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Central Oregon Irrigation District
Pilot Butte Canal EIS
Draft Water Resources Technical Report
Deschutes County, Oregon

Prepared for

Central Oregon Irrigation District

October 2025

Prepared by

Parametrix

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Pilot Butte Canal EIS
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CITATION

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CERTIFICATION

The technical material and data contained in the water rights, surface water hydrology, and surface water quality sections of this document were prepared under the supervision and direction of the undersigned, as a professional environmental planner.

The technical material and data contained in the groundwater analysis sections of this document were prepared under the supervision and direction of the undersigned, as a professional hydrogeologist.

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ACRONYMS, INITIALISMS, AND ABBREVIATIONS

ac	acre
AF	acre-feet
AID	Arnold Irrigation District
BMP	best management practice
cfs	cubic feet per second
CFR	Code of Federal Regulations
COID	Central Oregon Irrigation District
CWA	Clean Water Act
cyanoHAB	cyanobacterial harmful algal bloom
DBHCP	Deschutes Basin Habitat Conservation Plan
DEQ	Oregon Department of Environmental Quality
District	Central Oregon Irrigation District
DSL	Oregon Department of State Lands
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
GIS	geographic information system
HAB	harmful algal bloom
JPA	Joint Permit Application
LPID	Lone Pine Irrigation District
NHPA	National Historic Preservation Act of 1966
NMFS	National Marine Fisheries Service (NOAA Fisheries)
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NUID	North Unit Irrigation District
OAR	Oregon Administrative Rules
ORS	Oregon Revised Statute
OWRD	Oregon Water Resources Department
PBC	Pilot Butte Canal

ACRONYMS, INITIALISMS, AND ABBREVIATIONS (CONTINUED)

Reclamation	Bureau of Reclamation
RM	river mile
SDWA	Safe Drinking Water Act
SID	Swalley Irrigation District
sq ft	square feet
sq mi	square miles
TMDL	total maximum daily load
UIC	underground injection control
USACE	U.S. Army Corps of Engineers
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

The Upper Deschutes Basin has experienced significant urban population growth and development, as well as increased agricultural use since construction of the Central Oregon Irrigation District's (COID) Pilot Butte Canal (PBC) in 1904. The efficient use, allocation, and management of water resources within the Upper Deschutes Basin is critical to supporting continued agricultural land use, as well as to ensuring adequate streamflow for aquatic and riparian habitats and the native fish and other aquatic species that depend on them.

The construction and operation of irrigation infrastructure, including the modernization of existing irrigation canal and lateral systems, can have effects on or be affected by water rights frameworks, surface water quality and hydrology, and groundwater resources. This technical report identifies, describes, and evaluates the potential direct long-term impacts, short-term (i.e., temporary, construction-phase) and indirect impacts, and cumulative effects on water resources from the PBC Piping Project.

Modernization of the PBC would reduce water loss in COID conveyance systems and address existing water delivery and operation and maintenance inefficiencies. Water savings from the Project would increase water delivery reliability for irrigators throughout the irrigation season and improve water quality by reducing the potential for contaminants to enter the open canal system through runoff. Minor long-term adverse effects on groundwater resources could result because piping the PBC would eliminate seepage losses that currently result from the infiltration of water from the unlined canal into the porous underlying soils. However, effects on groundwater would attenuate with increasing depth and increased distance from the canal. Overall, the long-term effects on water resources from modernization of the PBC would be beneficial.

1. INTRODUCTION

As a part of the preparation of the Environmental Impact Statement (EIS) for the Pilot Butte Canal (PBC) Project (Project), this technical report has been prepared to identify and evaluate potential effects of the proposed action and alignment options on water resources within the project's Study Area. The Project Area is shown in Figure 1, and both the Project Area and Study Area are described in detail in Section 3.

This report describes the methods used to support the environmental evaluation and outlines the approach to evaluating the potential beneficial and adverse effects of the Project. The report includes a description of the Study Area, relevant laws and regulations, methods for collecting data and assessing impacts, and possible mitigation measures. The analysis is designed to comply with the National Environmental Policy Act and relevant federal, state, and local laws.

1.1 Project Location

The Central Oregon Irrigation District (COID or District) is analyzing piping approximately 18 to 21 miles of the PBC from NE 17th Street in Redmond, Oregon, to the diversion point from the Deschutes River in Bend, Oregon (Figure 1). The piping would extend from the piped section of the PBC approved under the 2020 *Smith Rock-King Way Infrastructure Modernization Project Final Watershed Plan-Environmental Assessment* (Plan-EA; USDA, NRCS 2020a). Additional portions along the existing alignment that have been piped or converted to box culverts during previous construction projects include the following:

- Major freeway or roadway crossings of US 97, Hwy 20, and Hwy 126, in Bend and Redmond (0.2 miles)
- Within the City of Bend and Deschutes County for the Juniper Ridge hydroelectric facility (3.3 miles)
- Within Deschutes County north of the Juniper Ridge hydroelectric plant (0.1 miles)
- Within urbanized Redmond (1.5 miles)

The portions to be piped for this Project are shown in Figure 1.

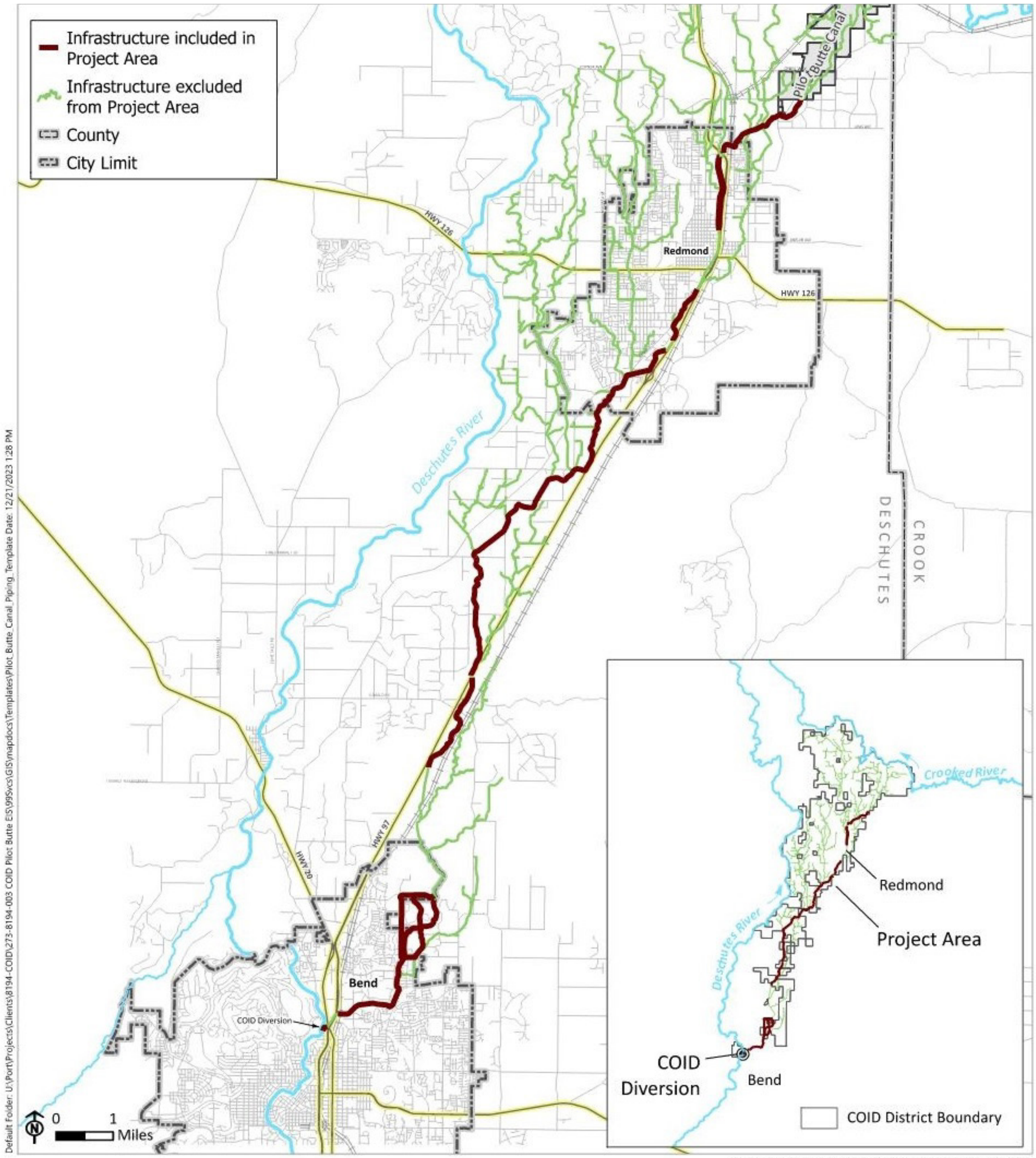


Figure 1. Project Area

1.2 Project Purpose and Need

The purpose of this Project is agricultural water management through irrigation water conservation in COID infrastructure, improvement of water delivery reliability to District patrons, and reduction of long-term operation and maintenance costs on approximately 18 to 21 miles of the District-owned PBC. The Project is needed to address watershed problems and resource concerns including water loss in District conveyance systems, water delivery and operation and maintenance inefficiencies, including risks to public safety. Implementation of the proposed action would address the District's objectives and goals to reduce seepage loss and provide better-managed water diversions for farm use, support agricultural land use, and increase public safety.

1.2.1 Water Loss in District Conveyance Systems

Construction of the District's open, unlined PBC was completed in 1904. Because of the highly porous volcanic soils and the arid climate in the Upper Deschutes Basin, the existing canal loses substantial amounts of water through seepage and evaporation. The unlined portion of the PBC currently proposed for modernization is estimated to lose up to approximately 136 cubic feet per second (cfs), or approximately 43,544 acre-feet (AF), annually over a total distance of approximately 18 miles through seepage and evaporation (FCA 2023; COID 2016a). Existing seepage and evaporation losses from the PBC are discussed in further detail in Section 5.3.4.

Open canal and lateral systems require additional water, known as operational water, to facilitate flow through the system and ensure that the necessary volume of water reaches all points of delivery based on patrons' needs and the District's water rights. Conveying irrigation water in this way creates inefficiencies in delivery volume and timing that can compound the losses from seepage and evaporation over the length of the PBC system (FCA 2023).

1.2.2 Water Delivery and Operations Inefficiencies

The open, unlined PBC and laterals make it difficult for the District to deliver the correct amount of water to patrons at the correct time, particularly early and late in the irrigation season when water rights require the District to divert water from the Deschutes River at a reduced rate. At reduced flow rates, small changes in streamflow at the diversion can impact when water is available at each point of delivery, and patrons may receive inconsistent flows. For example, a point of delivery near the end of a lateral may receive no water in the morning and excess water in the evening. Even with highly skilled and trained staff, efficient deliveries to patrons are hindered as water loss in the system must be accounted for and changes to diversion rates can take multiple days before successfully meeting demand.

In addition to water delivery efficiencies associated with normal ongoing operation of the canal, the potential exists for periodic canal failure. This represents a risk of serious operational disruption and sudden loss of water for irrigators downstream of the failure location, as well as damage to agricultural and urban property. Since 2005, there have been two incidents of canal failure that resulted in flood damage to homes and agricultural land. Potential for canal failure and flood damage is most pronounced in the Redmond Project Group due to burrowing activity by small mammals, which destabilizes the canal walls. However, the flooding and operational risks from canal failure are expected to increase over time throughout the entire length of the PBC due to continued degradation as the canal ages (Horrell 2023).

The potential for safety impacts will likely grow as urban development continues in the Project vicinity and more people and property are placed at risk.

Another safety risk of operating an open irrigation canal involves the potential for people and animals to fall into the open canal while it is flowing during the irrigation season. Along with multiple instances of injury, several drowning deaths have previously occurred in various central Oregon irrigation districts' canals, including in 1996, 1997, and 2004 (Flowers 2004). Public safety risks from flooding and drowning hazards are discussed in the Public Safety section of the Plan-EIS.

2. PROJECT ALTERNATIVES

2.1 No Action (Future without Federal Investment)

Under the No Action Alternative, the District would continue to operate and maintain the existing delivery system within the Project Area in its current condition. This alternative assumes that modernization of the District's infrastructure would not be reasonably certain to occur, as funding at the scale necessary to modernize District infrastructure is not anticipated from other sources. The No Action Alternative would be a continuation of the District's current operations and maintenance.

The No Action Alternative would not meet the project purpose and need. Water would continue to be lost to seepage and evaporation in District infrastructure. Inefficiencies in water delivery reliability for farmers would not be addressed. Streamflow and habitat conditions for fish and aquatic species, pollutant and sediment levels in irrigation water, and risks to public safety would not improve.

The No Action Alternative would fail to achieve the Federal Objective as set forth in the Water Resources Development Act of 2007, which specifies that federal water resources investments shall reflect national priorities, encourage economic development, and protect the environment by:

> (1) seeking to maximize sustainable economic development;
>
> (2) seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used; and
>
> (3) protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems.

The No Action Alternative would not resolve current insufficiencies in water supply to crops that result from the loss of water from District infrastructure. It would not resolve the public safety and property risks posed by flooding from potential canal failures or injuries and drownings from falls into the open canal (see the Public Safety section of the Plan/EIS for more detail). Further, it would not foster the economic well-being of present and future generations through sustainable use and management of water resources for irrigated agriculture in the Upper Deschutes Basin in coexistence with the health of the region's ecosystems.

2.2 Modernization Alternative (Future with Federal Investment)

The Modernization Alternative would focus on a single priority infrastructure modernization project: the District would replace the existing open PBC within the Project Area with a pressurized, closed conduit pipeline system (see Figure 2). When completed, the pipe would extend over approximately 18 to 21 miles of the COID system from the diversion point from the Deschutes River in Bend, Oregon, to NE 17th Street in Redmond, Oregon. Pipeline construction would begin in the northern portion of the Project Area at the piped section of the PBC that was approved under the 2020 Smith Rock-King Way Infrastructure Modernization Project Final Watershed Plan-Environmental Assessment (USDA, NRCS 2020a), and progress south to the North Canal Dam. Construction of the Modernization Alternative would occur over the course of 3 years; two project groups would be constructed each construction season. The six project groups are described in Table 1.

Table 1. Pilot Butte Canal Project Groups Comprising the Project Area and Construction Sequence

Project Group	Length of Project Improvements (ft)	Construction Year	Construction Start	Construction End
1 – King Way	11,000	0	October 2026	April 2027
2 – Redmond [a]				
Pilot Butte Canal Alignment Option	13,500	1	October 2027	April 2028
Watermaster Road Alignment Option	13,500	1	October 2027	April 2028
NW Canal Boulevard Alignment Option	13,500	1	October 2027	April 2028
3 – Veterans Way	16,700	2	October 2028	April 2029
4 – Canal	13,900	2	October 2028	April 2029
5 – Deschutes Market	22,000	1	October 2027	April 2028
6 – Rivers Edge	18,100 to 19,800			
Pilot Butte Canal Alignment Option	18,100	0	October 2026	April 2027
18th Street Alignment Option	19,300	0	October 2026	April 2027
Old Deschutes Road Alignment Option	19,800	0	October 2026	April 2027

a: Included in this project group is 1,100 feet of existing pipe that would be replaced with new pipe of a larger diameter.

Construction would occur during the non-irrigation season (October to April), with Project Group 1 (King complete, and all six project groups would be completed over the course of three construction seasons. Two project groups—Redmond and Rivers Edge—each contain a segment with multiple alignment options. The alignment options are discussed below. Under the Modernization Alternative, federal funding through Public Law 83-566 would be available and would be expected to cover approximately 75% of total costs. The District would cover the remaining 25% of total costs.

A section of the PBC in Deschutes County just south of the Juniper Ridge hydroelectric facility, in the Rivers Edge project group, and another section in the downtown area of Redmond, in the Redmond project group, include historic features listed in the National Register of Historic Places (NRHP). In 2019, a Section 106 programmatic agreement was signed by COID, the Oregon State Historic Preservation Office, and the Bureau of Reclamation. The Natural Resources Conservation Service (NRCS) was added as a signatory in 2023. The programmatic agreement identified that COID will maintain the downtown Redmond reach “such that the historic integrity of and identification of the historic property as representative of an irrigation conveyance system will not be adversely affected.” The alignment options for the Deschutes County/North Bend (in the Rivers Edge project group) and the City of Redmond (in the Redmond project group) NRHP-listed historic sections of the Project Area are described in Section 2.2.1 and Section 2.2.2, respectively.

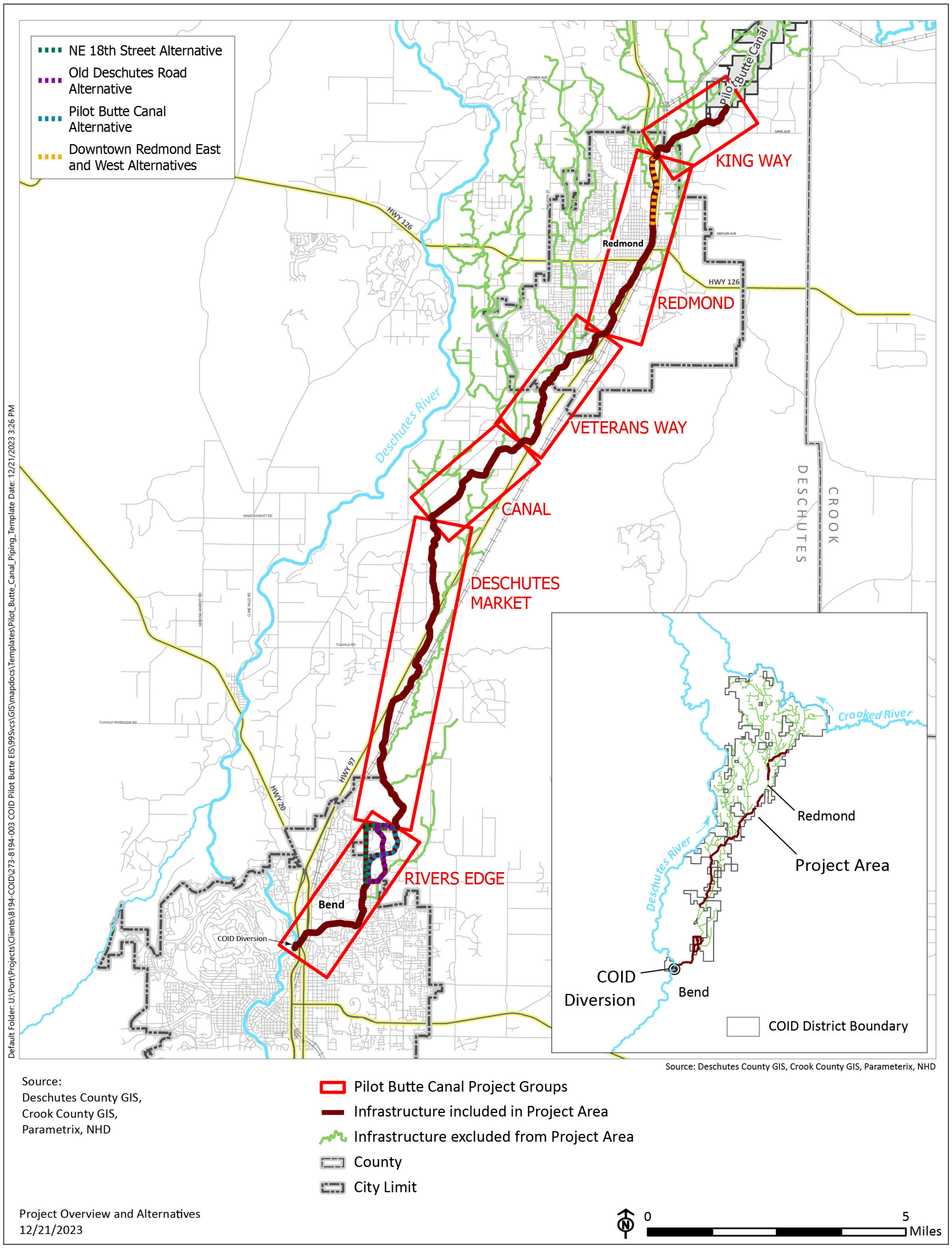


Figure 2. Project Groups

2.2.1 Deschutes County/North Bend Alignment Options

The Modernization Alternative has four options for piping the historic section of the canal between Yeoman Road and Cooley Road in Deschutes County and north Bend, in the Rivers Edge Project Group (see Figure 3).

