has been found in Lincoln County commonly are associated with coulees, suggesting these erosional features facilitate recharge to at least portions of the CRBG system, including the upper Grande Ronde (GWMA 2009c). The proposed pilot project will test this observation.

- Based on the physical geology of the CRBG summarized above, it seems likely that vertical groundwater movement into and through multiple, dense, CRBG basalt flow interiors is restricted and that groundwater movement into and through the aquifer system is primarily down-dip along interflow zones. With that, primary natural recharge pathways into the CRBG aquifer system are through erosionally thinned units, around erosional and emplacement pinch-outs, through open faults and tectonic fractures, and in up-dip areas where units thin and pinch out. All of these features have the potential to allow successive interflow zones to come into contact with each other and surface water sources, if present, forming direct hydraulic connections.

- Finally, the impact of uncased and unsealed wells on recharge in the aquifer system cannot be discounted. Uncased wells penetrating water-bearing units of both the Wanapum and Grande Ronde formations would allow for passive dewatering of the upper zones by cascading and down-hole flow into deeper zones.

- **Conceptual CRB Aquifer Groundwater Flow System.** The Priest Rapids and Roza Members of the Wanapum Basalts are exposed in many coulees in 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 southwest portion of the study area (Figures 19, 20). Therefore, the potential for recharge at exposed interflow zones and interbeds of the Frenchman Springs Member exists in those areas.

- The two members of the Grande Ronde Basalt with the most surface or near surface occurrence are the Sentinel Bluffs Member (the upper mapped member) and the Wapshilla Ridge Member (the deepest mapped member). The Sentinel Bluffs Member is at or near the surface beneath much of the western portion of the Crab Creek (and tributary) coulee system (Figure 22). In the northern part of the county, this member and the Wapshilla Ridge Member are exposed in the highlands and canyons overlooking Lake Roosevelt (Figures 22, 26). In both of these terrains, recharge directly into these units seems likely, if water is present. Recharge into the other three Grande Ronde Members would be hindered by their lack of near surface occurrence. However, the down-dip increase in units (shown in Figure 31) suggests one possible recharge pathway being formed as successive interflow zones bifurcate in the down-dip direct.

- Beneath the study area, groundwater flow directions in CRBG aquifers generally are toward the south-southwest (Drost and Whiteman 1986, USDOE 1988, Hansen et al. 1994). Potential discharge areas for deeper portions of the aquifer system, especially within the Grande Ronde Basalt, 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 the Grande Ronde 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.

- In and around the Lincoln County project area discharge from much of the shallow aquifer system, especially portions hosted by the Wanapum Basalt, may be fairly local because much of the system is completely dissected by Pleistocene Missoula flood-cut coulees. In such settings these shallower water-bearing zones, where they contain water, will discharge to coulees in spring lines. This would be to the lakes, streams, and surface springs that 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 in 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 counties.

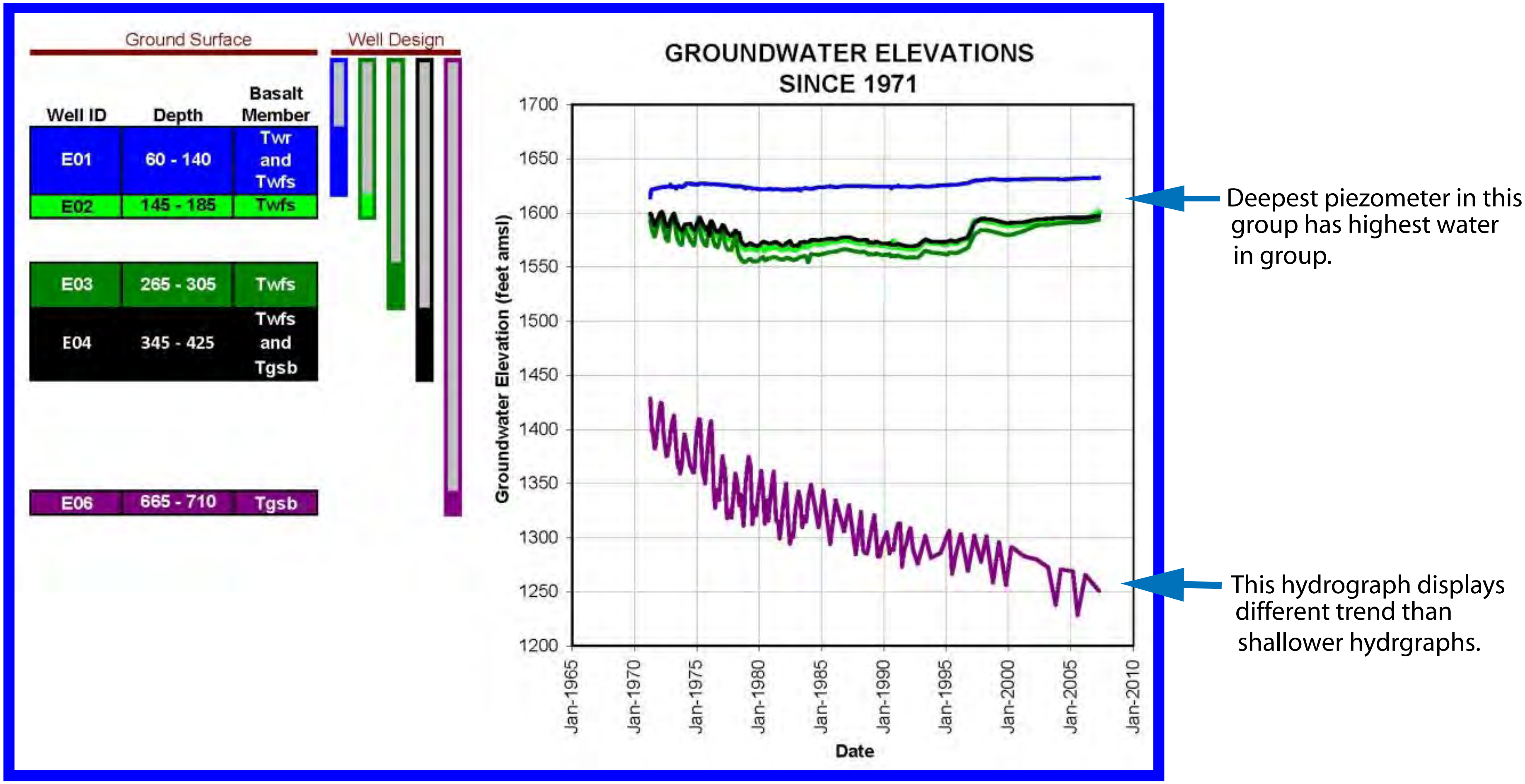


Figure 29. Hydrographs from a nested piezometer well in Lincoln County

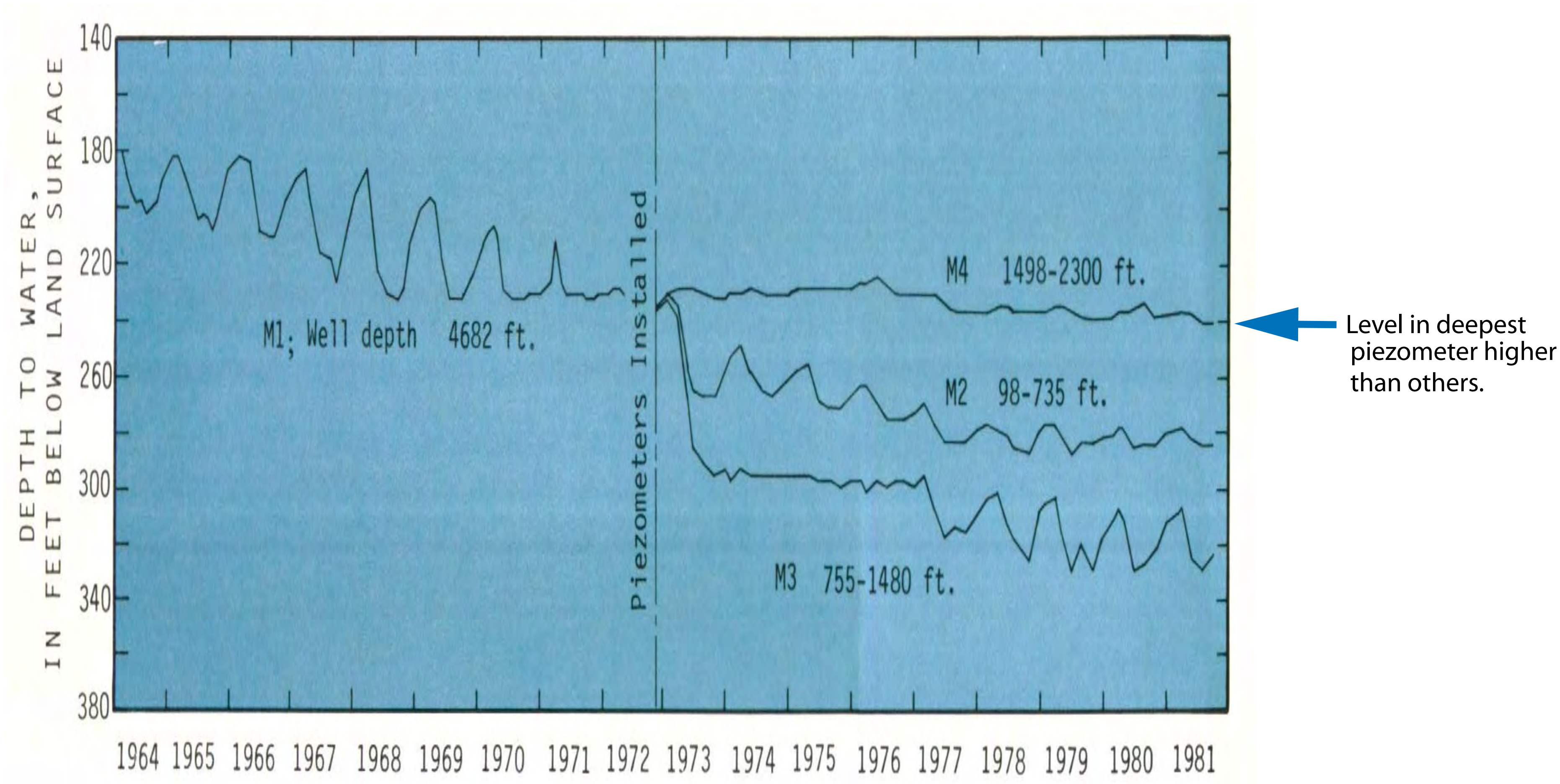


Figure 30. Hydrographs showing water level(s) in a well following reconstruction as a nested piezometer.

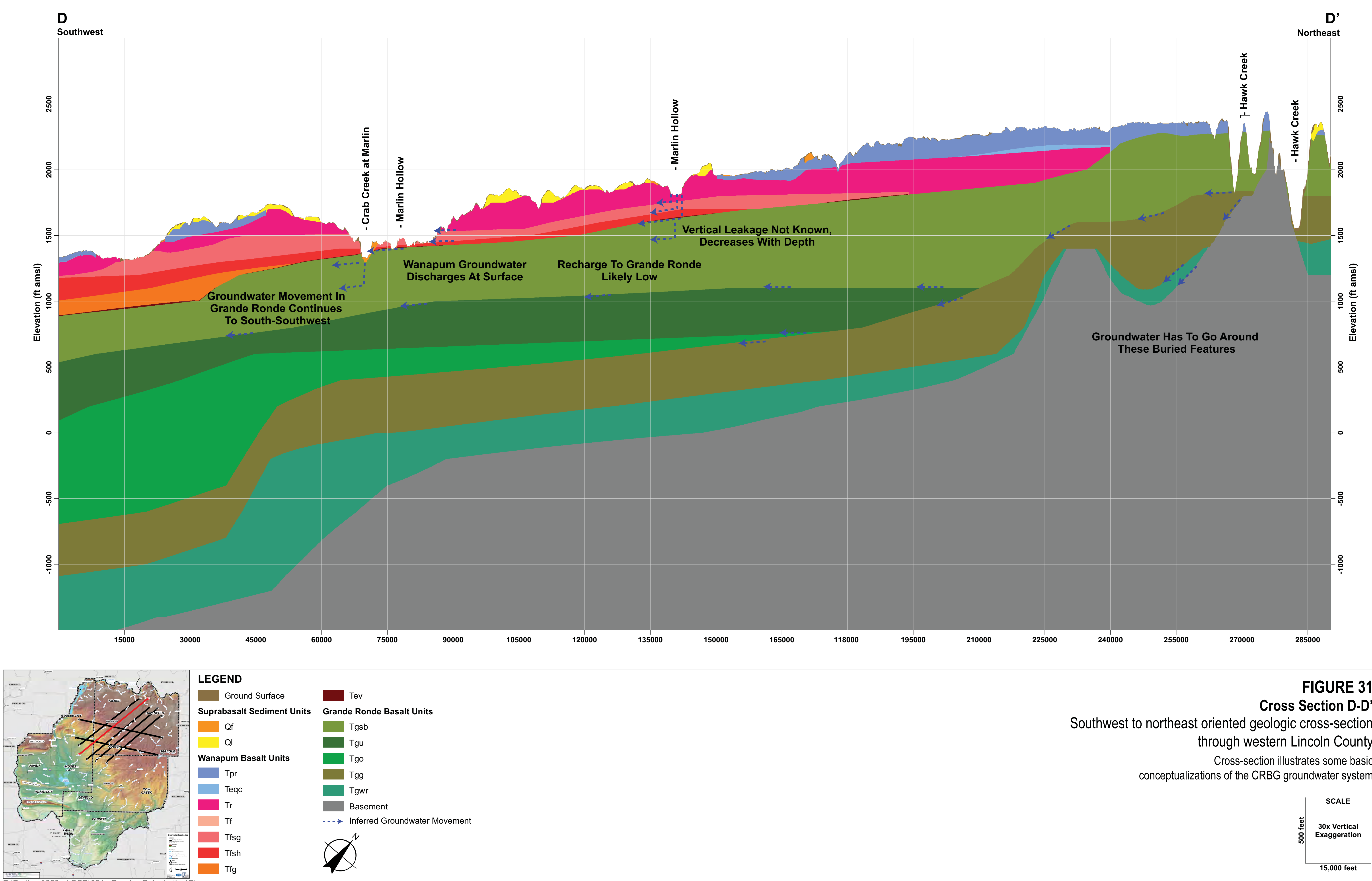


FIGURE 31
Cross Section D-D'
Southwest to northeast oriented geologic cross-section through western Lincoln County
Cross-section illustrates some basic conceptualizations of the CRBG groundwater system

Chapter 3: Water Availability and Governance

This chapter reviews several programmatic and regulatory issues potentially associated with the project. These include the following:

- Water rights needed to conduct a pilot rehydration project. This discussion also presents future options to develop a water right portfolio needed to run a longer-term, permanent project; these will be addressed in more detail if a pilot project is conducted and its results indicate that 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 was 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.

3.1 Water Rights

State of Washington 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) permanent or 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 cubic feet per second (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 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 in detail and a pathway selected at this time based on the following: (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 would be defined in the subsequent pilot test; (3) exact points of diversion for the final project would 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 Reclamation would be required to determine if the "new" water delivered via the project could be credited under other water rights, and would be further defined in the Feasibility Study.

The conveyance of Columbia River water would be to several drainages for the final project operation, to maximize the recharge to the basalt aquifers and the surface waters of Lincoln, Adams, and Grant counties. Although the goal is 50,000 to 200,000 acre-feet per year, the Feasibility Study and pilot project would attempt to develop a proposed solution for the maximum amount of conveyed and recharged water that had 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 the 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 Lincoln County Passive Rehydration Project would flow to Moses Lake and could 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. This would result in a net gain to the Columbia Basin Project and potentially reduce quantities that the Columbia Basin Project would need to divert from Banks Lake for the basin irrigation conveyance system. To determine a final buildout water quantity, the pilot project must be completed.

3.1.1 Columbia River Water

Since adoption of the Surface Water Code in 1917 (RCW 90.03), in order to receive a new water right in the State of Washington, a person must first file an application with Ecology to appropriate waters of the State. Ecology will issue a permit for a water right if the applicant can meet a four-part test consisting of (1) the proposed use of water is for a beneficial purpose; (2) there is water available for appropriation; (3) the proposed water would not impair existing water rights; and (4) the proposed use would be in the public interest.

The Lincoln County Passive Rehydration Project is attempting to acquire water for use in meeting the project purposes within the eastern part of the Odessa Ground Water Management Subarea. The project will attempt to deliver water through the passive rehydration delivery system, which will assist with fish and wildlife maintenance, and eventually infiltrate water into the basalt aquifers where irrigators, municipalities, and domestic users will put the water to beneficial use, meeting the requirements of RCW 90.03. Enhancing stream flows in the Crab Creek drainage, in addition to meeting the goals and objectives of RCW 90.90 to deliver water to the Odessa subbasin, would be in the public's interest, in the project team's opinion. There is a large regional support of this project throughout local landowners and water users. To achieve the project goals, water availability and impairment of existing water right criteria would need to be evaluated prior to issuance of a water permit. Issues associated with availability and impairment are addressed below in summaries of (1) Columbia River instream flow requirements, (2) the biological opinion, and (3) Reclamation appropriations of Columbia River water. These issues would be further addressed in the Feasibility Study phase of the project.

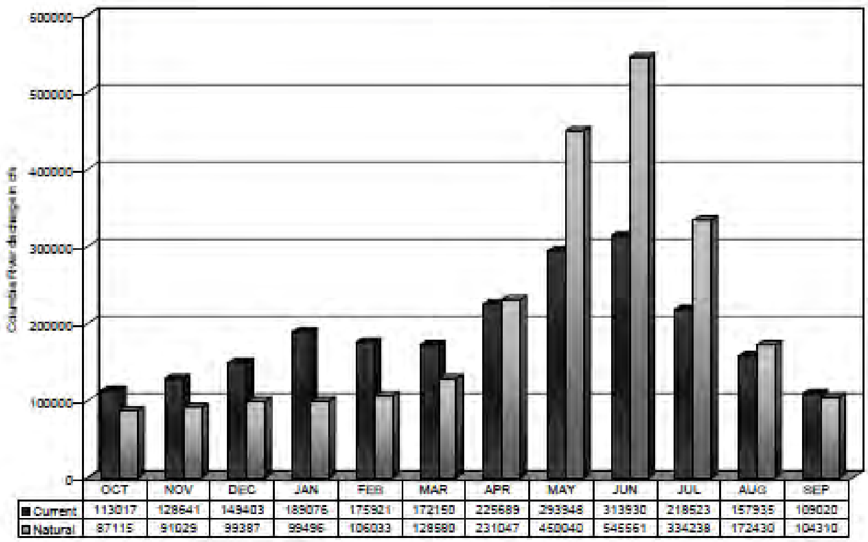
Columbia River Instream Flow

The proposed project intends to acquire available waters from the Columbia River system, and convey it to areas of southern Lincoln County. Flow regulation and water withdrawal have reduced the Columbia River's average flow, altered its seasonality, and reduced sediment discharge and turbidity as shown in the graph below (NOAA Fisheries 2008). In total, Reclamation's 23 irrigation projects in the Columbia Basin reduce the annual runoff volume at Bonneville Dam by about 5.5 million acre-feet (see Table 5.1-3 in NOAA Fisheries 2008). These depletions occur primarily during the spring and summer as the reservoirs are refilled and as water is diverted for irrigation (NOAA Fisheries 2008). Flows are monitored at most dam operations on the river. Annual discharge rate at The Dalles Dam fluctuates with precipitation, ranging from 120,000 cfs in a low water year to 260,000 cfs in a high water year (Ecology 2007). These flow rates are equivalent to between approximately 86,000,000 and 188,000,000 acre-feet/year.

The purposes for which the Columbia Basin Project and Lake Roosevelt were constructed are flood control, irrigation, and hydropower. For flood control, sufficient volume is maintained in Lake Roosevelt to control flow in the Columbia River at The Dalles Dam to a maximum of 450,000 cfs.

In 1980, Ecology passed an administrative instream flow rule (WAC 173-563) for the Columbia River main stem, which was amended in 1998 (Ecology 2007). Flows for the instream rule are measured at Chief Joseph, Wells, Ricky Reach, Rock Island, Wanapum, Priest Rapids, McNary, and John Day Dams. The table below presents the state administrative flows set at these control points under the Washington Administrative Code (WAC) and flow objectives specified in the 2004, 2008, and 2010 NOAA Fisheries Biological Opinion issued for the Federal Columbia River Power System (FCRPS) at the same location (Ecology 2007). This rule requires that any future appropriations of water not impair these flow allocations. If new water rights are acquired under the pilot testing program, and for subsequent buildout of the rehydration project, water rights will be conditioned to the instream flows set forth in WAC 173-563.

Figure 5.1-2. Simulated mean monthly Columbia River flows at Bonneville Dam under current conditions and flows that would have occurred without water development (water years 1929 – 1978. Source: Current Condition Flows – Bonneville Power Administration, HYDSIM model run FRIII_07rerun2004biop.xls; Pre-Development Flows – USBR (1999) Cumulative Hydrologic Effects of Water Use: An Estimate of the Hydrologic Impacts of Water Resource Development in the Columbia River Basin.



Flow Modifications of Columbia River from Storage Operations (NOAA Fisheries 2008)

Instream Flows Set by WAC 173-563 and the 2004 Biological Opinion

Date	Chief Joseph		Wells & Rocky Reach		Rock Island & Wanapum		Priest Rapids			McNary			John Day		Bonneville	The Dalles	
	WAC 173-563		WAC 173-563		WAC 173-563		WAC 173-563		2004 BiOp	WAC 173-563		2004 BiOp	WAC 173-563		2004 BiOp	WAC 173-563	
	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Flow Objective (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Flow Objective (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Flow Objective (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)
Jan	10	30	10	30	10	30	50	70	--	20	60	--	20	60	?[b]	20	60
Feb	10	30	10	30	10	30	50	70	--	20	60	--	20	60	?[b]	20	60
Mar	10	30	10	30	10	30	50	70	--	50	60	--	50	60	?[b]	50	60
Apr 1-2	20	50	20	50	20	60	50	70	--	50	100	--	50	100	?[b]	70	120
3-9	20	50	20	50	20	60	50	70	--	50	100	--	50	100	?[b]	70	120
10-15	20	50	20	50	20	60	50	70	135	50	100	220-260[a]	50	100	?[b]	70	120
16-25	20	60	30	60	30	60	50	70	135	70	150	220-260[a]	70	150	?[b]	70	160
26-30	20	90	50	100	50	110	50	110	135	70	200	220-260[a]	70	200	?[b]	70	200
May	20	100	50	115	50	130	50	130	135	70	220	220-260[a]	70	220	?[b]	70	220
Jun 1-15	20	80	50	110	50	110	50	110	135	70	200	220-260[a]	70	200	?[b]	70	200
16-20	10	60	20	80	20	80	50	80	135	50	120	220-260[a]	50	120	?[b]	50	120
21-30	10	60	20	80	20	80	50	80	135	50	120	220-260[a]	50	120	?[b]	50	120
Jul 1-15	10	60	20	80	20	80	50	80	--	50	120	200	50	120	--	50	120
16-31	10	90	50	100	50	110	50	110	--	50	140	200	50	140	--	50	140
Aug	10	85	50	90	50	95	50	95	--	50	120	200	50	120	--	50	120
Sep	10	40	20	40	20	40	36	40	--	50	60	--	50	85	--	50	90
Oct 1-15	10	30	20	35	20	40	36	40	--	50	60	--	50	85	--	50	90
16-31	10	30	20	35	20	40	50	70	--	50	60	--	50	85	--	50	90
Nov	10	30	10	30	10	30	50	70	--	50	60	--	50	60	125-160[b]	50	60
Dec	10	30	10	30	10	30	50	70	--	20	60	--	20	60	?[b]	20	60

NOTES:

Abbreviations: Min = Minimum; Qi = instantaneous flow; Avg. = Average; WAC = Washington State Administrative Code; kcfs = thousand cubic feet per second

a. Objective varies according to water volume forecasts.

b. Objective varies based on actual and forecasted water conditions. The dates to which this flow objective applies include 11/1 to emergence (spring season) which may vary each year.

c. The 2004 Biological Opinion was issued by NMFS regarding the Federal Columbia River Power System (FCRPS). The data in the table is from Bureau of Reclamation, Bonneville Power Administration, and U.S. Army Corps of Engineers (Action Agencies). 2004. Final Updated Proposed Action for the FCRPS Biological Opinion Remand. November 24, 2004.

WAC 173-563 Flows and 2004 Bi-Op Flows on the Columbia River (NOAA Fisheries 2008)

The Columbia River instream flow rule allows the director of Ecology to reduce the minimum flows for the Columbia River established in the rule by 25% if the director "deems it to be an overriding public interest requirement" (WAC 173-563-050(1), but the outflow at Priest Rapids Dam cannot fall below 36,000 cfs. The rule also authorizes the director to approve future uses of water that would conflict with the provisions of Chapter 173-563 "only in those situations when it is clear that overriding considerations of public interest (OCPI) will be served" (WAC 173-563-080), and to be conducted in consultation with the directors of the Washington State Department of Fish and Wildlife (WDFW), State Department of Agriculture, and the State Commissioner of Public Lands (Ecology 2006). Ecology has informed the project team that OCPI will not be an option for this project.

Within WAC 173-563-020 (4), a required consultation process is outlined for applications received by Ecology on or after July 27, 1997. The code states: "The department will consult with appropriate local, state, and federal agencies and Indian tribes in making this evaluation. Any permit which is then approved for the use of such waters will be, if deemed necessary, subjected to instream flow protection or mitigation conditions determined on a case-by-case basis through the evaluation conducted with the agencies and tribes." Applications for water rights under this project would be required to undergo this consultation process in which Ecology and the applicants would be required to hold "meaningful, consultation" with listed agencies and appropriate Indian tribes prior to rendering a decision on applications (PCHB case, *Yakama Nation v. Ecology* – PCHB 03-030-036). This consultation process was upheld in the Pollution Control Hearings Board (PCHB) ruling of *Yakama Nation v. Ecology* (PCHB 03-030-036) and court case *Kennewick Public Hospital District v. PCHB, et al.* (Nos. 22741-3-III, 22742-1-II, and 22758-8-III, 2005).

Biological Opinion

Potential future water allocations also must meet the flow criteria set forth in the 2004 and 2008 Biological Opinions (Bi-Op) and the 2010 NMFS Supplemental Bi-Op issued by NOAA Fisheries on the Columbia River. Section 9 of the Endangered Species Act (ESA) prohibits the "taking" of an endangered species and defines "take" to include "harm" (16 U.S.C. 1532(19)). Individual water rights may cause harm when the appropriation results in or contributes to the "lack of sufficient stream flow to sustain healthy fish populations" (Ecology 2006). The flows identified in the 2004 Bi-Op are identified in the table above. Any available waters requested under this proposed project would be conditioned for the need to meet these flows.

Reclamation Appropriation of Columbia River Water – Pending Application

RCW 90.40.10 states "The United States is hereby granted the right to exercise the power of eminent domain to acquire the right to the use of any water, to acquire or extinguish any rights, and to acquire any lands or other property, for the construction, operation, repairs to, maintenance or control of any plant or system of works for the storage, conveyance, or use of water for irrigation purposes, and whether such water, rights, lands or other property so to be acquired belong to any private party, association, corporation or to the state of Washington, or any municipality thereof; and such power of eminent domain shall be exercised under and by the same procedure as now is or may be hereafter provided by the law of this state for the exercise of the right of eminent domain by ordinary railroad corporations, except that the United States may exercise such right in the proper court of the United States as well as the proper state court." RCW 90.40.20 further states "The United States shall have the right to turn into any natural or artificial water course, any water that it may have acquired the right to store, divert, or store and divert, and may again divert and reclaim said waters from said water course for irrigation purposes subject to existing rights."

In December 2004, Reclamation submitted a letter to Ecology that "pursuant to the Act of Congress of June 17, 1902 (32 Stat.388), and acts amendatory thereof and supplementary thereto, the United States intends to make examinations and surveys for the utilization of the unappropriated waters of the Columbia River and its tributaries as may be required for operation of storage and distribution facilities under the Act of February 20, 2003 (PL 108-7)".

Ecology acknowledged this notice of withdrawal of water by Reclamation under the provisions of RCW 90.40.030 through December 28, 2005 in its letter dated March 30, 2005, to Reclamation. In this letter, Ecology states that the area of the affected proposed withdrawal is "the area of the Columbia River basin affected by the withdrawal includes the Columbia River above Priest Rapids Dam and all tributaries entering the Columbia River above Priest Rapids Dam but does not include the Columbia River or its tributaries below Priest Rapids Dam."

Reclamation's request for unappropriated waters affects requests for water allocation after December 28, 2004, including those of this project. Thus, the rehydration project application, if approved, would be junior to the Reclamation 2004 water allocation request. After acceptance of this water allocation request by Reclamation, Ecology was required to refer subsequent applications for new water rights filed after December 29, 2004, to Reclamation for consideration of a specific release. Ecology withholds any actions on these applications that are not granted a release by Reclamation, and will withhold any actions until Reclamation withdrawal expires or matures into water rights (Ecology 2005).

Reclamation has been conducting studies under this request for withdrawal, and Ecology in a letter dated December 23, 2009, extended this right of withdrawal of waters of the Columbia River and tributaries until December 22, 2011. For the proposed project, request for a permit of water to conduct the pilot project would need to be referred to Reclamation, and a release granted. Future long-term buildout of the project would be dependent on whether the Reclamation-approved use of Columbia River waters is extended beyond the current

December 22, 2011, approval, and if not extended, be approved through the consultation process described above.