- No Modernization within this section (no piping)
- Pilot Butte Canal Alignment (existing canal alignment)
- NE 18th Street Alignment
- Old Deschutes Road Alignment

2.2.1.1 No Modernization within this Section (No Piping)

This alignment option would keep the 7,800-foot NRHP-listed stretch of the PBC between Yeoman and Cooley Roads in its current configuration and functionality as an open canal. This option would require a pressure reducing station south of Yeoman Road to slow the flow velocity as it exits the pressurized pipe so that the existing open canal can function as currently designed.

2.2.1.2 Pilot Butte Canal Alignment (Existing Canal Route)

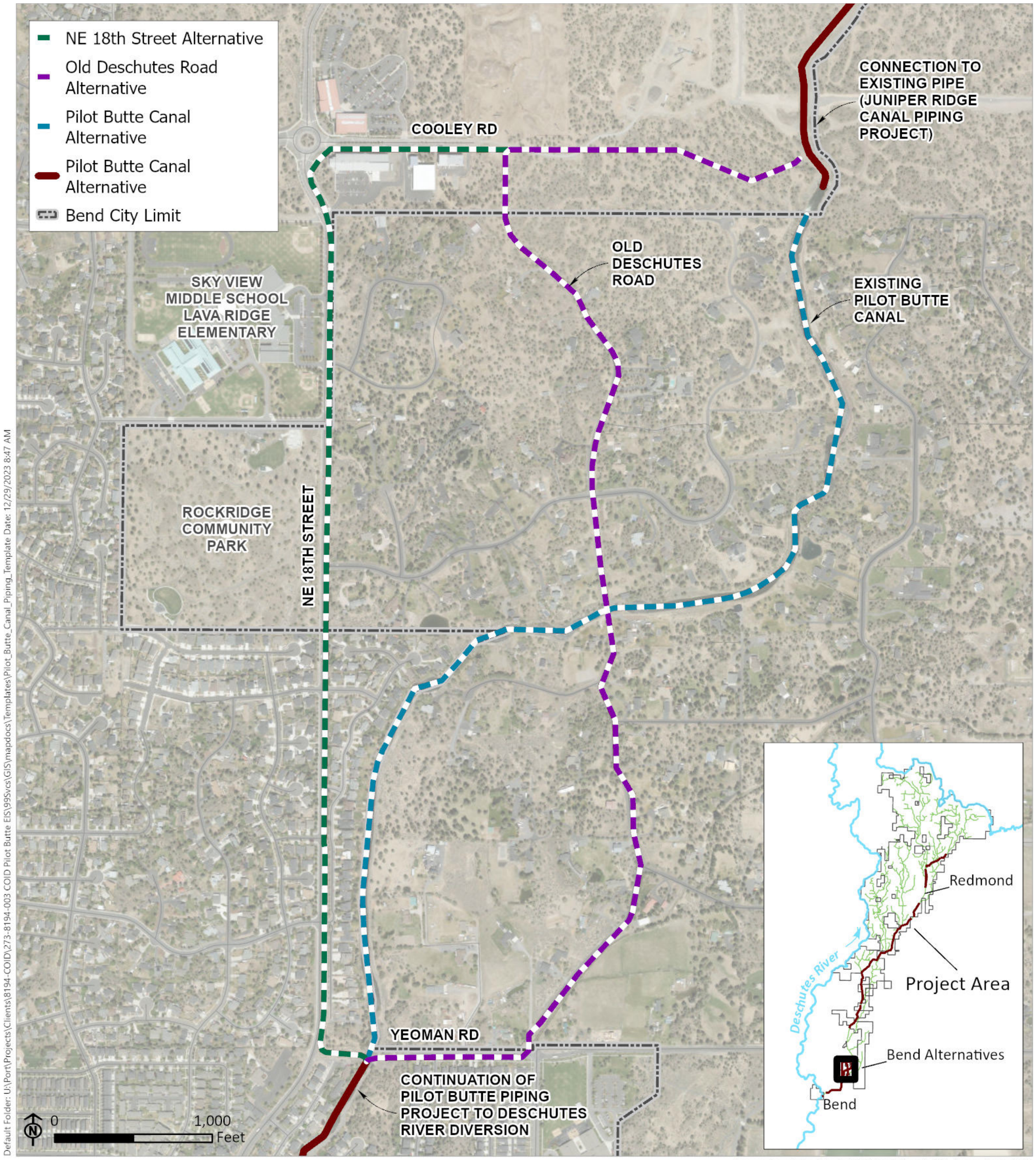
This alignment option would replace the open channel with pipe directly within the existing open channel alignment. This alignment option would be built wholly within the section of canal that is listed in the NRHP. This option would not pipe the open channel section immediately south of the Juniper Ridge hydroelectric facility (approximately 170 feet), and it would require installing a pressure reducing station prior to where flow enters the hydroelectric facility).

2.2.1.3 NE 18th Street Alignment

This option would pipe the PBC within a new alignment beginning at the intersection of the existing alignment and Yeoman Road. It would travel west and then north to follow NE 18th Street to its intersection with Cooley Road. At Cooley Road, the alignment option would make an approximately 90-degree turn to follow an alignment extending from near the eastern terminus of Cooley Road to the existing PBC. This option would avoid impacts to the section of the PBC that is listed in the NRHP. The historic section of canal would be left in place, but it would no longer receive irrigation water from the COID system.

2.2.1.4 Old Deschutes Road Alignment

The Old Deschutes Road Alignment option would place pipe in a new alignment beginning at Yeoman Road. It would travel east along Yeoman Road and then northeast to follow Old Deschutes Road. The alignment would travel generally north, cross the existing PBC, then continue north to Cooley Road. The alignment would make an approximately 90-degree turn to follow Cooley Road to the existing PBC. This option would avoid impacts to the NRHP-listed section of the PBC. The historic section of canal would be left in place, but it would no longer receive irrigation water from the COID system.



Source: Deschutes County GIS, Crook County GIS, Parameterix, NHD

Figure 3. Deschutes County/North Bend Alignment Options

2.2.2 City of Redmond Alignment Options

The Modernization Alternative has four options for piping within the NRHP-listed historic Downtown Redmond section between NW Dogwood Avenue and NW Quince Avenue (see Figure 4).

- No Modernization within this section (no piping)
- Pilot Butte Canal Alignment (existing canal alignment)
- Piping to the east in the Watermaster's Access Road
- Piping to the west within Northwest Canal Boulevard

2.2.2.1 No Modernization within this Section (No Piping)

This alignment option would keep the 6,800-foot NRHP-listed stretch of the PBC in Redmond in its current configuration and functionality as an open canal. This option would require installing a pressure reducing station near the intersection of SW Veteran's Way and US 97 to slow the flow velocity as it exits the pressurized pipe so that the existing open canal can function as currently designed.

2.2.2.2 Pilot Butte Canal Alignment (Existing Canal Route)

This alignment option would replace the open channel with pipe directly within the existing open channel alignment. This alignment option would be built wholly within the section of canal that is listed in the NRHP.

2.2.2.3 Piping to the east in the Watermaster's Access Road

This alignment option would install pipe to the east of the existing PBC and avoid impacts to the section of canal that is listed in the NRHP. The historic section of canal would be left in place, but it would no longer receive irrigation water from the COID system.

2.2.2.4 Piping to the west within Northwest Canal Boulevard

This alignment option would pipe to the west of the existing PBC, primarily within NW Canal Boulevard, and avoid impacts to the section of canal that is listed in the NRHP. The historic section of canal would be left in place, but it would no longer receive irrigation water from the COID system.

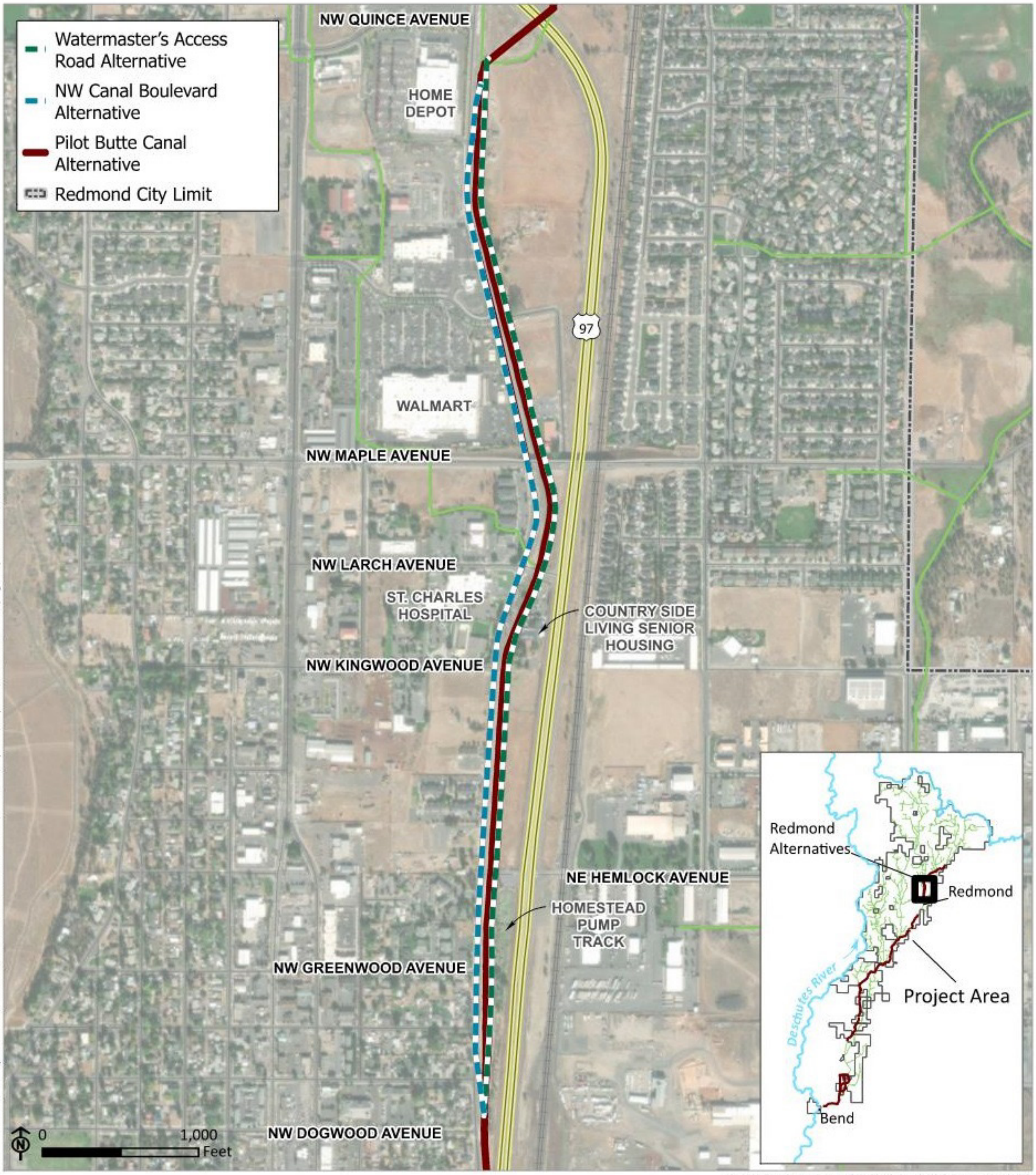


Figure 4. Redmond Alignment Options

3. DEFINITIONS

The following terminology is used when discussing geographic areas in this technical report.

Project Area. The area within which improvements associated with the Project alignment options would occur and the area needed to construct these improvements. The Project Area includes the area needed to construct all permanent infrastructure, including adjacent parcels where modifications would be required for associated work such as utility realignments or upgrades, and a 70-foot buffer on either side of the canal to ensure all construction impacts are accounted for.

Study Area. This is the general geographic area within which physical impacts to the environment could occur with the Project alternatives. The Study Area is resource-specific and differs depending on the environmental topic being addressed. For all topics, the Study Area encompasses the Project Area, and for some topics (such as for utilities), the geographic extent of the Study Area is the same as that for the Project Area. For other topics (such as transportation), the Study Area is substantially larger to account for impacts that could occur outside of the Project Area. The Study Area for water resources is defined in Section 5.1.

Project vicinity. The environs surrounding the Project Area. The Project vicinity does not have a distinct geographic boundary, but it is used in general discussion to denote the larger area.

Upper Deschutes Basin. The Upper Deschutes Basin encompasses approximately 4,500 square miles of the Deschutes River drainage, bounded on the north by the Crooked River, Jefferson Creek, the Metolius River, the Deschutes River, and Trout Creek; on the east by the geological change between the Deschutes Formation and the much less permeable John Day Formation; on the south by the drainage that divides the Deschutes Basin and the Fort Rock and Klamath Basins; and on the west by the crest of the Cascade Range. It is drained by the Deschutes River and its major tributaries the Little Deschutes, Crooked, and Metolius Rivers. Land surface elevations range from lower than 1,300 feet above mean sea level in canyon bottoms to more than 10,000 feet in the Cascade Range

4. LEGAL REGULATIONS AND STANDARDS

The following sections list and briefly describe applicable federal, state, and local laws and regulations protecting the condition of surface waterbodies and groundwater resources, as well as permitting activities related to water quality, groundwater protection, and protection of aquatic habitat.

4.1 Laws, Plans, Policies, and Regulations

4.1.1 Federal

4.1.1.1 Clean Water Act, 1977 as Amended, 33 USC 1251-1376

The Clean Water Act (CWA) requires states to set water quality standards for all contaminants in surface waters based on the “beneficial” or “designated” uses for the waterbody and makes it unlawful for a person to discharge a pollutant from a point source into navigable waters unless a permit was obtained under its provisions. It also recognizes the need to address the problems posed by nonpoint source pollution. The permitting processes within the purview of the CWA are summarized below.

Section 402 National Pollutant Discharge Elimination System Permits

The U.S. Environmental Protection Agency (EPA) requires National Pollutant Discharge Elimination System (NPDES) permits for industrial sites and construction activities, as well as for certain sizes of municipalities that discharge stormwater into waterways. In Oregon, these permits are administered through the Oregon Department of Environmental Quality (DEQ). Because these permits are administered by a state regulatory agency, their applicability is discussed under state regulations in Section 4.1.2.

Section 303(d) Impaired Waters and Total Maximum Daily Loads

Section 303(d) requires states and territories to issue water quality status reports every 2 years. These reports identify water quality trends, prioritize polluted waters, and target waters for total maximum daily load (TMDL) development. TMDLs identify the pollutant load reductions that are necessary from point and nonpoint sources and guide implementation work by federal, state, tribal, territorial, and local water quality protection programs. In Oregon, DEQ develops a Section 303(d) list for approval by the EPA.

Section 404 for Permitting Discharges of Dredge or Fill Material

Section 404 requires a permit authorization from the U.S. Army Corps of Engineers (USACE) for activities involving the discharge of dredge or fill material into waters of the United States, including wetlands. This permit would be required if any work associated with the Project would occur within a jurisdictional wetland or below the ordinary high-water mark of waterbodies within the Study Area. This permit would not be required for work in wetland areas created from uplands, as such areas are not considered jurisdictional.

Section 401 Water Quality Certification

Section 401 requires an applicant for a federal license, or a Section 404 permit applicant planning to conduct an activity that may result in a discharge to waters of the state or United States, to obtain a water quality certification that the activity complies with state water quality requirements and standards. Applicants must submit a pre-filing meeting request to the certifying state agency at least 1 month prior to submitting the Section 404 application to USACE. In Oregon, DEQ is the certifying state agency for Section 401 water quality certification.

After the Section 404 application is submitted to USACE, a copy of the application is forwarded to DEQ. Following, DEQ certifies whether the Project meets state water quality standards and does not endanger waters of the state or United States or wetlands and forwards the application to the EPA for review. Comments on the Section 404 application would be addressed by the applicant. Upon completion of EPA’s review, the Section 401 certification is issued by DEQ.

4.1.1.2 Endangered Species Act of 1973 and Amendments; 16 USC §1531 et. seq.

The Endangered Species Act (ESA) provides a framework to conserve and protect endangered and threatened species and their habitats from the effects of human development. These include effects to ESA-listed fish habitat from stormwater runoff into waterbodies (e.g., water quality and hydromodification).

4.1.1.3 Fish and Wildlife Coordination Act of 1934 and Amendments, 16 USC § 661 et seq.

The Fish and Wildlife Coordination Act protects fish and wildlife when federal actions result in the control or modification of a natural stream or body of water.

4.1.1.4 Safe Drinking Water Act. 1974, as amended, 42 USC 300f

The Safe Drinking Water Act (SDWA) requires many actions to protect drinking water and its sources including rivers, lakes, reservoirs, springs, and groundwater wells. The SDWA authorizes the EPA to set national health-based standards for drinking water to protect against both naturally occurring and humanmade contaminants. State drinking water programs provide direct oversight of water systems. This law would only apply if infiltration basins or underground injection control (UIC) measures were incorporated into the project design. These two types of measure are permitted under two separate programs: the Water Pollution Control Facilities program and the UIC program, respectively. The SDWA establishes requirements and provisions for these programs.

4.1.2 State of Oregon

4.1.2.1 ORS 468B, Water Quality

This Oregon Revised Statute (ORS) sets effluent limitations, describes the implementation of the CWA, and sets permit requirements. It prohibits any person from causing pollution of any waters of the state or placing or causing to be placed any wastes in a location where such wastes are likely to escape or be carried into the waters of the state by any means. The statute also prohibits the discharge of any wastes into waters of the state if the discharge reduces the quality of such waters below the water quality standards established by rule for such waters by the Oregon Environmental Quality Commission. Additionally, this statute sets policies for preventing contamination of groundwater and guidance for any activity that may affect Oregon's groundwater resources.

4.1.2.2 ORS 196.795-990, Oregon Removal-Fill Law.

Oregon's Removal-Fill Law requires individuals or entities that plan to remove or fill material in wetlands or waterways of the state to obtain a removal-fill permit from the Oregon Department of State Lands. The removal-fill law applies to all landowners, whether private individuals or public agencies. The purpose of the law is to ensure protection and the best use of Oregon's water resources for home, commercial, wildlife habitat, public navigation, fishing, and recreational uses. A permit is required if an activity will involve removing or filling 50 cubic yards or more of material in a wetland or waterway of the state. For activities in state-designated Essential Salmonid Habitat, State Scenic Waterways, and compensatory mitigation sites, a permit is required for any amount of removal or fill. The removal-fill permit application is typically addressed via a Joint Permit Application, in combination with the Section 404 permit application to USACE.