3.1.2 Pilot Test Water Rights Options

For the prefeasibility assessment, several options were evaluated for acquiring water rights to operate the proposed pilot testing program. The pilot testing program would seek a proposed diversion of 10 to 20 cfs. Potential options to acquire this quantity of water were evaluated. Water rights evaluated in a potential rehydration pilot test project included the following:

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 1-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 the most feasible alternative (Gregory e-mail February 15, 2011). A temporary permit is described in RCW 90.03.250, which states that "Any person, municipal corporation, firm, irrigation district, association, corporation or water users' association hereafter desiring to appropriate water for a beneficial use shall make an application to the department for a permit to make such appropriation, and shall not use or divert such waters until he has received a permit from the department as in this chapter provided. The construction of any ditch, canal or works, or performing any work in connection with said construction or appropriation, or the use of any waters, shall not be an appropriation of such water nor an act for the purpose of appropriating water unless a permit to make said appropriation has first been granted by the department: PROVIDED, That a temporary permit may be granted upon a proper showing made to the department to be valid only during the pendency of such application for a permit unless sooner revoked by the department: PROVIDED, FURTHER, That nothing in this chapter contained shall be deemed to affect RCW 90.40.010 through 90.40.080 except that the notice and certificate therein provided for in RCW 90.40.030 shall be addressed to the department, and the department shall exercise the powers and perform the duties prescribed by RCW 90.40.030."

The temporary application permit will require a specific release from Reclamation in accordance with its pending Columbia River allocation.

2. **A preliminary permit use authorization** issued by Ecology. 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 Ecology (Policy 1030). However, a preliminary permit does not authorize the beneficial use of water.

   Consultation with Ecology determined that a preliminary permit would not be the appropriate permit due to the limitations of putting the water to beneficial use. The pilot testing program primarily would be to conduct testing on the feasibility of the project, but water diverted would eventually be used downstream by others for potential beneficial use. Therefore, Ecology recommended the issuance of a temporary permit (Gregory e-mail dated February 15, 2011).

3. **Reclamation Municipal and Industrial (M&I) water** can be acquired from Reclamation under certain conditions. The project team met with Reclamation to discuss the potential option of using this program to develop water for the pilot project. The project is set up to provide water to municipal and industrial users under existing Reclamation water rights. This type of authorization is capped at 13 cfs, and based on the project team's discussions with Reclamation staff, this type of water for the proposed project would be of very limited availability based on the recent Bi-Op. In addition, the proposed project would require Reclamation to add or change the type of use and add the place of use within Lincoln County on the existing water right certificates in order to be utilized for the pilot testing program. Reclamation personnel determined that adding a purpose and place of use to its M&I water rights outside of what is already approved for municipal and industrial use would not be possible. Therefore, this option was determined to not be feasible.

4. The project team also approached Reclamation to determine if there were opportunities to utilize another **existing Reclamation water right** for the pilot project under a lease or cooperative agreement. Reclamation currently maintains numerous "irrigation" rights and "hydropower" rights, as presented in Table 4. Discussions with Reclamation determined that due to the multi-beneficial use of the proposed pilot project, existing rights may not be available for use under the proposed pilot project. Therefore, this option was determined to not be a feasible approach to obtaining water for the proposed pilot project, but may be an option for the long-term rehydration project.

Table 4. Reclamation Water Rights

Cert./Permit/ Application	Priority Date	Quantity	Purpose
Irrigation			
S3-01622C	5/16/1938	13,450 cfs 2,910,00 AF/yr	Irrigation of 590,000 acres, hydroelectric, recreation, municipal, industrial
C-9252	12/24/1941	40 cfs	Irrigation of 1,319 acres, Block 2
S3-00019C	4/22/1943	212 cfs 70,000 AF/yr (1)	Partial irrigation of 160,000 acres
C-10703	10/27/1958	80 cfs 23,121 AF/yr	Irrigation of 3,303 acres, Block 3
R3-00013P	4/22/1943	200,000 AF (2) Plus storage of project waste, seepage & return flow	Supplemental supply; irrigation of 234,000 acres
S3-25062C	10/27/1958	8.5 cfs 23,121 AF/yr	Irrigation of 350 acres, Block 3
S3-28586P	5/16/1938	1,140 cfs 214,000 AF/yr	Irrigation, hydroelectric, recreation, municipal, industrial
CBP Withdrawal	5/16/1938	10,410 cfs	Reserved for remainder of CBP
Withdrawal	6/16/1975	120 cfs	Block 1
Hydropower			
C-11543	5/16/1938	75,000 cfs continuously	Hydropower left and right bank of Grand Coulee Dam
C-11793	5/16/1938	6,400,000 AF	Live storage, FDR irrigation – hydropower
C-11794	8/12/1970	3,162,000 AF	Dead storage FDR
S3-26257C	5/9/1975	22,000 cfs continuously	Hydropower – 3rd power plant – increased capacity
S3-26258C	10/16/1969	184,000 cfs continuously	Hydropower – 3rd power plant – 6 units
S3-27615C	10/16/1969	7,400 cfs continuously	Hydropower – 4 pump turbine units
S3-01606C	10/16/1969	21,700 cfs continuously	Hydropower – increased capacity left and right bank – Grand Coulee (18,000 cfs), two pump turbines (3,700 cfs)

Cert./Permit/ Application	Priority Date	Quantity	Purpose
S3-01622C (old permit #15994)	5/16/1938	13,450 cfs continuously March - October	Low head power generation
R3-00013P	4/22/1943	200,000 AF	Low head power generation

From: *Reclamation – Managing Water in the West, Odessa Subarea Special Study Columbia Basin Project – Plan of Study, Reclamation*, February 2006

(1) From Lind Coulee

(2) Natural flows from Rocky Ford, Upper Crab Creek, tributaries to Moses Lake, and Potholes Reservoir.

5. **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) individual water rights would need to be identified, agreements reached, and extent and validity analyses completed to verify transferable quantities. For the purpose of a short-term pilot project, such an approach would be cumbersome, expensive, and likely not an effective way to secure water for a short duration (few years long) pilot project.

6. The project team also evaluated whether the proposed project would require a **reservoir permit** in addition to the issuance of a **preliminary and/or temporary permit** that authorizes withdrawal of water from Lake Roosevelt for the pilot project. RCW 90.03.370(3) states: "underground artificial storage and recovery project" means any project in which it is intended to artificially store water in the ground through injection, surface spreading and infiltration, or other department-approved method, and to make subsequent use of the stored water."

   The project would deliver diverted water into tributary basins and water would be percolated into the basalt aquifers, with some component being evaporated, consumed, and/or lost. Discussions with Ecology have resulted in Ecology's opinion that recharge of the aquifers by the means outlined in the proposed passive rehydration project may not meet the required definition of a "storage project" because there is no recovery mechanism, and thus the project would not require a reservoir permit. A more detailed analysis of requirements of a reservoir permit would be held with Ecology during the feasibility phase of the project.

As noted above, based on consultation with Ecology, the project team recommends that a temporary permit be sought for the pilot project. The purpose of the temporary permit would be to provide authorization for the use of Lake Roosevelt water for a potential pilot project. An application for Lake Roosevelt water would be made in accordance with RCW 90.03.250 prior to requesting a temporary permit. Issuance of the temporary permit would need to meet the four-part test of beneficial use, water availability, no impairment, and public interest. The initial screening under this task has determined that the temporary permit should be able to meet these standards. As stated previously, the beneficial use criterion is being met under several of the defined uses such as habitat enhancement, municipal, irrigation, and domestic uses. Any temporary water right application would need to receive a specific release from Reclamation. With this water approved under the temporary permit, a pilot project would test the operational feasibility of a project that moved water from Lake Roosevelt into one or more drainages in Lincoln County. The pilot project would also examine management and operations in the targeted drainages. Finally, the pilot project, using water supplied under the temporary permit, would provide a field-scale test of the 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 major positive benefit to aquifer recharge and habitat needs.

If the project is authorized for moving forward into the feasibility phase, a reservoir permit application may be completed and submitted to Ecology at the completion of the feasibility phase (assuming that the feasibility work suggests a project is potentially viable, and Ecology and the applicants determine the project meets the requirements of RCW 90.03.370(3)). The water right permit application, which would request issuance of a temporary permit for up to 20 cfs, would be accompanied by a project plan that likely included 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 would also name the authorities/entities responsible for management and operations.

3.1.3 Potential Long-Term Water Right Options

The project team also investigated several full-scale 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 rehydration project has not been determined. After completion of the pilot testing program, a proposed quantity would be recommended. Preliminary estimates of stream capacity for conveyance of Lake Roosevelt water are at least 50,000 acre-feet annually. Several potential water right options appeared feasible for the long-range operation of the project. These are described below.

1. **Reclamation Existing Water Rights:** As stated previously, Reclamation maintains numerous water rights in the project area. Upon implementation of the Lincoln County Passive Rehydration Project, water from the project would have some influence on the Reclamation project operations. This would primarily be by water introduced to the

Upper Crab Creek tributaries that did not infiltrate into the basalt aquifers, which would eventually return to Reclamation operations as the water flowed to Moses Lake and the Potholes Reservoir, thus reducing potential quantities Reclamation would need to divert from the Columbia River for its project area. In addition, water that infiltrated into the aquifers in the eastern portions of the Odessa Groundwater Management Area might reduce potential needs within the defined irrigable acreage area of the Reclamation project. During discussions with Reclamation representatives, they informed the project team that upon development of a known water quantity for the full-scale passive rehydration project, discussions could be initiated for potential agreements with Reclamation 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 whether 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 when available under the Bi-Op. This would result in available waters only in certain 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 3.1.4 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 the State of Washington. However, Ecology's water rights GIS database was not operating while this report was being prepared. A further evaluation of private water rights would 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 finding water for the long-term operation of the passive rehydration project. One option may be the development and operation of a potential water trust or 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 would 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” would 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 would most likely be the feasible option. The water right portfolio would consist of a mixture of several or even 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 would be required. Instituting a water portfolio would require a more detailed management program of the water rights. It is inferred that the operational entity developed for the project would manage the water rights. A more detailed analysis of the potential structure of a water right portfolio would be developed in the feasibility phase of the project.

3.1.4 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 was also 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 Reclamation. The *Appraisal Evaluation of the Columbia River Mainstem Off-Channel Storage Options* report completed in May 2007 by Ecology and Reclamation 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-Channel Storage Appraisal report are representative of determining the availability to divert water just downstream of the Priest Rapids Reservoir, the project team feels 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 consist of the Okanogan, Methow, Entiat, and Wenatchee rivers and Lower Crab Creek, as well as numerous other creeks and streams along the approximately 200-mile-long river course. The combined contribution of these streams is small compared to the total flow of the Columbia River through the reach between Grand Coulee Dam and Priest Rapids Dam.

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 was developed that is available for diversion in excess of existing diversions and downstream flow objectives under current operations. 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 below in Table 5.

The current estimate for total annual demands is approximately 3,368,000 acre-feet and include agricultural, domestic-commercial-municipal, and industrial (DCM&I), and flow augmentation. The largest demand for water is agriculture, which accounts for approximately 75% of the total diversions. The largest of these is the Columbia Basin Project, which has a demand of 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 the project team does not know what the potential authorization needs of a final, full-scale project would require. Based on this prefeasibility assessment, however, the project team suspects that a long-term, full-scale project would likely 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 was undertaken, it would not operate under a preliminary or temporary permit. A new water right application for the long-term project would be submitted at the same time as the request for a temporary permit for the conductance of the pilot test. This application would be submitted for the maximum estimated water under this evaluation of 200,000 acre-feet and 100 cfs. The application then could be modified/reduced depending on the results of the pilot testing program. It is the project team’s understanding that this application would be on hold until the final decision was made on the Reclamation unapproriated Columbia River water allocation currently scheduled to expire on December 22, 2011.

Table 5. Columbia River Water Available for Diversion (KAF) – 1929 to 1978 (Ecology, May 2007)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr(1)	Apr(2)	May	June	July	Aug(1)	Aug(2)	Sept	Total
Average	1,773	413	1,791	4,078	2,254	1,719	1,319	241	2,149	2,602	1,478	61	21	1,040	20,936
Maximum	4,693	3,082	7,443	10,999	7,484	5,846	4,269	2,216	8,134	15,620	7,671	1,453	1,062	5,103	54,485
Minimum	938	0	0	0	0	0	0	0	0	0	0	0	0	0	2,276
Driest 10-year Avg. (37–46)	1,582	0	758	2,557	559	1,033	689	63	1,217	483	340	0	0	597	---
Wettest 10-year Avg. (67–76)	1,510	401	2,217	5,950	4,251	2,294	1,787	335	3,407	3,885	3,144	211	106	1,375	---

(1) Data were provided by Reclamation (Appendix B of the Columbia River Water Availability Analysis – Preliminary Work Product dated September 5, 2006).

(2) Data represent volume of water available for diversion in excess of downstream flow objectives under current operations. Available to divert just downstream of Priest Rapids Reservoir.

3.2 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 instream uses. RCW 90.90 may be the source of the funding of a Lincoln County rehydration 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 instream, 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 instream 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 instream flows and producing gains to riparian habitat and water-based recreation. A portion of the extra water flowing down the creek could be diverted for use (as new supply) by authorized irrigation water users along the creek, or it could all be protected to continue flowing downstream to rehydrate all of the channel and lakes at the bottom of the basin. As water flowed downstream a portion of the supplemental water would seep into the ground and, presumably, contribute new water to the overall groundwater supply in the area, which is currently over-allocated. Any water that reached Crab Creek would continue down the water course and enter Moses Lake, enhancing the existing Reclamation project. In addition, a portion of the water would presumably return, unconsumed, to the Columbia River via the lower Crab Creek drainage.

Using the simple water balance model described in Section 4.7, a 10 cfs rehydration pilot project might produce an average outflow from Lake Creek of 8.3 cfs. This is contrasted with the existing estimated outflow volume of less than 2.3 cfs in wet years (in dry years the out-flow commonly is observed to be zero), to show a net gain to instream flow at the outlet of Lake Creek of 6.0 cfs, or more. 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 instream 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 likely, although they have not been estimated in this analysis. The simple water balance model will be re-evaluated in the feasibility phase if the project proceeds.

To achieve an exact division of water equal to one-third instream, 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 fully 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 instream 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 instream 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 instream 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.

3.3 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 will 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 the following:

- 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.

Chapter 4: Drainage and Routing Assessment

The purpose of this chapter is to describe the results of an assessment of the drainages selected for evaluation in this project. The grant calls for review of three to six sites that may be suitable for passive infiltration. Given the basic project concept, to introduce water into one or more drainages in Lincoln County along which the water can then infiltrate into the ground, the sites have been interpreted to mean streams. This seems to be consistent with language in the grant which appears to use site and drainage interchangeably.

For this prefeasibility assessment we investigated 10 streams (or drainages). Within each, the number of specific locations where water may infiltrate into the underlying aquifer system varies. Some streams appear to have more, and some fewer, losing reaches that have good potential for aquifer recharge. Given the current lack of hydrologic investigations for the vast majority of the potential project area Chapter 4 relies on anecdotal information, limited reconnaissance, GIS assessment, and the few available reports. It is largely qualitative in nature, supplemented with the very limited amount of quantitative information that is either available, or can be generated using GIS tools.

The first part of Chapter 4, Sections 4.1 through 4.3, focuses on a geographic assessment sub-divided into 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. For specific stream drainages we evaluate conditions to the extent we can, given available GIS coverage, information, and reconnaissance, as follows:

1. Physical characteristics, including drainage area size, channel size, headwater conditions, numbers of lakes, surface water flows, and related properties.
2. Land use and conveyance issues, including distance from potential water source(s), the nature of the route to deliver water, and channel conditions as they might pertain to conveying water through the drainage.
3. Habitat and recreational issues especially as they might be influenced by a stream hydration project.

Groundwater and water rights for the three sub-regions are assessed for each sub-region as a whole, and not-stream-by-stream. Later portions of Chapter 4 summarize:

1. General land ownership issues identified for the region in general, and several drainages in particular (Section 4.4).

2. A ranking of the assessed drainages for subsequent evaluation in the feasibility phase of the project (Section 4.5).

3. An initial evaluation of the primary preferred route currently identified in our ranking (Sections 4.6 and 4.7).

4. Section 4 concludes with a preliminary conceptual groundwater flow model that explores the possible fate of groundwater that has the potential to be recharged by a future project.

This is a very preliminary, or prefeasibility, 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.

4.1 Eastern Lincoln County

This portion of Lincoln County is drained by upper Crab Creek and two major tributaries, Bluestem Creek and Rock Creek (Figure 32). Surface conditions in these drainages are explored individually. Basic groundwater conditions are explored in a single assessment for the eastern Lincoln County area. Most of this assessment is based largely on anecdotal information, interview with area residents, and field reconnaissance in 2010. The hydrogeologic review is based on materials prepared by the Columbia Basin GWMA.

4.1.1 Upper Crab Creek

Physical Characteristics: Crab Creek is the trunk stream into which almost all surface drainages in Lincoln County flow. For this study upper Crab Creek is defined as that portion of the stream that flows generally north-south from the area near Reardan, Washington to the area west of Sprague, Washington (Figure 33). The area west of Sprague where Crab Creek turns west is sometimes referred to as Horseshoe Bend. Upper Crab Creek rises near Highway 2, west of Reardan.

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. In some reaches of this broad valley floor the actual channel may be actively farmed because surface water is rarely present, and as a result the channel is obscured. Near the mouth of Bluestem Creek the Crab Creek channel becomes more confined, being restricted to a narrower, rock walled canyon. Below the mouth of Bluestem Creek, the stream channel is more commonly rock-floored and surface flows are more commonly observed than upstream.

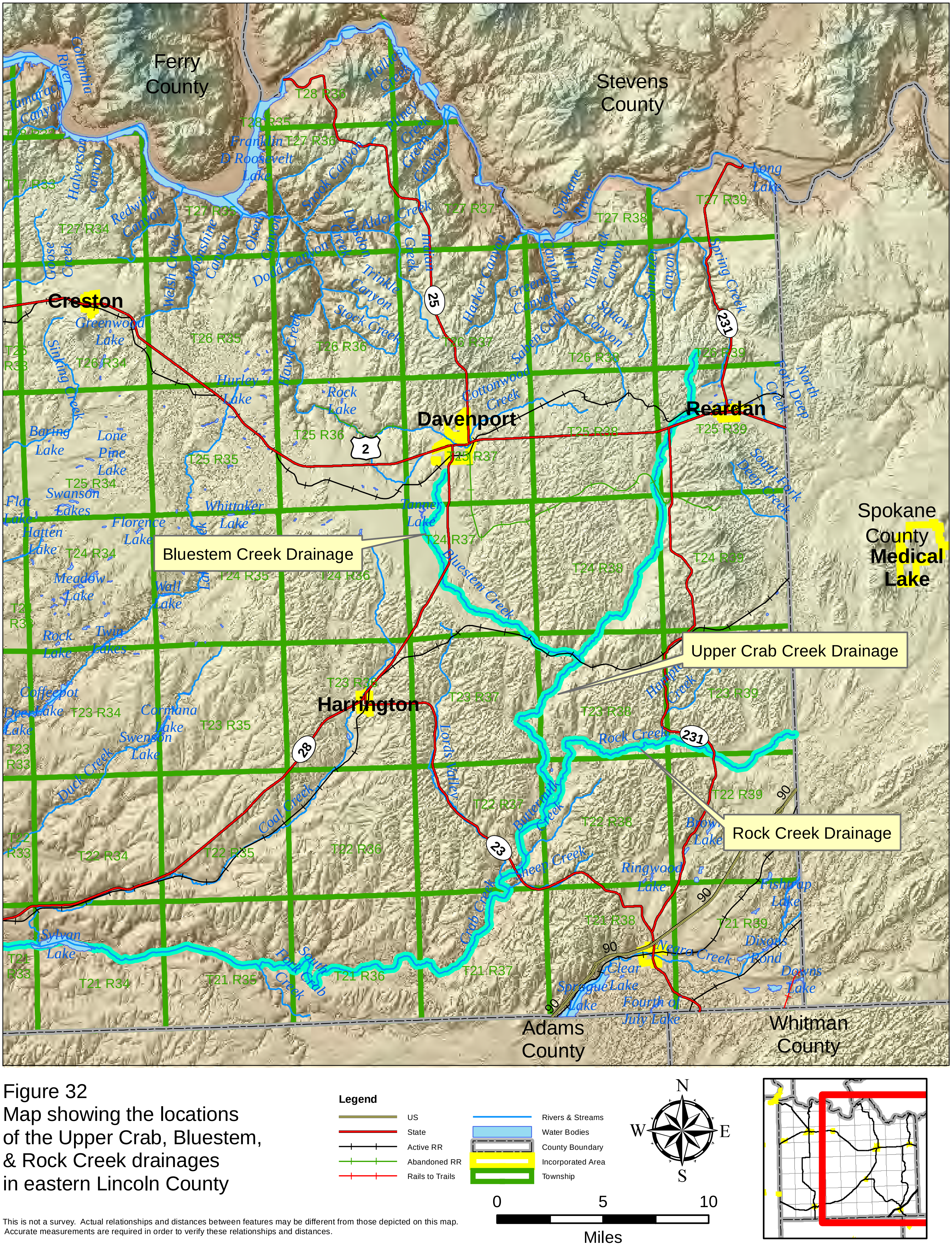


Figure 32
Map showing the locations of the Upper Crab, Bluestem, & Rock Creek drainages in eastern Lincoln County

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

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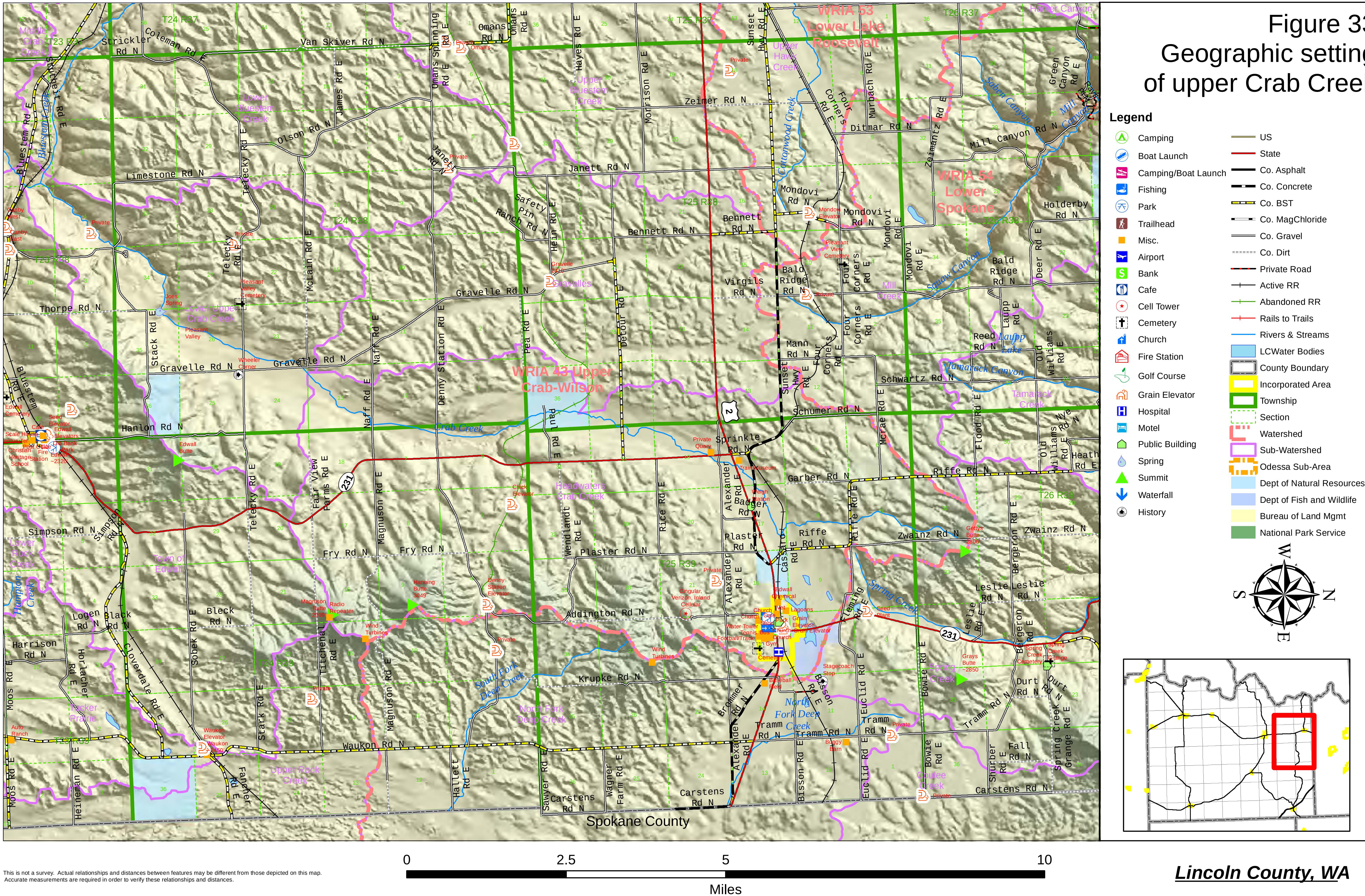
Figure 33
Geographic setting of upper Crab Creek



Lincoln County, WA

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

The creek, when and where it is flowing, usually occupies a channel approximately 5 to 20 feet across and less than 5 feet deep. Locally this channel may be incised into a much deeper ravine 10 or more feet deep. Anecdotal evidence suggests there are reaches of the stream where it only flows seasonally, during the winter and spring, when surface runoff is abundant, and/or following extremely rare large storms. These intermittent flow reaches tend to be those where the coulee is floored by alluvial gravel and sand, and the stream likely is feeding a shallow groundwater system in the alluvial sediment. The fate of this groundwater is not known; some may be recharging underlying CRB aquifers, and some may be flowing through a localized alluvial aquifer before emerging further downstream on Crab Creek, providing base flow.

Land Use and Conveyance: Land uses along the reaches of upper Crab Creek above the mouth of Bluestem Creek largely are devoted to a mix of small irrigated fields, dryland farming, and grazing. From the area near the mouth of Bluestem Creek to near where Highway 23 crosses Crab Creek land uses near the creek generally are devoted to grazing, and habitat conservation. Down-stream of Highway 23 land uses return predominantly to a mix of irrigated farming, dryland farming, and grazing. Over 95% of the upper Crab Creek is privately owned, with the remaining owned by the Department of Natural Resources (DNR).

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). Such a route up Mill Canyon would likely follow county road rights-of-way to potential discharge area near Highway 2 to 3 miles west of Reardan. This route could be shortened if permission to cross private lands was secured. From its headwaters near Reardan to the Horseshoe 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 dominance of private land holdings when coupled with presence of farmed fields and artificially channelized reaches intermittently along upper Crab Creek will need to be considered if water is delivered to the stream as part of a future project. With this, landowner acceptance of a stream flow augmentation project will be important on this stream.

Habitat and Recreation: Almost all of the upper Crab Creek area is privately owned. Therefore, public recreational opportunities likely will be limited, and require the cooperation of private landowners. There is a potential for habitat improvement projects on upper Crab Creek, but again, given the dominance of private land holdings, such projects would require the active participation of individual landowners.

4.1.2 Bluestem Creek

Physical Characteristics: Bluestem Creek (Figure 34) 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 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.

Land Use and Conveyance: 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. The headwaters of Bluestem Creek are approximately 20 miles from a likely water intake location on Lake Roosevelt near the mouth of Hawk Creek. One hundred percent of the Bluestem Creek stream channel is privately owned.

To deliver water to Bluestem Creek for a potential project a delivery route could follow county road rights-of-way up the Hawk Creek Valley, before crossing Highway 2 just west of Davenport. Once across the highway the route probably would be across private ground to a potential discharge location, also likely on private ground.

Habitat and Recreation: Because all of the Bluestem Creek area is privately owned, public recreational opportunities likely will be limited, and require the cooperation of private landowners. There is potential for habitat improvement projects on Bluestem Creek, but again, given the dominance of private land holdings, such projects would require the active participation of individual landowners.

4.1.3 Rock Creek

Rock Creek (Figure 35) 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 region. 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.

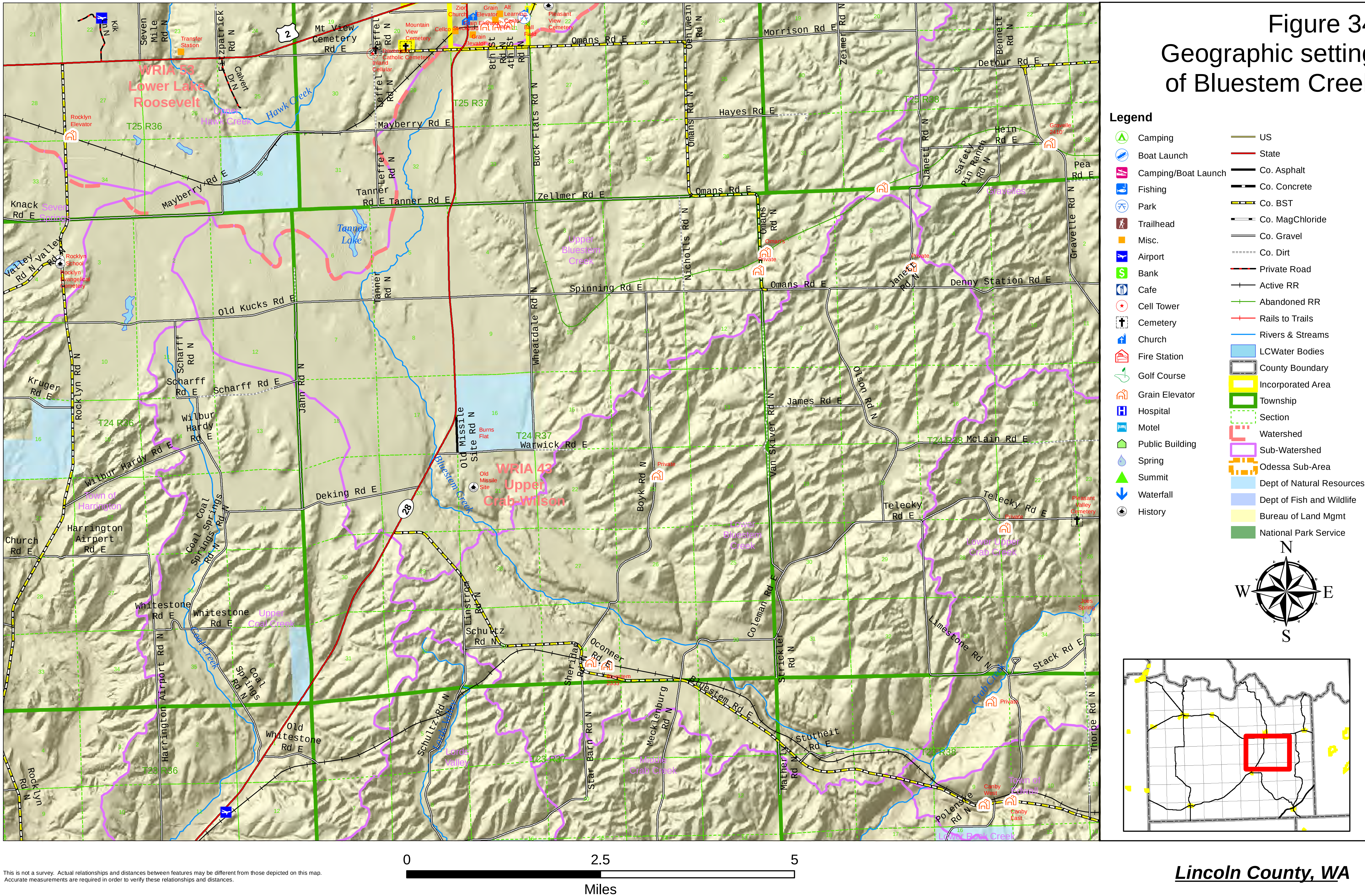
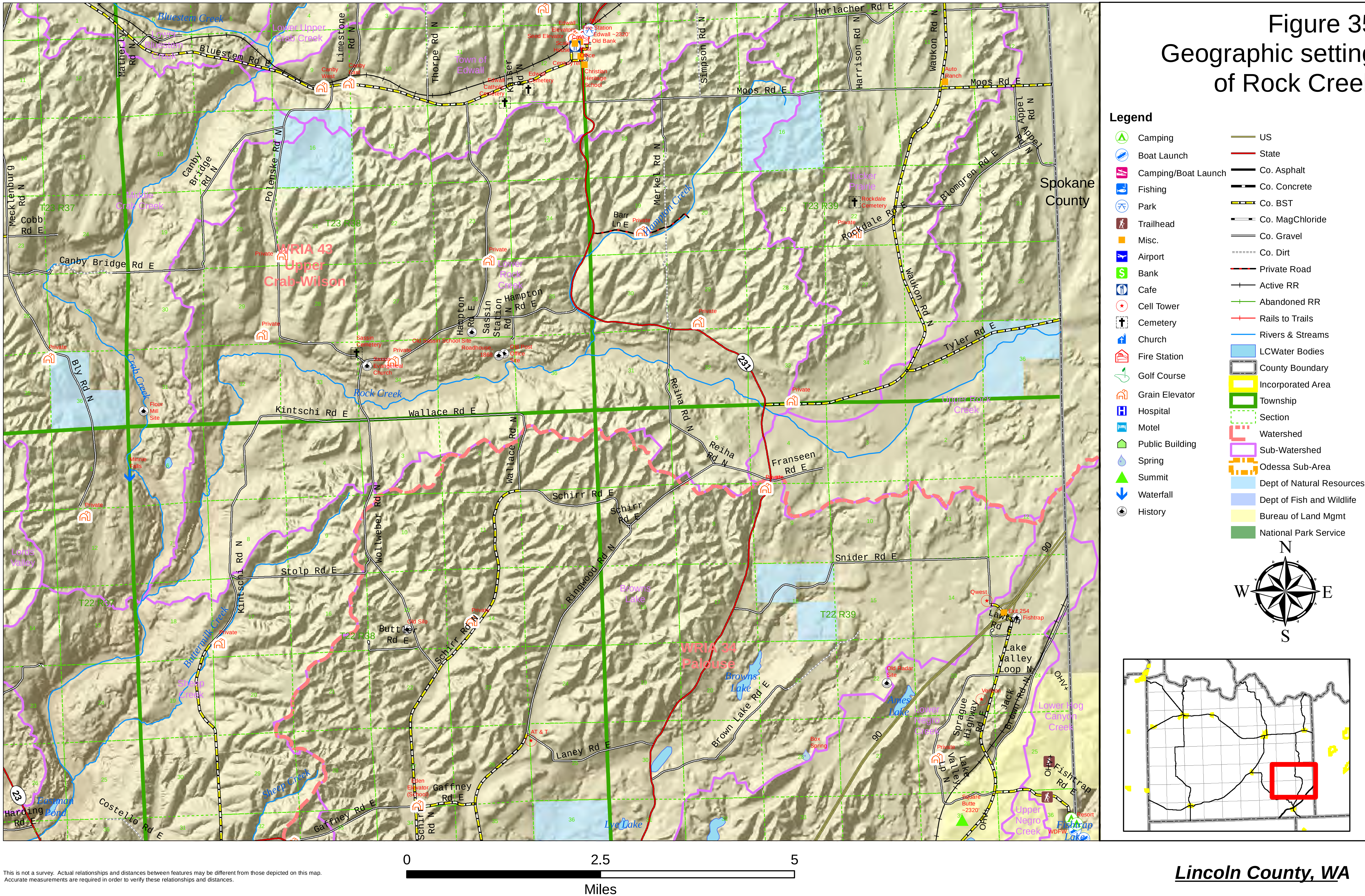


Figure 34 Geographic setting of Bluestem Creek

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Lincoln County, WA

Figure 35
Geographic setting of Rock Creek



This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Lincoln County, WA

4.1.4 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. Both are deeply incised and cross-cut by coulees, and both generally dip downwards to the south-southeast (Figures 15 and 16). Given the lack of down dip continuity in these units, water present in interflow zones in up dip areas will discharge into canyons that incise through them in down dip areas.

The only Frenchman Springs Member unit with any significant presence in the eastern Lincoln County area is the Sentinel Gap where it is found in the lower reaches of the eastern Lincoln County drainages (Figure 19). In this area, groundwater in Sentinel Gap interflow zones likely will move down dip, predominantly to the southwest. In reaches where Crab Creek is incised into the unit, groundwater could discharge into the creek. Conversely, in areas were the unit extends uninterrupted beneath Crab Creek, groundwater in it could be moving beneath the creek and southwest into northern Adams County.

The uppermost Grande Ronde unit in the eastern Lincoln County area, the Sentinel Bluffs Member, underlies essentially the entire area. Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of upper Crab Creek system near and north of Highway 23 (Figure 22). If recharged in the upper Crab Creek area, strike and dip of the unit suggests the predominant interflow zone orientation, and groundwater movement within such zones will be to the south-southwest. In these directions Sentinel Bluffs Member interflow zones are not incised into by Crab Creek or its tributaries. The absence of incision would allow groundwater moving down dip in these interflow zones to likely move into adjacent areas of northern Adams County.

Of the other Grande Ronde units present beneath eastern Lincoln County, the Wapshilla Ridge Member is only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. The other three members mapped in the area, the Umtanum Member, Ortley Member, and Grouse Creek Member, all pinch out beneath the southeastern part of the county. These units thicken down dip to the south-southwest. Given the depth of the Grande Ronde units underlying the Sentinel Bluffs Member, it seems likely that recharge pathways into them would be torturous and slow. For water moving into these deeper units, these recharge pathways would likely include (1) some cross-strata movement of groundwater into interflow zones in up dip areas where dense flow interiors are thin, or truncated; (2) down dip movement of water into multiple interflow zones as unit pinch-outs are encountered where the number of units increase. Water in these deeper Grande Ronde units likely would move generally to the south-southwest, down dip.

Groundwater is reported on water well reports for some wells that penetrate to the top of pre-basalt basement in eastern Lincoln County and adjacent portions of Spokane County. At this time our working hypothesis is that this groundwater is found in paleodrainages incised into the pre-basalt rock prior to the emplacement of the CRBG. The source of recharge for this portion of the aquifer system is not generally known, but it might range from (1) water moving cross-strata through the basalt where it is thin to (2) water getting underneath the basalt where it pinches out completely against pre-basalt outcrops. However, given that the top of pre-basalt rock generally lies hundreds, if not several thousand feet beneath Crab Creek and its tributaries in the eastern Lincoln County area, we generally are not concerned with it for the purposes of this prefeasibility assessment.

It is possible that feeder dikes for the Priest Rapids Member cross-cut the eastern Lincoln County area south of Reardan. Roza Member dikes may be present beneath the area where Crab Creek turns west. If present, regional mapping would suggest they have a general northwest-southwest trending orientation. At this time we do not have any direct evidence for the presence of these features in this area. However, if they are present, they would be generally oriented perpendicular to likely preferred south-southwest oriented down dip flow paths in the CRBG. If this is the case these dikes may disrupt the general flow path of CRBG groundwater in the units they cross cut. Such disruptions, if found to be present, could include slowing of groundwater flow velocity, deflection of movement paths, and possibly even blockage of groundwater movement on at least a local scale. At this time we do not know if these dikes significantly impact the groundwater flow system beneath eastern Lincoln County.

4.2 Central Lincoln County

Central Lincoln County is occupied by a series of more-or-less parallel northeast to southwest flowing stream drainages that empty into Crab Creek near and west of Odessa. The headwaters of these drainages lie near and 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 36). The assessment of these streams is based largely on anecdotal information, interviews with area residents, and field reconnaissance in 2010.

4.2.1 Coal Creek

Physical Characteristics: Coal Creek (Figure 37) rises in an area of uneroded loess hills and chaotic scabland topography southwest of the headwaters of Bluestem Creek and north of Harrington. The 35 mile long channel flows into Crab Creek approximately five miles east of Odessa, at Sylvan Lake. Naturally occurring lakes typically are not shown or seen on aerial photographs or maps of the Coal Creek drainage. The drainage area is approximately 105 square miles.

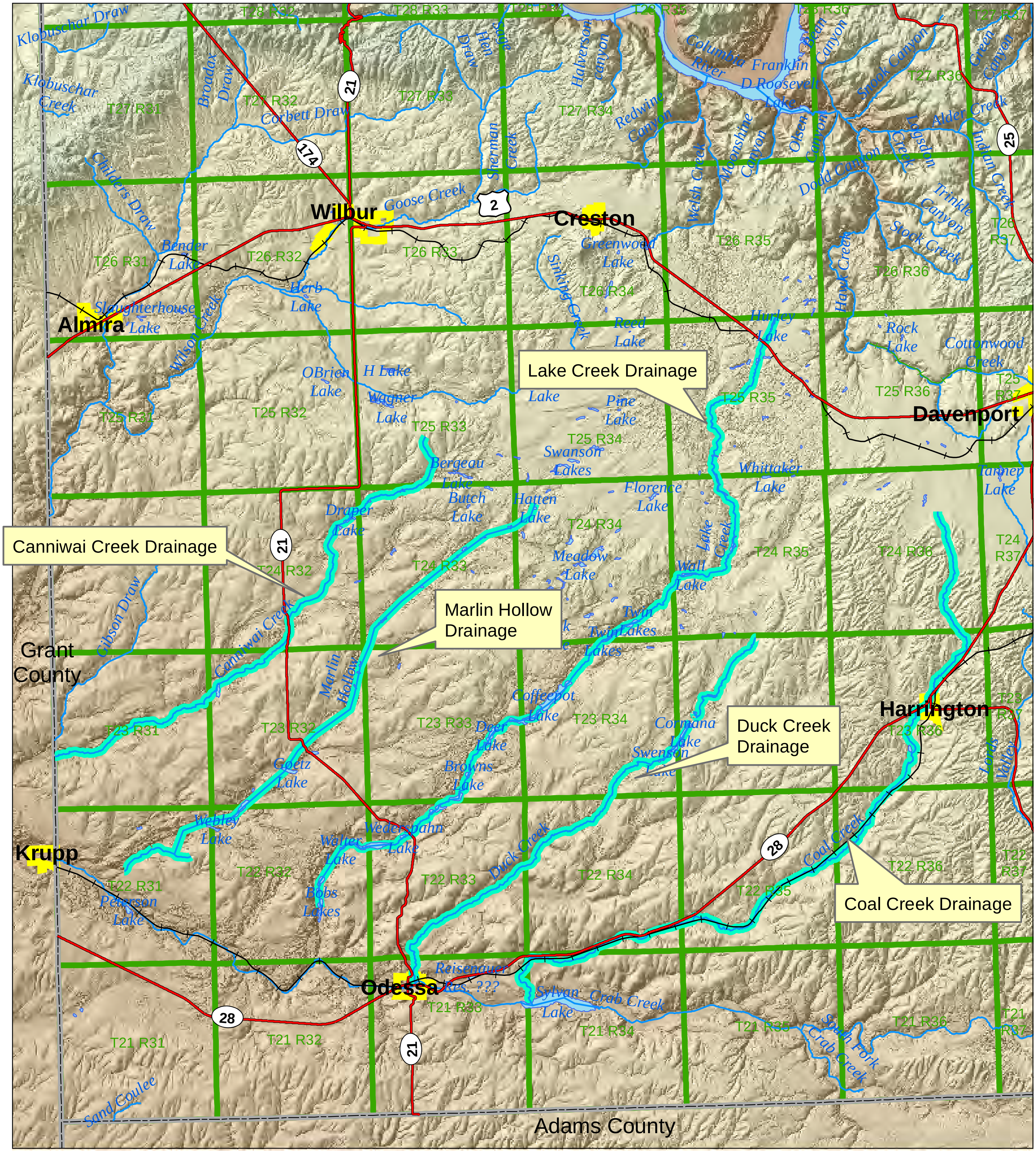
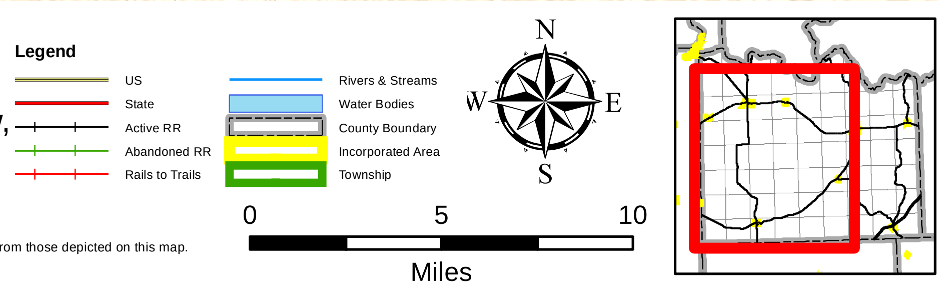


Figure 36
Map showing the locations of the Coal, Duck, Lake, Marlin Hollow, & Canniwai Creek drainages in central Lincoln County.



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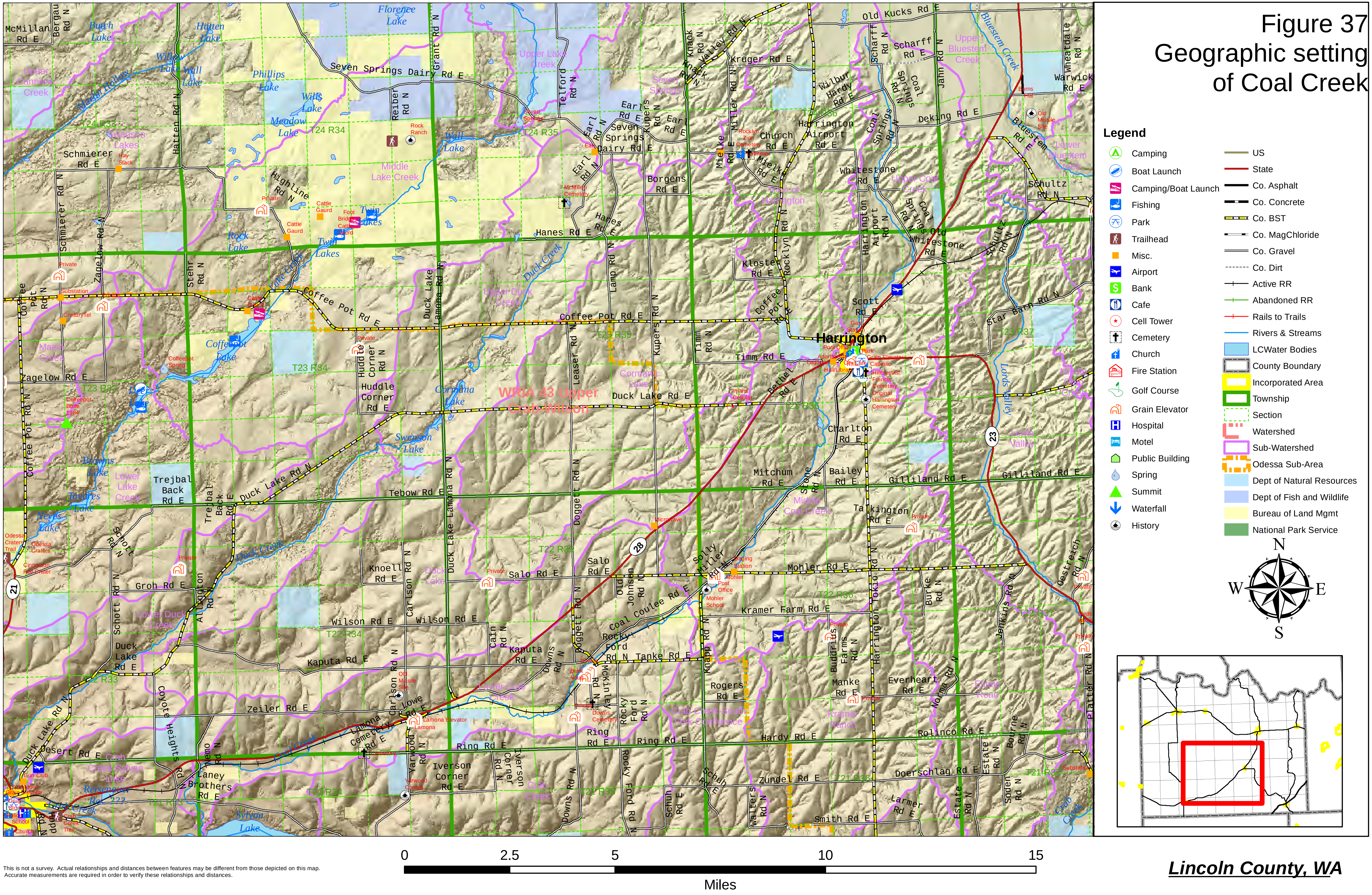


Figure 37 Geographic setting of Coal Creek

In its uppermost reaches the stream channel may be difficult to ascertain when water is not present. Within a few miles below its headwaters though 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. While basalt bluffs are present along portions of the creek, the stark scablands common to so many of the drainages in the area are not as strikingly developed. 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, although it is generally small. During field reconnaissance, crude visual flow estimates in it suggest flows of less than 1 cubic feet per second (cfs) to no more than 2 or 3 cfs are normal in the winter and spring. These could be higher though in the event of a rapid snow melt or rainstorm event. Flows are difficult to ascertain, or even observe, in the summer when the channel is overgrown with grasses and shrubs.

Land Use and Conveyance: 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. Approximately 85% of the Coal Creek channel is on private property; the remainder is on land owned by the Bureau of Land Management (BLM).

A potential rehydration project delivery area is approximately 3 miles south of Highway 2, on this streams headwaters near Old Kuchs Road E. This area is on private property approximately 27 miles from Lake Roosevelt, and direct access to it likely would be over a combination of public road rights-of-way and crossing of privately owned land. Much of this delivery route would be up the Hawk Creek valley before crossing Highway 2 and going south to a discharge location. Given that this stream flows through a town, enhanced flow 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.

Habitat and Recreation: Because most of this stream flows across privately owned land devoted to grazing, other farming, and residential/town development, we suspect habitat and recreational opportunities along it will be limited. At this time, and at this level of assessment, we therefore do not see significant opportunity for habitat or recreational benefit.

4.2.2 Duck Creek

Physical Characteristics: Duck Creek (Figure 38) is bounded by Lake Creek to the west and Coal Creek to the east. Its headwaters lay in an area of shallowly eroded scabland and surrounding loess hills, approximately 6 to 8 miles west-northwest of Harrington in the northern portion of T23N R35E. The creek drains approximately 115 square miles and is approximately 21 miles long. Duck Creek joins Crab Creek in the town of Odessa.

The upper drainage is a fairly broad, flat valley which contains several lakes, with Cormana Lake and Swenson Lake being the largest. The drainage is poorly developed above Cormona Lake, being a broad rather chaotic scabland topography, especially north of Hanes Road. Downstream from Swenson 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 and the stream flows through a number of channelized reaches where irrigated farming is common on the valley floor.

Our limited reconnaissance suggests water is only intermittently present in the upper portion of the drainage and that Cormona and Swenson Lakes do not commonly contain water. Below these lakes though the creek may see flows of a few cfs or less through much of the year in the scabland topography that dominates it above the Duck Lake Road crossing in T22N R34E. Downstream of this crossing surface flows generally are absent in the summer and the creek rarely experiences surface flows in its lower reaches near Odessa. Landowners we talked to during our limited reconnaissance and prefeasibility assessment work indicate the creek as seen diminished surface flows over the past few decades.

Land Use and Conveyance: Except for some BLM ground adjacent to the uppermost reach of the stream, the bulk of the land along this creek is privately owned. Along much of its length above the Duck Lake Road crossing the land along the creek is undeveloped or used for grazing. Below that crossing some irrigated farming is done. All the Duck Creek stream channel is on privately owned ground.

If a rehydration project were to deliver water to the upper reach of this stream, that delivery area would be in area between Hanes Road and Coffee Pot Road, in T23N R35E. However, this general area is approximately 38 miles from Lake Roosevelt near the town of Lincoln. A delivery route to this area would need to follow multiple rights-of-way and cross many areas of privately owned land.

Habitat and Recreation: A recharge project delivering water to Duck Creek could result in filling of Cormona and Swenson Lakes, and more flow through the scablands downstream of these lakes. This could have habitat and recreational benefits for water fowl and possibly even fisheries. However, given that this drainage lies almost entirely on privately owned land these landowners will need to agree that such outcomes are acceptable to them as owners and users of that land.

4.2.3 Lake Creek

In addition to reconnaissance done for this project, LCCD assessed basic steam flow and related conditions in this drainage in 1998 and 1999 (LCCD, 2000). That report supplements the anecdotal information, area resident interviews, and field reconnaissance done for this project in the Lake Creek drainage.

Physical Characteristics: The Lake Creek drainage area (Figure 39) covers 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, 1 to 2 miles east of Telford Road. 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.

The upper reaches of Lake Creek, north of Seven Springs Dairy Road, is a rocky scabland within which a poorly to moderately developed drainage exists. In this upper reach, the channel also is broken up in to a series of artificial ponds built to enhance wetlands and related habitat. South of Seven Springs Dairy Road, to the area below Delzer Falls, the stream, when it is flowing, occupies a fairly well developed channel flowing down the bottom of a well defined scabland coulee incised into bedrock. Through this reach Lake Creek connects the numerous lakes that give this drainage its name. From upstream to its confluence with Crab Creek these lakes include Wall, Upper Twin, Lower 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.

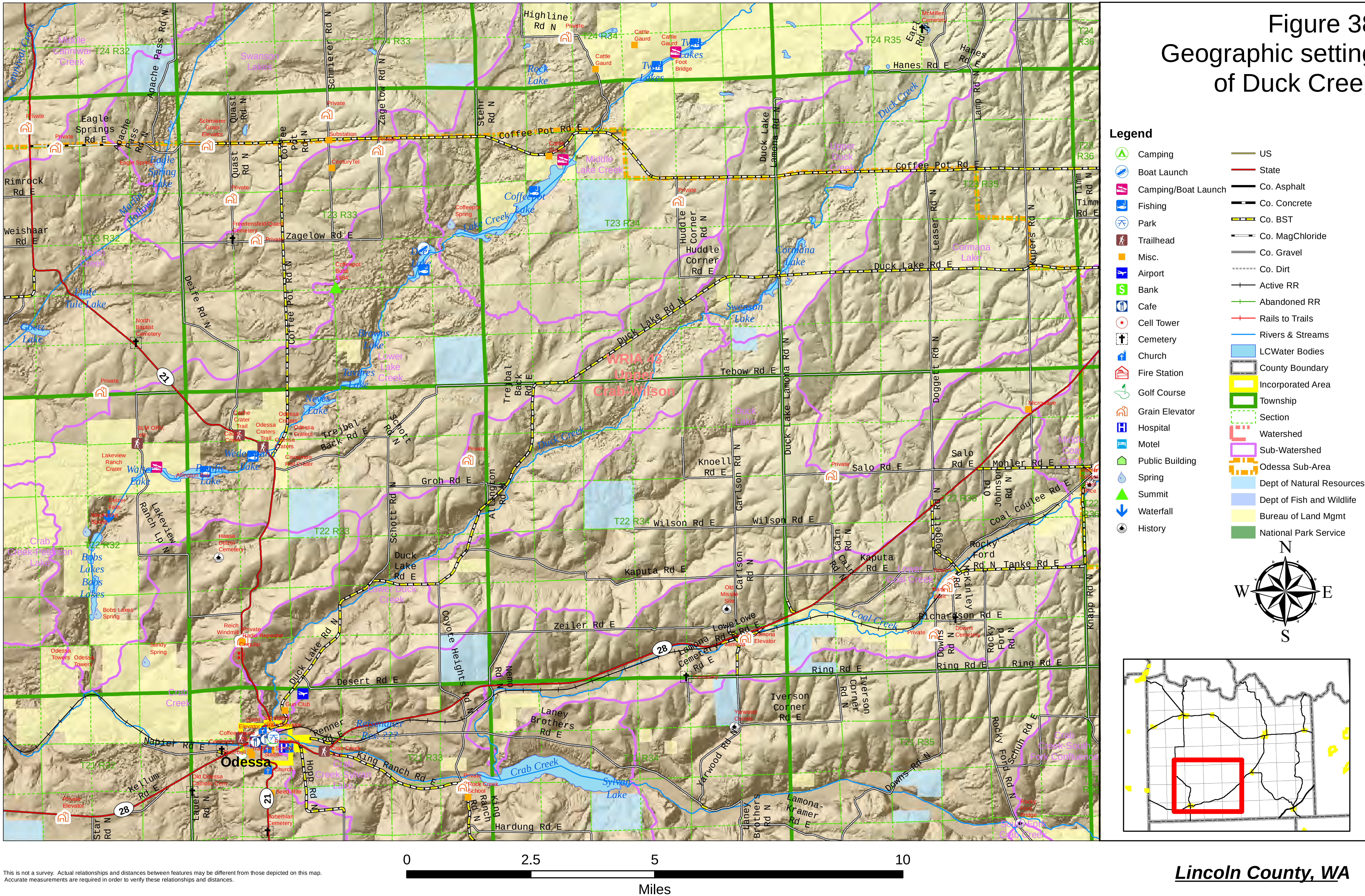
In 2010, and for much of the previous 20 years or more, the lower three Lake Creek lakes (Bobs, Pacific, and Neves) were dry. The next two major lakes above Neves Lake have been decreasing in volume in recent years, and in 2010 were almost completely dry (Figure 40). Local residents report that Deer Lake in 2010 was likely at about two-thirds of its normal volume, with lake levels being approximately 15 to 20 feet below historical normal levels seen 20 or more years ago. Coffee Pot Lake was observed to be within a few feet of normal levels during our 2010 reconnaissance and both Twin Lakes were observed to be at or above such levels. During 2010 reconnaissance Lake Creek was observed to be flowing through much of its length in the area above Seven Springs Dairy Road into Coffee Pot Lake. When we observed them these flows were visually estimated to range from less than 1 cfs to approximately 3 or 4 cfs. Below Coffee Pot Lake the creek was not observed to be flowing in 2010, with all locations visited being dry.

Land Use and Conveyance: Land uses along most of Lake Creek are devoted to habitat conservation and grazing. Much of the habitat conservation ground is located in the upper drainage above Twin Lakes 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). Both agencies have built structures in these reaches to restore pond, stream, wetland, and riparian habitat. Between Wall Lake and Seven Springs Diary Road and downstream of Coffee Pot Lake land ownership in along Lake Creek is predominantly private and grazing is the primary land use. The only significant areas devoted to cropping on the creek 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. Private and public land ownership on the stream channel, from the headwaters to the mouth, is approximately 44.5% and 55.5, respectively. Approximately three-quarters of the public ownership is held by the BLM.

A likely delivery location for Lake Creek is in the upper basin at Hurley Lake, or just south of nearby Highway 2. These locations lie 12 to 15 miles south of Lake Roosevelt near the town of Lincoln. To reach these locations a delivery route would likely be up Welch Creek Canyon following the county road right-of-way to the Miles-Creston Road. From there, a delivery route might be on county road rights-of-way, across private land, and across public lands to reach Hurley Lake and or a location on the creek south of Highway 2. Given that most of the lands on the upper portion of the creek are public lands, it seems likely that a discharge point into Lake Creek would be on these lands.

Habitat and Recreation: Habitat and recreation potential in the Lake Creek drainage would be high if a rehydration project were implemented in it. The basic reasons for this are three-fold, as follows. First, recently completed habitat projects have resulted in increased water storage and flow on the upper creek. Delivering more water to the creek could expand the benefits already seen from these projects. Second, successful delivery of water to the lower drainage will likely see restoration of currently dry lakes and the creek connecting them. Third, because much of the stream flows across public lands, a flow enhanced stream and associated lakes could be more accessible than those on private property.