4.1.2.3 ORS 545, Oregon Irrigation District Law

The Oregon Irrigation District Law, ORS Chapter 545, provides the foundations for formation, development, operation, and governance of irrigation districts in Oregon. The following are particular relevance to the Project's potential effects on water resources:

- ORS 545.221 Powers and duties of board as to management of district; water deliveries
- ORS 545.237, Right to enter upon lands for inspection and maintenance of water works
- ORS 545.271, Furnishing water

4.1.2.4 OAR 340-045-0005 to 340-045-0080, Department of Environmental Quality: Regulations Pertaining to NPDES and Water Pollution Control Facilities Permits and OAR 340-044-0005 to 340-044-0055, Construction and Use of Waste Disposal Wells or Other Underground Injection Activities (Underground Injection Control)

In Oregon, DEQ issues and enforces NPDES, Water Pollution Control Facilities, and UIC permits. A permit would be required for (1) the construction, installation, or operation of any activity that would increase the discharge of wastes into the waters of the state or would otherwise unlawfully alter the physical, chemical, or biological properties of any waters of the state; (2) an increase in volume or strength of any wastes in excess of the discharges authorized under an existing permit; (3) the construction or use of any new outlet for the discharge of any wastes into the waters of the state; and (4) any underground injection activity, including the construction, modification, operation, or maintenance of any injection system.

4.1.2.5 State Issuance, Monitoring, and Enforcement of Section 401 Water Quality Certification

In Oregon, a pre-filing meeting request to DEQ would be required at least 1 month prior to the submittal of a Joint Permit Application (JPA). The JPA would be submitted to the Oregon Department of State Lands, USACE (Portland District Office), and DEQ. DEQ would review the Project for Section 401 water quality certification and forward the JPA to the EPA for review. Frequently, applicants are required to incorporate protective measures into their construction and operational plans—measures such as bank stabilization, treatment of stormwater runoff, spill protection, and fish and wildlife protection. The DEQ water quality certification process requires a land use compatibility statement signed by the local government land use authority to ensure that permits affecting land use are compatible with local government comprehensive plans.

4.1.2.6 1200-C Construction Stormwater Permit

DEQ requires this permit for construction activities on sites that cover 1 or more acres and could potentially generate stormwater runoff into surface waters or conveyance systems leading to surface waters of the state. This permit requires a temporary erosion and sediment control plan, a list of selected best management practices (BMPs) for the Project, and a schedule for implementing the BMPs. Guidance on preparing the erosion and sediment control plan is provided in the DEQ March 2022 *Construction Stormwater Application and Forms Manual* (DEQ 2022a).

4.1.2.7 Oregon's Statewide Planning Goals and Guidelines, OAR 660-015-0000

In Oregon, Goal 6 instructs local governments to consider protection of air, water, and land resources from pollution and pollutants when developing comprehensive plans. The relevant pollutants considered include (but are not limited to) solid waste, water waste, and thermal pollution. The goal asks Cities and Counties to designate areas suitable for use in controlling pollution. It calls on them to use a variety of market, zoning, and management tools in creating these outcomes.

4.1.3 Deschutes County

4.1.3.1 Comprehensive Plan

The *Deschutes County Comprehensive Plan*, adopted in 2011, contains issues, goals, and policies to guide the County's land use planning decisions and public investments over a 20-year planning horizon. Section 2.5 of the comprehensive plan section provides the framework for evaluating the effects of land use actions on water resources and defines the County's responsibility to work in partnership with cities, agencies, nonprofits and others to achieve efficient use of water resources and effective management of water quality in the Upper Deschutes Basin.

4.1.3.2 Development Code

Deschutes County Code Title 18 establishes zoning districts and regulations governing the development and use of land within unincorporated Deschutes County. There is no specific chapter in Title 18 that provides standards and controls for land uses adjacent to water resources. However, provisions for the protection of stream and wetland habitat and surface water quality are incorporated into the development standards of applicable chapters. For example, Chapter 18.96, Flood Plain Zone, establishes minimum setbacks of 100 feet from all streams or lakes for buildings, structures, and similar permanent fixtures, as well as septic systems and drainfields.

4.1.4 City of Bend

4.1.4.1 Comprehensive Plan

The *City of Bend Comprehensive Plan*, most recently updated in March 2023, is a long-range planning guide for making land use decisions regarding future development and growth within the Bend urban growth boundary. The plan's basic aim is to organize and coordinate complex inter-relationships between people, land, resources, and facilities to meet the future needs of the citizens and to protect the livability of the community.

4.1.4.2 Integrated Water System Master Plan

The City of Bend's Integrated Water System Master Plan (City of Bend 2021) provides the factual baseline for the City's current and future water facilities and infrastructure planning and includes an inventory and general assessment of the City's water facilities and systems. It provides information and documentation of the City's water rights and supply, including consideration of factors that will influence both surface water and groundwater supplies such as droughts, forest fires, and extreme weather patterns caused by climate change.

4.1.4.3 Stormwater Master Plan

The Bend 2014 *Stormwater Master Plan* serves as the oversight plan for addressing stormwater quantity and quality issues. In addition to providing an overall strategy for addressing stormwater concerns, it delineates drainage areas and runoff quantities throughout Bend, and it describes programmatic goals for addressing stormwater quantity and quality concerns.

4.1.4.4 Development Code

Title 10 of the City of Bend Code establishes land use districts and development regulations and standards for all land within the incorporated city limits of Bend. Chapter 2.7, Article V of the Development Code establishes a Waterway Overlay Zone. The intent of the overlay zone is to conserve and enhance the natural resource values of areas along the Deschutes River and Tumalo Creek within the city of Bend by protecting and enhancing water quality for human use and aquatic life; conserving and restoring habitat for wildlife, fish, and other aquatic life; and conserving riparian areas and wetlands, among other goals.

4.1.5 City of Redmond

4.1.5.1 Comprehensive Plan

Adopted in 2020, the *Redmond 2040 Comprehensive Plan* is a guide to future growth, development, and redevelopment of the Redmond urban area. In the chapter entitled Air, Water and Land Resources Quality, the plan sets forth a framework of goals and policies for reducing pollutant impacts to air, water, and land resources; improving the quality of air, water and land resources; and participating in environmental quality planning efforts on a regional level.

4.2 Design Standards

4.2.1 Central Oregon Irrigation District Development Handbook

The COID *Development Handbook* provides guidance for design and construction of facilities on or near COID easements and rights-of-way, as well as guidelines for proper crossing and piping of COID canals. All relevant design standards would be reviewed in detail during the permitting process for the piping Project to ensure compatibility with existing water quality plans and regulations.

4.2.2 NRCS Irrigation Guide, Part 652

The NRCS Irrigation Guide, Part 652, is a component of the larger NRCS National Engineering Handbook series. This guidebook describes the basics and process for planning, designing, evaluating, and managing irrigation systems. It also provides the process for states to supplement the guide with local soils, crops, and irrigation water requirement information needed to plan, design, evaluate, and manage irrigation systems (USDA, NRCS 1997).

5. AFFECTED ENVIRONMENT

5.1 Study Area

The Study Area for water rights and surface water resources includes the Project Area as defined in Section 3 above, along with all waterbodies affected by District infrastructure and operations. These include the Upper Deschutes River, Crane Prairie Reservoir, and Wickiup Reservoir (see Figure 5).

The Study Area for groundwater includes approximately 40,435 acres located in the center of the Upper Deschutes Basin, consisting of areas within 1.4 miles of the Project Area portion of the PBC (see Figure 6). This is the distance within which the Modernization Alternative would be expected to have the most pronounced influence on groundwater levels based on analysis of groundwater monitoring and observation wells within the Project vicinity and review of groundwater studies for the larger Upper Deschutes Basin (Gannett et al. 2001; Gannett et al. 2003; Gannett and Lite 2013; Appendix A).

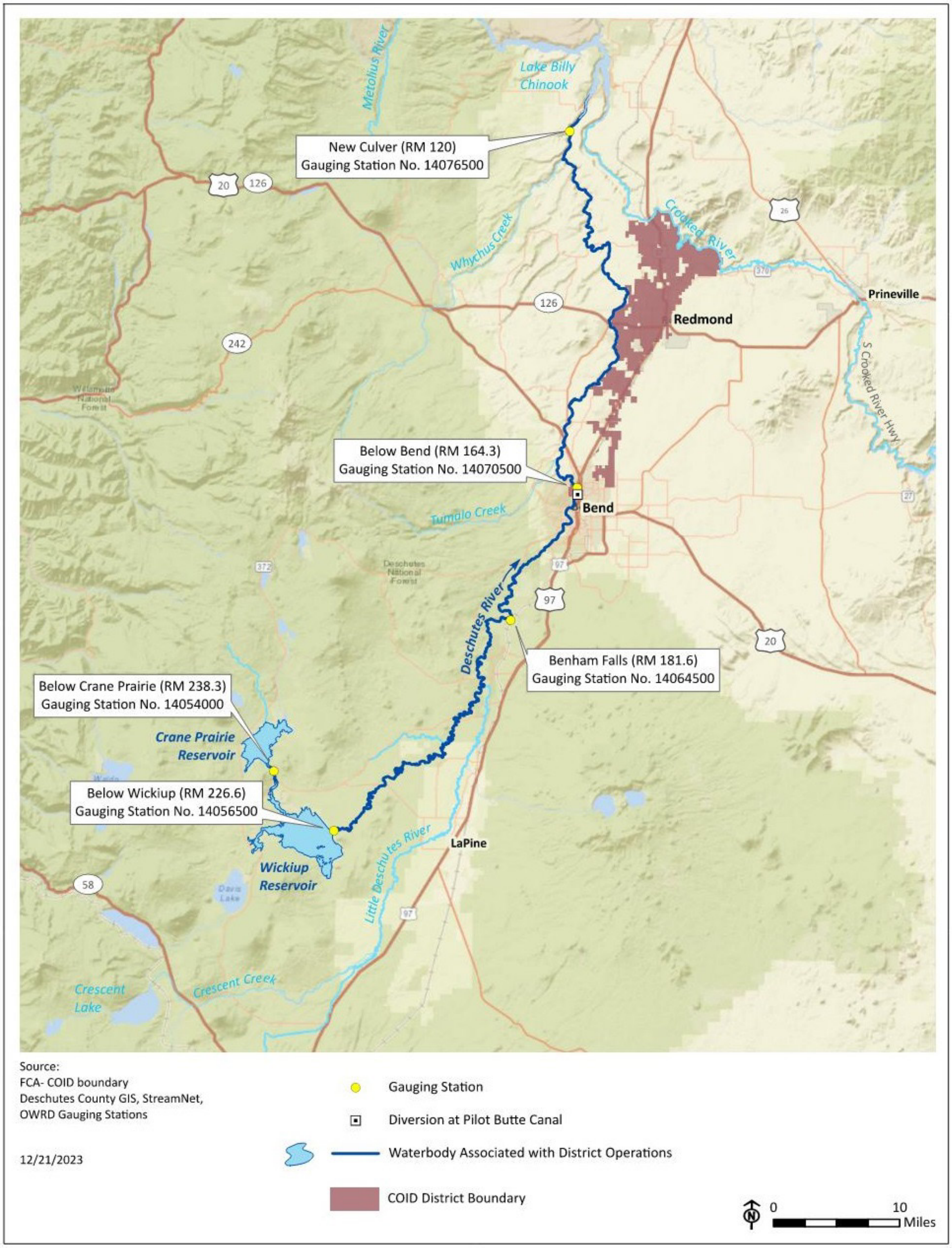


Figure 5. Waterbodies Associated with District Operations

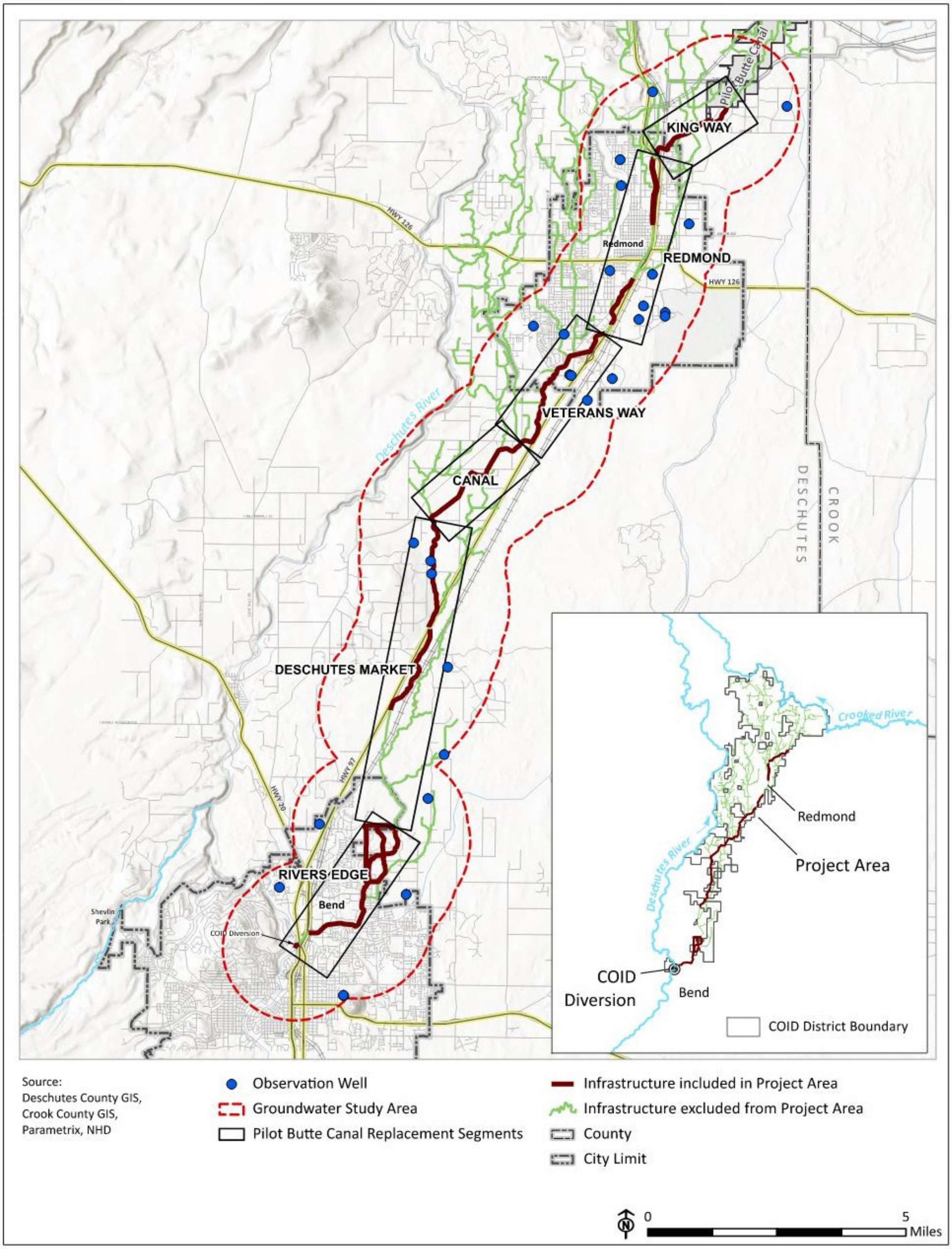


Figure 6. Groundwater Study Area and Observation Well Locations

5.2 Resource Identification and Evaluation Methods

The following data sources were used to identify existing conditions and provide the required information for analysis of the No Action Alternative (Future without Federal Investment) and Modernization Alternative (Future with Federal Investment) including the various alignment options.

5.2.1 Published Sources and Databases

Sources used to conduct this analysis include the following.

5.2.1.1 Studies and Plans from Local, State, and Federal Agencies

- U.S. Geological Survey (USGS) groundwater studies and modeling.
- Oregon Water Resources Department (OWRD) stream gauge data for the project reaches of the Deschutes River for water years 1985 to present.
- OWRD drought declaration notices.
- Previous watershed plan-EA documents for PL 83-566 irrigation modernization projects authorized or under way within the Upper Deschutes Basin.
- U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA) Fisheries (NMFS) *Deschutes Basin Habitat Conservation Plan* (DBHCP; USFWS and NMFS 2020).

5.2.1.2 Maps and GIS Data

- ESRI.
- Deschutes County GIS, water resources.

5.2.1.3 Water Quality Characterization Studies

- DEQ *EPA Approved Integrated Report* (DEQ 2022a).

5.2.2 Field Visits and Surveys

A reconnaissance-level site survey was conducted on October 14 and 15, 2021, to collect general observations of wetlands, waters, and biological resources along the canal. Parametrix scientist Irina Lapina, Professional Wetland Scientist, walked the length of the canal and recorded her visual observations. Herbaceous wetlands were observed along the canal, exhibiting varying degrees of continuity, often exceeding 6 feet in width. Aquatic bed vegetation was noted in areas where water was retained in canal bottoms after the water supply was shut off. No fish or aquatic species were observed. No potentially jurisdictional waters or wetlands were observed. See the Biological Resources technical report for additional detail.

5.3 Existing Conditions

5.3.1 District Water Rights and Operations

5.3.1.1 District Water Rights

The PBC conveys water to 17,149 acres of irrigated lands. The District is a senior water right holder on the Deschutes River. The District diverts live flow from the Deschutes River under Certificate 94956 , which carries 1900 and 1907 priority dates, to meet the majority of its water needs. The District also holds supplemental storage rights on Crane Prairie Reservoir, located in the upper reaches of the Upper Deschutes Basin upstream from the District's diversions on the Deschutes River. The District has historically been able to meet its water needs during most years through live flow or with the addition of stored water.

Crane Prairie Reservoir is federally authorized for irrigation and state-authorized for multiple purposes including in-stream flows for fish and wildlife. Crane Prairie Reservoir Dam is owned by Reclamation and operated by the District, which shares maintenance with Lone Pine Irrigation District (LPID) and Arnold Irrigation District (AID). The use and amount of stored water in Crane Prairie Reservoir and Wickiup Reservoir, located 5 miles downstream, is governed by Oregon Statute and an Inter-District Agreement first executed in 1938 among Reclamation, COID, North Unit Irrigation District (NUID), AID, and LPID. Three districts—COID, AID, and LPID—hold water rights to store a combined 50,000 AF in Crane Prairie Reservoir. The District holds 26,000 AF, or 52% of the total stored water rights, while AID holds rights to 13,500 AF, and the remainder (10,500 AF) is held by LPID. Stored water rights in Wickiup Reservoir are held entirely by NUID. Water from Crane Prairie Reservoir is released throughout the year and conveyed through Wickiup Reservoir and down the Deschutes River. COID's live flow water rights identify three seasons, each with different delivery rates (Table 2). These delivery rates are lower in season 1 and season 2 than in season 3. Supplemental stored water may be needed during season 1 and season 2 to accommodate modern irrigation practices that require full delivery to operate (i.e., pivots) and to accommodate changes from historical cropping (e.g., the potato crop has converted to primarily hay).

Table 2. Certified Delivery Rates and Irrigation Season Dates for the Pilot Butte Canal

Season	Start Date	End Date	Start Date	End Date	Season Duration (days)	Certified Delivery Rate (cfs)	Percentage of Full Rate
1	April 1	April 30	Oct. 1	Oct. 26	56	196.7	40.5
2	May 1	May 14	Sept. 15	Sept. 30	30	268.3	54.0
3 (1900)	May 15	Sept. 14	N/A	N/A	122	365.8	100.0
3 (1907)	May 15	Sept. 14	N/A	N/A	122	146.6	100.0

cfs = cubic feet per second; N/A = not applicable

In 2016, COID, four other irrigation districts in the Upper Deschutes Basin (AID, LPID, NUID, and Tumalo (TID)), and Reclamation reached a Stipulated Settlement Agreement with the Center for Biological Diversity and WaterWatch of Oregon with the intent of resolving two lawsuits related to Oregon spotted frog (*Rana pretiosa*). Among other outcomes, the settlement limited the total water available from Crane

Prairie Reservoir for irrigation use to 12,000 AF annually until July 31, 2019, or such time as time a basinwide habitat conservation plan could be approved for ESA-listed species in the Deschutes Basin, including Oregon spotted frog, bull trout (*Salvelinus confluentus*), Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), and steelhead (*Onchorynchus mykiss*) (Center for Biological Diversity et al. v. U.S. Bureau of Reclamation and Arnold Irrigation District et al. 2016). In response to the 2016 Settlement Agreement, COID, LPID, and AID approved a Reservoir Storage Allocation Agreement (AID et al. 2019) allocating the 12,000 AF annually amongst themselves. Additionally, COID and NUID approved an Agreement for Provision of Irrigation Water, implementing short-term changes to the operational rules of Crane Prairie Dam and Reservoir (COID and NUID 2017). These agreements, functioning as temporary amendments to the 1938 Inter-District Agreement, were designed to be in place for the duration of a supplemental interim biological opinion and extended incidental take statement for Oregon spotted frog and bull trout, and they were set to expire no later than December 31, 2020, or upon approval of a habitat conservation plan.