Figure 38
Geographic setting of Duck Creek



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Lincoln County, WA

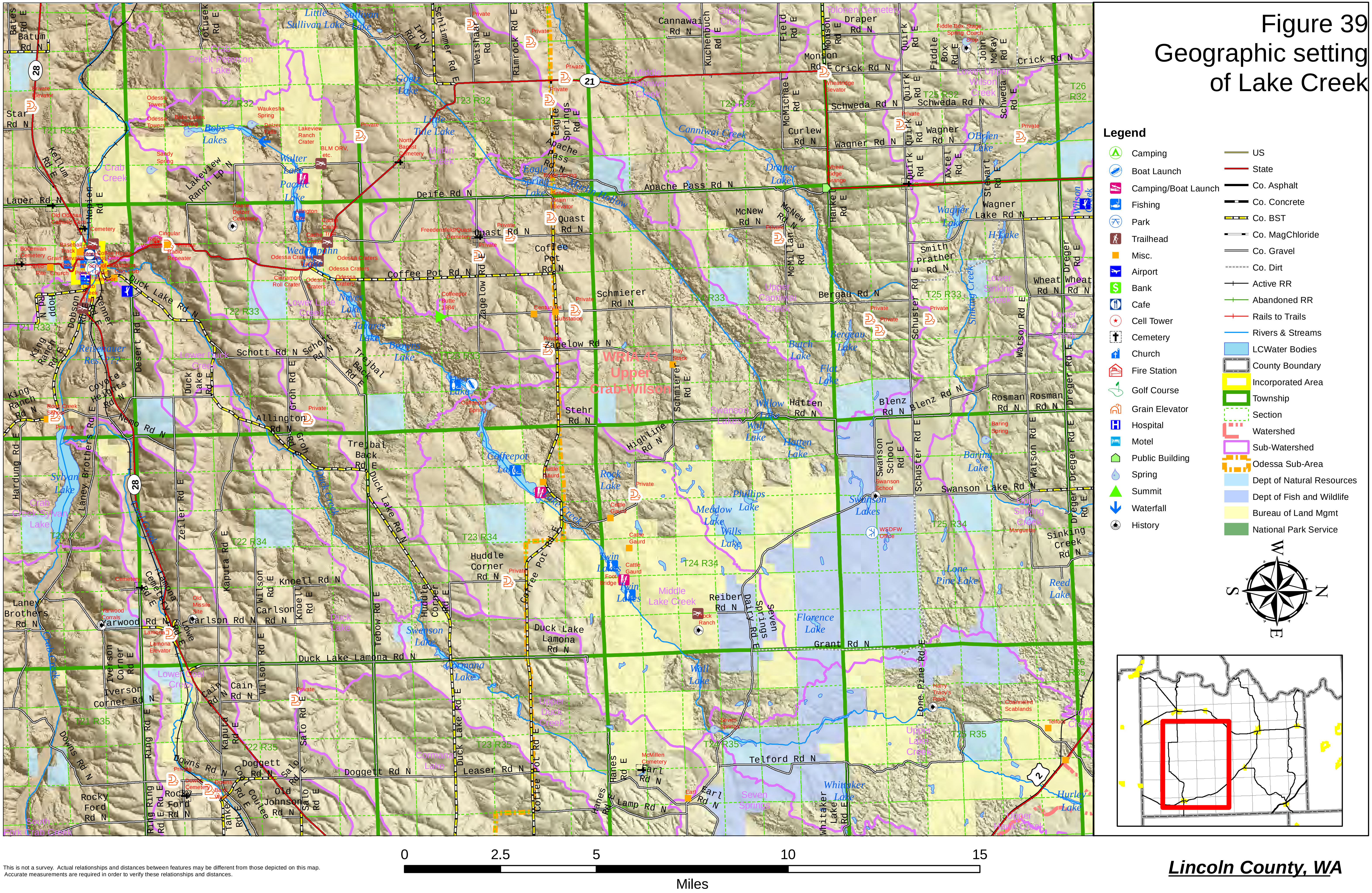


Figure 39 Geographic setting of Lake Creek

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Lincoln County, WA

Figure 40. Photograph of the almost completely dry bed of Taveres Lake, lower Lake Creek drainage.

4.2.4 Marlin Hollow

Physical Characteristics: The headwaters of Marlin Hollow (Figure 41) lie in the area between Willow Lake and Swanson Lakes. The drainage area is approximately 130 square miles and the stream is approximately 25 miles in length. Marlin Hollow enters Crab Creek about two miles southeast of Krupp/Marlin, on the western boundary of Lincoln County.

In the upper half of the drainage, essentially above Eagle Springs Lake, there generally is no well defined channel. Rather, in its upper reaches the stream valley is essentially a series of interconnected topographic lows and eroded scablands. In its lower reaches, where the stream channel is better defined, Marlin Hollow includes numerous lakes throughout its lower reaches. From upstream down, these lakes include 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 42). Throughout the investigation, during our reconnaissance of the area, water was not observed in the portions of the Marlin Hollow stream channel we visited.

Land Use and Conveyance: Land uses along the majority of Marlin Hollow are devoted to grazing and almost all of the land in the stream valley is privately owned. Public lands owned and/or administered by WDFW are found in the valley in its upper reaches around Swanson Lakes. Approximately 80% of the stream is privately owned, with the remaining 20% owned predominantly by the DNR, primarily around Swanson Lakes.

A potential rehydration project delivery location might be in upper Marlin Hollow in the vicinity of Swanson Lakes, about 20 miles from Lake Roosevelt. Like Lake Creek a likely delivery route could follow Welch Creek from Lincoln to the Miles Creston Road. At that point two basic routes might be used. One would be to follow a route into upper Lake Creek along existing county road rights-of-way before turning southwest and heading across undeveloped private and public lands to the Swanson Lakes area. The other would be to follow the Miles-Creston Road to the vicinity of Creston before crossing Highway 2 and following other county roads southwards to the vicinity of Swanson Lakes. This later course is longer than the other route, but likely would involve the use of more existing rights-of way.

Habitat and Recreation: A recharge project delivering water to Marlin Hollow could result in filling of a number of lakes, from Swanson Lakes in its headwaters to the series of lakes seen in its lower reaches. In addition, a project likely would result in more flow through the scablands occupied by Marlin Hollow. This could have habitat and recreational benefits for water fowl and possibly even fisheries. However, given that this drainage is predominantly on privately owned land these landowners will need to agree that such outcomes are acceptable to them as owners and users of that land.

4.2.5 Canniwai Creek

Physical Characteristics: Canniwai Creek (Figure 43) has its headwaters in the chaotic terrain south of Creston and Highway 2 and west of the headwaters of Marlin Hollow. Given the chaotic nature of this topography a specific headwaters location is difficult to define, although Bergeau Lakes seems to generally occupy the headwaters area. The stream flows into Crab Creek between the towns of Krupp and Wilson Creek, in Grant County. The drainage area is approximately 135 square miles and its length is 30 miles.

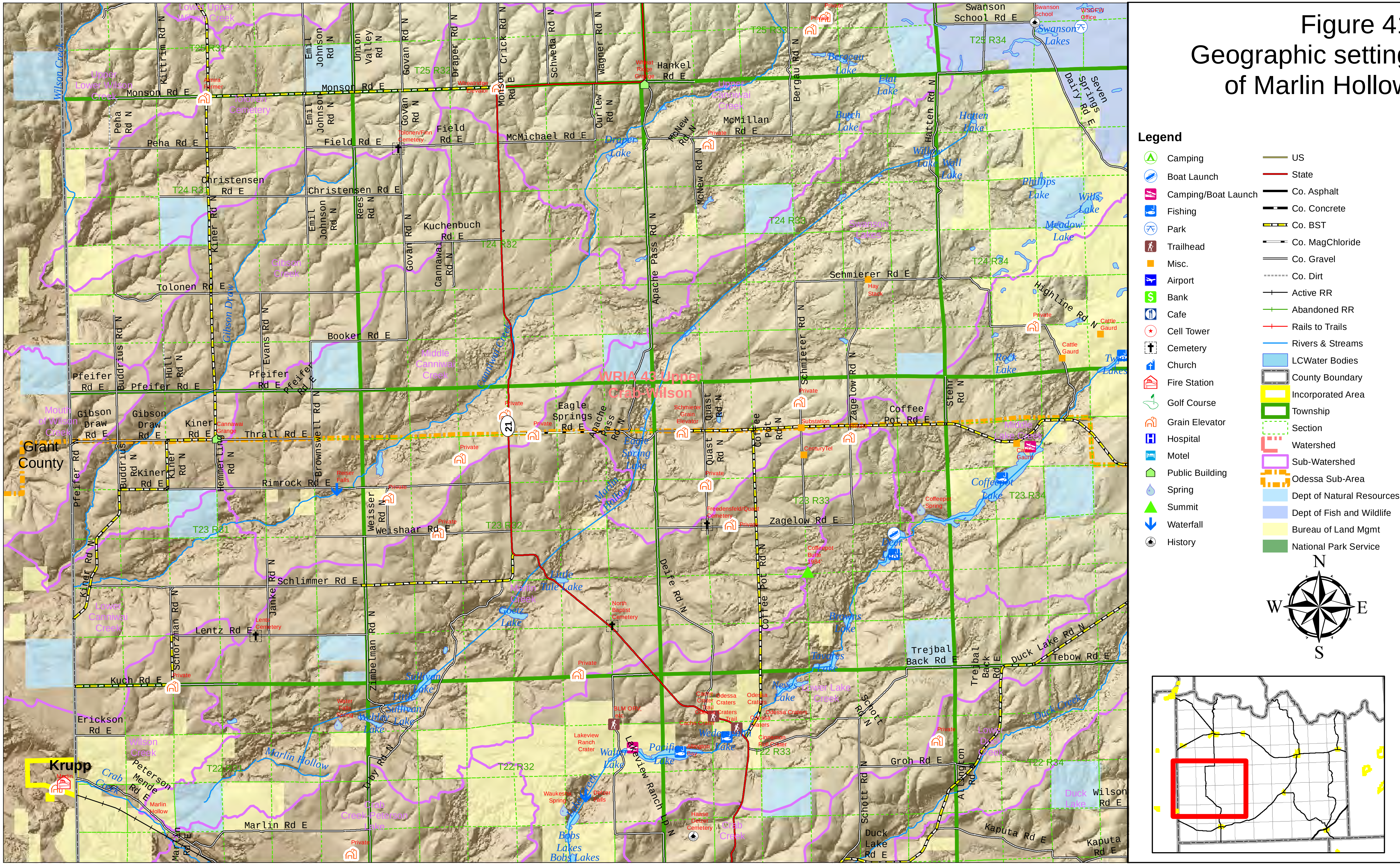
In its headwaters reach, between Bergeau Lake and Draper Lake, the stream occupies a well defined scabland tract, but the actual channel is less well defined. Below Draper Lake the stream channel is usually well defined, although it is fairly narrow (less than 10 feet across and 3 feet deep). From this area downstream to the mouth, the creek follows a well defined scabland coulee. Below Draper Lake, to the western county line, there are no mapped lakes on the creek. Throughout the investigation, during reconnaissance of the area, water was not observed in the portions of the Marlin Hollow stream channel we visited.

Land Use and Conveyance: 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 grazing. This drainage generally has more defined cropping activity than the other streams considered. Most of the land, approximately 96%, 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.

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 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.

Habitat and Recreation: A recharge project delivering water to Canniwai Creek would only fill lakes in its upper reaches, above Draper Lake. Below Draper Lake, with no lakes to fill, a recharge project would simply enhance flows in the normally dry modern creek channel. This could have habitat and recreational benefits for water fowl and possibly even fisheries. However, given that this drainage lies almost entirely on privately owned land these landowners will need to agree that such outcomes are acceptable to them as owners and users of that land.

Figure 41 Geographic setting of Marlin Hollow



0 2.5 5 10

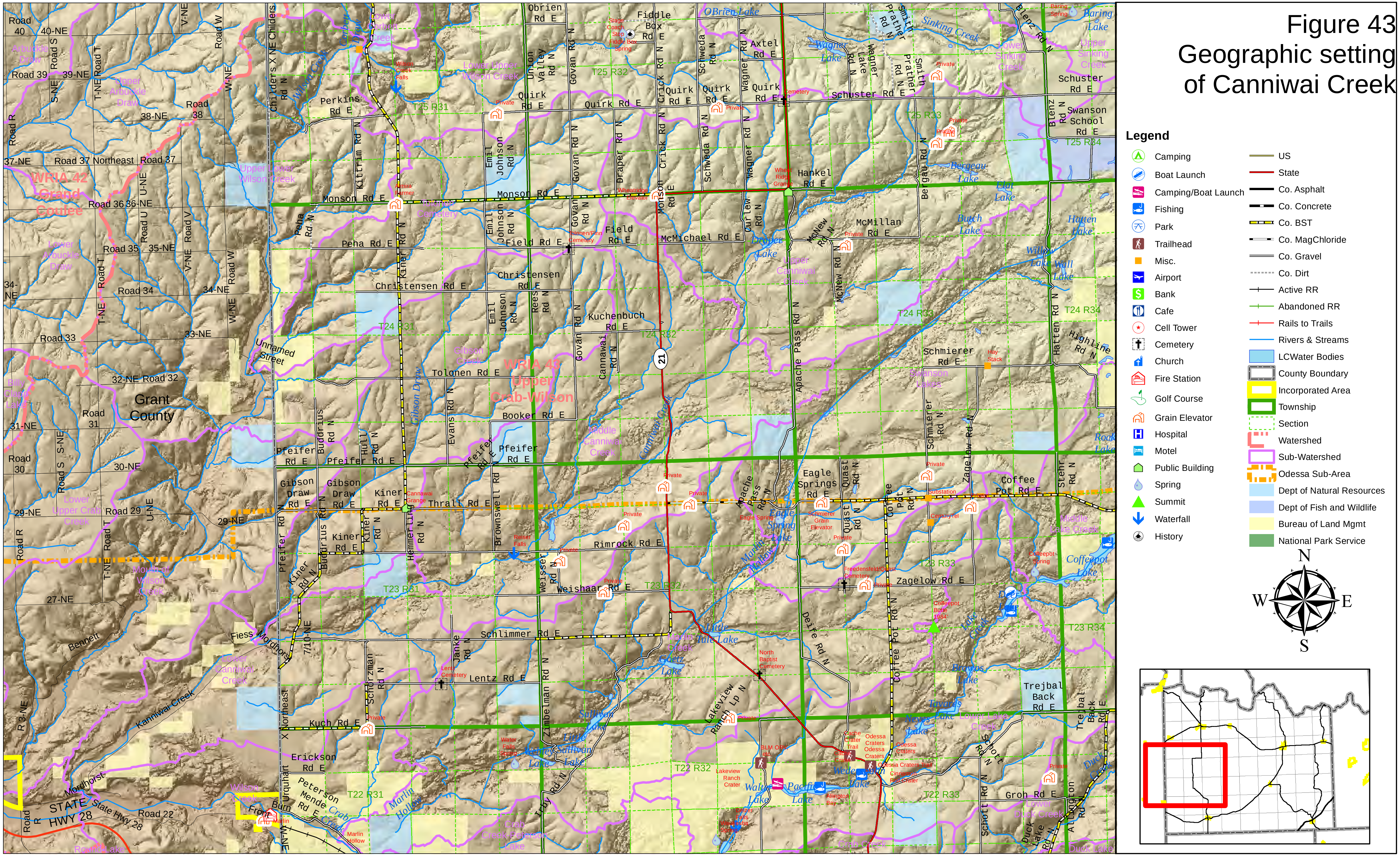
Miles

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Lincoln County, WA

Figure 42. Photograph of Lower Sullivan Lake in the lower Marlin Hollow drainage.
This lake is one of several lakes in that drainage showing water level declines in recent years.

Figure 43 Geographic setting of Canniwai Creek



0 2.5 5 10 15
Miles

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Lincoln County, WA

4.2.6 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 15 and 16). However, these units are completely eroded through in the middle to lower reaches the central Lincoln County drainages. In addition, in the case of the Priest Rapids Member, this unit is completely absent in the southern part of this area. Based on the northwest-southeast strike and southwest dip of these units, water moving through interflow zones will move predominantly to the southwest. Given unit distribution, if water is introduced into these units in the upper stream reaches, much of it will discharge into the canyons to the southwest where the units are fully incised through.

Two Frenchman Springs units, the Sentinel Gap and Sand Hollow, are present only in the lower reaches of the central County drainages. Based on unit distribution, it would be necessary to deliver water into the lower reaches of these drainages in order to get water into the interflow zones of these two Frenchman Springs units. If that were to occur, any recharged groundwater would predominantly flow southwest until the units are truncated in the Crab Creek coulee near and west of Odessa. Therefore, if interflow zones in these units were successfully recharged, they would likely discharge into the Crab Creek valley.

The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member, underlies almost the entire area (Figure 22). Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of all the drainages in central Lincoln County. Areas where the Sentinel Bluffs Member is at or near the base of these central County drainages include: (1) Canniwai Creek from the mouth upstream as far northeast as Highway 21, (2) from the mouth to above Highway 21 on Marlin Hollow, and (3) from the mouth to upstream of Twin Lakes on Lake Creek. Based on this distribution long reaches of these drainages might be candidates for recharge to the Sentinel Bluffs Member. If recharged, Sentinel Bluffs strike and dip suggests the predominant interflow orientation, and groundwater movement within the unit will be to the southwest. The top of the Sentinel Bluffs Member is exposed in Crab Creek near and west of Odessa. This area is down dip of potential recharge areas along many of the central County drainages. Given that, one could expect some discharge from the shallowest interflow zone(s) of the Sentinel Bluffs into the Crab Creek drainage. However, because of the depth of incision into the top of the Sentinel Bluffs Member generally is less than 100 feet and because its regional dip is to the south-southwest, one should expect that the multiple interflow zones present deeper in the unit would carry recharged water in that direction. In such cases, groundwater movement would be to the southwest into eastern Grant County and northwestern Adams County.

Of the other Grande Ronde units present beneath central Lincoln County, the Wapshilla Ridge Member is only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. The other three members mapped in the area, the Umtanum Member, Ortley Member, and Grouse Creek Member, all pinch out beneath the southern part of the county. These units thicken down dip to the south-southwest. Given the depth of the Grande Ronde units underlying the Sentinel Bluffs Member, it seems likely that recharge pathways into them would be torturous and slow. For water moving into these deeper units, these recharge pathways would likely include: (1) some cross-strata movement of groundwater into interflow zones in up dip areas where dense flow interiors are thin, or truncated and (2) down dip movement of water into multiple interflow zones as new units are encountered in down dip areas. Water in these deeper Grande Ronde units likely would move generally to the south-southwest, down dip.

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. However, beneath the central Lincoln County drainages pre-basalt basement is only encountered in the highlands near Lake Roosevelt before dipping into the Columbia Basin to the south where it is several thousand feet deep. Given this depth 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.

It is likely that feeder dikes for the Roza Member may be present beneath the central Lincoln County drainage area. Based on the few outcrops of feeder dikes and near vent facies observed during our field reconnaissance such a dike system would generally be northwest-southeast oriented and trend from the area around Sylvan Lake (on Crab Creek east of Odessa) to the area around Taveres Lake (on Lake Creek north of Odessa). Such an orientation is generally perpendicular to likely preferred south-southwest oriented down dip flow paths in the CRBG. If a well developed dike system proves to be present, it may disrupt the general flow path of CRBG groundwater in the units cross cut by it. Such disruptions, if found to be present, could include slowing of groundwater flow velocity, deflection of movement paths, and possibly even blockage of groundwater movement on at least a local scale. At this time we suspect, but do not know if, these dikes significantly impact the groundwater flow system beneath central Lincoln County.

4.3 Western Lincoln County

Western Lincoln County is drained by Wilson Creek and its two main tributaries, Goose Creek and Sinking Creek (Figure 44). The following summary of western Lincoln County drainages is generally shorter than the preceding sections because the Wilson Creek drainage is not considered suitable for feasibility and possible subsequent pilot scale testing. The reason for this is two-fold. One is a complex and contentious history of competing groundwater and surface water rights and the other is our assessment that the western Lincoln County drainages are too far west for the basic goal of recharging groundwater in the area targeted by this project.

4.3.1 Goose Creek

Goose Creek rises about 5 miles to the northwest of Creston, Washington. The contributing drainage area is 90 square miles and Goose Creek is about 18.5 miles long. It passes through the town of Wilbur, Washington before converging with Sinking Creek to form Wilson Creek. The creek has a well defined channel that is 5 to 15 feet across and up to 5 feet deep along much of its course. There are no natural lakes found on Goose Creek.

The Creek generally flows year round. Most road crossings appear to be large enough to handle additional flow. Because the Creek appears to flow most of the year, it does not appear to be experiencing significant losses due to water infiltrating into the underlying aquifer system.

Land ownership along the entire course of the creek is in private hands. If Goose Creek where to become a target for a rehydration project, one possible water delivery location is found 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.

4.3.2 Sinking Creek

Sinking Creek rises just south of the town of Creston in a headwater area that 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. However, much of the upper 10 to 15 several miles of this stream does not have a well defined channel, and in its upper two to four miles the much of the channel is plowed over and farmed. Where a channel can be found, it is a few feet to 20 feet wide and generally less than 5 feet deep.

Historically Sinking Creek flowed year-round and several lakes were found along its course, including Baring Lake, Wagner Lake, and Herb Lake. However, beginning in the 1980's (or even earlier) stream flows diminished, Sinking Creek ceased to flow year round, and the lakes experienced declines. Currently, Sinking Creek only flows in the winter and spring when there is abundant runoff.

Almost the entire Sinking Creek channel (99%) is in private hands. If Sinking Creek where to become a target for a rehydration project, one possible water delivery location is found just southwest of Creston, approximately 11 miles from Lake Roosevelt via Redwine Canyon. However, given the farming currently seen in this headwater area, water may need to be carried 4 to 5 miles further south before it is discharged to a more well defined channel.

4.3.3 Wilson Creek

For the purpose of this prefeasibility assessment the main channel for Wilson Creek begins at the confluence of Sinking Creek and Goose Creek, approximately 3 miles southwest of Wilbur, Washington. From there it flows in a southwesterly direction for 38 miles before entering Crab Creek at the town of Wilson Creek in Grant County. The drainage area encompasses 440 square miles and it is the westernmost stream considered in the Prefeasibility Assessment. Wilson Creek generally occupies a channel a few feet to several tens of feet wide and a few feet deep which is located on the floor of a well defined coulee. No natural lakes are found along Wilson Creek before it exits Lincoln County.

The majority of the stream channel, approximately 88%, with the exception of a reach just below the confluence of Goose and Sinking Creeks lies on private land. These public lands are owned by the BLM.

A likely potential rehydration project delivery location would be approximately one mile south of Highway 2 where Gavon Road crosses the creek. This location is approximately 26 miles from Lake Roosevelt near the town of Lincoln.

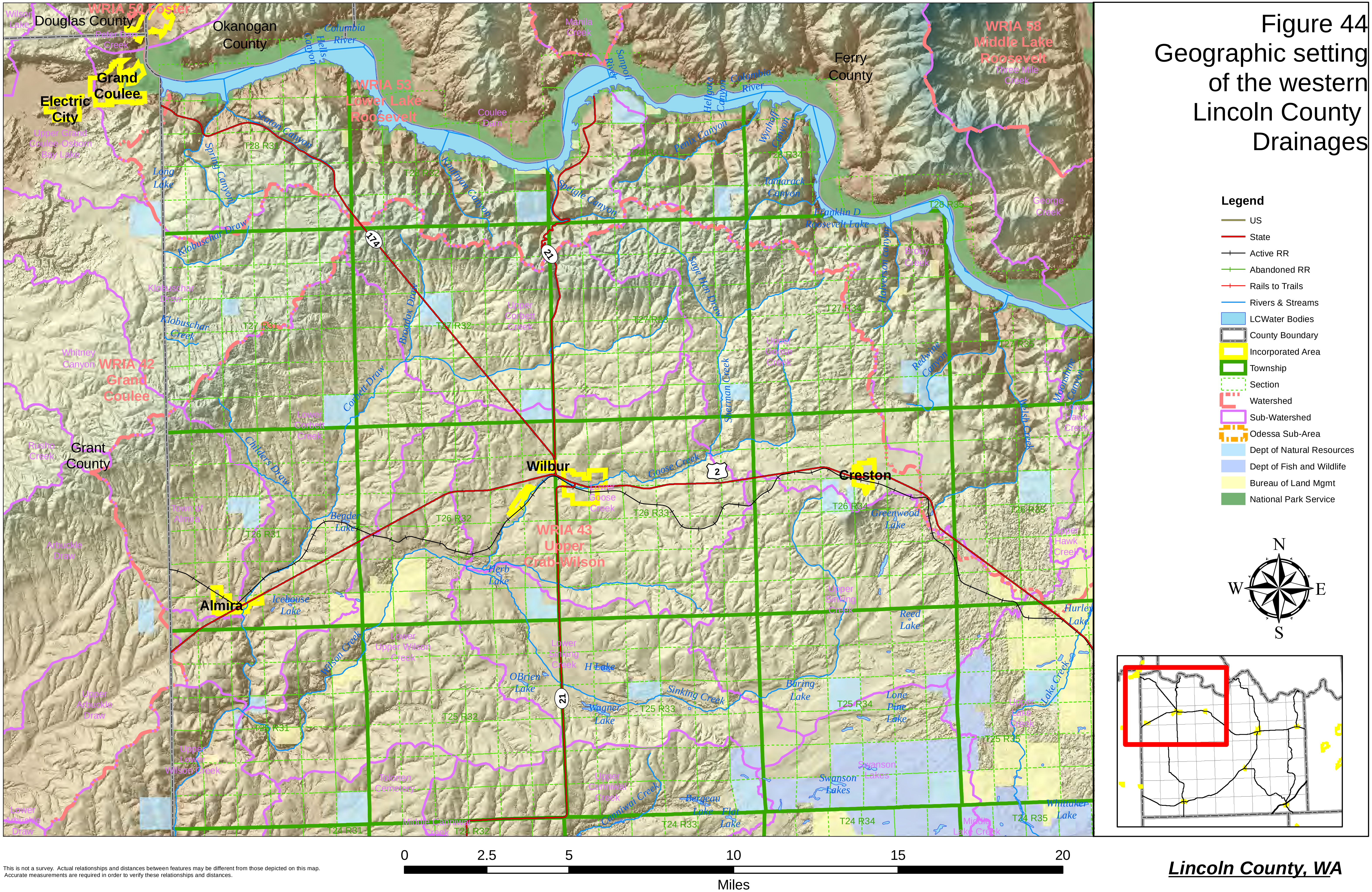


Figure 44
Geographic setting of the western Lincoln County Drainages

4.3.4 Western Lincoln County Hydrogeology

Like in the central and eastern portions of Lincoln County 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 15 and 16). 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 likely will discharge into canyons to the southwest where these units are incised through.

The Sentinel Gap, Sand Hollow, and Ginkgo, all Frenchman Springs Member units, only are present in the lower portions of the Wilson Creek drainage in westernmost Lincoln County. Based on this distribution, water in this drainage would have to flow into the westernmost part of the County to recharge interflow zones in these units. Furthermore, once these units receive recharge, GWMA's maps for northeastern Grant County show these units are dissected by the Crab Creek coulee to the southwest. Given that distribution, interflow zones in these Frenchman Springs units which are recharged in western Lincoln County likely would discharge into Crab Creek in adjacent Grant County.

The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member, is found within 200 feet of the bottom of large reaches of all the drainages in western Lincoln County. 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. This area is down dip of potential recharge areas along many of the western County drainages. Given that, one could expect some discharge from the shallowest interflow zone(s) of the Sentinel Bluffs into the Crab Creek drainage. However, because of the depth of incision into the top of the Sentinel Bluffs Member generally is less than 100 feet and because its regional dip is to the south-southwest, one should expect that the multiple interflow zones present deeper in the unit would carry recharged water in that direction. In such cases, groundwater movement would be to the southwest into north-central Grant 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, 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. However, beneath the western Lincoln County drainages pre-basalt basement is only encountered in the highlands near Lake Roosevelt before dipping into the Columbia Basin to the south where it is several thousand feet deep. Given this depth, it is unlikely that significant volumes of recharge water would reach it because the water would need to migrate into, through, and between multiple CRBG interflow zones in the Grande Ronde to reach to top of the pre-basalt basement.

Based on our current understanding of feeder dike distribution in the CRBG, it seems likely that the western Lincoln County drainages lie west, and down dip, of the main projected Roza and Priest Rapids dike systems. Based on that, we suspect that these dikes will have little to no impact on groundwater flow in this portion of Lincoln County.

4.4 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.

4.4.1 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 associated with the reintroduction of water to the area and re-establishment of flowing streams and refilling of now dry lakes 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.

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.

7. Sedimentation. With increased stream flow there is the increased potential for erosion of stream banks and downstream deposition of that eroded sediment. Several residents who own land on currently flowing reaches raised this concern and emphasized the need to manage enhanced stream flow to minimize this potential issue.

In addition to these issues, there was an often repeated concern about the involvement of the Department of Ecology. For example, would 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 associated with the periodic rehydration of one or more streams is as follow:

- Fence construction adjacent to stream courses or lakes to protect water quality will become an issue.
- Loss of 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. We propose that these be specifically addressed in the feasibility phase.

4.4.2 Public Entities

The three primary public land managers in the drainages being assessed are the U.S. Bureau of Land Management (BLM), the Washington Department of Fish and Wildlife (WDFW), and the Washington Department of Natural Resources (DNR).

At this stage of the project, the conceptual and prefeasibility stage, the WDFW and DNR field representatives we talked to about the project expressed little major concern about the prospect of revitalized stream flows in the area. The primary concern they had was related to flooding of shrub-steppe habitat ground. Because the project as currently conceived only envisions flooding of now dry lakes, the staff we discussed the project with appeared to be generally supportive, and from their perspective had no regulatory issues associated with the project were identified. Given that, if a pilot project is undertaken, WDFW and DNR will need to be consulted as part of the SEPA process.

In June 2010, project staff met with BLM staff to discuss the project concept. BLM staff indicated they are generally receptive to a project that revitalizes lost stream flow and lake capacity, 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 (ROW) authorization will need 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. If the project proceeds to the feasibility phase the ROW authorization process will be further pursued with the BLM.

4.5 Drainage Rankings

The ten streams were evaluated according to six criteria using a qualitative ranking of one, two, or three. For each of the six criteria a three meant the ranking was generally favorable to further evaluation in the feasibility phase, a one meant the ranking was generally unfavorable, and a two was neutral. The six criteria are as follows:

- Available Information: Relatively more is known about the stream based on the number of field visits and availability of prior studies.
- Landowners/Stream Channel Issues: Lower likelihood of adverse issues associated with landowners along the stream and number of anticipated culvert issues along the re-watered channel.
- 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).
- Hydrogeology Benefits: Higher likelihood of hydrologic benefit to the underlying aquifer.
- 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.
- Water Rights: These were looked at from the perspective of potential conflict to the extent we can currently identify them. This is not an analysis of water rights that could be serviced or are needed for the project to proceed.

The following summarizes our current ranking of each stream using the six criteria and based on the discussions in Sections 4.1 through 4.4. Table 6 presents a tabulation of our rankings.

Table 6. Color-Coded Rankings of the Drainages Assessed in this Report

Green is favorable for the proposed project, red is not favorable for the proposed project, and yellow is neutral.