On December 31, 2020, USFWS announced its approval of the DBHCP and the issuance of USFWS incidental take permits specific to bull trout and Oregon spotted frog—both federally listed as threatened. NMFS announced its approval of the DBHCP and the issuance of NMFS incidental take permits specific to steelhead and sockeye salmon on October 18, 2022. Conservation measures in the DBHCP are designed to minimize and mitigate impacts caused by the incidental take of listed species that may result from the storage, release, diversion, and return of irrigation water by the Districts and the City of Prineville for a period of 30 years until 2050. The conservation measures in the DBHCP for bull trout and frogs adjust the allowed timing, volume, and duration of irrigation releases to better align with the life history needs of bull trout and frogs while continuing to enable the districts to deliver water for irrigation (USFWS 2021). In response to the approval of the DBHCP, the 1938 Inter-District Agreement among COID, NUID, LPID, and AID was again revised to reflect the final conservation measures and other provisions of the DBHCP (hereafter referred to as the 2020 Revised Inter-District Agreement) (AID et al. 2020). The 2020 Revised Inter-District Agreement codifies long-term requirements and parameters for coordination among COID, NUID, LPID, and AID for the filling and allocation of water in Crane Prairie and Wickiup Reservoirs. The 2020 Revised Inter-District Agreement will last for the full 30-year duration of the DBHCP (AID et al. 2020).

The conservation measures in the DBHCP require management of Crane Prairie and Wickiup Reservoirs for specific minimum and maximum water surface levels and related storage volumes on a seasonal basis. For Crane Prairie Reservoir, this management includes filling the reservoir during the winter despite typically low inflow and holding reservoir storage volume relatively constant during the spring and summer when inflow normally fluctuates. The DBHCP also sets minimum and maximum daily flow levels for the reach of the Deschutes River between Crane Prairie and Wickiup Reservoirs (see Table 3).

To achieve storage volumes and maintain flow levels identified in the DBHCP conservation measures, the 2020 Revised Inter-District Agreement limits the amount of stored water from Crane Prairie Reservoir that is available to the irrigation districts. As part of the 2020 Revised Inter-District Agreement, COID has agreed to forgo the use of stored water in Crane Prairie Reservoir in exchange for up to 5,000 AF of stored water from Wickiup Reservoir. In exchange for the use of this volume of NUID's stored water, COID provides NUID with an equal volume of Deschutes River water from COID's live flow rights, contingent on the availability of sufficient water in-stream for COID to fully compensate NUID without calling on AID's and LPID's junior live flow rights. In addition, under the Revised Inter-District Agreement, NUID makes available to AID and LPID a total of up to 12,000 AF of its stored irrigation water from Wickiup Reservoir. An equal amount is replaced from Crane Prairie Reservoir later in the season. The actual amount of Wickiup Reservoir water provided by NUID to AID and LPID depends on the amount of stored water available to pay back NUID later in the same irrigation season, which is determined by the reservoir elevation requirements in the DBHCP (AID et al. 2020).

Table 3. Required Ranges and Allowable Ranges of Deviation for Crane Prairie Reservoir Water Surface Elevation and Deschutes River Flow Between Crane Prairie and Wickiup Reservoirs

		Required Range		Allowable Range of Deviation	
Time Period	**Metric**	**Elevation[1]**	**Approximate Storage Volume (acre-feet) [2]**	**Elevation**	**Approximate Storage Volume (acre-feet) [2,3]**
Mar 15–Jul 15	Water surface elevation (feet) and corresponding volume	4,443.23–4,443.48	46,800–48,000	4,443.05–4,443.69	46,000–50,000
Jul 16–Mar 14	Elevation (feet) and corresponding volume	4,441.23–4,443.48	37,870–48,000	4,441.03–4,443.69	37,000–49,000
Jul 16–Jul 31	Decrease in water surface elevation (feet/day) and volume	≤0.05	225	≤0.06	270
Aug 1–Oct 31	Decrease in water surface elevation (feet/day) and volume	≤0.10	450	≤0.11	495
Time Period	**Metric**	**Flow (cfs)**		**Flow (cfs)**	
Jan 1–Dec 31	Deschutes River flow between Crane Prairie and Wickiup Reservoirs (cfs)	≥ 75; ≥ 30		≥ 70; ≥ 25	

Source: USFWS 2021.

1 Denotes water surface elevation above mean sea level.

2 Approximate storage volumes are provided for reference purposes only. DBHCP compliance will be based on water surface elevation alone.

3 There is also a provision that allows for Crane Prairie Reservoir to be drawn down by an additional 5,000 AF twice during the first 7 years of the DBHCP as available water allows, and then once every 5 years after that.

cfs = cubic feet per second

5.3.1.2 District Operations

Central Oregon Irrigation District

The District diverts both live flow and stored water from the Deschutes River near Bend, Oregon, to meet its patrons' water needs. On average, 95% of the District's water comes from live flow in the Deschutes River. Another 5% has historically come from storage in Crane Prairie Reservoir. The District holds 1,370 cfs of live flow water rights in the Deschutes River, which is primarily diverted at two diversions. The Central Oregon Canal diversion diverts water into the Central Oregon Canal at river mile (RM) 171. The PBC diversion diverts water from the Deschutes River at North Canal Dam at RM 164.8. The water is transported north through the PBC approximately 21.6 miles from the diversion before reaching the northernmost extent of the Project Area. After this point, the PBC conveyance continues north beyond the Project Area limits through the piped section of canal constructed under the Smith Rock-King Way Infrastructure Modernization Project, for roughly another 7 miles to the PBC system's northern terminus. Water is delivered to COID patrons directly from the PBC, as well as through an extensive system of laterals that branch off the PBC. Patron turnouts from the PBC and laterals are gate-regulated and weir-measured by COID field staff.

Daily responsibility and financing for operation and maintenance of the Reclamation-owned Crane Prairie Reservoir has been transferred to COID. Water is conveyed from Crane Prairie Reservoir, down a 5-mile reach of the Deschutes River, through Wickiup Reservoir, and then again north through the Deschutes River. As part of the 2020 Revised Inter-District Agreement, COID has agreed to forgo the use of its stored water in Crane Prairie Reservoir for irrigation in exchange for up to 5,000 AF of NUID's stored water from Wickiup Reservoir. The stored water is then reimbursed to NUID from a portion of COID's live flow water rights in the Deschutes River, on the condition that COID may not call on LPID's and AID's junior water rights to fully compensate NUID for use of its stored water.

Water from Crane Prairie Reservoir is released throughout the irrigation and non-irrigation seasons at levels prescribed by the DBHCP to maintain reservoir levels and year-round flows in the Deschutes River that better align with the life history needs of listed species present in the Upper Deschutes Basin. As the operator of Crane Prairie Dam and Reservoir, COID is responsible for operating in a manner consistent with the conservation measures in the DBHCP and with the 2020 Revised Inter-District Agreement.

Lone Pine Irrigation District

In addition to serving its patrons, COID delivers water to LPID at the Lone Pine Weir near the northern end of the PBC, which is outside of the Project Area. LPID holds a live flow water right for up to 29.1 cfs with a priority date of 1900. LPID supplements its live flow right with stored water from Crane Prairie and Wickiup Reservoirs in accord with an accounting arrangement formalized in the 2020 Revised Inter-District Agreement.

District personnel operate and manage the Lone Pine Weir throughout the irrigation season in accord with water delivery orders requested by LPID. Infrequently, COID has operationally spilled water into the Crooked River (RM 27.7) at the Lone Pine Weir. The Lone Pine Weir spillway is used only in emergencies, typically less than once a year. LPID is currently in the process of modernizing its system and reconfiguring its water delivery infrastructure, and a new turnout is also being added near the northern end of the currently piped Smith Rock section of the PBC to allow for a change in the location of LPID's delivery. As a result, the Lone Pine Weir and spillway will be removed within 2 to 3 years and no longer used (Horrell 2024).

North Unit Irrigation District

The District is responsible for delivering water to NUID. The water is passed to the NUID main canal via the NUID-PBC point of delivery, which is located at the northern end of the currently piped Smith Rock section of the PBC, outside of the Project Area. Given that NUID is a junior water right holder in the Deschutes Basin, it can only divert live flow when live flow in the Deschutes River exceeds 1,250 cfs. Historically, 70% of the water diverted by NUID has been from storage in Wickiup Reservoir (USDA, NRCS 2023). With the approval of the DBHCP and the 2020 Revised Inter-District Agreement, NUID's commitment to make up to 5,000 AF of stored water from Wickiup Reservoir available to COID provides access to additional Deschutes River water from COID live flow rights; however, this is contingent on COID's ability to provide the water without making a call on AID or LPID junior live flow rights. NUID may also receive up to 29.4 cfs (9,392 AF) of water that is saved from the Smith Rock-King Way

Modernization project during the irrigation season, whereby such water is either delivered to NUID at the point of delivery at the northern end of the currently piped Smith Rock section of the PBC, or NUID may divert the saved water at its point of diversion on the Deschutes River at North Canal Dam. In response, NUID legally protects the same volume of stored water for release into the Deschutes River downstream from Wickiup Reservoir during the non-irrigation season, where such protection may occur through secondary water rights for the use of storage for flow augmentation.

Arnold Irrigation District

AID diverts both live flow and stored water from the Deschutes River at the Arnold Canal Diversion (RM 174.5) near Bend. AID's primary source of water is live flow. It holds total live flow water rights of up to 150 cfs from two certificates: the first with a priority date of February 1, 1905, for 25 cfs and the second with a priority date of April 25, 1905, for 125 cfs.

The District does not deliver water directly to AID. However, the District's live flow water rights in the Deschutes River are senior to AID's water rights and the District has the ability to make a call on AID's junior water rights if needed to serve COID patrons. The two districts are also required by the 2020 Revised Inter-District Agreement to coordinate closely with one another along with NUID and LPID regarding the filling and allocation of water in Crane Prairie and Wickiup Reservoirs for the full 30-year duration of the DBHCP. Similar to LPID, AID supplements its live flow right with stored water from Crane Prairie and Wickiup Reservoirs in accordance with an accounting arrangement formalized in the 2020 Revised Inter-District Agreement.

A separate agreement among COID, AID, and Swalley Irrigation District (SID) requires the three districts to coordinate winter stock water diversions and other live flow diversions from the Deschutes River between November 1 and March 31. The purpose of the agreement is to prevent the 1-day average flow below Bend (OWRD Gage 14070500) from falling below 250 cfs.

5.3.2 Surface Water Hydrology

Waterbodies associated with District operations are presented in Table 4 and are shown in Figure 5. The upstream end of Lake Billy Chinook, at the confluence of the Deschutes, Crooked, and Metolius Rivers, serves as the downstream boundary of the area associated with District operations.

Table 4. Waterbodies Associated with District Operations

Name	Reach	Size	Tributary To	Project Nexus
Crane Prairie Reservoir	N/A	55,300 AF	N/A	COID holds 26,000 AF of stored water rights in this reservoir. Per the DBHCP and the 2020 Revised Inter-District Agreement, COID has forgone the use of stored water in Crane Prairie Reservoir in exchange for up to 5,000 AF of stored water from Wickiup Reservoir, which is reimbursed to NUID through exchange of an equal volume of Deschutes River water from COID's live flow rights.

Name	Reach	Size	Tributary To	Project Nexus
Upper Deschutes River	Crane Prairie Reservoir (RM 238.5) to Wickiup Reservoir (RM 233.5)	N/A	N/A	Releases from Crane Prairie Reservoir affect flow levels in this reach as prescribed by the DBHCP.
Wickiup Reservoir	N/A	200,000 AF	N/A	Water from Crane Prairie Reservoir is conveyed through Wickiup Reservoir and into the Deschutes River. NUID makes available up to 12,000 total AF of irrigation water to AID and LPID from Wickiup Reservoir. An amount equal to that released for AID and LPID is replaced from Crane Prairie Reservoir later in the season. COID may utilize up to 5,000 AF of stored water from Wickiup Reservoir, which is reimbursed through exchange of an equal volume of Deschutes River water from COID's live flow rights.
Upper Deschutes River	Wickiup Reservoir (RM 226.8) to North Canal Dam (RM 164.8)	N/A	Columbia River	Releases from Crane Prairie and Wickiup Reservoir affect flows in this reach.
Middle Deschutes River	North Canal Dam (RM 164.8) to Lake Billy Chinook (RM 120)	N/A	Columbia River	COID's diversion affects flows in this reach.

AF = acre-feet; AID = Arnold Irrigation District; COID = Central Oregon Irrigation District; DBHCP = Deschutes River Basin Habitat Conservation Plan; LPID = Lone Pine Irrigation District; N/A = not applicable; NUID = North Unit Irrigation District; PBC = Pilot Butte Canal; RM = river mile

Historically, the spring-fed Deschutes River had relatively consistent streamflow seasonally and annually (DRC 2012). Hydrologic conditions in the Deschutes River have changed with the construction and operation of reservoirs, dams, and diversions on the river and its tributaries. Water management for irrigation use has resulted in lower flows downstream from reservoirs during the storage season (i.e., late fall, winter, and early spring), higher flows downstream from reservoirs during the irrigation season (April to October), and lower flows farther downstream due to irrigation diversions during the irrigation season. Immediately downstream of Wickiup Dam, flows are highest in the summer and lowest in the winter. The same general trend is evident 45 miles downstream at Benham Falls, but the total flow is increased roughly 500 cfs due to input from surface tributaries and groundwater inflow. Another 17 miles downstream, just below Bend, the annual flow pattern is quite different due to irrigation diversions. Typical winter flows in the Deschutes River below Bend are not appreciably different from those at Benham Falls because there is limited inflow and diversion between these two points, but summer flows have typically been much lower below Bend due to irrigation diversions (USFWS and NMFS 2020).

The Upper Deschutes Basin has experienced a general drying trend for several decades (Gannett and Lite 2013) and is susceptible to future changes in precipitation and the amount and timing of spring runoff (Shelton and Fridirici 2001). The State of Oregon has issued drought declarations for Deschutes and Jefferson Counties each year from 2020 through 2023 (OWRD 2023a) that have led to recent curtailments in deliveries to District patrons during late summer (COID 2023). Models suggest that increased rain and a decrease in snowpack combined with an accelerated rate of spring snowmelt will have a progressively greater influence on the future water supply in the area; these changes will make managing the water supply more difficult (Shelton and Fridirici 2001; Reclamation 2016). This trend has potential for a decrease in annual mean streamflow and decreases in groundwater discharge to spring-fed streams (Gannett and Lite 2013). The following sections summarize surface water hydrology in each waterbody.

5.3.2.1 Crane Prairie Reservoir

Crane Prairie Reservoir relies on snowmelt, tributary inflows, and precipitation for inflow. Crane Prairie Dam and Reservoir are operated in coordination with Wickiup Dam and reservoir, as directed by the 2020 Revised Inter-District Agreement. Storage and releases are directed by the Oregon watermaster and are executed by COID personnel. Water levels in Crane Prairie Reservoir are based primarily upon the requirement under DBHCP Conservation Measure CP-1 to maintain reservoir surface levels within a constant elevation range (corresponding to a storage volume of between approximately 38,000 and 48,000 AF) and to maintain a consistent outflow to Wickiup Reservoir of approximately 75 cfs throughout the year. The 2020 Revised Inter-District Agreement allows for up to 12,000 AF from Crane Prairie Reservoir to be used at the end of the irrigation season to replace NUID water withdrawn from Wickiup Reservoir for AID and LPID irrigation use (AID et al. 2020).

5.3.2.2 Wickiup Reservoir

Wickiup Reservoir is 5 miles downstream from Crane Prairie Dam and relies on snowmelt, tributary inflows, releases from Crane Prairie Reservoir, and precipitation for inflow. The OWRD regional watermaster releases water from Wickiup Reservoir throughout the year based on an accounting arrangement whereby the storage accounts for COID, NUID, LPID, and AID are balanced over the course of the irrigation season. During the irrigation season, water is released as directed by the OWRD regional watermaster and operated by NUID personnel. The water is conveyed through the Deschutes River to the appropriate COID, AID, or NUID diversion point on the Deschutes River. During the non-irrigation season, water is released from the reservoir to meet the districts' commitments per the DBHCP and the 2020 Revised Inter-District Agreement.

5.3.2.3 Deschutes River (RM 238.5) to the PBC Diversion at North Canal Dam (RM 164.8)

Reservoir releases, tributary inflows, irrigation diversions, and groundwater interactions drive streamflow in the reaches of the Deschutes River from Crane Prairie Reservoir (RM 238.5) to Wickiup Reservoir (RM 233.5) and from Wickiup Reservoir (RM 226.8) to North Canal Dam (RM 164.8). Crane Prairie Reservoir and Wickiup Reservoir operations have historically contributed to lower winter streamflow and higher summer streamflow in both of these reaches. A portion of the streamflow through these reaches enters into the groundwater aquifer through the porous volcanic riverbed and banks upstream from the City of Bend.

During the non-irrigation season, irrigation districts have historically released approximately 20.8 cfs into the Deschutes River downstream from Wickiup Reservoir. As a result of the 2016 Settlement

Agreement, the irrigation districts agreed to voluntarily increase this amount to a minimum of 100 cfs. With approval of the DBHCP, the minimum winter flow from Wickiup Reservoir remains at 100 cfs for the first 7 years (2021–2027), then increases to 300 cfs for years 8 through 12 (2028–2032), and finally increases to 400 cfs at year 13, in 2033.

The Deschutes River downstream from Wickiup Dam to the PBC Diversion has in-stream water rights as identified in Table 5. OWRD holds these in-stream water rights[1] in trust to support public uses such as recreation, pollution abatement, navigation, and maintenance and enhancement of fish and wildlife and their habitats (ODFW 1997).

Table 5. In-Stream Water Rights [a] in the Deschutes River between Wickiup Reservoir and North Canal Dam

Certificate	River Miles Associated with Certificate	Year-Round Rate (cubic feet per second)
#59776	RM 226.8 to RM 192.5	300
#59777	RM 192.5 to RM 190.4	400
#59778	RM 190.4 to RM 164.8	660

Source: USDA-NRCS 2020a
a Held in trust by OWRD.
RM = river mile

5.3.2.4 Deschutes River, PBC diversion at North Canal Dam (RM 164.8) to Lake Billy Chinook (RM 120)

Five irrigation districts—COID, AID, LPID, NUID, and SID—divert water from the Deschutes River at Bend, influencing streamflow patterns in the Deschutes River between North Canal Dam (RM 164.8) and Lake Billy Chinook (RM 120). Historically, these irrigation districts maintained a minimum of 30 cfs in-stream in this reach under a voluntary agreement. Extensive conservation efforts by the irrigation districts and their partners starting in the 2000s have enhanced streamflow during the irrigation season. Since the 2016 Settlement Agreement, the irrigation districts have maintained flows of approximately 130 cfs downstream from their diversions at Bend during the summer irrigation season. The DBHCP projects that no appreciable change to this flow level is likely as the DBHCP is fully implemented. Outside of the irrigation season, the DBHCP's conservation measures for covered fish species require winter flows in the Deschutes River below Bend to be maintained at or above 250 cfs (USFWS and NMFS 2020).