Drainage	Available Info	Landowner/ Stream Channel Issues	Hydro-geology	Con-veyance Distance/ Issues	Recreation and Habitat	Water Rights	Total Ranking
Upper Crab Creek	2	3	3	1	2	2	13
Bluestem Creek	2	1	2	1	1	2	9
Rock Creek	1	1	1	1	1	1	5
Coal Creek	2	1	2	1	1	2	9
Duck Creek	2	2	3	1	2	2	12
Lake Creek	3	2	3	2	3	2	15
Marlin Hollow	2	3	3	1	2	2	13
Canniwai Creek	2	2	3	1	2	2	12
Wilson Creek	3	1	1	1	2	1	9
Goose Creek	3	1	1	1	2	1	9
Sinking Creek	3	1	1	1	2	1	9

Upper Crab Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership; generally well defined, relatively large (>10 cfs) channel; rank = 3
- Hydrogeology: History of channel losses suggests recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: Long distance to source (15 to 30 miles) depending on route; rank = 1
- Recreation/Habitat: Mostly private ground, but with well defined scabland coulees; trout fishery present in reaches; rank = 2
- Water Rights: no issues currently defined; rank =2
- Total = 13

Bluestem Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership; upper reaches poorly defined; channel in lower reaches generally small (<2 to 5 cfs); rank = 1
- Hydrogeology: Little anecdotal information found; Unknown history of channel loss, but reconnaissance suggests small; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 2
- Conveyance Distance/Issues: Long distance to source (20 miles); rank = 1
- Recreation/Habitat: Mostly private ground; no history of dried lakes; well defined scabland coulees; rank = 1
- Water Rights: no issues currently defined; rank =2
- Total = 9

Rock Creek:

Not evaluated further because of long distance (>30 miles) from source water to headwaters area. Ranked one (1) for all categories.

Coal Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership; generally well defined, small to medium (< 5 cfs) channel; creek flows through a town results in a flood control concern; rank = 1
- Hydrogeology: No anecdotal history of channel losses found, suggests small recharge potential; if recharge occurs CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 2
- Conveyance Distance/Issues: Long distance to source (>20 miles) from poorly defined headwater area; rank = 1
- Recreation/Habitat: Mostly private ground, significant areas of active agriculture; rank = 1
- Water Rights: no issues currently defined; rank =2
- Total = 9

Duck Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership; upper reaches poorly defined, but with stream channel and lake losses suggested throughout drainage; Generally small to moderate channel size (< 5 cfs) channel; rank = 2
- Hydrogeology: History of channel and lake losses suggests recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: Long distance to source (>30 miles); rank = 1
- Recreation/Habitat: Mostly private ground, but with several lakes and well defined scabland coulees; rank = 2
- Water Rights: no issues currently defined; rank =2
- General: Given the distance to its headwaters, and the lack of a well defined drainage in its upper valley, Duck Creek probably is not favorable for a pilot project
- Total = 12

Lake Creek:

- Available information: WRIA 42 general information, and LCCD Lake Creek study; rank = 3
- Landowner/stream channel issues: Mix of public and private land ownership, with private owners concerned about stream access and erosion issues; generally have a well defined, moderate sized channel (5 to >10 cfs) and numerous lakes, many of which have dried up; rank = 2
- Hydrogeology: History of channel and lake losses suggests recharge potential; Numerous lakes provide potential water storage and recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: for the project areas, moderate distance to source (12 to 15 miles) depending on route; some private land access issues to address; rank = 2
- Recreation/Habitat: abundant public ground and lakes; formerly an active trout fishery throughout the system; rank = 3
- Water Rights: no issues currently defined; rank =2
- Total = 15

Marlin Hollow:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Headwaters publically owned, remaining drainage predominantly private land ownership; lakes are drying/decreasing; generally well defined, moderate (5 cfs) channel; rank = 3
- Hydrogeology: History of channel losses and diminished lakes suggests recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: Long distance to source (20 miles); upper reaches poorly defined; might potentially be linked to a Lake Creek delivery system if ever developed; rank = 1
- Recreation/Habitat: With upper reaches in public ownership, and presences of lakes there is potential for improvement; rank = 2
- Water Rights: no issues currently defined; rank =2
- General comment: Potential issues with this stream are related to conveyance of water to the headwaters over open ground. It has positive issues related to channel conveyance, recreation, and habitat.
- Total = 13

Canniwai Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership, with significant channelized reaches and construction adjacent to creek; small to moderate channel size (2 to 5 cfs) with few lakes; rank = 2
- Hydrogeology: History of channel losses suggests recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: Long distance to source (>20 miles); upper reaches poorly defined; might potentially be linked to a Lake Creek delivery system if ever developed; rank = 1
- Recreation/Habitat: predominantly private ownership with some scabland; rank = 2
- Water Rights: no issues currently defined; rank =2

- 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.
- Total = 12

Wilson, Goose, and Sinking Creeks:

Given water rights concerns discussed earlier in this prefeasibility assessment these drainages were not favorably ranked. The following rankings apply to each of these three western Lincoln County drainages.

- Available information: Early Sinking Creek evaluations provide a fair amount of useful information; rank = 3
- Landowner/stream channel issues: Predominantly private with numerous existing water rights concerns; channels are small to moderate in size; rank = 1
- Hydrogeology: Recharge potential suggested by early water rights work, but overall location suggests minimal recharge potential for Odessa Groundwater Management Subarea to the south; rank = 1
- Conveyance Distance/Issues: Generally short distances to source, but via steep gradient canyons; rank = 1
- Recreation/Habitat outcomes: Predominantly private land, but with some lakes and stream access; rank = 2
- Water Rights: Previous contentious issues, especially with regards to groundwater and surface water continuity; rank = 1
- General comment: These creeks may be too far to the west to have a significant hydrogeologic connection or provide benefit to areas along Crab Creek in the Odessa Groundwater Management Subarea
- Total = 9

Table 6 summarizes how well each stream meets the respective criteria. In the matrix, Green indicates relatively higher positive characteristics, ranking of 3. Yellow indicates neutral or a mix of positive and negative characteristics, ranking of 2. Red indicates relatively lower or negative characteristics or issues that may count as fatal flaws for the purposes of this selection process, ranking of 1. Because significant information is missing for many streams and criteria, the matrix is highly subjective and qualitative. Additional information and research may alter these preliminary ratings.

The qualitative evaluation based on the six criteria described above, and shown in Table 6, ranks the drainages in the following order, from most acceptable to least acceptable:

1. Lake Creek – 15
2. Marlin Hollow and upper Crab Creek – 13
3. Duck Creek and Canniwai Creek – 12
4. Bluestem Creek, Coal Creek, Wilson Creek, Goose Creek, Sinking Creek – 9
5. Rock Creek – 5

Based on these rankings we recommend that Lake Creek be the initial focus of subsequent work during the feasibility phase of the project. In addition, we recommend that Marlin Hollow and Canniwai Creek be further evaluated in the feasibility phase because of generally high rankings, including their proximity to Lake Creek. If a Lake Creek pilot project is undertaken, the proximity of these other two creeks may facilitate expansion of a delivery system into these additional drainages.

Upper Crab Creek and Duck Creek, also ranked highly, are not recommended for further evaluation at this time because of distance to source water (over 15 miles). With respect to the 5 drainages with a ranking of 9, all offer some positive aspects, but each also has one or more negative aspects that lead us to remove them from further consideration for a potential pilot project. Conveyance from the source to Bluestem Creek and Coal Creek is long and both creeks are relatively small. In addition, Coal Creek flows through a town. Wilson Creek, Goose Creek, and Sinking Creek have several favorable aspects, but the history of water rights disputes and their location far to the west and not directly up gradient of the Odessa Groundwater Management Subarea all argue against their use in a pilot project.

This qualitative review suggests that based on our current state of knowledge, 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.

4.6 Pipeline Infrastructure Assessment – Lake Creek

This section addresses potential pilot project infrastructure needs for the pipeline that could deliver water to the Lincoln County Passive 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 45, and a preliminary pump station layout is shown on Figure 46. 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.

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

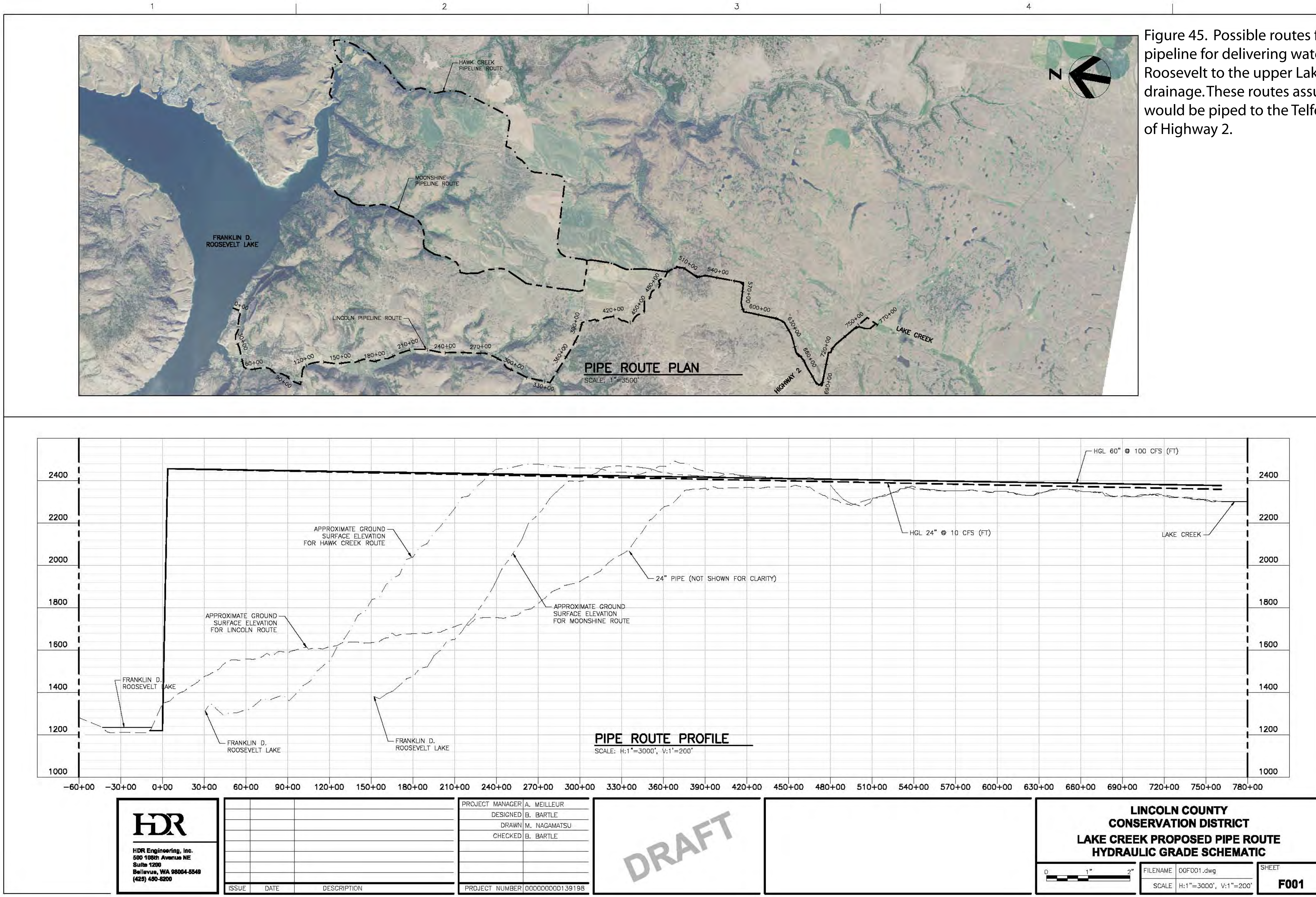
For a 10 cfs pilot project, a 24-inch-diameter pipeline is proposed. The pilot project could be expanded to the full 100 cfs future flow by adding a 48-inch-diameter pipeline parallel to the pilot project pipeline. Conversely, depending on the project funding, a single 60-inch-diameter pipeline could be built which would handle the full build out flows and the pilot project flows (100 cfs). There are three proposed pipeline routes shown on Figure 45: 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 7.

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 47 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 48. There is a substantial culvert crossing along Redwine Canyon Road, shown in Figure 49. 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 because of accessibility and potential access to Lake Roosevelt.

Figure 45. Possible routes for a potential pipeline for delivering water from Lake Roosevelt to the upper Lake Creek drainage. These routes assume water would be piped to the Telford area south of Highway 2.



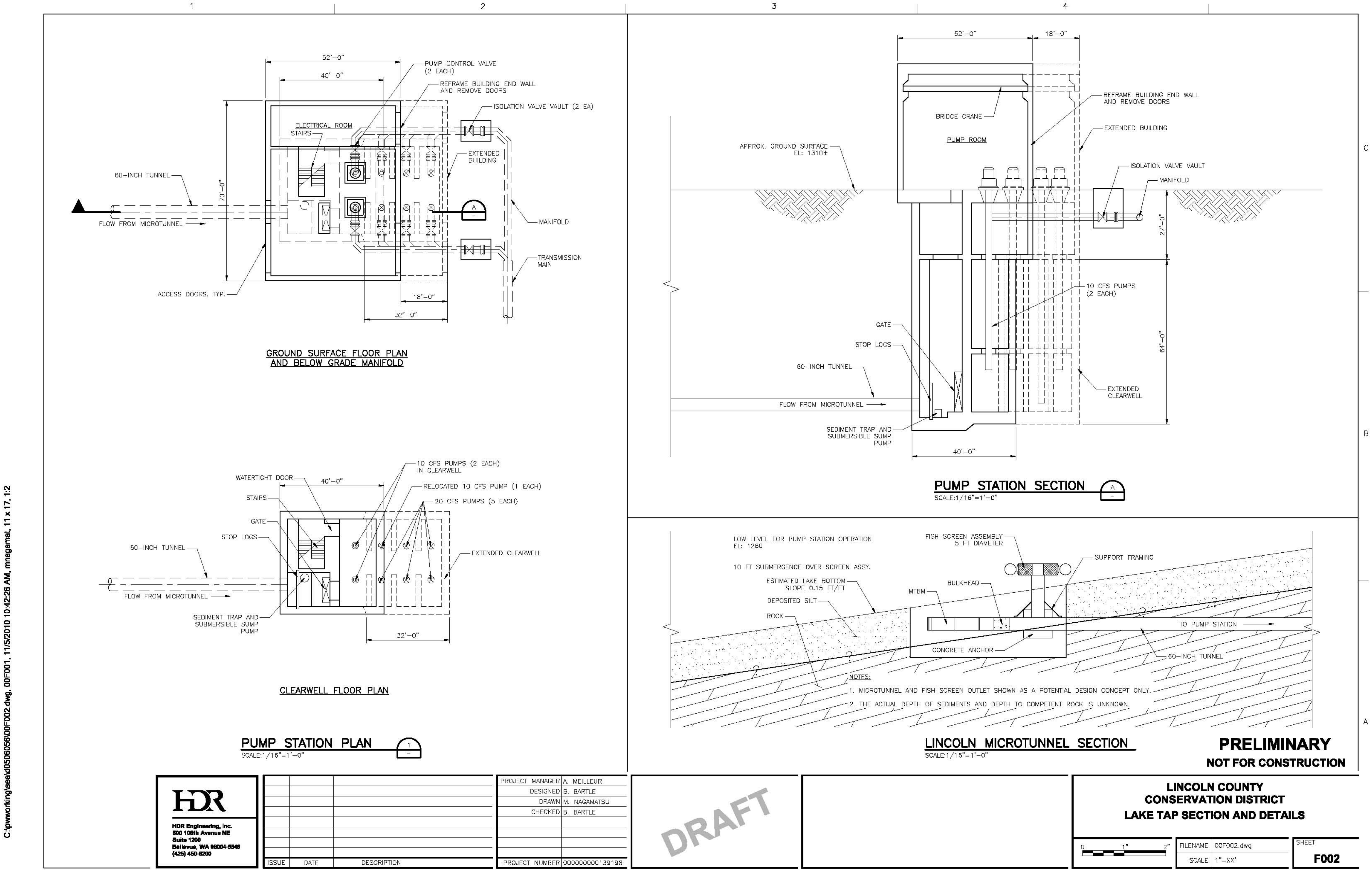


Figure 46. Potential pumping station configurations for a pump station(s) on Lake Roosevelt.

Figure 47. The geographic setting of the Moonshine Canyon Route along Copenhaver Road. This view is to the north down the canyon.

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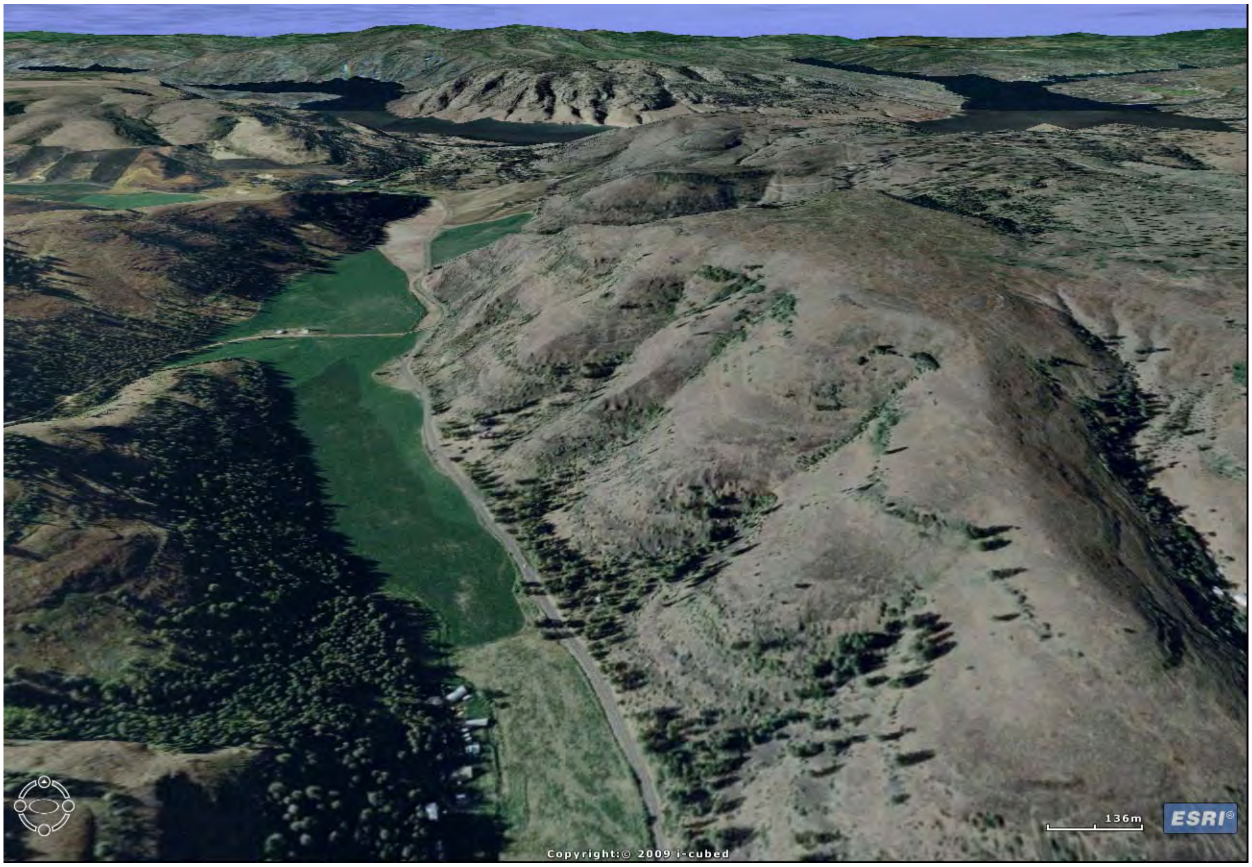

Figure 48. The geographic setting of the Welch Creek Road route.
This view is to the north down the canyon.

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Figure 49. Culverts along the Welch Creek Road route on Redwine Canyon Road.

Table 7 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 100 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 project would be 0.51 feet per second; at final build out, the velocity would be 5.1 feet per second.

Table 7. Summary of Potential Pipeline Route Hydraulics

	Moonshine Pipeline Route	**Hawk Creek Pipeline Route**	**Lincoln Pipeline Route**
Pipeline length (ft)	62,000	74,000	77,000
Start elevation (ft)	1,320	1,240	1,200
Highest elevation (ft)	2,480	2,500	2,360
Total static head (ft)	1,160	1,260	1,160
10-cfs Pilot Study – 24-inch Pipeline			
Pipeline headloss (ft)	81.5	97.3	100.6
Velocity (ft/sec)	3.2	3.2	3.2
Total dynamic head (ft)	1,242	1,357	1,261
100-cfs Full Buildout – 57-inch Equivalent Pipeline			
Pipeline headloss (ft)	85.8	102.4	106
Velocity (ft/sec)	5.6	5.6	5.6
Total dynamic head (ft)	1,246	1,362	1,266
100-cfs Full Buildout – 60-inch Pipeline			
Pipeline headloss (ft)	66.9	79.8	82.6
Velocity (ft/sec) Pilot/Full Build	0.50/5.1	0.50/5.1	0.50/5.1
Total dynamic head (ft)	1,226	1,340	1,243

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 45.

As shown in Figure 45, 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 report, the entire pipeline route is assumed to be steel. The steel pipe thicknesses used are presented in Table 8.

Table 8. Steel Pipe Thicknesses

Pipeline Diameter (inches)	Segment 1 (7 miles at 565 psi) (inches)	Segment 2 (7.5 miles at 90 psi) (inches)
24	0.300	0.200
48	0.560	0.200
60	0.700	0.250

4.6.2 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 50.

Figure 50. Photograph of the old Lincoln lumber mill site. This is one of several potential location on Lake Roosevelt where water might be pumped for the possible project. Lake Roosevelt lies just beyond the kiln and in the front of the hills in the background.

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 46. 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 microtunneling into the reservoir. Each has benefits and drawbacks which must be examined. For the purpose of this prefeasibility report, microtunneling is the preferred option.

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 46; 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.

4.7 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, and recharge to the underlying CRB aquifer.

4.7.1 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 9.

Table 9. Measured (Bold) and Estimated (Italics) Flows in Lake Creek, 1998–1999 Used to Develop Water Budget

Date	Inlet to Upper Twin Lakes (cfs)	Inlet to Coffee Pot Lake (cfs)	Highway 21 crossing above Pacific Lake (cfs)	Upstream of Confluence with Crab Creek (cfs)
Aug-98	**0.5**	*0*	**0**	**0**
Sep-98	*0.5*	*0*	*0*	*0*
Oct-98	**0.86**	*0*	**0**	**0**
Nov-98	**0.87**	**0.037**	**0**	**0**
Dec-98	**2.5**	*5*	*3*	*0*
Jan-99	**14.4**	*20*	*15*	*0*
Feg-99	**40**	**44.6**	**33.4**	**0**
Mar-99	**34.0**	*38*	*25*	*0*
Apr-99	**13.7**	**16.6**	**17.2**	**18.1**
May-99	*5*	**6.61**	**8.58**	**5.36**
Jun-99	**2.24**	**0**	**0**	**0**
Jul-99	**0.639**	**0**	**0**	**0**

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.

4.7.2 Basin Areas and Lake Geometry

The Lake Creek drainage basin was sub-divided into four sub-basins (Figure 51), 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 9 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 10.

Table 10. Estimate of Seepage Rates for Lake Creek Sub-basin using Spot Data from August 1988 to July 1999

Location	Estimated Baseflow	Estimated Seepage Loss
Above and within upper Twin Lake	-0.5 cfs	
Above and within Coffee Pot Lake	-0.4 cfs	3.0 cfs
Above and within Pacific Lake		8.4 cfs
Above Crab Creek confluence		3.6 cfs

Examination of the measured and estimated flow in Table 10, 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.

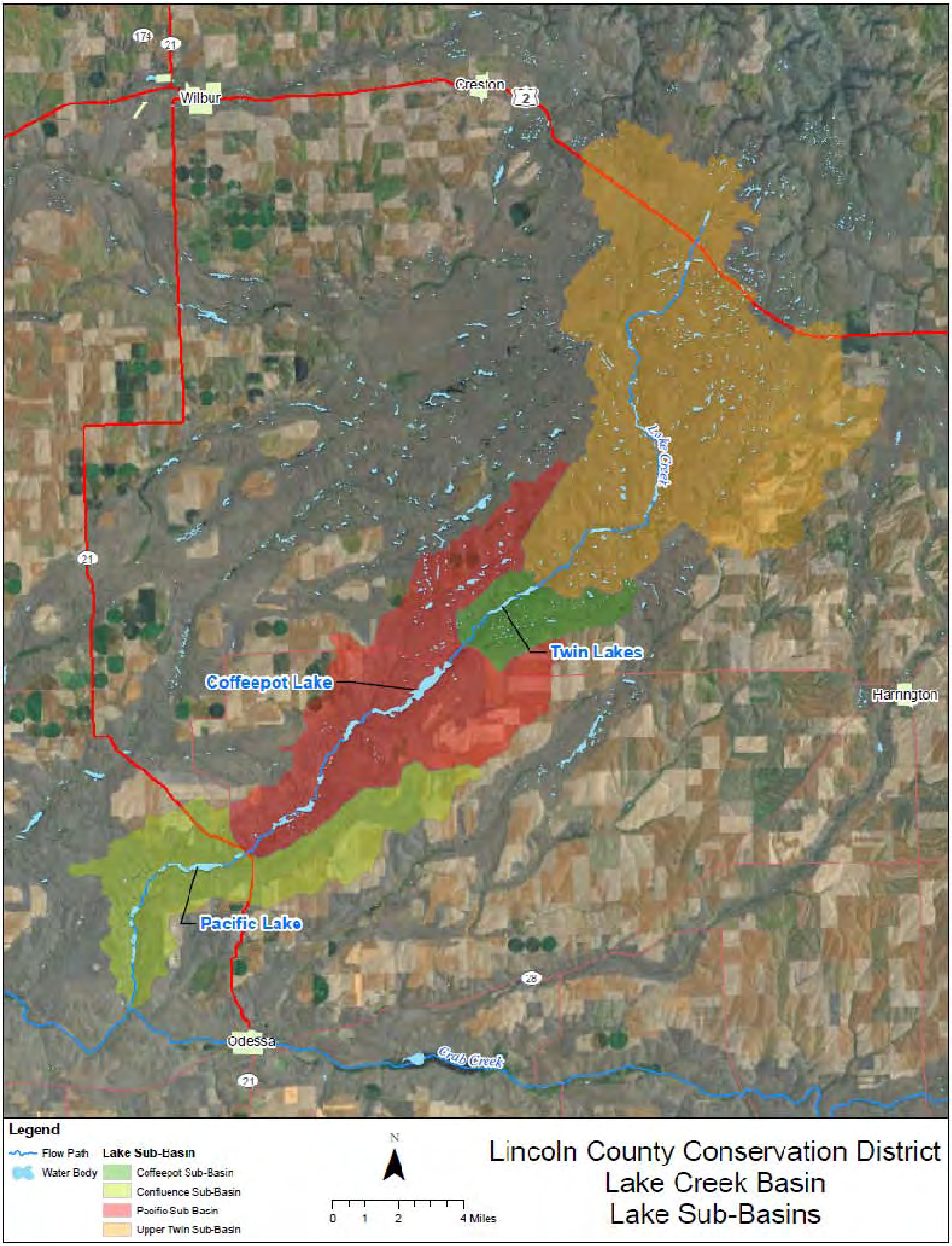

Figure 51. Map of the Lake Creek sub-basin showing the main lakes in the drainage.

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4.7.3 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 the historically measured/observed function of the basin.
3. Use the model to estimate the effects of adding pilot program flows to Lake Creek.

Runoff Losses

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

Rloss = (PxA)+Qin -Qout -S

Where:

Rloss is runoff loss

P is precipitation

A is sub-basin area

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

Qout 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 (Closs) of 85%. A runoff loss of 85% means that 15% of the precipitation on the basin contributes to flow in the stream, prior to losses from seepage or reservoir evaporation. This value was subsequently reduced, as described below.

∑ Rloss

closs = 1¬

∑P xA

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 = closs (P x A) + Qin -Qout

Where:

S is seepage (+ infiltration, -discharge)

P is precipitation

A is sub-basin area

Qin is inflow from the sub-basin upstream, Table 9

Qout is outflow into the sub-basin downstream, Table 9

Closs 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.

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 51. The order that the water balance calculates water flow through the basin is shown in Figure 52.

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.

4.7.4 Sub-Basin Analysis

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

= Qin + closs (P x A)

Qout

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 53. 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 54. 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.

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 11. 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 12. 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 55. The estimated storage in each modeled lake is shown in Figures 56 through 58.

Table 11. Estimate of Seepage Rates for Lake Creek Sub-basin Based on Long-Term Water Balance Model, January 1985 to August 2010

Location	Estimated Baseflow	Estimated Seepage Loss
Above and within upper Twin Lake	-0.5 cfs	
Above and within Coffee Pot Lake	-1.0 cfs	5.5 cfs
Above and within Pacific Lake		12 cfs
Above Crab Creek confluence		3.0 cfs

Table 12. Summary of Predictive Results for when Water Is and Is Not Added to Lake Creek

Added inflow for 10 months per year (cfs)	Predicted # of years out of 26 Pacific Lake would fill	Predicted average annual flow from Lake Creek into Crab Creek (cfs)	Predicted increase in groundwater seepage (cfs)
0	5	1.4	0
5	16	3.0	2.4
10	24	5.5	3.8
15	26	8.4	4.6

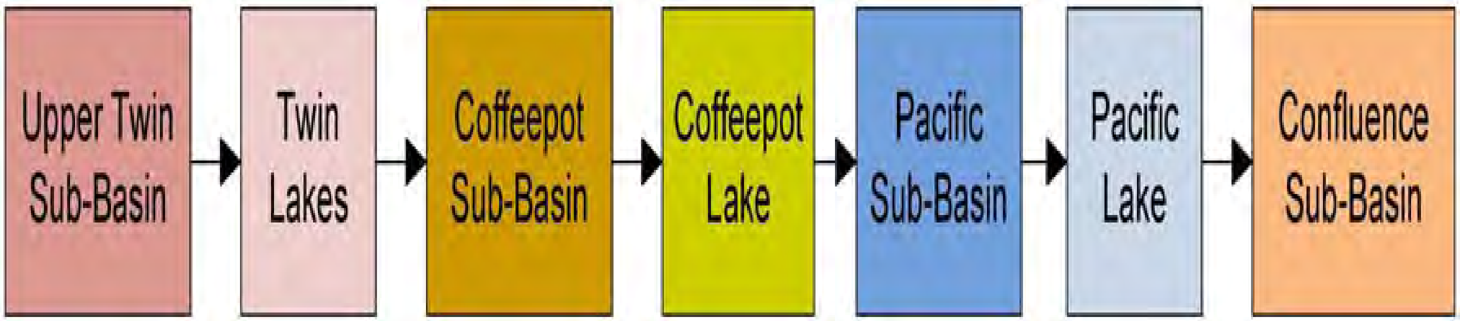

Figure 52. The order water flows through the four subdivisions of the Lake Creek sub-basin modeled for this effort. Each box represents an equation or a set of equations used in the water balance model.