The Oregon Department of Fish and Wildlife has a pending water right in this reach that identifies a year-round flow of 250 cfs for recreation or for fish and wildlife and their respective habitat quality from the North Canal Dam (RM 164.8) to Lake Billy Chinook (RM 120) (USDA, NRCS 2023).

[1] In-stream rights are enforced in the same manner as all other water rights. By law, in-stream applications cannot take away or impair any legally established water use having an earlier priority date (ODFW 1997).

5.3.3 Surface Water Quality

DEQ maintains a list of all surface waters in the state that are identified as impaired because they do not meet water quality standards under Section 303(d) of the CWA (33 United States Code [USC] 1251 et seq.). All waterbodies associated with District operations are included on Oregon's Section 303(d) impaired list, per DEQ's 2022 integrated report on surface water quality and list of water quality–limited waters (DEQ 2022b). Table 6 lists the water quality impairment parameters that each waterbody exceeds.

Table 6. Impaired Waterbodies Associated with District Operations [a]

Waterbody Name	River Miles Associated with District Operations	Parameters Included on Oregon's 303(d) list
Crane Prairie Reservoir	N/A	Dissolved Oxygen pH Temperature Harmful Algal Blooms
Wickiup Reservoir	N/A	Temperature Harmful Algal Blooms
Deschutes River	Crane Prairie Dam (RM 238.5) to Wickiup Reservoir (RM 233.5)	Temperature Dissolved Oxygen pH
Deschutes River	Wickiup Reservoir (RM 226.8) to PBC diversion at North Canal Dam (RM 164.8)	Temperature Sedimentation Turbidity Dissolved Oxygen Flow Modification Habitat Modification pH
Deschutes River	PBC diversion at North Canal Dam (RM 164.8) to Lake Billy Chinook (RM 120)	Flow Modification Temperature Dissolved Oxygen
Crooked River	RM 27.7 to the mouth (RM 0)	Flow Modification Biological Criteria pH Temperature Phosphorus

Source: DEQ 2022b.

a Chlorophyll a and harmful algal blooms are also on the Section 303(d) list for the Crooked River from RM 0 to RM 5. However, this stretch is considered Lake Billy Chinook and therefore is not included in this section.

N/A = not applicable; RM = river mile

Water management in the Deschutes Basin has altered seasonal streamflow patterns, increasing streamflow above historical levels in some reaches and decreasing streamflow below historical levels in other reaches. Low streamflow affects water quality in the Deschutes River by exacerbating temperature and dissolved oxygen problems. In addition, water quality often influences the spread and extent of invasive aquatic species, and these problems interact synergistically to degrade wildlife habitat within and around the Deschutes River. The following sections describe existing Section 303(d)–listed impairments in the waterbodies associated with District operations. DEQ is required to develop TMDLs for rivers and streams in the Upper Deschutes Basin (these impairments may extend upstream or downstream of the reaches identified in Table 6).

5.3.3.1 Temperature

The Deschutes River and the Crooked River do not meet stream temperature criteria within the area associated with District operations (DEQ 2022b; Table 6). The temperature criterion that applies throughout the area is 64.4 degrees Fahrenheit (F). These standards are set to protect designated beneficial uses within the Deschutes Basin, including salmon and trout rearing and/or migration, public and private domestic water supply, wildlife and hunting, and aesthetic quality (DEQ 1995; DEQ 2008). Elevated stream temperatures affect aquatic species, including native fish, by exacerbating conditions that cause stress and disease, raise their metabolism, and reduce growth rates. Low streamflow, reduced streamside vegetation, and widened channels can all contribute to elevated stream temperatures.

5.3.3.2 Dissolved Oxygen

In the Deschutes River, the dissolved oxygen levels in all reaches are not high enough to meet Oregon's standards during the trout spawning season from January 1 to May 15, and they do not meet Oregon's standards year-round from Deschutes RM 171.7 to RM 223.3. (DEQ 2022b; Table 6). Low dissolved oxygen levels can affect aquatic life by reducing habitat quality and quantity, changing behavior, or reducing growth rates. Excess nutrient inputs, associated algae growth and die-off, and elevated stream temperatures can all contribute to lower dissolved oxygen levels.

5.3.3.3 Harmful Algal Blooms

Crane Prairie and Wickiup Reservoirs exceed water quality impairment parameters for harmful algal blooms. Certain environmental conditions in waterbodies can intensify algae growth and cause algal blooms. Blooms with the potential to harm human health or aquatic ecosystems are referred to as harmful algal blooms or HABs. In freshwater systems, cyanobacteria (previously known as blue-green algae) are microorganisms that can produce HABs. Some cyanobacterial HABs, or cyanoHABs, can produce toxins. CyanoHABs and their toxins can harm people, animals, aquatic ecosystems, the economy, drinking water supplies, property values, and recreational activities including swimming and commercial and recreational fishing (EPA 2023a).

5.3.3.4 pH

A waterbody's pH is a measure of its acidity or basicity. The Deschutes River 2.2 miles above the PBC diversion (RM 164.8) and all of the Deschutes River from the PBC diversion (RM 164.8) to Lake Billy Chinook (RM 120) exceeds Oregon's pH standard with higher, or more alkaline, pH values (DEQ 2022b; Table 6). The Crooked River from RM 27.7 to the mouth does not meet Oregon's pH standards during the summer (DEQ 2022b; Table 6). Higher pH can affect aquatic life by changing the solubility or biological availability of chemicals in the water.

5.3.3.5 Sedimentation

Sedimentation refers to deposits of silt, sand, or other small particles in a river. In the Deschutes River, the 62 river miles between Wickiup Reservoir (RM 226.8) and the PBC diversion (RM 164.8) do not meet Oregon's standards for sedimentation (DEQ 2022b; Table 6). DEQ set this standard to protect resident fish and aquatic life and salmonid fish spawning and rearing in the river. In the Deschutes River, lower winter flows and higher summer flows have contributed to increased bank erosion. Increased bank erosion contributes to increased sediment in the river. The river carries this sediment downstream and deposits it along the riverbed. Deposited sediment can affect fish and aquatic life by reducing the quantity and quality of available habitat.

5.3.3.6 Turbidity

Turbidity is a measure of water cloudiness. In the Deschutes River, the 62 river miles between Wickiup Reservoir (RM 226.8) and the PBC diversion (RM 164.8) do not meet Oregon's turbidity standard during the spring and summer (DEQ 2022b; Table 6). This standard is set to protect aesthetics, resident fish and aquatic life, and water supply in the river. Suspended sediment, algae, and other suspended or dissolved materials contribute to increased turbidity.

5.3.3.7 Biological Criteria

The biological criteria parameter on the Section 303(d) list indicates that a waterbody does not meet standards for biological integrity of aquatic communities (primarily macroinvertebrates). The Crooked River does not meet Oregon standards year-round for biological criteria (DEQ 2022b; Table 6). Oregon's rules for biocriteria (OAR 340-041-0011) require waters of the State to be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.

5.3.3.8 Phosphorous

The Crooked River from RM 27.7 to the mouth does not meet standards for phosphorous (DEQ 2022b; Table 6). High concentrations of phosphorus may result from poor agricultural practices, runoff from urban areas and lawns, leaking septic systems, or discharges from sewage treatment plants. Too much phosphorus can cause increased growth of algae and large aquatic plants, which can result in decreased levels of dissolved oxygen—a process called eutrophication. High levels of phosphorus can also lead to algae blooms that produce algal toxins which can be harmful to human and animal health (EPA 2023b).

5.3.3.9 Flow Modification

Flow alteration is identified as an impairment for the Deschutes River from Wickiup Reservoir (RM 226.8) to the PBC diversion at North Canal Dam (RM 164.8) (DEQ 2022b; Table 6). Flow alteration refers to modification of flow characteristics relative to reference or natural conditions. Human activities can significantly alter flow and may lead to biological impairment. For example, human activities may change how much water reaches a stream, divert flow through humanmade channels, or alter stream shape and location. Changes to streamflow characteristics may benefit some aquatic organisms while harming others, thereby changing biotic community composition (EPA 2023c).

5.3.3.10 Habitat Modification

The Deschutes River from Wickiup Reservoir (RM 226.8) to the PBC diversion at North Canal Dam (RM 164.8) is identified as impaired due to habitat modification (DEQ 2022b; Table 6). Habitat modification activities include channelization and channel modification, dams, and streambank and shoreline erosion. A frequent result of channelization and channel modification activities is a diminished suitability of in-stream and streamside habitat for fish and wildlife. Such modification activities can also alter in-stream patterns of water temperature and sediment type, as well as the rates and paths of sediment erosion, transport, and deposition (EPA 2023d).

5.3.4 Groundwater

5.3.4.1 Hydrogeology

Groundwater generally flows east and then north through the Upper Deschutes Basin. Approximately half of this groundwater discharges into streams through springs along the edge of the Cascade Mountains. The remainder of this groundwater discharges into streams and rivers near the confluence of the Metolius, Deschutes, and Crooked Rivers (Gannett et al. 2001).

Due to the porous geology of the area, groundwater levels and stream discharge are associated with movement of water between surface water and groundwater systems. The rivers, streams, and irrigation canals in the Upper Deschutes Basin generally all show seepage losses, indicative of the area's permeable geology (Gannett et al. 2001).

The water table in the Bend area is generally hundreds of feet below the land surface. In the Study Area around Bend (elevation 3,625 feet above mean sea level [AMSL]) and Redmond (elevation 2,999 feet AMSL), the groundwater table is relatively flat between an elevation of 2,600 and 2,800 feet with a slight downward vertical gradient from south to north (Gannett et al. 2001). The northward slope of the water table is less steep than the northward slope of the land; therefore, the water table is closer to the land surface in the Redmond area than it is near Bend.

The unsaturated zone (the portion of the subsurface above the groundwater table) in the Bend area is typically more than 200 feet thick, and in many areas it is more than 500 feet thick. The unsaturated zone is comprised of volcanic and pyroclastic rocks that are younger than the Deschutes Formation. The unsaturated zone extends into the Deschutes Formation. The thickest zones are northeast of the city where wells are drilled on buttes, and the thinnest zones are near the Deschutes River (Gannett et al. 2001).

The unsaturated zone in the Redmond area is typically more than 150 feet thick, and in many areas, more than 400 feet thick. The thinnest unsaturated zones occur where wells were drilled near the Deschutes River. The unsaturated zone is comprised of volcanic rocks that are younger than the Deschutes Formation. Similar to the Bend area, the unsaturated zone extends into the upper portion of the Deschutes Formation. Also similar to the Bend area, the thickest unsaturated zones in the Deschutes Formation occur where wells are drilled on buttes.

5.3.4.2 Groundwater Level Change

Cascade Range aquifers in the Upper Deschutes Basin have experienced a general drying trend since the 1950s. (Gannett and Lite 2013). The aquifers in the Upper Deschutes Basin are susceptible to future changes in precipitation and the amount and timing of spring runoff (Shelton and Fridirici 2001). Climate oscillations remain the primary driver of these changes (Gannett et al. 2001; Gannett et al. 2003). Climate models suggest that increased rain and a decrease in snowpack combined with an accelerated rate of spring snowmelt will have an increasingly greater influence on the future water supply in the area; these changes will make managing the water supply more difficult (Shelton and Fridirici 2001; Reclamation 2016). A USGS study focusing on groundwater level changes during the period of 1997 to 2008 investigated the influence of canal piping and/or lining, groundwater pumping, and climate on water level trends in the region (Gannett and Lite 2013). The study noted that 5- to 14-foot declines in groundwater levels have occurred in the central part of the Upper Deschutes Basin since the mid-1990s. There are a number of likely causes for these declines, including climate-related decreases in basinwide groundwater recharge from precipitation, decreases in local groundwater recharge as a result of lining and piping of irrigation canals, and increased groundwater pumping for domestic and agricultural use.

Gannett and Lite (2013) found that substantial canal lining and piping within the Upper Deschutes Basin between 1994 and 2008 likely contributed to decreased recharge and declining groundwater levels, particularly near affected canals. However, Gannett and Lite (2013) concluded that while both pumping and canal lining affect groundwater levels, impacts from climate variations have the largest influence on groundwater levels throughout the Upper Deschutes Basin. Pumping (both domestic and agricultural) and canal lining are largely restricted to the central part of the basin extending north from near Benham Falls to Lower Bridge and east from Sisters to the community of Powell Butte. Outside of the central portion of the Upper Deschutes Basin, the water level response from changes in pumping and irrigation canal seepage cannot be discerned from the larger response to climate-driven changes in recharge. At the basinwide scale, natural fluctuations in groundwater discharge largely mask the effects of development on discharge from the regional aquifer (Gannett et al. 2001).

5.3.4.3 Canal Seepage

Groundwater recharge caused by seepage from leaky irrigation canals has elevated groundwater levels in the central part of the Upper Deschutes Basin over the past century. Previous studies (Sceva 1968; Gannett et al. 2001) have shown that canal seepage is a significant component of the groundwater budget and also has resulted in increased baseflow to the lower Crooked River. Canal seepage rates have been found to vary greatly within the Upper Deschutes Basin depending on the geology of the canal bottom, the degree to which cracks and voids have been filled by sediment, and the wetted perimeter of the canal. Groundwater level measurements from the early 1900s prior to construction of the canal network are virtually nonexistent; therefore, it is not possible to know how much groundwater levels have risen in direct response to irrigation canal seepage.

A comparison of seepage loss assessments by Farmers Conservation Alliance, COID, and Parametrix indicated that up to approximately 43,544 AF per year may be lost from the PBC via canal seepage (FCA 2023; COID 2016a; Appendix A). Due to variations in geology and hydraulic conductivity, seepage losses are not uniform throughout the Project Area. In general, the highest rates of canal seepage occur in reaches farther south within the Project Area and are especially high in the vicinity of Bend. Existing conditions of canal seepage to groundwater are discussed in detail in Appendix A.

5.3.4.4 Groundwater Pumping

Groundwater pumping in the Study Area is overwhelmingly for domestic use and municipal drinking water supplies. The City of Bend maintains eight groundwater facilities with 20 active wells and large pumps to augment its municipal water supply, which is primarily sourced from surface water in the Bend Municipal Watershed (City of Bend 2024). The City of Redmond's municipal water supply relies entirely on the eight groundwater wells that pump water from the Deschutes Formation year-round (City of Redmond 2024). A query of the OWRD Well Report Database identified 2,344 domestic water wells in the Study Area, primarily concentrated in the Rivers Edge Project Group in the south and the King Way and Redmond Project Groups in the north. The greatest concentration of domestic water wells was identified in the immediate vicinity of Bend and Redmond (OWRD 2023b). Figure 7 shows the relative concentrations of domestic water wells identified within the six project groups. Relatively few agricultural irrigation wells (only 11) were identified by the OWRD Well Report Database query. In addition to domestic and agricultural wells, 28 groundwater observation wells were identified in the Study Area. Data from these 28 observation wells, whose locations are shown above in Figure 6, were used to assess the potential long-term impacts of the alternatives on groundwater levels as detailed in Section 7.2.

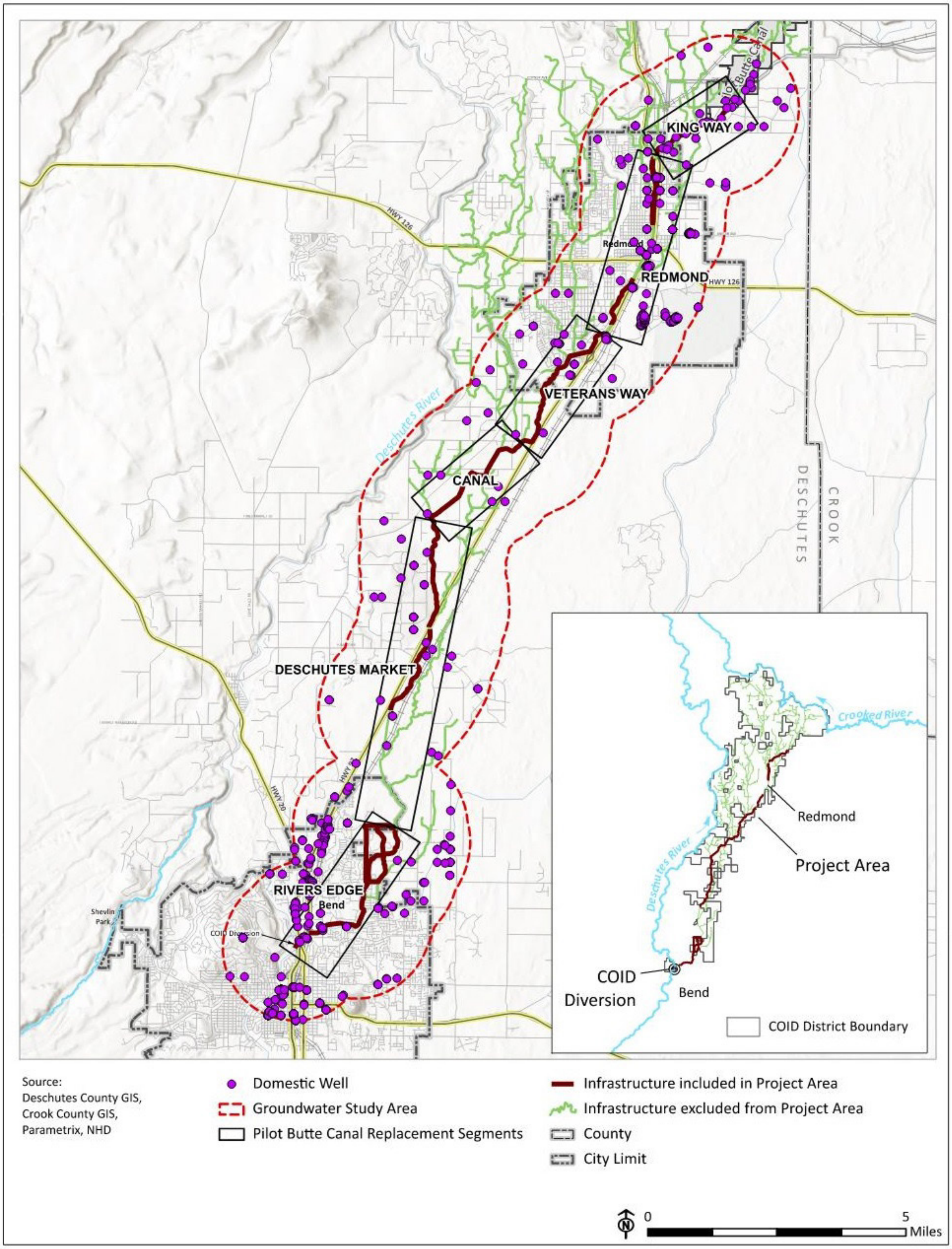


Figure 7. Domestic Water Well Locations in the Study Area

6. IMPACT ASSESSMENT METHODOLOGY AND DATA SOURCES

6.1 Long-Term Impact Assessment Methods

Potential adverse and beneficial long-term impacts of the alternatives on surface water and groundwater resources were determined by analyzing and reviewing the following:

- **Impacts to Water Rights**. Potential long-term impacts were assessed based on the potential effects of the No Action and Modernization Alternatives on the ability of COID to deliver sufficient irrigation water to its patrons and the other districts as allocated by each district's water rights.
- **Impacts to Surface Water Hydrology**. Potential long-term impacts to surface water hydrology were assessed based on and comparisons of current and anticipated streamflow trends in the Upper Deschutes Basin relative to the amount of water saved or not saved as a result of the Project.
- **Impacts to Surface Water Quality**. Potential long-term impacts to surface water quality were assessed based on review of existing activities currently affecting surface water quality and the potential for the alternatives to affect levels of pollutants and contaminants, sediment, and temperatures in the Study Area.
- **Groundwater Impacts.** Assessment of potential long-term groundwater impacts from the No Action and Modernization Alternatives used published USGS groundwater model results that estimated reduced canal seepage due to piping in the Project vicinity over the 14-year period from 1994 to 2008 (Gannett and Lite 2013). The model was applied to groundwater level measurement data from observation wells located within 1.4 miles of the PBC (see Figure 6) for the 14-year period from 2009 to 2023. Appendix A contains detailed discussion of the methodology, data inputs, and results of the assessment, as well as conclusions on the potential groundwater impacts of the Modernization Alternative.
- **Beneficial Impacts.** Water saved through modernization of the PBC system would help COID and NUID to meet their patrons' agricultural irrigation demands more reliably. Additionally, reduction in water loss through PBC modernization would potentially help to mitigate future water shortages that could result from the competing needs to meet the year-round stream flow requirements of the DBHCP while delivering sufficient irrigation water to District patrons. As a result, beneficial impacts are discussed where applicable.

6.2 Short-Term Impact Assessment Methods

Short-term impacts of the Modernization Alternative and its alignment options on water resources were assessed based upon the potential for construction activities to affect surface water hydrology and surface water quality in the Deschutes River and groundwater quality beneath the Project Area. Short-term impacts of the No Action Alternative were assessed based on the presumed absence of construction activities that would otherwise be associated with the Modernization Alternative.

6.3 Indirect Impact Assessment Methods

Indirect impacts include those that are not a direct result of the Project but would potentially occur later in time or farther in distance as a result of the alternatives. Potential indirect impacts were determined by evaluating how the alternatives could change conditions for other water resources, uses, or projects in light of the existing development, climate impacts, and ongoing water resource trends occurring in the Deschutes Basin.

6.4 Cumulative Impact Assessment Methods

Known past, ongoing, and reasonably foreseeable future actions with potential to affect water resources in the Study Area were identified through desktop research and review of recent and pending irrigation modernization projects in the Upper Deschutes Basin. Cumulative actions in the Study Area include previous development in the Upper Deschutes Basin and other ongoing, authorized, or proposed modernization projects by COID and other irrigation districts. Based on the analysis of potential long-term impacts of the No Action and Modernization Alternatives, it was determined whether the alternatives have the potential to result in additive impacts on water resources that are also impacted by other past, present, and future projects.

7. ENVIRONMENTAL CONSEQUENCES

7.1 Introduction

Table 7 summarizes the potential long-term effects of the Project alternatives and alignment options on water resources. These effects are discussed in detail in Section 7.2.2.

Table 7. Water Resources Effects by Alternative

Alternative	Water Rights	Surface Water Hydrology	Surface Water Quality	Groundwater
No Action Alternative	No change.	Seasonal flow regimes in the Deschutes River would shift to higher winter flows and lower summer flows due to changes in reservoir management and timing of releases as required by the DBHCP conservation measures. Water levels would likely become lower over time within the Deschutes Basin, primarily due to climate change. Water availability for NUID patrons would diminish due to continued evaporation and seepage losses from the PBC.	Potential to deteriorate as water levels in surface waterbodies become gradually lower and average water temperatures become higher within the Deschutes Basin as a result of continued drying due to climate change.	No Change. Groundwater levels are anticipated to continue to decline throughout the Upper Deschutes Basin primarily due to climate change[1].

Alternative	Water Rights	Surface Water Hydrology	Surface Water Quality	Groundwater
Modernization Alternative (full piping), including impacts common to all piping options for Deschutes County/North Bend and City of Redmond segments	COID would reduce its water right certificate(s) by an amount equal to the water savings provided by piping. NUID would change the character of its water use right in Wickiup Reservoir to protect a portion of its water for flow augmentation during the non-irrigation season.	Similar to the No Action Alternative. Surface water hydrology would not substantially change from that described for the No Action Alternative, due to implementation of the DBHCP independent of the Project. Summer flows between Wickiup Reservoir and North Canal Dam in Bend would decrease, while winter flows would increase. During the first year of Project implementation, a volume of water equivalent to that saved and passed to NUID during the irrigation season would be added to the minimum 100 cfs winter release below Wickiup Dam. This would have a minimal effect on surface water hydrology. After the first year of Project implementation, minimum winter releases below Wickiup Dam will increase to 300 cfs and the Project would have no effect on surface water hydrology.	Surface water quality in waterbodies associated with District operations would likely be unaffected. Piping would reduce storm drainage from urban areas and agricultural operations, which would help to reduce contaminant loads in irrigation water. Irrigation water in the pipes would also not be subjected to sunlight and warm ambient temperatures during the summer. This would reduce the potential for elevated water temperatures that could contribute to greater concentrations of contaminants and bacterial growth, reducing the risk of crop contamination and foodborne illnesses.	Canal seepage loss eliminated through piping would result in an approximately 43,544-AF reduction in infiltration to the upper portion of the regional aquifer. Localized reductions in groundwater levels of up to a maximum of 68 feet could occur; this would depend on the location within the Study Area and the distance from the PBC. Water levels are anticipated to continue to decline independently of the Project due to climate change[1].
No Modernization (no piping) within Deschutes County/North Bend section	Same as the Modernization Alternative with full piping options.	Same as Modernization Alternative with full piping options.	Similar to Modernization Alternative with full piping options above. This option would pipe approximately 7,800 fewer linear feet of canal, leaving the unpiped section susceptible to continued mobilization of pollutants in stormwater runoff.	Leaving approximately 7,800 feet of canal unpiped and susceptible to seepage would result in an approximately 37,967-AF total reduction in infiltration to the upper portion of the regional aquifer. Water levels are anticipated to continue to decline independently of the Project due to climate change[1].

Alternative	Water Rights	Surface Water Hydrology	Surface Water Quality	Groundwater
No Modernization (no piping) within City of Redmond segment	Same as the Modernization Alternative with full piping options.	Same as Modernization Alternative with full piping options.	Similar to Modernization Alternative with full piping options. This option would pipe approximately 6,500 fewer linear feet of canal, leaving the unpiped section susceptible to continued mobilization of pollutants in stormwater runoff.	Leaving approximately 6,500 feet of canal open and susceptible to seepage would result in an approximately 42,701-AF total reduction in infiltration to the upper portion of the regional aquifer. Water levels are anticipated to continue to decline independently of the Project due to climate change[1].

[1] Appendix A; Shelton and Fridirici 2001; Gannett and Lite 2013; Reclamation 2016; OWRD 2021; Frankson et al. 2022

AF = acre-feet; PBC = Pilot Butte Canal

7.2 Long-Term Effects

7.2.1 No Action (Future Without Federal Investment)

Under the No Action Alternative, no federal funding would be provided under PL 83-566 for system modernization improvements. The existing open portions of the PBC would remain unpiped, and the District's delivery system within the Project Area would remain in its current condition. Modernization of the District's infrastructure along the PBC would not be reasonably certain to occur.

No water would be saved under the No Action Alternative. Losses associated with seepage and evaporation would continue at current levels. Water delivery reliability for District patrons would not improve, and current concerns regarding water availability for agricultural use would not be addressed. As the ongoing drying trend in the Deschutes Basin continues, the No Action Alternative would potentially contribute to continued reductions in streamflow, decreased water delivery reliability, increased water temperatures and deterioration in surface water quality, and declines in aquatic and riparian habitat conditions. The ability to achieve the conservation goals of the DBHCP would also be diminished.

7.2.1.1 Water Rights

Under the No Action Alternative, COID's water rights would not change. There would be no change to the water rights of other irrigation districts in the Upper Deschutes Basin. Current system operations and maintenance practices would remain the same. Ongoing drying and warming trends in the Upper Deschutes Basin would be expected to persist (Appendix A; Shelton and Fridirici 2001; Gannett and Lite 2013; Reclamation 2016; OWRD 2021; Frankson et al. 2022). Curtailments in irrigation water delivery for patrons of COID and other districts relying on Deschutes River water, as has happened during recent drought years (COID 2023), could continue. Without the available benefit of additional saved water, COID's future ability to deliver water to NUID and LPID at the north end of its system could also be constrained. This would be exacerbated when the full in-stream flow requirements of the DBHCP are implemented beginning in 2033, at year 13 (USFWS and NMFS 2020). Streamflow in the stretch of the river between North Canal Dam and Lake Billy Chinook could also potentially fall short of OWRD's 250 cfs pending in-stream water right that serves as a flow target.

7.2.1.2 Surface Water Hydrology

The No Action Alternative would have no direct effect on existing surface water hydrology in waterbodies associated with District operations, including storage levels in Crane Prairie and Wickiup Reservoirs and flows in the Deschutes River from Wickiup Reservoir (RM 226.8) to North Canal Dam (RM 164.8), and from North Canal Dam to Lake Billy Chinook (RM 120). Implementation of the DBHCP would result in lower summer flows and higher winter flows in the Deschutes River between Wickiup Reservoir and North Canal Dam. The District would continue to divert water in volumes that calculate for water loss due to seepage and evaporation. No additional water would be saved for pass-through as live flow to NUID.

7.2.1.3 Surface Water Quality

The No Action Alternative would have no effect on existing surface water quality in waterbodies associated with District operations (see Table 7). Under the No Action Alternative, the open irrigation canal would continue to collect stormwater runoff from urban areas and agricultural crop and livestock operations, subsequently delivering contaminants such as herbicides, pesticides, fecal coliform bacteria (including *E. coli*), and other pollutants to patrons downgradient in the system. This could create concerns for some patrons within the District as it could affect the safety of the local food system. There would be no change in potential turbidity related to mobilization of sediment into the canal via stormwater inflow or erosion of canal banks. There would be no effect on the Deschutes River's inclusion on Oregon's 303(d) list and the river would continue to be listed as not meeting water quality standards for metrics including flow modification, temperature, dissolved oxygen, pH, phosphorus, and biological criteria.

7.2.1.4 Groundwater

The No Action Alternative would have no effect on existing groundwater conditions in the Project Area or the Upper Deschutes Basin. Annually, approximately 43,544 AF of water would continue to seep from the PBC into the upper portion of the Deschutes Basin aquifer beneath the Project Area each year. Groundwater levels are anticipated to continue to decline due to climate change (Appendix A; Shelton and Fridirici 2001; Gannett and Lite 2013; Reclamation 2016; OWRD 2021; Frankson et al. 2022).

7.2.2 Modernization Alternative (Future With Federal Investment)

7.2.2.1 Impacts Common to all Full Piping Options, including Deschutes County/North Bend and Redmond Pipe Alignment Options

The Modernization Alternative would have identical impacts on water resources under all of the full piping alignment options. For the Deschutes County/North Bend section, these include the PBC Alignment (existing canal route), NE 18th Street Option, and Old Deschutes Road Option. This is because independently of alignment option, the entire flow of the PBC through the Project Area would be conveyed through a pipe, resulting in identical canal seepage reduction and therefore the same volume of water saved. The following discussion therefore applies to all of the Modernization Alternative alignment options universally. The potential effects resulting from no modernization of the Deschutes County/North Bend and Redmond historic sections of the Project Area are discussed in Section 7.2.2.2.

For all full piping options, the Modernization Alternative would result in a combined savings of approximately 43,544 AF per year (136 cfs) from canal seepage reduction. The saved water would be passed through to NUID. NUID would then release an equal volume from Wickiup Reservoir during the non-irrigation season. Water savings would accrue over the course of the 3-year construction period for the Modernization Alternative. The amount of water savings attributable to each project group is shown in Table 8.

Table 8. Water Savings by Project Group for the Modernization Alternative

Project Group	Length of Project Improvements (ft)	Length of Project Improvements (mi)	Amount Conserved (AF)
King Way	10,955	2.1	3,927.1
Redmond (all options)[a]	12,400	2.3	2,023.1
Veterans Way	16,650	3.2	8,612.7
Canal	13,850	2.6	8,810.5
Deschutes Market	22,000	4.2	8,398.9
Rivers Edge	18,125 to 19,825	3.4 to 3.8	11,771.8
Pilot Butte Canal Option	18,125	3.4	-
18th Street Option	19,325	3.7	-
Old Deschutes Road Option	19,825	3.8	-
TOTAL [a]	**93,980 to 95,680**	**17.8 to 18.2**	**43,544.1**

AF = acre-feet; ft = feet; mi = miles
[a] Does not include 1,100 feet of existing pipe within the Redmond segment that would be replaced with new pipe of a larger diameter

Water Rights

Under the Modernization Alternative, COID would diminish its water right certificate(s) by an amount equivalent to the full volume that is saved from piping. Saved water would be passed through as live flow to NUID. Because LPID's and AID's water rights are senior in priority to NUID's, these districts have signed a baseline forbearance agreement allowing NUID to use water saved from COID piping projects ahead of LPID and AID. This agreement would be modified as the proposed action is implemented. All of the signatory districts to the 2020 revised inter-district agreement would need to acknowledge each increment of conserved water that will be "forborne" and made available to NUID as additional projects are proposed/completed. The baseline forbearance agreement would therefore be effectively re-executed as future piping projects by COID and other districts are implemented. . As part of the transfer of live flow water rights from COID, NUID would complete a transfer of character of use of its storage right to include a combination of storage for irrigation and flow augmentation purposes. Then, NUID would secure a secondary use right to release storage for flow augmentation downstream of Wickiup Reservoir. During the non-irrigation season, NUID would release an amount of water equaling up to 100% of the volume of saved water passed through from COID to NUID during the irrigation season. COID would coordinate with AID, LPID, and NUID to ensure that stored water allocation and system operations at Wickiup Reservoir align with the conservation measures in the DBHCP and the 2020 Revised Inter-District Agreement. Compared to the No Action Alternative, the likelihood that NUID would be able to satisfy its patrons' irrigation demands on a consistent basis as the DBHCP approaches full phase-in would be higher.

Surface Water Hydrology

The Modernization Alternative would allow COID to more efficiently meet its patrons' water needs relative to the No Action Alternative. In addition, water conserved through elimination of operational water losses and canal seepage would be passed through to NUID. The pass-through of saved water to NUID would enable NUID to more reliably meet its patrons' water needs as full implementation of the DBHCP's conservation measures is phased in.

The Modernization Alternative would have no effect on Crane Prairie Reservoir because it would not influence Crane Prairie Reservoir operations. It would have minimal beneficial effects during the first year of Project operation, and no effects thereafter, on surface water hydrology in Wickiup Reservoir and the Deschutes River from Wickiup Reservoir (RM 226.8) to Lake Billy Chinook (RM 120). Because water savings would begin accruing during the irrigation season following construction of the first project groups (2027, or DBHCP year 7), a minimal amount of additional saved water would be held by NUID for wintertime release from Wickiup Reservoir beyond that required to meet minimum DBHCP winter flow requirements. The water would be managed under the DBHCP's Year 1 to 7 management prescriptions. As a result, a volume of water equivalent to that saved and passed to NUID during the 2027 irrigation season would be added to the DBHCP-prescribed minimum winter release of 100 cfs. Thus, there would be a minimal increase in wintertime flows in the Deschutes River below Wickiup Dam for the first year of Project operation. In DBHCP Year 8, minimum wintertime releases from Wickiup Reservoir will increase to 300 cfs, and all effects on flows from the Modernization Alternative would cease.

In the long term (DBHCP Year 8 and beyond), the Modernization Alternative would help to facilitate winter flow levels below Wickiup Reservoir that align with the requirements of the DBHCP conservation measures, while bolstering both COID and NUID's abilities to continue delivering sufficient water as live flow for irrigation as the DBHCP phases into full implementation. The changes in NUID water rights associated with the pass-through of saved COID water to NUID would support winter flow augmentation in the Deschutes River below Wickiup Reservoir season in conformance with the DBHCP conservation measures and would not add flow beyond the required minimum releases below Wickiup Dam.

Surface Water Quality

The Modernization Alternative would prevent contaminants from entering the irrigation water supply where the open canal is converted to pipe. These contaminants largely consist of urban runoff, but depending on the location along the canal, can also include herbicides, pesticides, fertilizers, and bacteria from livestock waste. By preventing contaminants from entering the PBC in stormwater runoff, thus reducing nonpoint source contamination carried on-farm through irrigation water delivery, the Modernization Alternative would result in beneficial effects on irrigation water quality.

Groundwater

No groundwater resources would be extracted or consumptively used as part of the Modernization Alternative. However, piping approximately 18 miles of the PBC would affect groundwater recharge by reducing canal seepage. Implementation of the Modernization Alternative would reduce canal seepage by up to approximately 43,544 AF annually and reduce groundwater recharge by a roughly corresponding amount. Localized effects on groundwater would differ throughout the area as geology, water table depths, and hydraulic conductivity of formation materials differ over the extent of the Study Area (see Appendix A). These effects would be most prominent at shallow depths (upper portion of the aquifer) closest to the PBC and would be likely to attenuate with increasing depth and increased distance from the canal (Gannet and Lite 2013).

The groundwater impacts analysis in Appendix A indicates that the effects of modernization on groundwater levels would differ depending on location from the south to north ends of the PBC and the distance from the canal. The greatest water level declines would be observed in the Rivers Edge and Deschutes Market Project Groups and attenuate toward the Canal and Veterans Way Project Groups. Based on results of modeling using a USGS groundwater model (Gannett and Lite 2013), the analysis in Appendix A concluded that up to -68 to -50 feet of groundwater level decline may occur in the groundwater Study Area within the upper 100 feet of the saturated zone. These declines would occur adjacent to the canal and decrease to a -10-foot decline extending up to 5 miles away from the canal. Groundwater level decline 200 to 300 feet below the water table would be attenuated and would range from -2 feet to less than -5 feet.

The Modernization Alternative could contribute to adverse impacts on nearby domestic and irrigation wells by decreasing seepage to groundwater. As noted in Sections 5.3.4.2 and 7.2.1.4 above and detailed in Appendix A, a continued decline in groundwater levels is anticipated throughout the Upper Deschutes Basin due to climate change. Additionally, the effects on groundwater availability at wells would diminish with distance from the PBC and the depth to groundwater at the well location. Therefore, it is difficult to predict the specific potential impacts of the Modernization Alternative on local domestic and irrigation wells. Overall, the Modernization Alternative would be expected to have minor long-term adverse effects on groundwater levels and groundwater availability in the Study Area.

7.2.2.2 No Modernization within the Deschutes County/North Bend Section

This alignment option would not pipe approximately 7,800 linear feet of canal within the NRHP-listed section between Yeoman and Cooley Roads, located in the northern portion of the Rivers Edge Project Group. Instead, this section of the PBC would remain open and in its current unlined condition. As a result, this section of the PBC would remain susceptible to the same water resources effects described for the No Action Alternative in Section 7.2.1.

This section of the PBC makes up a small portion of the overall length of the PBC that is proposed for piping under the Modernization Alternative: 7,800 feet, or less than 1.5 miles out of approximately 18 total miles (8% of total length). As a result, it is assumed that impacts to water rights and surface water hydrology would not differ from those described for the Modernization Alternative.

Leaving the NRHP-listed section between Yeoman and Cooley Roads open would continue to leave it susceptible to the introduction of pollutants from stormwater runoff into the canal. However, because the length of this section is 8% of the total length of canal proposed for modernization, this option would not be expected to detract from the overall beneficial water quality effects of fully piping the PBC.

This option would result in continued water loss to seepage and evaporation within the NRHP-listed section of canal. Because this section is confined entirely to the Rivers Edge Project Group of the PBC piping project, it is assumed that the reduction in water savings across the entire segment can be computed using the per-linear-foot. Table 9 illustrates the estimated amount of water that would be conserved with no modernization through the Deschutes County/North Bend NRHP-listed segment.