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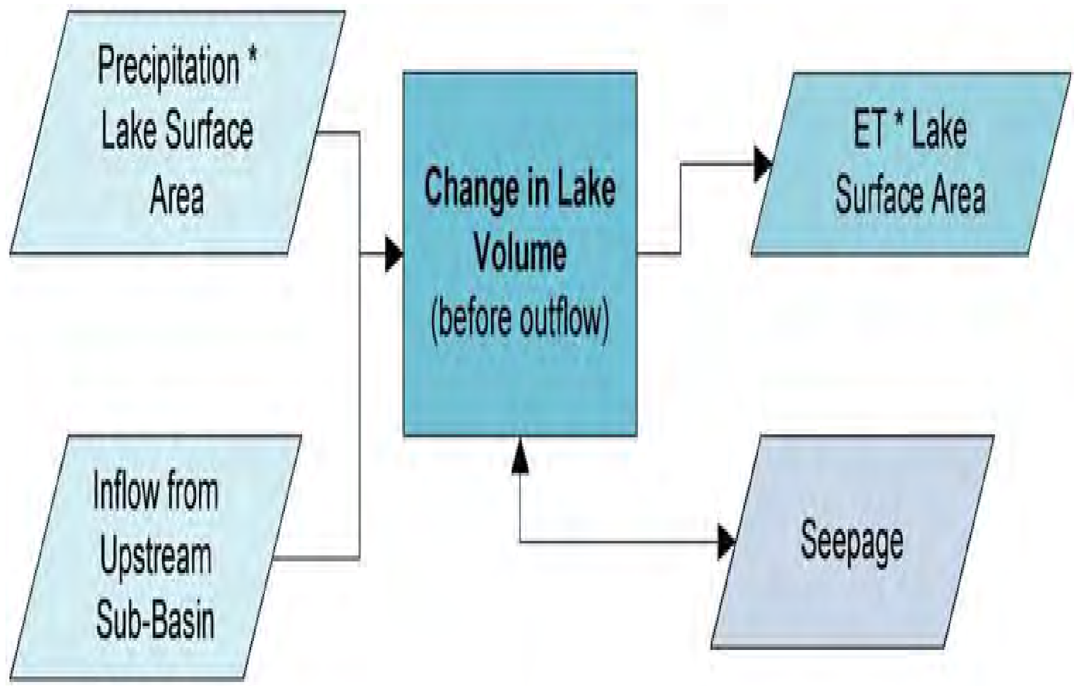

Figure 53. Diagram showing the relationship between the parameters used to calculate changes in lake volume.

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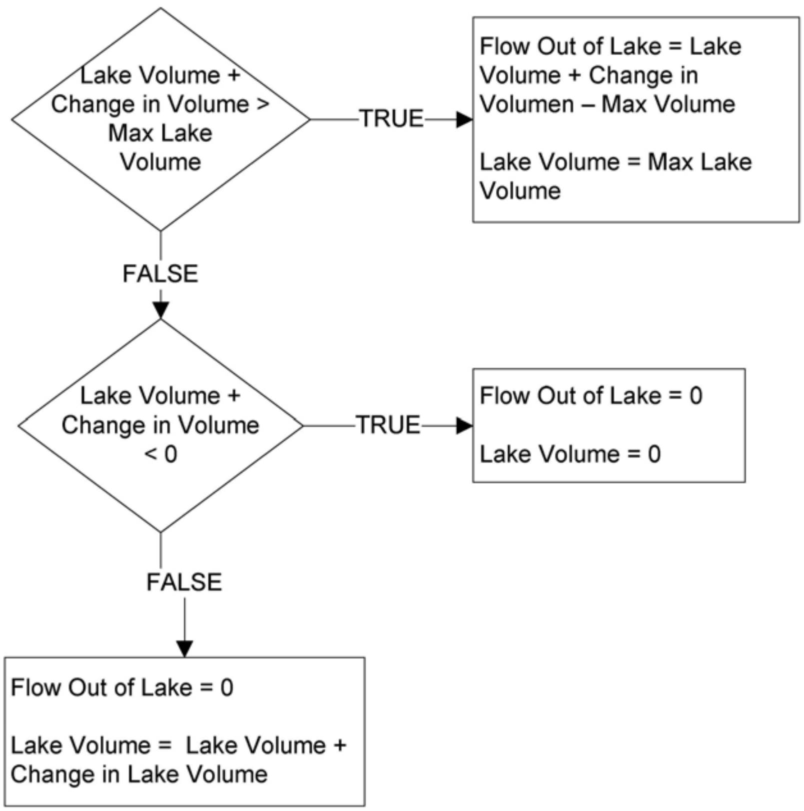

Figure 54. Diagram showing the logic used for calculating lake volume and the flow out of a lake for each time step in the water balance model.

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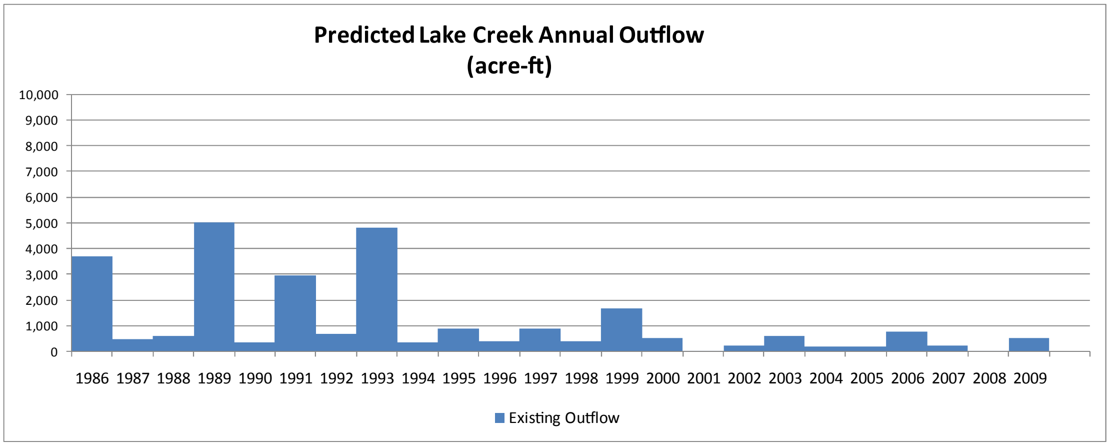

Figure 55. Graph showing predicted annual flow in Lake Creek at its confluence with Crab Creek. Predicted flow is from the long-term water balance model.

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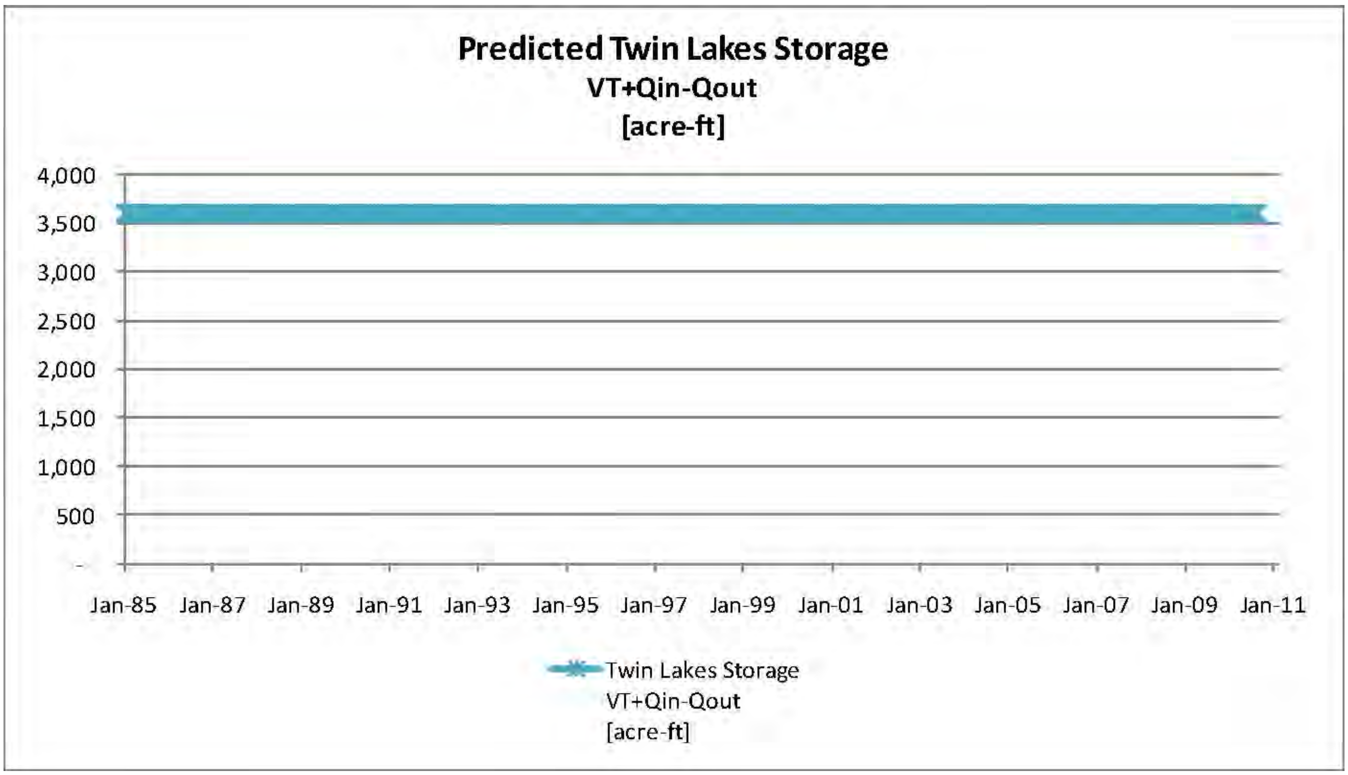

Figure 56. Graph showing predicted volume in Twin Lakes derived from the long-term water balance model.

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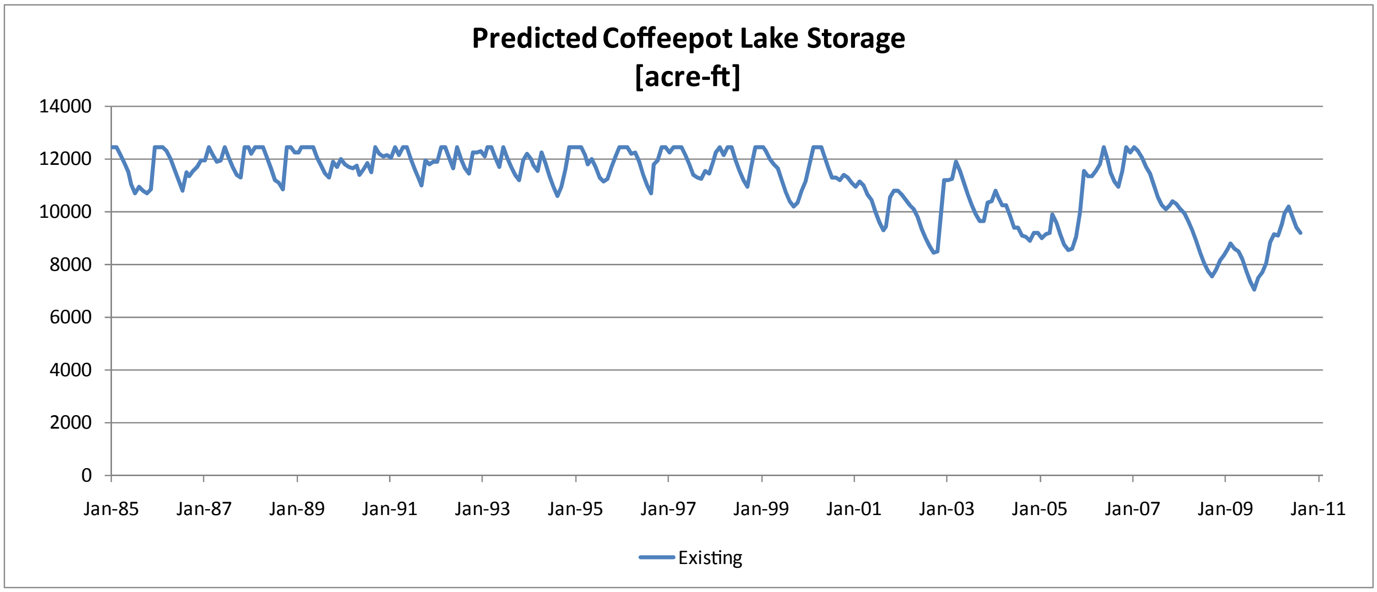

Figure 57. Graph showing predicted volume in coffee Pot Lake derived from the long-term water balance model.

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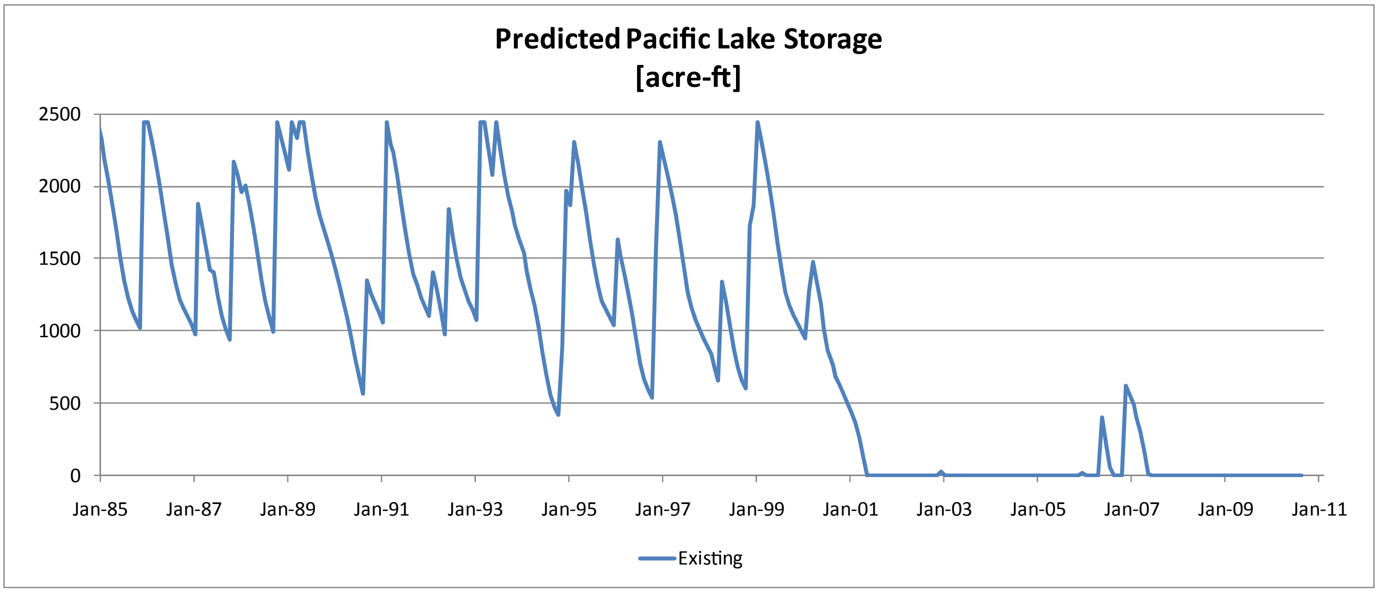

Figure 58. Simulated historical volume in Pacific Lake derived from the long-term water balance model.

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4.7.5 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 and the Odessa Groundwater Management Subarea. 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 59.

4.8 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 water seeping from stream channel and lake beds, 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 groundwater flow is predominantly within interflow zones and 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, as indicated by generally unchanged 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 one-third of its volume, Browns Lake approximately one-half, Taveres Lake over 90%, 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 the upper stream reaches, much of it will discharge into the canyons to the southwest where the units are fully incised through, including Crab Creek (Figure 60). 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 22). Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of all the drainages in central Lincoln County (Figure 22, 61). This system includes reaches as far northeast as Highway 21 on Cannawai Creek, above Highway 21 on Marlin Hollow, and upstream from the mouth of Lake Creek to Twin Lakes. Based on the strike and dip of the unit, groundwater (naturally occurring and artificially recharged) movement within it will be predominantly down dip in interflow zones, to the southwest (Figure 61). However, the presence of at least one Roza Dike between Deer Lake (still contains water) and Pacific Lake (dry) may influence this flow path (Figures 61, 62). If this dike system is a significant barrier to groundwater movement, the best recharge opportunities for the Sentinel Bluffs would be southwest of it, down dip of the dike system. In Lake Creek that would be the area downstream of Deer Lake.

GWMA maps show the top of the Sentinel Bluffs Member 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 (Figure 61). 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 recharged groundwater can flow unimpeded to the south-southwest, it would flow into eastern Grant County and the northwestern of Adams County (Figure 61).

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 (Figurer 31). 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. Generally though, given the current project concept to deliver water down the Lake Creek system, we would speculate that recharge of these deeper Grande Ronde units by a potential recharge project would be limited.

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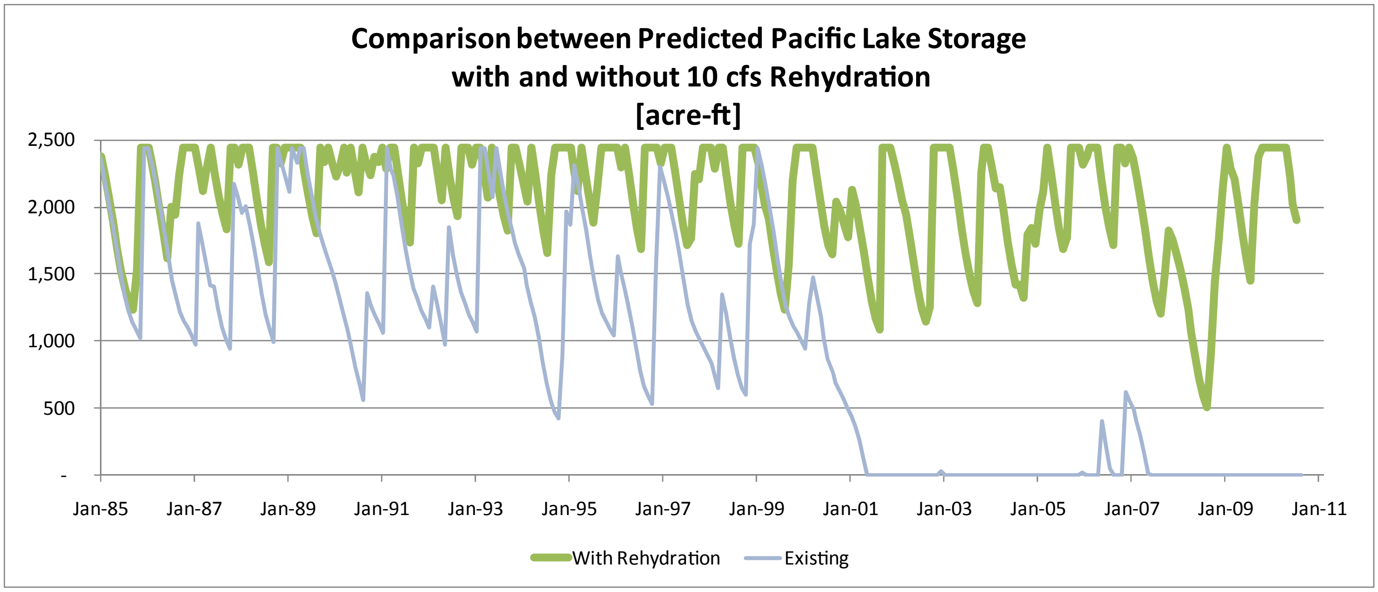

Figure 59. Predicted water volume in Pacific Lake with and without artificial rehydration. The graphs are derived from the long-term water balance model.

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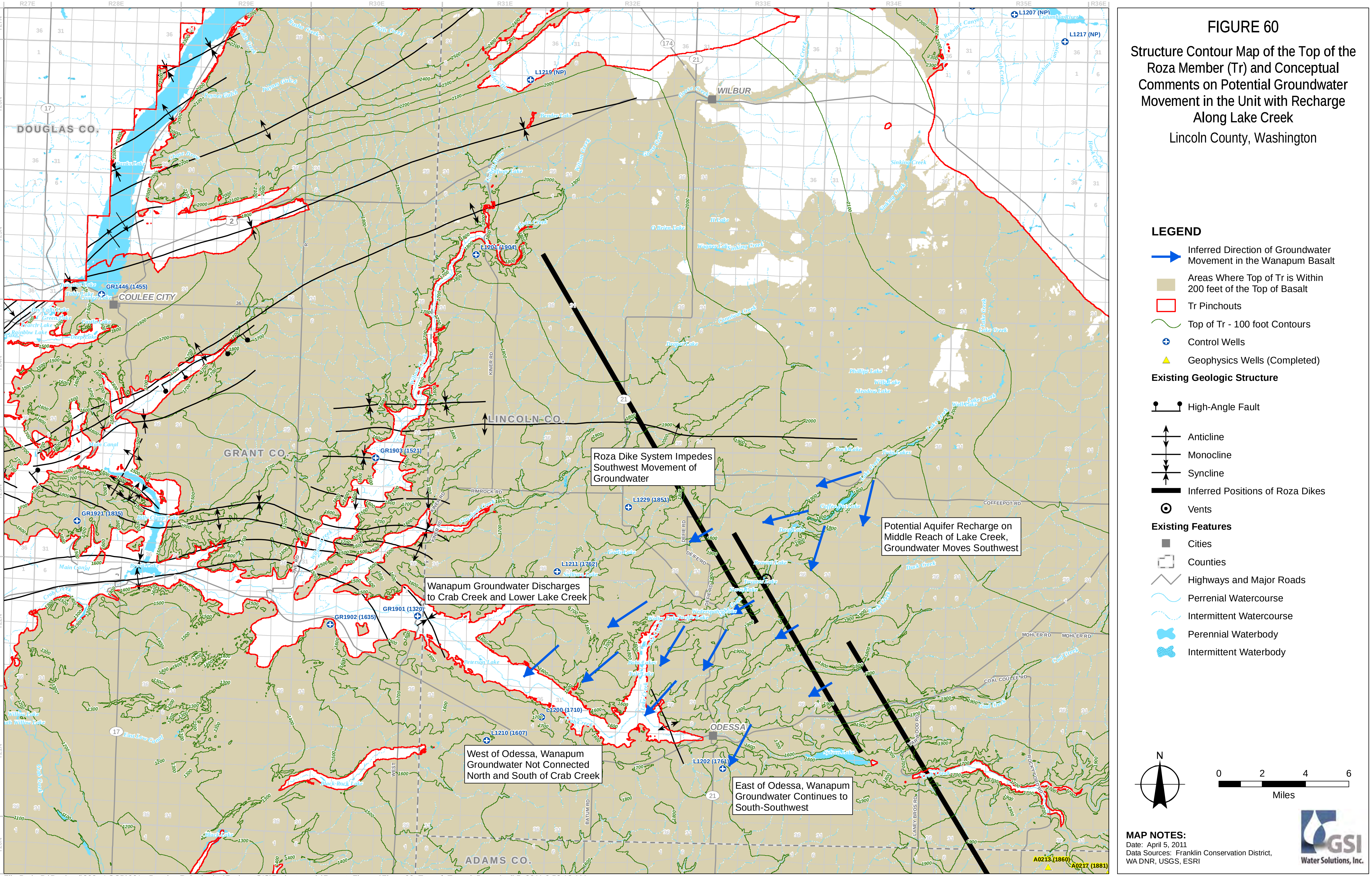

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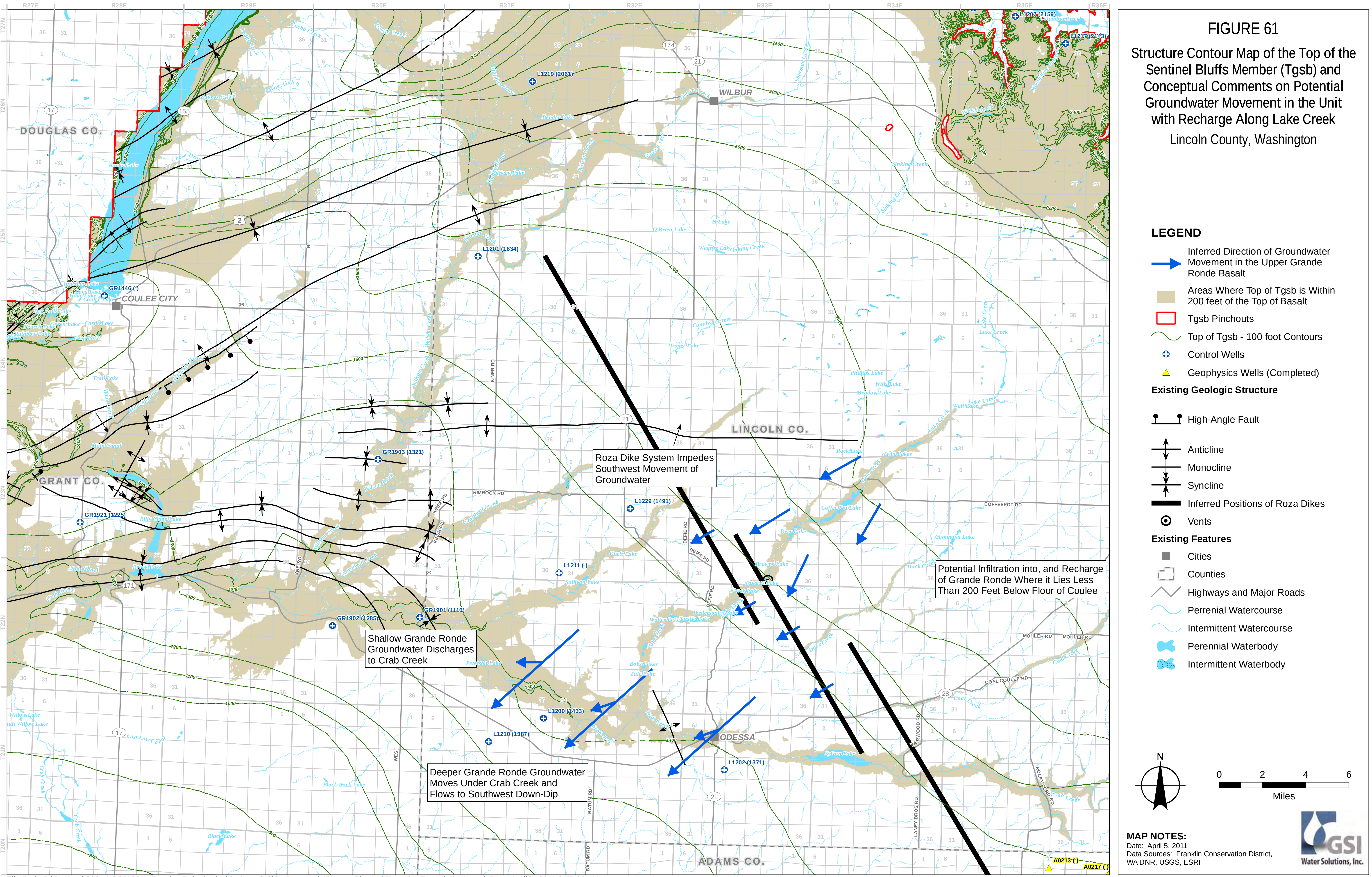

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Chapter 5: Prefeasibility Phase Conclusions and Recommendations

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, 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.

5.1 Conclusions

Based on the Prefeasibility Assessment, it is the project team's conclusion that the rehydration project envisioned by LCCD meets the goals, objectives, and intent of RCW 90.90. 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 prohibit project implementation. While many challenges to this project were identified, none were found to be insurmountable.

With respect to one portion of RCW 90.90 (the one-third instream, two-thirds out of stream division of water), the pilot study may, or may not meet this goal. 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 instream 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 watershed would flow downstream, contributing to instream flows and likely producing gains to riparian habitat and water-based recreation. A portion of 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. A portion of the flow, 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 contribute to the water supply 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 a review of potential water rights options that might be used for a pilot project, a temporary permit application would be the most feasible approach to obtaining the use of water for the pilot project. Other options reviewed include municipal and industrial use water acquired from Reclamation, long-term water rights agreements with Reclamation, a preliminary permit , and private water right lease and/or purchase. The temporary permit would provide authorization for the use of Lake Roosevelt water for a potential pilot project in which testing and subsequent beneficial use of water could occur. If the project is authorized for moving forward into the feasibility phase, a water right permit application would be completed and submitted to Ecology at the completion of a successful feasibility phase. This application would name the responsible authority that would take on the planning, permitting, construction, and operation of the pilot project. Other water right use options other than a new water right permit would be used to compile a water right portfolio to operate the system, inclusive of but not limited to, leasing water, purchase and transfer of water rights, and development of an Upper Lake Roosevelt water banking program.

Governance and landowner 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, landowner 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 system 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 Groundwater Management Subarea.

5.2 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 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:

- 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.
- 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.

- 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.
- Prepare a monitoring plan to include surface water and groundwater 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. Groundwater monitoring would create a groundwater baseline for two primary uses. One use of the baseline would be for documenting changing conditions, if any, from the perspective of non-degradation of existing groundwater resources. The other use of the baseline would be to see if the project has a measurable impact on groundwater resources, e.g., is recharge occurring, if so when and where, and what is the fate of the recharged groundwater. 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.

- While the preparation of a water rights 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 water rights permit application requesting a temporary permit, once that entity is in place. The basic goal of the temporary permit will be conduct a pilot scale project, the results of which will be used to assess the potential for a larger project meeting the goals and objectives of RCW 90.90.

5.2.1 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. If the feasibility phase is authorized, the feasibility phase report will describe the proposed pilot project.

5.2.2 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 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 groundwater and surface water 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.

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Chapter 6: Next Steps

6.1 Phases 2 Through 5

Although premature to describe in detail at this time, the potential goals and objectives of subsequent project phases are outlined. These will be refined and changed as needed, if the project proceeds through these subsequent phases.

6.1.1 Phase 2 – Feasibility Evaluation and Design of a 10 to 20 cfs Pilot Project

Phase 2, if stakeholders and Ecology decide to proceed to it, will focus on a pilot project Feasibility Evaluation of the drainage(s) recommended in the Prefeasibility Assessment (Phase 1) and the preparation of a proposed pilot project design for a single drainage. At this time Phase 2 will be funded using the balance of the Grant awarded to LCCD for this project. As currently conceptualized, such a pilot project will be a 10 to 20 cfs project delivering water into the targeted drainage for 50 to 150 days per year, for 2 to 3 years, in the autumn, winter, and spring. If authorized, Phase 2 likely will consist of several main elements:

- Identify and engage an entity that will be the permit holder for the pilot project (for such things as water rights, SEPA, construction, etc.), own and operate the pilot project, and execute any needed land access agreements, subcontracts, and reports.
- Secure an access to a route for the pilot project, including a point of withdrawal on Lake Roosevelt, delivery pipeline routing and pump station location(s), and the targeted drainage itself – especially to satisfy the needs and concerns of public and private landowners within the targeted drainage.
- Once the route is secured:
    - Develop a preliminary engineering design for the water withdrawal, transport, and delivery system, including potential modifications within the targeted drainage as needed to alleviate landowners concerns and potential choke points.
    - Refine the conceptual hydrogeologic model based on a more detailed field examination of the targeted drainage with the purpose of better predicting areas within it that have greater and lesser aquifer recharge potential. This effort might utilize the soon to be completed GWMA groundwater model.
    - Prepare preliminary characterization and monitoring plans for the proposed pilot project.

With completion of Phase 2 the project proponents will have selected and secured a route, and prepared pilot project characterization and monitoring plans, engineering plans with associated costs, and an implementation plan. With these documents the owning-operating entity should be in a position to prepare and submit permits needed to authorize and implement a 10 to 20 cfs pilot scale Rehydration Project, secure funding to build it, and execute contracts needed to make the pilot project happen. Permitting, funding, contracting, construction, and implementation of a pilot scale Rehydration Project will be done under Phase 3.

6.1.2 Phase 3 – Implementation of a 10 to 20 cfs Pilot Project in a Single Drainage

The current project concept for Phase 3 is to permit, fund, contract, construct, and implement a 10 to 20 cfs pilot scale Rehydration Project in one targeted drainage. This pilot project will deliver water from Lake Roosevelt to the targeted drainage approximately 50 to 150 days per year (depending on availability), generally in the autumn, winter, and spring, for 2 to 3 years. Such a project would deliver between approximately 1,000 and 6,000 acre-ft per recharge season. During the pilot project monitoring data will be collected in the target drainage and be compared to pre-project baseline data to see how the surface water and groundwater systems are responding to rehydration. Operational data will be collected and evaluated in an attempt to identify optimal operational scenarios and practices. At the completion of the pilot project several decisions will be evaluated. These include:

- Termination of the project as it is shown to not be a cost-effective way to deliver water into the project area, or
- Construction of additional pilot projects in other drainages is they are available and feasible and/or
- Expansion of the pilot project to maximize the rehydration and recharge potential in the targeted drainage.

Construction of additional pilot projects might result in an additional four 5 to 20 cfs projects in other drainages. Assuming these operate for 50 to 150 days per year, potential delivery volumes could range from approximately 1,000 to 12,000 acre-ft per season. This expansion would be done under Phase 4. Expansion in the target drainage could yield a 20 to 50 cfs project, operating 50 to 150 days per year. Such a project could deliver approximately 2,000 to 15,000 acre-ft of water to the targeted drainage each year. This expansion would be done under Phase 5. The decisions to proceed to Phase 4 and/or 5 would be based on performance and cost data collected in Phase 3.

6.1.3 Phase 4 – Expansion of 5 to 20 cfs Pilot Projects into Multiple Drainages and Phase 5 – Construction of a Full Sized, 50 to 250 cfs Rehydration Project in Multiple Drainages

In our estimation is clearly is premature to speculate at this time what potential Phase 4 and Phase 5 projects might look like. This is simply because work assessing the basic feasibility of the entire Rehydration Project being done under Phase 1 is just now complete and to be done under Phase 2 has not even been implemented. For broad brush planning purposes these projects might entail the delivery of water on the order of 25,000 to 75,000 acre-feet per year.

Nevertheless, if such a project occurs the potential water delivery and recharge volumes have the potential supply a significant part of the water currently being used by the 50,000 plus acres of groundwater supplied irrigation pumping now underway in the northeastern portion of the Odessa Groundwater Management Subarea. Under a final build-out scenario that currently envisions delivery of up to 250 cfs into the project area via several drainages in an average 150-day per year recharge window, approximately 75,000 acre-feet of water would be delivered into the project area. While this does not completely replace the groundwater pumping on the 50,000 plus irrigated acres in the project area, it would offset some of that pumping. More water would obviously be better, and would be needed to begin to replace groundwater already removed from aquifer storage. At this time though, we simply cannot predict if a larger project is feasible. That is the objective of Phase 3.

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Chapter 7: References

Bailey, M.M., 1989, Revisions to stratigraphic nomenclature of the Picture Gorge Basalt Subgroup, Columbia River Basalt Group, in, Reidel, S.P., and Hooper, P.R., eds., Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 67-84.

Bauer, H.H., and Hansen, A.J., Jr., 2000, Hydrology of the Columbia Plateau regional aquifer system, Washington, Oregon, and Idaho: U.S. Geological Survey Water-Resources Investigations Report 96-4106, 61 p.

Beeson, M.H., Fecht, K.R., Reidel, S.P., and Tolan, T.L., 1985, Regional correlations within the Frenchman Springs Member of the Columbia River Basalt Group - new insights into middle Miocene tectonics of northwestern Oregon: Oregon Geology, v. 47, no. 8, p. 87-96.

BPA, 1999, Lake Roosevelt Fisheries Evaluation Program; Limnological and Fisheries Monitoring, 1999 Annual Report. BPA Report DOE/BP-32148-8, Project No. 199404300, 226 p.

Camp, V.E., Ross, M.E., and Hansen, W.E., 2003, Genesis of flood basalts and Basin and Range volcanic rocks from Steens Mountain to the Malheur River Gorge, Oregon. Geological Society of America Bulletin, v. 115, p. 105-128.

Camp, V.E. and Ross, M.E., 2004, Mantle dynamics and genesis of mafic magmatism in intermontane Pacific Northwest. Journal of Geophysical Research, v. 109, B08204, doi: 10-129/2003JB002838.

Derkey, R.E. and Hamilton, M.M., 2009, Geologic map of the Olsen Canyon 7.5-minute quadrangle, Lincoln and Stevens Counties, Washington. Washington Division of Geology and Earth Resources Map GM-71.

Dion, N.P., Bortleson, G.C., McConnell, J.B., and Nelson, L.M., 1976, Reconnaissance data on Lakes in Washington, Adams, Benton, Douglas, Franklin, Grant, Lincoln, Walla Walla, and Whitman Counties. Department of Ecology Water-Supply Bulletin 43, vol 6.

Drost, B.W., and Whiteman, K.J., 1986, Surficial geology, structure, and thickness of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water-Resources Investigations Report 84-4326, 11 sheets.

Ecology, March 30 2005, Letter from Jay Manning, Director of Ecology, to William McDonald, Reclamation, acknowledging receipt of letter for request of "Withdrawal of Water for Yakima Basin Storage from Columbia River, 2 pp.

Ecology, October 5, 2006, Draft Programmatic Environmental Impact Statement for the Columbia River Water Management Program, Ecology Publication #06-11-030, 387 pp.

Ecology, February 15, 2007, Final Programmatic Environmental Impact Statement For the Columbia River Water Management Program Under Chapter 90.90 RCW, Volume 1 and 2, Ecology Publication #07-11-009, 446 pp.

Ecology, August 28, 2008, Final Supplemental Environmental Impact Statement for the Lake Roosevelt Incremental Storage Release Program, Ecology Publication #08-11-034, 514 pp.

Ecology, December 23, 2009, Letter from Ken Slattery, Ecology Program Manager, to William McDonald, Reclamation, for "Extension of Withdrawal of Water of the Columbia River and Tributaries", 4 pp.

Ecology and Reclamation, May 2007, Appraisal Evaluation of Columbia River Mainstem off-Channel Storage Options, Volume 1 and 2, 230 pp plus appendices.

Ecology and Reclamation, October 2010, Draft Environmental Impact Statement, Odessa Subarea Special Study. http://www.usbr.gov/pn/programs/eis/odessa/drafteis/draft-eis-odessa.pdf.

Ecology, n.d. Office of Columbia River. http://www.ecy.wa.gov/programs/wr/cwp/crwmp.html.

Farley, J.P., Solomon, M.D., Hinds, J.J., Grader, G.W., Bush, J.H., and Rand, A.L., 2006, Latah County Hydrologic Characterization Project, Final Report. Report submitted to Idaho Department of Water Resources.

Fecht, K. R., Reidel, S.P., and Tallman, A.M., 1987, Paleodrainage of the Columbia River system on the Columbia Plateau of Washington State—A Summary, in Schuster, J.E., ed., Selected papers on the geology of Washington: Washington Division of Geology and Earth Resources Bulletin 77, p 219 248.

Gephart, R.E., Arnett, R.C., Baca, R.G., Leonhart, L.S., Spane, F.A., Jr., 1979, Hydrologic studies within the Columbia Plateau, Washington - an integration of current knowledge: Richland, Washington, Rockwell Hanford Operations, Report RHO-BWI-ST-5.

Gulick, C.W., 1990, Geologic map of the Ritzville 1:100,000 Quadrangle, Washington. Washington Division of Geology and Earth Resources Open File Report 90-2.

Gulick, C.W. and Korosec, M.A., 1990, Geologic Map of the Banks Lake 1:100,000 Quadrangle, Washington. Washington Division of Geology and Earth Resources Open-File Report 90-6.

GWMA, 2009a, A summary of Columbia River Basalt Group geology and its influence on the hydrogeology of the Columbia River Basalt aquifer system, Columbia Basin Ground Water Management Area of Adams, Franklin, Grant, and Lincoln Counties, Washington: Consultant report prepared for Columbia Basin GWMA, prepared by GSI Water Solutions, Inc., June 2009.

GWMA, 2009b, Geologic framework of selected sedimentary and Columbia River Basalt Group units in the Columbia Basin Ground Water Management Area of Adams, Franklin, Grant, and Lincoln Counties, Washington, Edition 3: Consultant report prepared for Columbia Basin GWMA, prepared by GSI Water Solutions, Inc., and the Franklin County Conservation District, June 2009.

GWMA, 2009c, Groundwater geochemistry of the Columbia River Basalt Group aquifer system – Columbia Basin Ground Water Management Area of Adams, Franklin, Grant, and Lincoln Counties, Washington: Consultant report prepared for Columbia Basin GWMA, prepared by S.S. Papadopoulos and Associates, Inc., and GSI Water Solutions, Inc., June 2009.

GWMA, 2009d, Groundwater level declines in the Columbia River Basalt Group and their relationship to mechanisms for groundwater recharge: A conceptual groundwater system model for the Columbia Basin Ground Water Management Area of Adams, Franklin, Grant, and Lincoln Counties, Washington: Consultant report prepared for Columbia Basin GWMA, prepared by GSI Water Solutions, Inc., June 2009.

Hansen, A.J., Jr., Vaccaro, J.J., and Bauer, H.H., 1994, Ground-water flow simulation of the Columbia Plateau regional aquifer system, Washington, Oregon, and Idaho: U.S. Geological Survey, Water-Resources Investigations Report 91-4187, 81 p., 15 sheets.

Hodges, C.A., 1978, Basaltic ring dike structures of the Columbia Plateau. Geological Society of America Bulletin, v. 89, p. 1281-1289.

Jaeger, W.L., Keszthelyi, L.P., Burr, D.M., McEwen, A.S., Baker, V.R., Miyamoto, H., and Beyer, R.A., 2003. Ring dike structures in the channeled scabland as analogs for circular features in Athabasca Valles, Mars. Lunar and Planetary Science, Volume XXXIV.

Joseph, N.L., 1990, Geologic map of the Spokane 1:100,000 Quadrangle, Washington. Washington Division of Geology and Earth Resources Open File Report 90-17.

Kahle, S.C., Olsen, T.D., and Morgan, D.S., 2009, Geologic setting and hydrogeologic units of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho. U.S. Geological Survey Scientific Investigations Map 3088, 1 sheet.

Kennedy/Jenks Consultants, 2005, Watershed assessment report, Water Resource Inventory Area 43, Upper Crab Creek – Wilson Creek watershed: Consultants report prepared for Lincoln County (Davenport, Washington). November 2005.

LCCD, 2000, Lake Creek Watershed Water Reuse Feasibility Study Report. Prepared by Lincoln County Conservation District for Department of Ecology.

Myers, C.W., and Price, S.M., eds., 1979, Geologic studies of the Columbia Plateau – a status report: Rockwell Hanford Operations, Richland, Washington, Report RHO-BWI-ST-4, 520 p.

Newcomb, R.C., 1959, Some preliminary notes on ground water in the Columbia River basalt: Northwest Science, v. 33, no. 1, p. 1-18.

NOAA Fisheries, May 5, 2008, Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and other Tributary Actions: 194 pp.

Packard, F.A., Hansen, A.J., Jr., and Bauer, H.H., 1996, Hydrogeology and simulation of flow and the effects of development alternatives on the basalt aquifers of the Horse Heaven Hills, south-central Washington: U.S. Geological Survey Water-Resources Investigations Report 94-4068, 92 p.

PNNL (Batelle-Pacific Northwest National Laboratory), 2002, Natural gas storage in basalt aquifers of the Columbia Basin, Pacific Northwest USA – a guide to site characterization: Pacific Northwest Laboratory, Richland, Washington, Report PNNL-13962.

Reidel, S.P., Fecht, K.R., Hagood, M.C., and Tolan, T.L., 1989a, The geologic evolution of the central Columbia Plateau, in Washington, Oregon, and Idaho, in Reidel, S.P. and Hooper, P.R., eds., Volcanism and Tectonism in the Columbia River Flood-Basalt Province. Geological Society of America Special Paper 239, p. 247-264.

Reidel, S.P., Tolan, T.L., Hooper P.R., Beeson, M.H., Fecht, K.R., Bentley, R.D., and Anderson, J.L., 1989b, The Grande Ronde Basalt, Columbia River Basalt Group: Stratigraphic descriptions and correlations in Washington, Oregon, and Idaho, in Reidel, S.P. and Hooper, P.R., eds., Volcanism and Tectonism in the Columbia River Flood-Basalt Province. Geological Society of America Special Paper 239, p. 21-53.

Sabol, M.A., and Downey, S.E., 1997, Support document for consideration of the eastern Columbia Plateau aquifer system as a sole-source aquifer: Seattle, Washington, U.S. Environmental Protection Agency, Document 910/R-97-002, 35 p.

Scott, P.G. 2008. Aquifer Recharge and Storage, Ongoing Implementation Concerns. The Water Report, Issue 54. Envirotech Publications. http://www.gsjw.com/catalogs/catalog110/section175/file554.pdf.

Smith, G.A., Bjornstad, B.N., and Fecht, K.R., 1989, Neogene terrestrial sedimentation on and adjacent to the Columbia Plateau: Washington, Oregon and Idaho, in Reidel, S.P., and Hooper, P.R., eds., Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 187-198.

Swanson, D.A., Wright, T.L., Camp, V.E., Gardner, J.N., Helz, R.T., Price, S.M., Reidel, S.P., and Ross, M.E., 1980, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1139, scale 1:250,000.

Swanson, D.A., Wright, T.L., Hooper, P.R., and Bentley, R.D., 1979a, Revision in the stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p.

Swanson, D.A., Anderson, J.L., Bentley, R.D., Camp, V.E., Gardner, J.N., and Wright, T.L., 1979b, Reconnaissance geologic map of the Columbia River Basalt Group in Washington and adjacent Idaho: U.S. Geological Survey Open-File Report 79-1363, scale 1:250,000.

Tolan, T.L., and Reidel, S.P., compilers, 1989, Structure map of a portion of the Columbia River flood-basalt province, in, Reidel, S.P., and Hooper, P.R., eds., Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, Plate 1, scale 1:576,000.

Tolan, T.L., Martin, B.S., Reidel, S.P., Anderson, J.L., Lindsey, K.A., and Burt, W., 2009, An introduction to the stratigraphy, structural geology, and hydrogeology of the Columbia River Flood Basalt Province: A primer for the GSA Columbia River Basalt Group field trips, in O'Conner, J.E., Dorsey, R.J., and Madin, I.P., eds., Volcanoes to Vineyards: Geologic Field Trips through the Dynamic Landscape of the Pacific Northwest: Geological Society of America Field Trip Guide 15, p. 599-643.

Tolan, T.L., Reidel, S.P., Beeson, M.H., Anderson, J.L., Fecht, K.R., and Swanson, D.A., 1989, Revisions to the estimates of the areal extent and volume of the Columbia River Basalt Group, in, Reidel, S.P., and Hooper, P.R., eds., Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 1-20.

USDOE (U.S. Department of Energy), 1988, Site characterization plan, Reference Repository Location, Hanford Site, Washington - consultation draft: Washington, D.C., Office of Civilian Radioactive Waste Management, DOE/RW-0164, v. 1 - 9.

US Department of Interior-Reclamation, December 28, 2004, Letter from William McDonald, Reclamation, to Joe Stohr, Ecology Water Resource Program Manager, requesting "Withdrawal of Water for Yakima Basin Storage from the Columbia River", 3 pp.

Waggoner, S.Z., 1990a, Geologic map of the Coulee Dam 1:100,000 Quadrangle, Washington. Washington Division of Geology and Earth Resources Open File Report 90-15.

Waggoner, S.Z., 1990b, Geologic map of the Rosalia 1:100,000 Quadrangle, Washington. Washington Division of Geology and Earth Resources Open File Report 90-7.

Whiteman, K.J., Vaccaro, J.J., Gonthier, J.B., and Bauer, H.H., 1994, Hydrological framework and geochemistry of the Columbia Plateau aquifer system in parts of Washington, Oregon, and Idaho: U.S. Geological Survey Professional Paper 1413-B, 73 p.

WDFW, 2005, 2003 Warmwater Fisheries Surveys of Upper and Lower Twin Lakes, Lincoln County, compiled by Marc Divens and Randall Osborne, Washington Department of Fish and Wildlife Fish Program Science Division.

Glossary

Term	Definition
alluvium	Detrital deposits made by streams on river beds, floodplains and alluvial fans; especially a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include subaqueous sediments of seas and lakes.
anticline	A fold, generally convex upward, whose core contains the stratigraphically older rocks.
aquifer	A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.
brecciated	Angular broken rock fragments held together by a mineral cement or a fine-grained matrix.
colluvial	Pertaining to colluviums, which is a general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity. Talus and cliff debris are included in such deposits.
coulee	In the northwestern U.S. it is a dry or intermittent stream valley, especially a long trench-like gorge that once carried melt water from an ice sheet.
dike	A tabular body of igneous rock that cuts across the structure of adjacent rocks or cuts massive rocks.
dip	The angle that a stratum or any planar feature makes with the horizontal, measured perpendicular to the strike and in the vertical plane.
emplacement	The process of intrusion of igneous rocks. The localization of ore minerals by any process; ore deposition.
evapotranspiration	That portion of the precipitation returned to the air through evaporation and transpiration.
facies	The aspect, appearance, and characteristics of a rock unit, usually reflecting the conditions of its origin; especially as differentiating from adjacent or associated units.
felsic	A mnemonic adjective derived from feldspar and silica and applied to an igneous rock having abundant light-colored minerals; also applied to those minerals (quartz, feldspars, feldspathoids, muscovite) as a group.
hardpan	A hard, impervious, often clayey layer of soil at or just below the surface, produced by cementation of soil particles by relatively insoluble materials such as silica, iron oxide, and organic matter.

Term	Definition
Holocene	An epoch of the Quaternary period, from the end of the Pleistocene, approximately 8,000 years ago, to the present time; also the corresponding series of rocks and deposits.
hydrograph	A graph showing stage, flow, velocity, or other characteristics of water with respect to time.
hydraulic continuity	The scientific term that describes how easily water flows between groundwater and surface water (streams, rivers, lakes and wetlands.)
infiltration	The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock.
interbed	A bed, typically thin, of one kind of rock material occurring between alternating with beds of another kind.
loess	A blanket deposit of buff-colored calcareous silt, homogeneous, nonstratified, weakly coherent, porous, and friable. A rude vertical parting allows it to stand in steep or vertical faces. It is considered to be windblown dust of Pleistocene age.
Miocene	An epoch of the early Tertiary period, after the Oligocene and before the Pliocene; also the corresponding worldwide series of rocks.
Missoula flood	Also known as the Spokane Floods or Bretz Floods, refer to the cataclysmic floods that swept periodically across Eastern Washington and down the Columbia River Gorge during the last ice age. Geologists estimate the flooding occurred around a 2,000-year period between 15,000 and 13,000 years ago.
monocline	A local steepening in an otherwise uniform gentle dip.
paleoslope	The direction of initial dip of a former land surface, such as an ancient continental.
perched aquifer	An aquifer that occurs above the regional water table, in the vadose zone. This occurs when there is an impermeable layer of rock or sediment, above the main water table but below the surface of the land.
piezometer	A small diameter observation well used to measure the hydraulic head of groundwater in aquifers.
Pleistocene	An epoch of the Quaternary period, after the Pliocene of the Tertiary and before the Holocene; also the corresponding worldwide series of rocks. It began 2 to 3 million years ago and lasted until the start of the Holocene some 8,000 years ago.

Term	Definition
Quaternary	The second period of the Cenozoic era, following the Tertiary; also the corresponding system of rocks. It began 2 to 3 million years ago and extends to the present.
scabland	An elevated area, underlain by flat-lying basalt flows, with a thin soil cover and sparse vegetation, and usually with deep, dry channels scoured into the surface. In Eastern Washington the lava plateau was widely and deeply eroded by glacial melt waters.
steptoe	An isolated hill or mountain of older rock surrounded by a lava flow.
suprabasalt	Sedimentary strata above the basalt.
syncline	A fold of which the core contains the stratigraphically younger rocks; it is generally concave upward.
tholeitic flood basalt	A basalt characterized by the presence of orthopyroxene and/or pigeonite in addition to clinopyroxene and calcic plagioclase. Olivine may be present.
vesicle	A small cavity in an aphanitic or glassy igneous rock, formed by the expansion of a bubble of gas or steam during the solidification of the rock.

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LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE

Comment Number	Comment Submitted By:	Comment	Comment Response
1	Adrea Bezdicek	General supporting comments: "I would like to see the Lincoln County Passive Rehydration Project looked into further and possibly put to use." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
2	Jim Bauer	General comment: "With the economic situation the state is in and the federal government as well, why don't they just shut down the deep well irrigators and solve the problem at the source."	Comment noted
3	Clint Campbell	General supporting comments: "I believe that the Odessa aquifer needs to be rehydrated to help farmers keep their crops growing in an ever increasing dry area. The extra water would help create a micro climate that would increase rainfall around the area making the local crops that much more productive which would in turn help the economy."	Positive supporting comment. No response required.
4	Everett and Karen Cole, EKCO Ranchers	Numerous concerns regarding impact to there property: 1) Increased stream flows will cut ranch in half through the Tracy Meadow area; 2) Increased water in creek may lead to regulating cows away from the creek for water quality standards, possibly causing removal of cattle and loss of winter feeding and calving area; 3) Project will cause some ground to be lost for alfalfa production of 2 ton per acre; 4) Upper feed lot may be inundated and not be available for use; 5) Lower feed lot may be lost due to proximity of stream; 6) Water conveyed from Lake Roosevelt may have nonnative plant seeds casing problems with noxious weed laws; 7) New stream flows will bring recreation seekers, thus causing problems with trespassers; 8) Increase of recreational users can bring increase of noxious weed issues from transport on vehicles, equipment, etc.; 9) Increase recreational users would drastically increase probability of range fires; 10) Their driveway to lower ranch would need to be relocated, and a culvert near house would need to be replaced with a bridge or larger culvert; 11) Fencing will be required to keep cattle from stream.	Comment noted. These concern's will be addressed with the property owner during Feasibility Phase when property owner agreements are developed.

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE

Comment Number	Comment Submitted By:	Comment	Comment Response
		Everett's have concern that the project may jeopardize their 100 year old ranch operation.	
5	Robert Derkey	General Supporting Comments: "Funding for this study, I feel has an excellent chance for success. That success could revitalize an area that could then continue to contribute to the economic well-being of the state." Other comments supporting geologic viability of project. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
6	Dale Deife, Deife Farms	General supporting comments: "I am writing in support of the Lincoln County Passive Rehydration Project. I live and operate an irrigated farm in the Odessa area. I believe that the Rehydration Project is a great way to recharge the Odessa aquifer." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
7	Mark DeWulf, Brock Carpenter, McGuiire & DeWulf, P.S.	General supporting comment: "I am absolutely in favor of the Passive Rehydration Project. In my experience in dealing with my clients, there is a shortage of water in the area. The geographic area in which this pre-feasibility study was performed is in dire need of water to correct or at least help correct the problem of the declining water table and over allocation of water in the Odessa subarea in general and in the Lake Creek drainage specifically." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
8	Drew Fink	General supporting comment: " I personally would like to see this rehydration project come to pass…, I don't know if this project will solve all our problems for the area, but it would be nice to see water in Pacific Lake again." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
9	Leslie Fink	General supporting comments: "After reading over the information on the website, it is important to continue to look into replenishing the surface and groundwater in the Odessa Sub area. We cannot go back to the "could have, should have" but instead move forward to solutions that will benefit the area farmers, recreation, wildlife, etc.". (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
10	Neil Fink	General supporting comments: "I would like to express my support of the Lincoln County Passive Rehydration Project." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
11	Steven Fink	General supporting comments: " I believe it is in everybody's	Positive supporting comment. No response required.

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE

Comment Number	Comment Submitted By:	Comment	Comment Response
		best interest to continue with the rehydration plan." (*Additional comment on attached sheet.)*	
12	GWMA	General Supporting comments: "We support the proposed pilot project concept to evaluate the effectiveness of rehydration as proposed in the reports." - We suggest that watershed small storage and other proposed improvements within the selected watershed could easily enhance the effectiveness of surface storage and passive rehydration potential. - We encourage the State Legislature and the State DOE to favorably consider the request for temporary and potential permanent water rights from the Columbia River. We recognize the Columbia River as the only significant source of water available to address these water issue needs. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
13	Kris Hubbard	We do not want to stand in the way of the Passive Rehydration Project but, the economic loss to our ranch and cost of restructuring would catastrophic, if it ran through our ranch. With this in mind, we would support - piping the water past us, and delivering it into Z Lake, below our ranch.	Comment noted. These concern's will be addressed with the property owner during Feasibility Phase when property owner agreements are developed.
14	Clark Kagle	General comments supporting the work the GWMA has done and the need to move forward with the feasibility phase of the project. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
15	Matthew Kagele	General supporting comments: "I would like write in support of this project. I do realize that this one project alone will not recharge the aquifers by itself. However, this project could be just what we need to get the ball rolling for the start of other projects to bring water across this sub-area in all of the other channels. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
16	Joanne Keller	General supporting comments: "As a Tax paying Land Owner, you have my sincere support in asking to work to improve the ground water supply to the Odessa Lincoln, Adams County, area…. As advised in the currant publication of the Odessa Record, please accept a resounding affirmative to the request for action to solving this problem. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
17	Alex King	General supporting comment: " Please start the rehydration process for Lincoln County." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE

Comment Number	Comment Submitted By:	Comment	Comment Response
18	Faye King	General Comment supporting the findings of the report and recommendation to "fast track" this project as soon as possible. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
19	Wes King	General Supporting comment: "Please start the rehydration process. If our ranch loses its water supply it will definitely decrease our tax base and land values."	Positive supporting comment. No response required.
20	Clinton Knight	General supporting comments: "I am writing to express my support of the Lincoln County Passive Rehydration Project." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
21	Marcella Knight	General supporting comment: "I would like to see this project move forward. I see great potential benefits for community members and visitors."	Positive supporting comment. No response required.
22	Lincoln County Board of County Commissioners	General Supporting comments: "We support the proposed pilot project concept to evaluate the effectiveness of rehydration as proposed in the reports." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
23	Lincoln County EDC	General supporting comment: "On January 20th, 2011 the Board of Directors of the Lincoln County Economic Development Council voted unanimously to support moving forward with the Feasibility Study and Pilot Testing Program in 2011." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
24	Mayor Doug Plinski, Town of Odessa	General supporting comments: " I commend you and your team for the excellent explanations and presentations throughout Lincoln County regarding the Passive Rehydration project. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
25	Robert McKee	General supporting comments	Positive supporting comment. No response required.
26	Keith Nelson	General supporting comments: "Lincoln County Passive Rehydration is a good project. If Passive Rehydration can help this area it is a good use of money spent. This project hopefully will mitigate some of the damage done by irrigation." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
27	Tom Null	General supporting comments	Positive supporting comment. No response required.
28	Odessa Chamber of Commerce	General supporting comments: " The Odessa Chamber of Commerce, on behalf of its members, would like to convey its support for the additional study of the feasibility of rehydrating the Odessa subaquifer. We support moving forward with the feasibility study and with efforts to determine the best way to achieve rehydration of the Lake Creek System." (*Additional*	Positive supporting comment. No response required.