Table 9. Water Conservation Savings by Project Group with No Modernization through the Deschutes County/North Bend NRHP-Listed Segment

Project Group	Length of Project Improvements (ft)	Length of Project Improvements (mi)	Amount Conserved (AF)
King Way	10,955	2.1	3,927.1
Redmond (all options)[a]	12,400	2.3	2,023.1
Veterans Way	16,650	3.2	8,612.7

Canal	13,850	2.6	8,810.5
Deschutes Market	22,000	4.2	8,398.9
Rivers Edge	10,325	2.0	6,195.0
Total [a]	**86,180**	**16.4**	**37,967.3**

AF = acre-feet; ft = feet; mi = miles

[a] Does not include 1,100 feet of existing pipe within the Redmond segment that would be replaced with new pipe of a larger diameter

Leaving the PBC open through the Deschutes County/North Bend NRHP-listed segment would save approximately 6,195 AF of water within the Rivers Edge Project Group, resulting in substantial water savings relative to the No Action Alternative (approximately 37,967 AF). However, this represents a 5,577-AF reduction in savings compared to the roughly 11,772 AF that would be saved by fully piping the PBC within the Rivers Edge Project Group (see Table 8). Considering the overall estimated water savings of approximately 43,544 AF under the Modernization Alternative, forgoing modernization of the Deschutes County/North Bend NRHP-listed segment would reduce total water saved by approximately 13% relative to the full piping options. This would not change the character of overall water resources effects and would represent a minor reduction in water savings compared to the other Modernization Alternative alignment options.

7.2.2.3 No Modernization within the City of Redmond Section

This alignment option would not pipe approximately 6,500 linear feet of canal within the NRHP-listed section in downtown Redmond. This alignment option is located in the northern portion of the Redmond Project Group. Instead, this section of the PBC would remain open and in its current unlined condition. As a result, this section of the PBC would remain susceptible to the same water resources effects described for the No Action Alternative in Section 7.2.1.

Similar to the NRHP-listed section of the PBC through Deschutes County/North Bend, this section represents slightly more than a mile of the approximately 18-mile total length of PBC that is proposed for piping under the Modernization Alternative (7% of total length). As a result, all water resource impacts would be comparable in character to those described in Section 7.2.2.2 for no modernization in the Deschutes County/North Bend section.

This option would result in continued water loss to seepage and evaporation over a 6,500-foot open section of the PBC. Because this section is confined entirely to the Redmond Project Group of the Project Area, it is assumed that the amount of water saved across the entire project group can be adjusted based on the percentage length represented by this 6,500-foot stretch to compute the difference in water savings from the other Modernization Alternative options. Table 10 illustrates the estimated amount of water that would be saved with no modernization through the Redmond NRHP-listed segment.

Table 10. Water Savings by Project Group with No Modernization through the Redmond NRHP-Listed Segment

Project Group	Length of Project Improvements (ft)	Length of Project Improvements (mi)	Amount Saved (AF)

King Way	10,955	2.1	3,927.1
Redmond[a]	5,900	1.1	1,180
Veterans Way	16,650	3.2	8,612.7
Canal	13,850	2.6	8,810.5
Deschutes Market	22,000	4.2	8,398.9
Rivers Edge	18,125 to 19,825	3.4 to 3.8	11771.8
Total [a]	**87,480 to 89,180**	**16.6 to 17.0**	**42,701.0**

AF = acre-feet; ft = feet; mi = miles

[a] Does not include 1,100 feet of existing pipe within the Redmond segment that would be replaced with new pipe of a larger diameter. Leaving the PBC open through the Redmond NRHP-listed segment would save approximately 1,180 AF of water within the Redmond Project Group. This would represent substantial water savings compared to the No Action Alternative (approximately 42,701 AF), but a 843-AF reduction in water savings compared to fully piping the Redmond Project Group. Considering the overall estimated Project water savings of 43,544 AF under the Modernization Alternative, forgoing modernization of the Redmond NRHP-listed segment would reduce total water saved by approximately 2% relative to the full piping options . This would not change the character of overall water resources effects and would represent a minor reduction in water savings compared to the other Modernization Alternative options.

7.3 Short-Term Effects

7.3.1 No Action Alternative

Under the No Action Alternative, modernization of the District's infrastructure would not occur. The District would continue to operate and maintain the existing delivery system within the Project Area in its current condition. No construction activities would take place under the No Action Alternative; therefore, no short-term impacts would result from this alternative.

7.3.2 Modernization Alternative

Potential short-term impacts of the Modernization Alternative would be attributable to construction activities and would be expected to abate following completion of construction. Short-term impacts would be expected to be similar in character for all of the Modernization Alternative alignment options, including the no modernization options for the Deschutes County/North Bend and Redmond sections.

Potential short-term construction impacts would depend on the following:

- Area of total disturbance.
- Impacts from fine sediment and contaminants (e.g., hydraulic oil, fuel).
- Erosion or soil characteristics.
- Depth to groundwater.
- Streambank or slope steepness.

No short-term impacts to water rights are anticipated because construction of piping within the six project groups is expected to last three total non-irrigation seasons. Construction would take place outside of the period when irrigation water is being delivered to COID patrons and would not be expected to create disruption to patrons' use of water under the District's water rights. Other districts' water rights in the Deschutes River would likewise not be disrupted.

No short-term impacts to surface water hydrology are anticipated because no work is proposed within waterbodies affected by District operations and no structures are proposed for placement within the Deschutes River. All construction work would take place within the channel of the existing PBC or, in the case of the alignment options, in upland areas where new pipe alignments would be excavated. Work within the existing PBC would take place during the non-irrigation season when no water is flowing through the channel.

Construction activities can potentially affect surface water quality by facilitating increased erosion and mobilization of sediment in stormwater. The accidental discharge of fuels, fluids, and construction materials can impact both surface water quality via stormwater runoff and groundwater quality via infiltration. No work is proposed within or adjacent to the Deschutes River itself; therefore, discharge of sediment and contaminants directly to surface waterbodies is not anticipated. The anticipated excavation depth to install the pipeline would be insufficient to result in direct contact with or introduction of contaminants into groundwater.

Construction-phase erosion and sediment control measures would be installed during project construction to prevent stormwater runoff from mobilizing sediment and pollutants into surface water. The District or its construction contractor would be required to provide an erosion and sediment control plan as part of its 1200-C construction stormwater permit application; the plan would detail the measures to be implemented and approaches for maintaining them. Pollution control and spill prevention BMPs would be implemented to avoid and minimize impacts from accidental spills of fuels, fluids, solvents, oils, and other hazardous materials typically associated with construction vehicles and equipment. A construction-phase spill prevention control and countermeasures plan would include protocols for storing and handling hazardous substances, as well as cleanup response protocols to be used in the event of inadvertent releases.

Proposed BMPs to reduce or control environmental health hazards would likely include but may not be limited to the following:

- Routinely inspect equipment, tools, and vehicles for leaks or damage.
- Promptly repair or replace leaking connections, pipes, hoses, and valves.
- Use drip pans under equipment when maintaining, repairing, or servicing in the field.
- Remove oil and grease buildup on equipment.
- Use nontoxic solvents whenever possible.
- Keep spill kit, including cleanup materials such as dry absorbent materials, on-site for prompt cleanup of small spills related to equipment failure.
- Prohibit discharge of wastewater to stormwater drains or surface stormwater facilities such as ditches and swales.

- Perform equipment and vehicle maintenance in areas that prevent discharges to storm drain systems or surface stormwater facilities.
- Collect and properly manage (recycle or dispose of) used materials: grease, oil, oil filters, antifreeze, cleaning solutions, lead-acid batteries, tires, and hydraulic and transmission fluids.
- Clean surfaces following any discharge or spill incident.

Construction-phase erosion, sediment, and pollution control and spill prevention BMPs would minimize the potential for stormwater runoff to mobilize sediment and pollutants into surface waters and prevent the introduction of contaminants into surface water and groundwater. Following construction, new pipelines would be buried. All disturbed areas would be re-contoured and planted with a seed mix of native grasses and forbs in consultation with NRCS, mitigating the potential for soil erosion and the mobilization of sediments in stormwater. The potential for soil erosion along the banks of the PBC would be eliminated where the open canal is replaced with a buried pipe. Based on the forgoing, short-term impacts to surface water or groundwater resources are expected to be negligible.

7.3.3 Potential Off-Site Construction Staging Areas

The construction contractor may use one or more off-site staging areas outside the Study Area to store or assemble materials that would then be transported by truck to the construction site. Off-site staging could occur with any of the alignment options. Whether, where, and how to use such sites would be the choice of the contractor; therefore, the actual site or sites cannot be known at this time. Given this uncertainty, detailed analysis of impacts is not possible at this time. It is assumed that because of regulatory and time constraints on the contractor, any site they choose would need to be already developed with road access. It is also assumed that the contractor would be responsible for relevant permitting or mitigation that could be required for use of a chosen site. The EIS identifies the types of impacts that could occur from off-site staging, based on the above assumptions. This analysis is not intended to identify any specific site as free from sensitive resources, potential impacts, or hazards. Rather, the objective is to ensure disclosure of the general types of impacts.

The following types of impacts could occur from off-site staging:

- Mobilization of soils, sediments, and contaminants in stormwater runoff from the site.

If a contractor chooses to use an off-site staging area, local, state, and federal water quality regulations could apply. These would depend on the site selected, as use of a developed site would generally not trigger water-related permitting requirements. Use of an undeveloped site could trigger the requirement for NPDES compliance, which would come in the form of a 1200-C construction stormwater permit from DEQ.

7.4 Indirect Effects

7.4.1 No Action Alternative

The No Action Alternative would not improve the efficiency or reliability of water delivery to COID and NUID patrons. It would not be expected to provide sufficient delivery of irrigation water to satisfy all patrons' irrigation demands in the long term as the flow requirements of the DBHCP are fully phased in.

The No Action Alternative would not allow for precision in diversion amounts and timing, and thus would not be likely to facilitate other on-farm efficiency improvements by COID and NUID patrons. It would be likely to result in increased areas of agricultural land being left fallow or taken out of production due to shortages in available irrigation water. Associated decreases in agricultural production would diminish the Districts' contribution to the regional agricultural economy.

7.4.2 Modernization Alternative

The Modernization Alternative would improve the efficiency and reliability of water delivery to COID and NUID patrons. It would thus enable more sufficient delivery of irrigation water to satisfy patrons' irrigation demands in the long term as the flow requirements of the DBHCP are fully phased in.

The Modernization Alternative, once fully piped, would allow for precision in diversion amounts and timing at turnouts and laterals. It would thus be expected to facilitate piping and pressurization of laterals by making such improvements more feasible and beneficial. The propensity for other on-farm projects to be implemented may increase as well.

By contributing to the long-term sustainability of irrigated agriculture in the Upper Deschutes Basin, the Modernization Alternative would indirectly benefit the region's agricultural economy and the locally grown food supply. It would also support the continued use of agricultural lands for agricultural production and may help to discourage the potential future conversion of agricultural lands to more intensively developed urban and suburban land uses.

7.5 Cumulative Effects

The combined, incremental effects of past, present, and reasonably foreseeable actions are referred to as cumulative effects. While they may be insignificant by themselves, cumulative effects accumulate over time from one or more sources and can result in the degradation of important resources. The PBC piping project could potentially contribute to cumulative effects on water resources when considered in combination with other water resource development and conservation projects in the Upper Deschutes Basin.

7.5.1 No Action Alternative

Under the No Action Alternative, no federal funding would be forthcoming to support the Project and modernization of the PBC system would not take place. No new direct effects on water resources would result from the Project, and existing conditions would remain unchanged. The Project would, therefore, not contribute to cumulative impacts to water resources over current conditions.

7.5.2 Modernization Alternative

Past actions over the last 120 years that have affected water resources in the Upper Deschutes Basin include urban and agricultural development, construction and maintenance of the roadway network, water impoundment projects, and other irrigation projects. Since the early 1990s, COID and other Deschutes Basin irrigation districts have implemented various water conservation efforts in the recent past, which have included piping existing irrigation canals, on-farm conservation, water management changes, and changes to crop production. These have resulted in increased streamflow in the Deschutes River and decreased seepage into the groundwater table.

Ongoing and reasonably foreseeable future actions that could affect waterbodies associated with District operations include on-farm water conservation efforts, additional irrigation piping projects by COID and other Deschutes Basin irrigation districts that divert water from the Deschutes River, and continued implementation of the DBHCP.

On-farm water conservation projects throughout the Deschutes Basin typically consist of smaller efforts implemented on a project-by-project basis that can involve many active collaborators within the Deschutes Basin. These may include the NRCS Oregon Regional Conservation Partnership Program, local soil and water conservation districts, the Deschutes Basin Board of Control, and nongovernmental organizations such as the Deschutes River Conservancy. The projects can range from piping of laterals for individual patrons or groups of patrons to renewable energy projects and on-farm irrigation system efficiency projects.

Irrigation canal piping projects by COID and other districts would increase streamflow in the Deschutes River and its tributaries and result in beneficial effects on surface water resources. Ongoing and reasonably foreseeable future irrigation piping projects in the Upper Deschutes Basin are listed in Table 11.

Table 11. Potential Water Saved In-Stream from other Public Law 83-566 Projects [a] Occurring in the Deschutes Basin

Irrigation District	Project	Status [b]	Total Water Saved In-Stream (cfs) [c]	Reach Affected [a,c]
Tumalo Irrigation District	TID Infrastructure Modernization Project	Ongoing	48.0	Approximately 30 cfs would be allocated to Tumalo Creek during the irrigation season, and 18 cfs would be allocated to Crescent Creek during the non-irrigation season. Both creeks are tributaries to the Deschutes River.
Swalley Irrigation District	SID Infrastructure Modernization Project	Ongoing	15.2	The entire 15.2 cfs would be allocated to the Middle Deschutes River, from RM 164.8 to RM 120, during the irrigation season.
Lone Pine Irrigation District	LPID Infrastructure Modernization Project	Future	5.0	Up to 5 cfs would be allocated to the Upper and Middle Deschutes River from RM 226.8 to RM 120, for use by NUID during the irrigation season. An equal amount would be released from Wickiup Reservoir by NUID for stream flow augmentation during the non-irrigation season and protected in-stream by OWRD lease.
North Unit Irrigation District	NUID Infrastructure Modernization Project	Future	8.4	Up to 6.3 cfs would be allocated to the Deschutes River as live flow to satisfy NUID water rights. Up to 2.1 cfs would be protected and stored in Wickiup Reservoir for use in the Deschutes River below Wickiup Reservoir during the non-irrigation season.

Irrigation District	Project	Status [b]	Total Water Saved In-Stream (cfs) [c]	Reach Affected [a,c]
Arnold Irrigation District	AID Main Canal Modernization Project	Ongoing	33.8	Up to 33.8 cfs would be protected in the Deschutes River below Wickiup Reservoir during the non-irrigation season through an in-stream lease.
COID	PBC Smith Rock-King Way Piping Project	Completed	30	This first phase of the PBC piping project has protected 30 cfs in the Deschutes River below Wickiup Reservoir during the non-irrigation season through an in-stream lease.
	Siphon Power Property Canal Piping Project (COID 2016b)	Completed	5.0	This completed project piped 3,000 linear feet of the Central Oregon Canal in southwest Bend, protecting up to 5 cfs within the Deschutes River.
	J and L Laterals Piping Project (NRCS 2020b)	Completed	2.0	This completed RCPP project included piping part of the J Lateral and the L Lateral, which would protect up to 2 cfs in the Deschutes River below Wickiup Reservoir during the non-irrigation season through an instream lease.
	G and G2 Laterals Piping Project (Jessi Talbott, COID. Personal communication, February 2025)	Future	3.4	This project, scheduled for winter (non-irrigation) season 2025-2026, will pipe 12,522 linear feet of the G lateral and 15,350 linear feet of the G2 lateral in the Smith Rock-King Way area. The project is funded by a Reclamation WaterSmart grant with matching funding from OWRD.

a The numbers presented for the listed Irrigation District Projects are from plan-EAs, which have already been authorized.

b Ongoing projects are currently under construction. Future projects are authorized but not yet initiated.

c Flows allocated in-stream during the irrigation season are shown as maximum flows. See each District's plan-EA for more information regarding the anticipated timing and location of in-stream flows.

RCPP = NRCS Oregon Regional Conservation Partnership Program

The ongoing and reasonably foreseeable irrigation canal and lateral piping projects by districts listed above could reduce seepage to groundwater in the project vicinity by as much as 31,478 AF annually.[2] In consideration of the effects of climate variability, COID's project would have a minor cumulative effect on local groundwater level decreases (Section 7.2.2.1; Appendix A; Gannett and Lite 2013). The effects of local groundwater reduction due to piping may be partially offset by increased streamflow during the non-irrigation season; some of the increased streamflow would likely infiltrate into the regional aquifer.

[2] This number assumes that the projects listed in Table 11 would reduce annual seepage to groundwater as follows (based on their respective plan-EAs): SID: 6,172 AF; NUID: 2,728 AF; AID: 11,083 AF; LPID: 2,103 AF; COID Smith Rock-King Way: 9,392 AF.

Cumulative effects on surface water quality could result from nonpoint source pollution such as erosion and runoff associated with construction of the projects listed above. The proposed action would be constructed when there is no water in the canal system; construction timing for other irrigation system piping projects is expected to be similar. Proposed cumulative actions are anticipated to contribute to water quality improvements by reducing nonpoint source pollution from erosion of canal banks and agricultural runoff and increasing streamflow in waterbodies affected by the districts' operations. The proposed action would contribute overall beneficial impacts to water quality.

The ongoing phase-in to full implementation of the DBHCP is expected to result in higher overall winter streamflows and lower overall summer streamflows, particularly between Wickiup Reservoir and North Canal Dam. This will help to return the hydrology to a more natural state and reduce effects from scouring and flooding of wildlife habitats. In combination with the cumulative amount of water saved in-stream (or as stored water in Wickiup Reservoir) by other irrigation districts' piping projects, this would be anticipated to contribute to beneficial cumulative impacts to streamflows, overall hydrology, and aquatic habitat function throughout the Upper Deschutes River system.

Under the Modernization Alternative and its alignment options, implementation of the proposed action could contribute to increased streamflows, improve surface water quality, and reduce groundwater infiltration. Other past, present, and reasonably foreseeable future actions are anticipated to result in overall beneficial effects on water resources, although they would also contribute cumulatively to reductions in groundwater levels. Overall, the Modernization Alternative would be expected to have a minor beneficial contribution to overall beneficial cumulative effects on water

7.6 Compliance with Laws, Regulations, and Standards

The proposed action would align with the intent of the federal clean water laws described in Section 4.1, including the CWA and SDWA, because it would ultimately have beneficial effects on water quality. Because work associated with the proposed action would not take place within the Deschutes River and construction of the Modernization Alternative would be undertaken during the non-irrigation season when no water is flowing through the PBC, it would not directly affect wetlands or waters of the United States or trigger requirements for federal clean water permits. Ground disturbance during construction, which has the potential to facilitate mobilization of sediments or contaminants in stormwater runoff, would be subject to the requirements of CWA Section 402. These would be addressed via the requirement to obtain a 1200-C construction stormwater permit through DEQ. In addition to laws protecting water quality, applicable laws protecting federally listed fish and wildlife species—including the ESA and Fish and Wildlife Coordination Act—would not entail project-specific permits or consultation. The DBHCP is an outcome of USFWS and NMFS ESA consultation processes, and the water savings that would result from the Modernization Alternative would help to support the achievement of the DBHCP conservation goals.