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE

Comment Number	Comment Submitted By:	Comment	Comment Response
		comment on attached sheet.)	
29	Darrel Parsons	Numerous comments documenting concerns with the project relative to stream flows through owner's property. Concern flows in creek will have unintended environmental consequences to fish habitat in parts of Lake Creek. Also concerned current marsh lands may be flooded beyond what is useful for waterfowl raising of their young. Increased stream flows may also prevent usage of ranch land on the north side of Lake Creek. Skeptic of project success. Concern's outlined in more detailed in attached sheet.	Comment noted. These concern's will be addressed with the property owner during Feasibility Phase when property owner agreements are developed.
30	Harry & Roylin Price	General supporting comments: "After reading the study and reports it appears to us that rehydration via Lake Creek from Lake Roosevelt is the most likely and practical approach. We are (definitely) in favor of this project and look forward to further updates." *(Additional comment on attached sheet.)*	Positive supporting comment. No response required.
31	Richard Quirk	General supporting comment: "I am in favor of moving ahead on this project".	Positive supporting comment. No response required.
32	Mayor Sherman Johnson, Town of Reardan	General supporting comments: " As mayor of the Town of Reardan, representing the opinions and concerns of our Town Council, we strongly support the Prefeasibility Report and vigorously support the concept of passive rehydration." *(Additional comment on attached sheet.)*	Positive supporting comment. No response required.
33	George Rodeck	General comments supporting the project as beneficial to farmers, small business, small community governments, schools, churches, recreation, wildlife and to the economy. *(Additional comment on attached sheet.)*	Positive supporting comment. No response required.
34	Jerry Schafer	General supporting comments. Also recommends construction of small dams. "This is a project that can do so much for the environment, recreation, wildlife enhancement, and a multitude of positive things much needed." *(Additional comment on attached sheet.)*	Comment noted
35	Paul Scheller	General supporting comments: "I am writing to show my support of the Passive Rehydration Project in Lincoln County". *(Additional comment on attached sheet.)*	Positive supporting comment. No response required.
36	Dennis Schlimmer	General supporting comments to stop declining aquifers and fill lakes.	Positive supporting comment. No response required.
37	Rodney Schlimmer	General supporting comments: "As a Lincoln county land owner who's property includes part of Goetz and Sullivan Lakes in	Positive supporting comment. No response required.

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE

Comment Number	Comment Submitted By:	Comment	Comment Response
		what is referred to as Marlin Hollow I want to be counted as one in favor of the rehydration plans currently being discussed. Count me in!"	
38	Steve Schmierer	General supporting comments. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
39	Alan Schorzman, Schorzman Farms JV	General supporting comments: "I am writing in support and stress the utmost urgent need to move forward in a positive direction continuing the feasibility assessment studies of engineering, water availability from the BOR, Ecology, or any other potentially available water rights leading to the ultimate objective of delivering water from Lake Roosevelt into the Crab Creek drainage watershed…." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
40	Mary Schorzman	General supporting comments: "The prefeasibility studies of the rehydration of the Crab Creek drainage has the one of the greatest potentials of beginning the reversing of rehydrating the Crab Creek drainage and the aquifer by filling and keeping full all the lakes and streams between the withdrawal discharge point and including Crab Creek." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
41	Jay Scrupps Farm	General supporting comments. Discusses the properties dropping well levels. Supports benefit of the project to agriculture and wildlife. Discusses benefits to economy. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
42	Lorus Scrupps	General supporting comments. Discusses his dropping wells and has property in Lake Creek drainage on which a 30 acre lake could be refilled. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
43	Sally Siegel	Discussion of ongoing water shortages in the Odessa area. Discusses family farm issues occurring. Concerned of future growth further impairing water supplies without implementing more of the Columbia basin Irrigation Project. (*Additional comment on attached sheet.)*	Comment noted. No action required.
44	Spokane Tribe of Indians	Letter submitted documenting the Tribe's interests and concerns that their rights will be affected if the project progresses. Summarized concerns are the affect of project on Tribe's ancestral fishing and water resources. Specifically: 1) Water Quality – the proposed project has the potential to degrade water quality in portions of the Spokane	Comments noted. Most of these questions will be addressed during the feasibility phase of the project, at which time some consultation with the tribe will be conducted over these concerns.

Comment Number	Comment Submitted By:	Comment	Comment Response
		Tribe's jurisdiction. Any future feasibility study must analyze water quality effects within the Spokane and Columbia Rivers. 2) Water Quantity – the Tribe holds unquantified water rights for both in stream and out of stream purposes in both the Columbia River and Spokane River with a priority date of 1877. The project has the potential to infringe on the Tribe's rights and the Tribe is very skeptical of all projects within its jurisdiction that claim there is surplus water available. 3) The Columbia River Treaty is currently under review. As the Treaty is changed so will water availability for projects such as this one. It is critically important that any future feasibility study analyze water supply issues beyond what may be available currently. 4) Fishery – this proposed project has the potential to affect the Tribe's fishery and any future feasibility studies must adequately address potential negative effects. Additionally, the Tribe is pursuing the reintroduction of anadromous fish above Grand Coulee and any future projects must ensure that future projects will not infringe on this Tribal goal. 5) Pollutants in Lake Roosevelt – Lake Roosevelt contains numerous pollutants including, but not limited to metals, uranium mining waste, and PCBs. Any future study should address the potential effects of utilizing contaminated water in an attempt to refill an aquifer, irrigate and add to stream flows. Furthermore, piping polluted water and introducing it via a point source to another location will likely present a variety of permitting issues. 6) Cultural Resources – any projects of this scale will need to address cultural impacts off the Reservation. Additionally, Lake elevations changes due to the project may very well affect the numerous cultural sites along the Rivers and affect the stability of the banks along the Rivers. The routing infrastructure needed for this project will have the potential to affect cultural resources and these concerns will need to be	

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE

Comment Number	Comment Submitted By:	Comment	Comment Response
		considered during future studies. 7) Economic Interests – The Tribe operates the Two Rivers Resort which includes a houseboat rental operation, a marina, a boat launch, RV camping, an amphitheatre for music events and a small casino. Potential lowering of lake elevations from the proposed project that may affect these operations must be part of any future feasibility study. *(Additional comment on attached sheet.)*	
45	Richard Teel	The current proposed 24" pipe line is a fraction of the size needed to do any good. … I don't feel just because the money is available this small test project should be done….Make this test a size that will actually rehydrate." (*Additional comment on attached sheet.)*	Comment noted
46	Chester Templin	General supporting comment. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
47	Alan Voise	General supporting comment: " Please keep working on the passive rehydration project to get it completed." (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
48	James Walter	General supporting comment. Discussion on historical reduction of flow in Coal Creek on property. (*Additional comment on attached sheet.)*	Positive supporting comment. No response required.
49	John Watson	General comments regarding sinking creek. Passive appears to be a good idea but some concern to spend money on Feasibility Studies without having a good idea where the money would come from to complete the project. (*Additional comment on attached sheet.)*	Comment noted
50	Dean White - LCCD	1) I could not find much supporting text that describes the fracture zone box in Figures 14-15, 17-18 and 20-25 that runs from southeast to northwest in the Lincoln County. This fracture zone box covers the upper reaches of Lake Creek just south of Highway 2 where surface water from Lake Roosevelt would most likely be introduced Lake Creek, should the pilot project for passive rehydration project proceed forward. What if any affect would the fracture zone have on water introduced to the upper reaches of Lake Creek just south of Highway 2? What affect on hydrogeology, if any, does the fracture zone have on the rest of the county to the southeast towards Sprague Lake?	Edits made in report to clarify questions.

Comment Number	Comment Submitted By:	Comment	Comment Response
		2) The two Roza dike/vent boxes shown in Figures 14-15, 17-18 and 20-25 that run from southeast to northwest in the Lincoln County have been drawn using inferences from known Roza dikes/vents that have been found to the southeast of Lincoln County, according to the text on page 14. One Roza dike that has been found in the county at Tavares Lake is located on the figures, but this is the only one noted. Is there more information that helps to support the existence of more Roza dikes that are buried underground and that can't be seen? There seems to be a lot of unknowns about where the actual dikes may be located within the two box areas. How does one infer how continuous or discontinuous the Roza dikes may be within the boxes? Is there well information for wells to the NE and to the SW of the Roza dike boxes that indicate that there are vertical Roza dike barriers affecting the hydrogeology of the wells NE and SW of the Roza dike boxes? The presence (or absence) of Roza flow dikes would appear to be very important for infiltrating water into the lower Wanapum and upper Grande Ronde basalts because any vertical Roza dikes would have to cut up through many feet of basalt below the Roza flow in order to have supplied the basalt for the Roza flow, and could act as a barrier to water moving in the basalt interflow zones from northeast to southwest. 3) The text on page 14 mentions that Priest Rapids flow dikes are also inferred to be present in the eastern and north central part of Lincoln County, based on projections from known Priest Rapids dikes to the southeast of the county. However, the two dike boxes listed on Figure 14, the structure contour map for the Priest Rapids flow, are listed as being Roza dike boxes, and the location and extent of these dike boxes are identical to the Roza dike boxes listed in other figures. Are there dikes for the Priest Rapids flow located in the same area as the dikes for the Roza flow? Any dikes for the Priest Rapid flow would cut even higher up through to the uppermost layers of basalt in the county. 4) It would be helpful to have an additional full size map with aerial photo base and important roads (Redwine Canyon, Welch Creek, Moonshine Canyon, Copenhaver, and Telford roads along with Highway 2) to give the reader a better idea of where	

Comment Number	Comment Submitted By:	Comment	Comment Response
		the 3 proposed pipe routes and the current preferred Lincoln pipe route option would run. The map in Figure 31 is a little small and hard to follow. 5.) The caption for Figure 33, Moonshine Canyon route, mentions that the view is looking SOUTH up the canyon. As far as I can tell, the view appears to be to the NORTH, down Moonshine Canyon toward Lake Roosevelt at the top center of the map photo. 6) The caption for Figure 34, Welch Creek Road route, mentions that the view is looking SOUTH up the canyon. As far as I can tell, the view appears to be the NORTH, down Welch Creek Canyon toward Lincoln and Lake Roosevelt at the top center of the map photo. I have been doing well level measuring for the WRIA 53 watershed planning unit in both areas covered by Figure 33 and Figure 34 for the past year, and I recognize both views as looking towards the north towards Lake Roosevelt. (*Additional comment on attached sheet.)*	

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE TO ECOLOGY COMMENTS

Comment Number	Comment Submitted By:	Comment	Comment Response
1	Ecology - ERO	The report establishes "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 Columbia River Basin (CRB) aquifer system, and if feasible conduct a pilot scale demonstration project." The analysis does not quantify or project what those needs might be. The report notes "long term operational requirements for instantaneous and annual quantities are not known at this time" (section 4.1). Thus, an initial assessment of project feasibility is not possible.	Edits made to draft report: The introduction to the report was revised to more clearly describe the overall project concept and its phases, from pre-feasibility to completion (as envisioned conceptually right now). The revised introduction now clearly states where this report fits into an overall concept of what the project intends to accomplish with this report, and what isintended to accomplish with subsequent phases, if they are authorized.
2	Ecology - ERO	The report suggests that the long term goal is to acquire and "recharge a minimum of 50,000 acre-feet" or "200,000 acre-feet" , or "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 " (Section 4.1). Elsewhere, it shifts emphasis (section 5.7) to lake storage and Crab Creek flows, although, there is no attempt at quantification of the ability of any discussed drainage to receive additional flow. (Reference sections 5.1-5.3)	Edit made to report describing the water volumes/targets envisioned in each project phase and a differentiation between the surface water and groundwater goals, for all potential phases of the project.
3	Ecology - ERO	Lincoln County Conservation District (LCCD) needs to establish and describe specific goals and objectives for the project to permit assessment of alternative ways of achieving them. It should be clear at this point that a project that has the goal of reestablishing surface water flows in Lincoln County is significantly different than one that has the goal of rehydrating ground water supplies for the Odessa Sub-area. It is not clear which objective this project intends to achieve. Project objectives should be made clearer in the final draft of this report.	Edit made to report –The goals/objective statement will be clarified as part of the revised introductions noted in items 1 and 2 above.
4	Ecology - ERO	No attempt at a water right survey is present. While the discussion in section 4 presents an overview, the grant agreement contemplated assembling basic information on water rights in the Crab Creek drainage to determine water needs, and in the Columbia River to determine water availability. Much of that information should be available from the watershed plan for WRIA 43.	Edit made to report in Section 3.1 to address potential availability of water rights. The water rights sections address where water could come from for a pilot, and potential future large project. At this time we do not address consumptive uses in Crab Creek system because that is premature.
5	Ecology - ERO	No cost structure, or alternative structures are proposed in the governance section. Who pays?	Kevin – As written the grant states that a preliminary evaluation will be conducted so that preliminary scenarios can be developed to determine proposed management and cost operational cost structure. The preliminary evaluation was done. An operational structure will be defined in the feasibility phase, at which point funding structure, including who pays, will be able to be addressed.

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE TO ECOLOGY COMMENTS

Comment Number	Comment Submitted By:	Comment	Comment Response
6	Ecology - ERO	No estimate of spatial, temporal, and volumetric water requirements for each candidate drainage to meet project objectives is prepared. (Task 3.1 (3)(b)) See above comment on project objectives.	Kevin – The report proposes 10 to 20 cfs for a pilot project, likely done in the winter spring, preferably on Lake Creek. Since that is not clear to the reviewer, we will clarify that in the executive summary, introduction, and elsewhere. With respect to longer term needs the report describes the general targets (in section 1 and section 6).
7	Ecology - ERO	Place names are not located on maps, and figures are not located with places in the study area. Please thoroughly edit to ensure all place names in the document are located on a map, and all photographs are from named places within the study area.	Edits made in report throughout document.
8	Ecology - ERO	In Section 1.0: Please reference the "300,000 acres irrigated with groundwater" report. This figure seems high, and would need to include many irrigating with artificially stored groundwater or other water potentially subject to the Columbia Basin Project in the Quincy Basin, or the so-called "508-14" area.	Acreages checked, and revised as needed.
9	Ecology - ERO	In Section 2.0: Please revise objectives to reflect the grant contract. The basic objective of this project is to evaluate the feasibility of pumping surface water from Lake Roosevelt into the upper portion of a yet to be determined surface drainage in the northern portion of Lincoln County and then letting that water flow down that drainage, refilling currently dry or diminished lakes and recharging alluvial and basalt aquifers under natural conditions. The pre-feasibility project was to evaluate engineering, hydrogeologic, regulatory, permitting, ownership, water rights, and other issues related to developing a pumping and storage/infiltration project	Edits made in report as outlined in comment 1, 2, and 3.
10	Ecology - ERO	In Section 3.1: All geographic features named in the report should be located on a map. Also, "Pleistocene Cataclysmic Flood Waters" is a bit dramatic, and should not be capitalized.	Edits made in report to reflect Ecology's request.
11	Ecology - ERO	In Section 3.1: The final paragraphs of this section, and the first two paragraphs of Section 3.2, are redundant to the remaining portions of the respective sections. Please edit.	Edit made in report to remove redundancy.
12	Ecology - ERO	In Section 3.2: Please discuss fish species.	Fish species of concern added to document in Section 2.2 for Crab Creek and Columbia River.
13	Ecology - ERO	In Section 3.3.2, page 12: The 4th paragraph of this section does not make sense. Please revise.	Edit made to report for clarification.
14	Ecology - ERO	In Section 3.3.2, final paragraph: Please revise considering recharge seasonally rather than on an annual basis, or otherwise reflect the importance of spring snowmelt on recharge to shallow groundwater	Edits made to note that recharge is largely confined to the spring snowmelt and runoff season. The development of a more detailed hydrologic analysis in

LINCOLN COUNTY PASSIVE REHYDRATION PREFEASIBILITY REPORT
COMMENT RESPONSE TABLE TO ECOLOGY COMMENTS

Comment Number	Comment Submitted By:	Comment	Comment Response
			the Feasibility Phase of the study will help to confirm seasonality.
15	Ecology -ERO	In Section 3.3.3.1: The dominant features on the maps of this document are a dike swarm inferred from one exposure and no mapped "tephra" deposits? Please factually justify the inferred boundary and extent of these features, and document their hydrogeologic significance.	Edits made to report to support the case that dikes are likely present in the area.
16	Ecology -ERO	In Section 3.3.3.1: Figure 19 indicates ring dikes are associated with Roza and Priest Rapids formations, and the symbol used indicates they are all the same size. Please revise so that text and figure are consistent.	Edits made to Figure and text.
17	Ecology -ERO	In Section 3.3.4: Steptoes are not "extruded".	Typo corrected in text.
18	Ecology - ERO	In Section 3.3.5: Please reference any postulated structural origin for steptoes.	Addressed to extent we deem appropriate given purpose of report.
19	Ecology - ERO	In Section 3.3.5: Please reference any tectonic hypothesis for the structural and hydrologic divide in basalt in northern Lincoln County.	Addressed to extent we deem appropriate given purpose of report.
20	Ecology - ERO	In Section 3.3.6: Rewrite to distinguish between litho-and hydro-stratigraphic units. Substantial field evidence supports an upper, high-head aquifer system, and a lower, low head aquifer system generally hosted in the Grande Ronde Basalt. That hydrostratigraphic framework and nomenclature has been widely adopted and published by numerous researchers and organizations. Please discuss the commonly accepted hydrostratigraphic nomenclature of the Columbia Basin, as published by the USGS in the Regional Aquifer System Analysis program, culminating in: Bauer, H.H., and Hansen, A.J., Jr., 2000, Hydrology of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho: U.S. Geological Survey Water-Resources Investigations Report 96-4106, 61 p. as applied in the Lincoln County portion of the Columbia basin.	Report edited and citations provided as necessary to support project team's conceptual model and related conclusions.
21	Ecology - ERO	In Section 3.3.6: Your interpretation of recharge mechanisms is consistent with some GWMA publications similarly authored by GSI, though does not acknowledge the deep percolation recharge mechanism Bolke and Vaccaro proposed in the 1980's. Both interpretations have inconsistencies. Yours outlines the common criticisms of deep percolation; all current proposals suffer from a lack of field data. When data is available, it tends to suggest less significance than generally believed. For example, recent research in the Palouse and elsewhere indicates the marginal percolation notion may not be viable. See, for example Farley and others, 2006, Latah County Hydrogeologic Characterization Project, available at http://www.webs.uidaho.edu/pbac/pubs/HCP_FinalReport.pdf.	Report edited/revised the recharge discussion and conceptual model as needed to support project team's conclusions/inferences.
22	Ecology - ERO	Page 19: "Members of the Grande Ronde Basalts have minimal surface	Reviewer judgement. Addressed to extent we deem

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		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." Based on this statement it would appear that the goal of this project might be in jeopardy.	appropriate given purpose of report.
23	Ecology - ERO	In Section 4.0: Please complete this section in accordance with the grant requirements. See general comments on project goals and objectives. This prefeasibility report discussion should describe how the project would expect to obtain a water right and meet the four part test for issuance of a Temporary Permit or ultimately a permanent permit.	Edits made to water availability section to discuss obstacles and pathways to acquiring potential water rights for the pilot test and long range project.
24	Ecology - ERO	In Section 4.0: The report does not adequately explore or express the difficulties in obtaining a new water right from the Columbia River to consume 20,000 to 200,000 acre-feet of water out of the river. Even should water be physically available, a full SEPA evaluation would be required prior to issuance of a Temporary Permit. This report does not express the time and constraints of a full SEPA evaluation. Additionally, please include a discussion of the consultation process for new water rights from the Columbia.	Edits made to water availability section to discuss obstacles and pathways to acquiring potential water rights for the pilot test and long range project. SEPA will be addressed at conclusion of feasibility phase as that is when we have a defined project to evaluate. Discussion of consultation process for new water rights added to report in water availability section
25	Ecology - ERO	In Section 4.0: A Water Right Application in the amount requested would be subject to the Federal Withdrawal of unappropriated water subject to the Columbia Basin Project, the more recent Federal Withdrawal of Unappropriated Water above Priest Rapids Dam. In addition, this new water right application is subject to consultation under WAC 173-563. Please discuss the implications for the project of USBR's current Priest Rapids reserve.	Report edited to include a discussion on the USBOR application that is pending for unappropriated waters of the Columbia River above Priest Rapids dam. An overview of CR ISF also inserted in the water availability section, and a discussion of OCPI for issuance of a new water right (WAC 173-563-080) was added to the report.
26	Ecology - ERO	In Section 4.1: Include water availability as described in the Biological Opinion.	Report edited to include discussion of Bi-Op flows and water availability. Graphs added to support water availability.
27	Ecology - ERO	In Section 4.1: This proposal is going to require the filing of an Application for Permit and a request for a Temporary Authorization to use the water for testing purposes. The application should reflect the total quantity of the project, the request for Temporary Permit should reflect only the pilot amount. This is identified in Section 4.1.1.	Report edited to include a preliminary discussion on the path forward for submitting of water right applications for a temporary use authorization.
28	Ecology - ERO	In Section 4.1: Please summarize the consultant's opinion regarding water availability for this project, rather than indicating availability "will not be	Edits made to report in water availability section to summarize project team's opinion of potentially

Comment Number	Comment Submitted By:	Comment	Comment Response
		addressed further".	available water and potential obstacles.
29	Ecology - ERO	In Section 4.1, option 2: While lack of availability of Municipal and Industrial (M&I) water is attributed to the Bi-Op, please describe how in the absence of the Bi-Op this use could be envisioned as municipal or industrial use?	Report edited for clarification.
30	Ecology - ERO	In Section 4.1, option 5: Preliminary Permits do not authorize the beneficial use of water. Please outline how a preliminary permit for a reservoir entitles one to a diversion on a stream. In addition, please describe how this project is a "reservoir" as defined in statute? The proposal does not include construction of a reservoir. The Application for Permit is not a Reservoir Application but should be a new application requesting authorization to divert water for an explicit, explained purpose. The water is not placed into a reservoir, but discharged to a basin and will be consumed, lost, percolated or evaporated. The application/Request for Temporary Permit must meet the four part test of a water right; water availability, no impairment, public interest, and beneficial use, to be issued. This prefeasibility report should address all four tests to adequately explore the issues in obtaining a new water right for this project.	Edit made to document to proceed with temporary use authorization per Ecology's recommendation. Preliminary permit discussion revised to not be preferred alternative. Clarification made in document to uncertainty of requirement of reservoir permit, and revised to not include as preferred alternative under Ecology's recommendation that this project most likely will not require reservoir permit. Ecology is struggling with how to interpret reservoir regulations under scenario such as the passive infiltration proposal.
31	Ecology - ERO	In Section 4.2: Quantify, or reference "Extremely high water needs in this area". This section suffers from a lack of focus on the objective. See general comment on purpose of project, and revise to reflect whether the purpose is aquifer recharge or stream flow enhancement, and evaluate compliance with RCW 90.90 against that purpose.	Edit and modifications made to document.
32	Ecology - ERO	In Section 4.3: Can Lincoln County PUD operate facilities outside the political boundaries of Lincoln County?	This is being reviewed concurrently, thus why we have several governance choices. Will be finalized in feasibility phase, prios to pilot, if the project moves forward.
33	Ecology - ERO	In Section 5.0: These sections need focus. The document presents a qualitative assessment of these issues. The grant contemplated a more quantitative comparison. Outline criteria for discrimination between drainages. Map place names. Quantify existing water rights. Quantify land use and ownership. Estimate channel capacity. If you prefer to continue with a subjective qualitative assessment, indicate at least the issues of concern, their general weight between themselves, what elements of a qualitative criterion is bad or good, in an expansion of Table 5.	Edit in document made to clarify qualitative assessment.

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34	Ecology - ERO	In Section 5.1.4: Postulated Roza Dikes would extend through the lithostratigraphic column. These, if present, would have the same hydrological effect regardless of depth. Please revise these sections accordingly.	Addressed to extent we deem appropriate given purpose of report.
35	Ecology - ERO	In Section 5.2.5: Please explain why construction on existing roads is preferred over open ground construction. Include analysis of costs for construction management, traffic control, and reconstruction.	Addressed to extent we deem appropriate given purpose of report. Second comment is beyond the scope of prefeasibility.
36	Ecology - ERO	In Section 5.2.6: The report states the Priest Rapids and Roza members of the Wanapum Formation are "completely eroded through in the middle to lower reaches [of] the central Lincoln County drainages, and in the case of the Priest Rapids, completely absent". It also notes "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. Coupled with suspected discontinuity at the inferred Roza dike locations, recharging the Grande Ronde is very problematic. Please review the text and make consistent with included figures and the conceptual model.	Addressed to extent we deem appropriate given purpose of report.
37	Ecology - ERO	In Section 5.7.5: These calculations suggest Lake Creek loses 19 cfs, likely independent of stream geometry. That corresponds to a maximum leakage to the aquifer systems of about 14,000 af/year. Please discuss this figure in light of achieving an aquifer recharge objective consistent with the range of values elsewhere in the report.	The 19 cfs of loss is the current estimate. This number will be refined during Feasibility Phase of project. If this loss is typical of the other drainages in the area, infiltrating 50,000 af/yr would likely require rehydrating about four streams.
38	Ecology - ERO	In Summary Section: The conclusion states : "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".	No comment to respond to here. Reviewer just providing quote from report.
39	Ecology - ERO	At this stage of the draft, Ecology disagrees. The conceptual model lends	Document has been edited to address points 1 through

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		significant doubt whether the drainages can discharge an amount necessary to remedy aquifer declines. The water rights section does not indicate if water is available, and who might own the water or what demands might be placed on it if it was secured. Environmental regulations and other program needs are not addressed at all, but are likely beyond the scope of the existing grant. In order to finalize this project, LCCD should 1. Describe clear objectives for the project 2. Complete the water rights section (Task 2.1) Edit, and render internally consistent the geologic setting and conceptual models. 3. Establish range of considerations and weighting for qualitative drainage selection (3.2.2) 4. Identify potential sites for rehydration (Task 3.1.3)	4 in this comment as follows: Sections 1 and 6 describe both near term and long term project objectives. Water rights addressed with respect to potential sources for pilot project water. Consumptive use water rights from a pilot not addressed as that is not the goal of the pilot. If project moves beyond pilot, consumptive uses will be addressed as part of a larger project. Geology/hydrogeology clarified/simplified to the extent needed for prefeasibility assessment. Qualitative ratings further explained and expanded upon (most of section 4). Lake Creek defined as preferred pilot test target (potential recharge site). Specific assessment of Lake Creek details (for pilot recharge sites) will be done in feasibility.

22 April 2011

Mr. Guy Gregory
Water Resources Program, Eastern Regional Office
Washington Department of Ecology
N. 4601 Monroe St.
Spokane, Washington 99205

RE: Submittal of Revised Lincoln County Passive Rehydration Project Prefeasibility Assessment Report

Dear Mr. Gregory:

The Lincoln County Conservation District is pleased to submit to the Department of Ecology the attached Revised Prefeasibility Assessment Report (the Revised Report) for the Lincoln County Passive Rehydration Project. This project was funded by the Department of Ecology (Ecology) under Grant Number G1000097 from the Columbia River Basin Water Supply Developments Account. Also attached to this submittal letter we have included the comment-response forms we compiled for Ecology's comments and public comments on the review draft of the Prefeasibility Assessment Report. As we note in the Revised Report, the basic goals and objectives of the Prefeasibility Assessment Phase of the Rehydration Project are to identify water right needs for future project phases, possible mechanisms by which those water rights may be secured, how a potential future project might be governed and operated, and present the results of a preliminary, qualitative geographic/hydrologic/hydrogeologic review of drainages that could potentially host a future passive rehydration project(s). In the Revised Report we also describe basic project elements for the potential next phase of the Project, the Feasibility Evaluation.

In response primarily to Ecology's comments (see attached comment-response form) the Prefeasibility Assessment Report has been revised and reorganized generally as follows:

1. **Chapter 1: Introduction** has been rewritten to better describe the overall project goals and objectives, and more importantly the goals and objectives of the Revised Report within the context of the very first phase, the Prefeasibility Assessment Phase, of a potentially much longer project. Future elements of the larger project, including more detailed feasibility evaluations of a 10 to 20 cfs Pilot Project, permitting, Pilot design, operations, and performance, and a potential future 100+ cfs project will be described in future reports if the project proceeds beyond the Prefeasibility Assessment Phase.
2. **Chapter 2: Study Area Description** focuses on presenting the basic background physical setting to the extent we deemed appropriate for a Prefeasibility Assessment for the whole project area, and not a specific well defined project location.
3. **Chapter 3: Water Availability and Governance** identifies water rights availability and governance issues associated with implementing a potential Pilot Project, if such a project

comes out of the next proposed phase of the Lincoln County Passive Rehydration Project, the Feasibility Phase. These issues will be resolved in the Feasibility Phase and Pilot Project Phase.

4. **Chapter 4: Drainage and Routing Assessment** describes drainages assessed for their potential suitability for use in a Pilot Project, and includes our basic recommendations from that assessment. Based on the Prefeasibility Assessment we do conclude the Lake Creek, and possibly nearby Canniwai Creek and Marlin Hollow might be viable candidates for a Pilot Project and warrant further study in a subsequent Feasibility Evaluation.
5. **Chapter 5: Prefeasibility Phase Conclusions and Recommendations** presents our conclusions and recommendations, ***which as noted above are to proceed to the Feasibility Evaluation Phase***, and describes the basic work activities that need to be done in the Feasibility Evaluation.
6. **Chapter 6: Next Steps** provides a basic outline of the entire project concept beyond the current Prefeasibility Assessment Phase. As we point out in Chapter 6 these next steps are largely conceptual and will be refined and changed as work is conducted in a phase-by-phase approach, starting with the materials described in the attached Revised Report.

For your information you also will find included with this submittal letter a copy of the comment-response form for the public comments received during public review of the draft Prefeasibility Assessment Report. Copies of these public comments are on-file, and available for review, at the Lincoln County Conservation District Office in Davenport, Washington.

We appreciate the opportunity of providing Ecology with the Revised Report, we look forward to discussing it with you and your colleagues on the PAG, and we eagerly anticipate moving forward to the next phase of the project – designing a Pilot Rehydration Project if it feasible.

Sincerely,

David Lundgren

David Lundgren,
Manager, Lincoln County Conservation District

Cc: A. Josephy, CRO
D. Sandison, CRO

Attachments (3)