In Oregon, DEQ issues and enforces NPDES permits. In order to ensure that stormwater runoff from project construction does not mobilize sediments and contaminants into waterbodies, the Project would require the issuance of a 1200-C construction stormwater permit through DEQ. No other state permits would be required to construct or operate the Project, as work would remain outside of wetlands or waters of the state, and the Project would not include UICs. The Project would have overall beneficial impacts to water resources and, as such, would align with the provisions of Oregon Statewide Planning Goal 6. The construction-phase BMPs outlined in Section 7.3.1 would align with the water pollution control requirements and policies articulated in ORS 468B.

The Modernization Alternative would align with the relevant local development plans, policies, and regulations of Deschutes County and the Cities of Bend and Redmond.

7.7 Conclusion

Modernization of the PBC would have minimal to no beneficial impacts and no adverse impacts on surface water hydrology. The Modernization Alternative would have overall minor long-term beneficial impacts on surface water quality. Seepage reduction resulting from piping the open canal would contribute to ongoing decreases in groundwater levels. However, groundwater levels in the Upper Deschutes Basin are also affected by other ongoing and proposed irrigation district water conservation efforts, domestic groundwater pumping, and fundamentally, by changing climate and an ongoing basin-wide drying trend. The proposed action would save irrigation water diverted into the PBC as live flow from the Deschutes River during the irrigation season. This would better enable water delivery to COID patrons and particularly NUID patrons, while helping to facilitate the conservation goals of the DBHCP. In combination with other past, present, and reasonable future actions affecting the Upper Deschutes Basin, the Project would contribute to beneficial cumulative impacts on water resources.

8. MITIGATION MEASURES

Overall, the proposed action is expected to have beneficial long-term effects on water resources in the Upper Deschutes Basin. As a result, no long-term mitigation measures are proposed. Avoidance and minimization measures would be implemented during construction to ensure that adverse effects on surface water and groundwater are prevented to the greatest extent practicable. Post-construction mitigation and restoration actions would be implemented following construction to ensure that post-construction site conditions do not contribute to ongoing effects on water resources. These are discussed in greater detail in Section 7.3.

9. CONTACTS AND COORDINATION

No individuals or organizations were contacted as part of the preparation of this technical report.

10. PREPARERS

Name	Professional Affiliation	Education	Years of Experience
Rick Malin, RG	Parametrix	MS Geohydrology/Geology	35
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Appendix A

Groundwater Analysis

APPENDIX A. GROUNDWATER IMPACT ASSESSMENT

A.1 Methodology and Data Sources

This assessment of potential long-term groundwater level impacts from decreased canal seepage due to piping the Pilot Butte Canal (PBC) included an examination of groundwater level measurement data from current and non-current observation wells located within approximately 1 mile of the PBC, as identified by Oregon Water Resource Department (OWRD's) Groundwater Information System Mapping Tool (OWRD GIS). Groundwater level data was evaluated to understand past and recent levels and the extent of water level change that has occurred. This groundwater level data was also evaluated in the context of published results from groundwater model simulations completed by the U.S. Geological Survey (USGS) that examined groundwater level responses to estimated decreases in canal seepage in the Upper Deschutes Basin for the period of 1997 to 2008 (Gannett and Lite 2013).

The 2013 USGS groundwater model for the Upper Deschutes Basin was based on results and findings of an earlier hydrologic investigation conducted by USGS, OWRD, and cities and tribes in the Upper Deschutes Basin (Gannett et al. 2001). Model calibrations and simulations used data for the period of 1978 through 1997 (Gannett and Lite 2004). The 2013 USGS study was used to gain insights into groundwater level change from 1997 to 2008. To evaluate the relative contributions of climate variations, groundwater pumping, and piping and lining of irrigation canals, the model was run with updated input files to 2008 and then run again holding pumping and/or canal recharge rates at 1994 levels. Estimated canal seepage in the Upper Deschutes Basin was 356,000 acre-feet (AF) per year in 1994, and by 2008 it had decreased to an estimated 58,000 AF/year (Gannett and Lite 2013). The model was used again as presented in a 2017 report (Gannett et al. 2017), but because simulations in the 2017 report were focused on the interaction of groundwater and surface water flows, it was found to be of minimal utility for this analysis. Based on review of the relevant published modeling studies, the USGS 2013 study was found to contain the most comprehensive and recent analysis of irrigation channel seepage and groundwater levels.

A query using OWRD GIS identified a total of 28 wells with at least two water level measurements and that were located within 1.4 miles of the PBC. Of these 28 wells, only 7 wells were identified as current observation wells. Current observation wells have water level measurement data collected during 2022 and/or 2023. For several of the wells identified as non-current, water level data was most recently collected during 2021. Thirteen of the 28 wells have water level measurements collected within the past 3 years (i.e., since 2020). Because some of the greatest groundwater level changes have occurred in the past 20 years, water levels prior to 2000 provide minimal use for evaluating recent water level changes. However, water level changes for the period of 1994 through 2008 (the 14-year USGS 2013 model canal seepage analysis period) are of interest because the period of 2009 to 2023 represents a similar time period (14 years) following the model simulation period. This allows for comparison of two equivalent time periods in assessing potential long-term groundwater level impacts from the proposed PBC piping project.

Table A lists the OWRD GIS-identified observation wells. Wells in Table A are listed in order of their location from southernmost to northernmost. As identified in Table A, the median well depth is 606 feet; however, this median includes three outlier deep wells with depths over 1,000 feet: two city supply wells and one federal water supply well. These wells are far deeper than the other identified observation wells and tend to skew the analysis. The median well depth is 558 feet if the three wells with depths greater than 1,000 feet are not considered. Average depths are slightly less (596 feet; 537 feet excluding the 1,000-foot wells). The median oldest water level depth is 348 feet with a median measurement year of 1984, while the median most-recent water level depth is 378 feet (30 feet lower) with a median measurement year of 2013. The deepest water level depths occur in the southernmost wells. Water level depths decrease toward the north.

The USGS 2013 report (Gannett and Lite 2013) presents two figures (Figures 28A and 28B) showing simulated groundwater level declines from estimated decreases in annual canal seepage due to canal lining during the years 1994 through 2008. Figure 28A shows simulated groundwater level declines in model Layer 1 (which corresponds to the upper 100 feet of the saturated zone), while Figure 28B shows declines in model Layer 3 (which corresponds 200 and 300 feet below the water table). Both figures show simulated groundwater water level declines due to canal lining and/or piping during the period of 1994 to 2008. The greatest groundwater level declines occur in model Layer 1 adjacent to canals with the largest estimated decreases in seepage. Simulated declines in model Layer 3 were attenuated and less than Layer 1 projected water level declines. The greatest simulated groundwater level declines were associated with canals not owned by the Central Oregon Irrigation District (COID) or associated with the PBC.

Table B presents groundwater level data for wells listed on Table A that had a water level measurement collected during 1994 and again during 2009, representing a 14-year period. As indicated on Table B, only six wells had measurements collected during 1994 and again during 2009. Five wells had measurement dates that were within this data period but represent a shorter time period. Groundwater level changes during this period range from a 9.71-foot increase to a 68.08-foot decrease. Examination of median and average water level changes for selected wells during this period indicated a general water level decline of 16 to 18 feet. These declines are on the outer range of, and generally greater than, the 2013 groundwater model simulation Layer 3 results associated with pumping increases and seepage reductions from canal piping or lining.

Similar to Table B, Table C presents groundwater level data for wells listed on Table A with water level measurements collected during 2009 and during 2023, also representing an approximately 14-year period. As indicated on Table C, only two wells had measurements collected during 2009 and again during 2023 (measurements were posted on OWRD GIS as of September 2023). Five wells had measurements collected in 2009 and again during 2021. Five other wells had shorter time periods. Groundwater level changes listed for the 2009 through 2023 period range from a 4.05-foot increase to a 41.95-foot decrease. The average and median 2009 through 2023 listed water level changes are both 15 feet.

Median and average groundwater level changes for the 2009 through 2023 period shown in Table D are similar and slightly less than for the 1994 through 2008 period presented in Table B. Table D indicates that only one well had water level measurements corresponding with the two groundwater level change periods examined. The water level decrease at well DESC 5045 was 16.3 feet during the 1994 through 2008 period and 21.0 feet during the following 2009 to 2023 period. This represents a 4.8-foot difference between the two periods.

Tables A through D indicate that there is limited groundwater level data available in general proximity to the project's Study Area. Furthermore, the USGS groundwater model simulation results showing estimated decreases in annual canal seepage between 1994 and 2008 are dominated by estimated decreases in the North Unit Irrigation District (NUID) canal northeast of Bend, the Tumalo Irrigation District (TID) canal located northwest of Bend, and the Swalley Irrigation District (SID) canal north of

Bend. However, the results can be used to generally assess potential groundwater level changes for the PBC piping project.

A.2 Canal Seepage Assessment

The USGS 2013 report (Gannett and Lite 2013) modeled the estimated canal seepage for an approximately 12-mile length of the NUID main canal from the diversion at the Deschutes River to the east side of the Pronghorn Golf Club. The modeled decrease in canal seepage due to lining ranged from 10,000 to 17,000 AF/year, averaging 13,500 AF/year.

Gannett et al. (2001) noted that the highest rates of canal seepage occur in reaches of the NUID and PBC canals in the areas immediately east and north of Bend. In these reaches, canals were cut through highly fractured, blocky basalt. Reported rates of canal seepage are also high through the Canal and Veterans Way Project Groups of the Project Area.

Table E presents estimated canal seepage decreases for the six project groups of the PBC Project Area that would result from piping. Estimated canal seepage rates range from 4.35 cubic feet per second (cfs) per mile for the southernmost Rivers Edge Project Group to 1.07 cfs per mile for the Redmond Project Group. The lowest estimated seepage rates occur in the two northernmost project groups: Redmond and King Way. Table E also presents an examination of USGS (Gannett and Lite 2013) estimates of decreased canal seepage due to lining from 1994 to 2008 for the first approximately 12 miles of the NUID main canal from Bend toward Redmond. The USGS estimated canal seepage for this section of the NUID canal ranges from 1.98 to 1.17 cfs per mile with an average of 1.58 cfs per mile. These values are similar to slightly lower than the canal seepage rates in the six PBC project groups.

A.3 Groundwater Model Results Review

The USGS model (Gannett and Lite 2013) indicates that canal seepage reductions for the southern portion of the NUID main canal would result in up to -68 to -50 feet of groundwater level decline in Layer 1 of the model, or the upper 100 feet of the saturated zone (Table E). The amount of simulated groundwater level decline would be greatest adjacent to the canal and decrease to -10 feet of decline extending up to about 5 miles away from the canal and toward the canal's northern end. Model results indicate attenuated groundwater level declines in Layer 3 (representing 200 to 300 feet below the water table). The model indicates that groundwater level declines would range from less than -5 feet to -2 feet in Layer 3. Similar to Layer 1, model results suggest groundwater level declines would be less (not greater than -2 feet) toward the northern end of the area of simulated canal seepage decrease. Model-estimated decreases in groundwater levels from estimated decreases in annual canal seepage were derived by running the USGS model with 2008 data and again with 1994 data. The difference between groundwater levels for the 2008 and 1994 simulations represents the projected groundwater level change. Assuming that both model simulations represent steady-state simulations, the resulting groundwater level difference represents a worst-case long-term impact.

Observation well DESC 5045 (USFS Bend Pine Nursery) has one of the most complete water level records of the identified observation wells located within 1.4 miles of the PBC. As listed in Table D, well DESC 5045 is located in the eastern portion of the Pine Nursery and approximately 0.15 miles from the NUID main canal. In this area, groundwater model results indicate up to -5 feet of groundwater level decline in response to decreased canal seepage. As indicated in Table D, a water level decrease of -16.27 feet occurred in this well during the period of 1994 through 2008. During the following 14-year period of

2009 to 2023, the measured groundwater level decrease was -21.03 feet. These decreases are greater than predicted by the model due to canal seepage reduction alone. The results indicate that other factors (assumed to include climate change and likely additional pumping) are resulting in greater groundwater level decreases than predicted by the USGS groundwater model simulation in response to canal seepage reduction.

A.4 Infiltration Rate Assessment

The USGS groundwater model (Gannett 2001) used the same hydraulic conductivity (30 to 100 feet per day) zone in Layer 1 that includes the PBC Project Area. In Layer 3, a higher hydraulic conductivity (500 to 1,000 feet/day) is applied in the northern portion of the Project Area beginning approximately with the Veterans Way Project Group. Layer 3 hydraulic conductivity in the southern portion of the Project Area was assumed to be 30 to 100 feet/day. Vertical hydraulic conductivity applied in the model used the same spatial distribution as horizontal hydraulic conductivity. Higher vertical conductivity occurs in the vicinity of Bend. However, as indicated on Table F, the vertical hydraulic conductivity of geologic units at or near ground surface in the Bend area are three times higher than in the Redmond area. The values presented in Table F are derived from infiltration tests completed on underground injection controls (UICs) used for stormwater. Stormwater flow into UICs represents a short-duration test method with volumes infiltrating significantly less than volumes of water infiltrating from canal seepage. The average linear pore water velocity in the unsaturated zone is directly proportional to the moisture content in the unsaturated zone. As such, the UIC-derived vertical conductivities are assumed to be higher than those associated with canal seepage. However, results in Table F provide insight into the overall shallow geologic unit infiltration rates in the area of Bend compared with the area of Redmond.

A.5 Impact Assessment

As presented in Table E, estimated canal seepage losses for the Rivers Edge, Deschutes Market, Canal, and Veterans Way Project Groups of the PBC Project Area are slightly higher than the southern portion of the NUID main canal. Analysis indicated that hydraulic conductivity conditions generally decrease from the Bend area northward toward Redmond. Based on these observations, replacing the existing open PBC within the Project Area with a closed pipeline system would result in a long-term decrease in groundwater levels.

Based on USGS groundwater model results (Gannett and Lite 2013), the greatest water level declines would be observed in the Rivers Edge and Deschutes Market Project Groups and attenuate toward the Canal and Veterans Way Project Groups. Based on the information presented in the preceding sections, up to -68 to -50 feet of groundwater level decline in the upper 100 feet of the saturated zone may occur. These declines would occur adjacent to the canal and decrease to a -10-foot decline extending up to 5 miles away from the canal. The groundwater level decline 200 to 300 feet below the water table is attenuated and would range from less than -5 feet up to -2.0 feet.

Anticipated groundwater level declines in the Canal and Veterans Way Project Groups would be slightly less, even though estimated seepage losses for these project groups are similar to those for Rivers Edge and Deschutes Market Way. The relatively smaller anticipated groundwater level decline in this portion of the groundwater Study Area is due to decreasing hydraulic conductivity conditions in the upper portion of the unsaturated zone and the presence of shallower groundwater levels. Less than -50 feet and up to -10 feet of groundwater level decline in the upper 100 feet of the saturated zone may occur along the canal in these two project groups. These declines would be most pronounced adjacent to the canal and decrease to -5 feet of decline extending up to 2 miles away from the canal. The groundwater level decline 200 to 300 feet below the water table is attenuated and anticipated to be less than -2 feet.

Anticipated groundwater level declines in the Redmond and King Way Project Groups are less than those anticipated for Canal and Veterans Way Project Groups. A less-pronounced groundwater level decline in this area of the PBC Project Area is due to decreasing shallow unsaturated hydraulic conductivity conditions, generally shallower groundwater levels, and higher hydraulic conductivity conditions in the deeper portion of the saturated zone. Less than -25 feet and up to -10 feet of groundwater level decline in the upper 100 feet of the saturated zone may occur along the canal in these two project groups. These declines would occur adjacent to the canal and decrease to -2 feet of decline extending up to 1.5 miles away from the canal. The groundwater level decline 200 to 300 feet below the water table is attenuated and anticipated to range from less than -2 feet to -1 foot.

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Figures

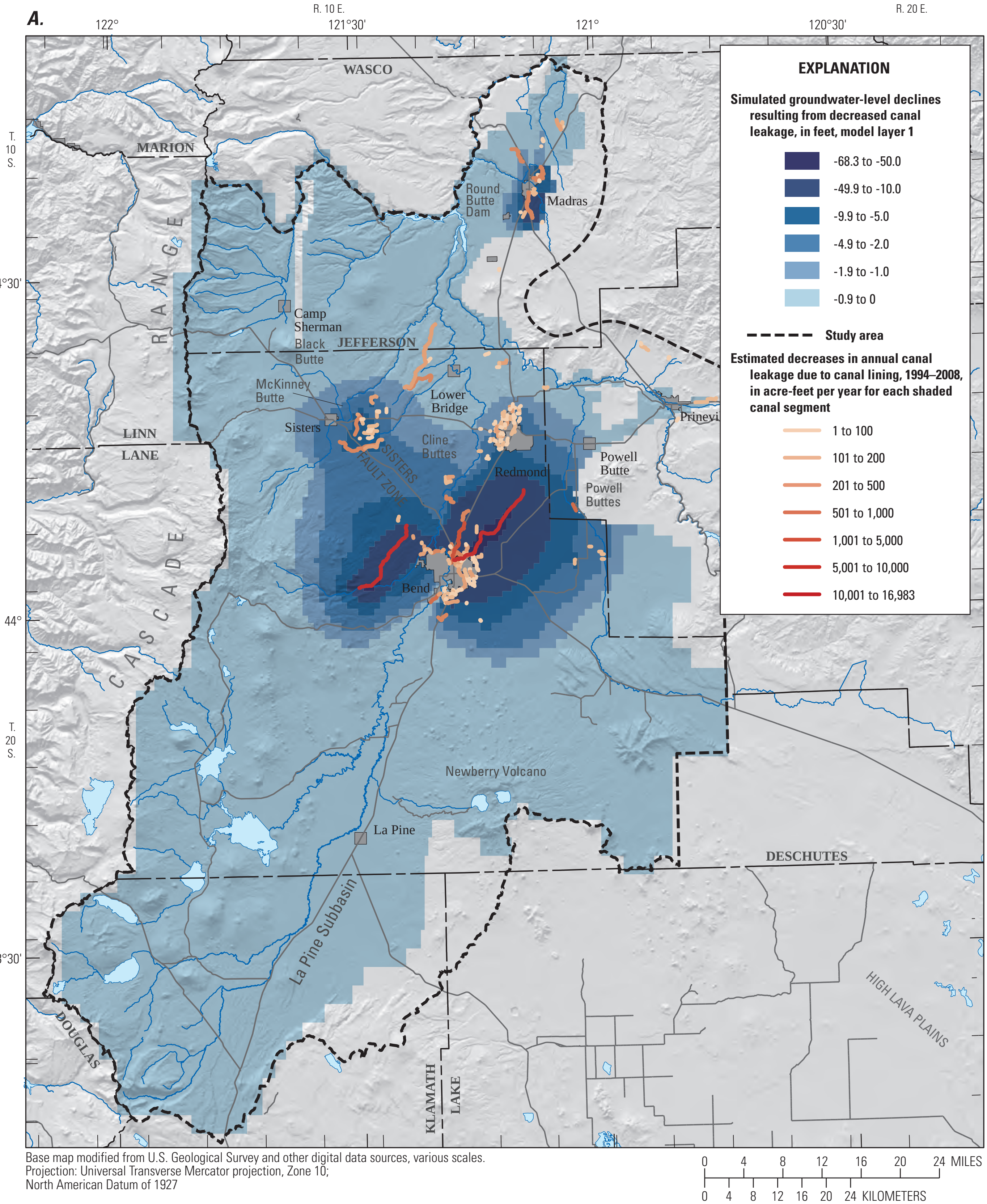

Figure 28. Upper Deschutes Basin, Oregon, showing estimated decreases in annual canal leakage due to canal lining between 1994 and 2008, and simulated groundwater-level declines resulting from decreased canal leakage. (*A*) model layer 1; (*B*) model layer 3.

Source: Gannett 2013

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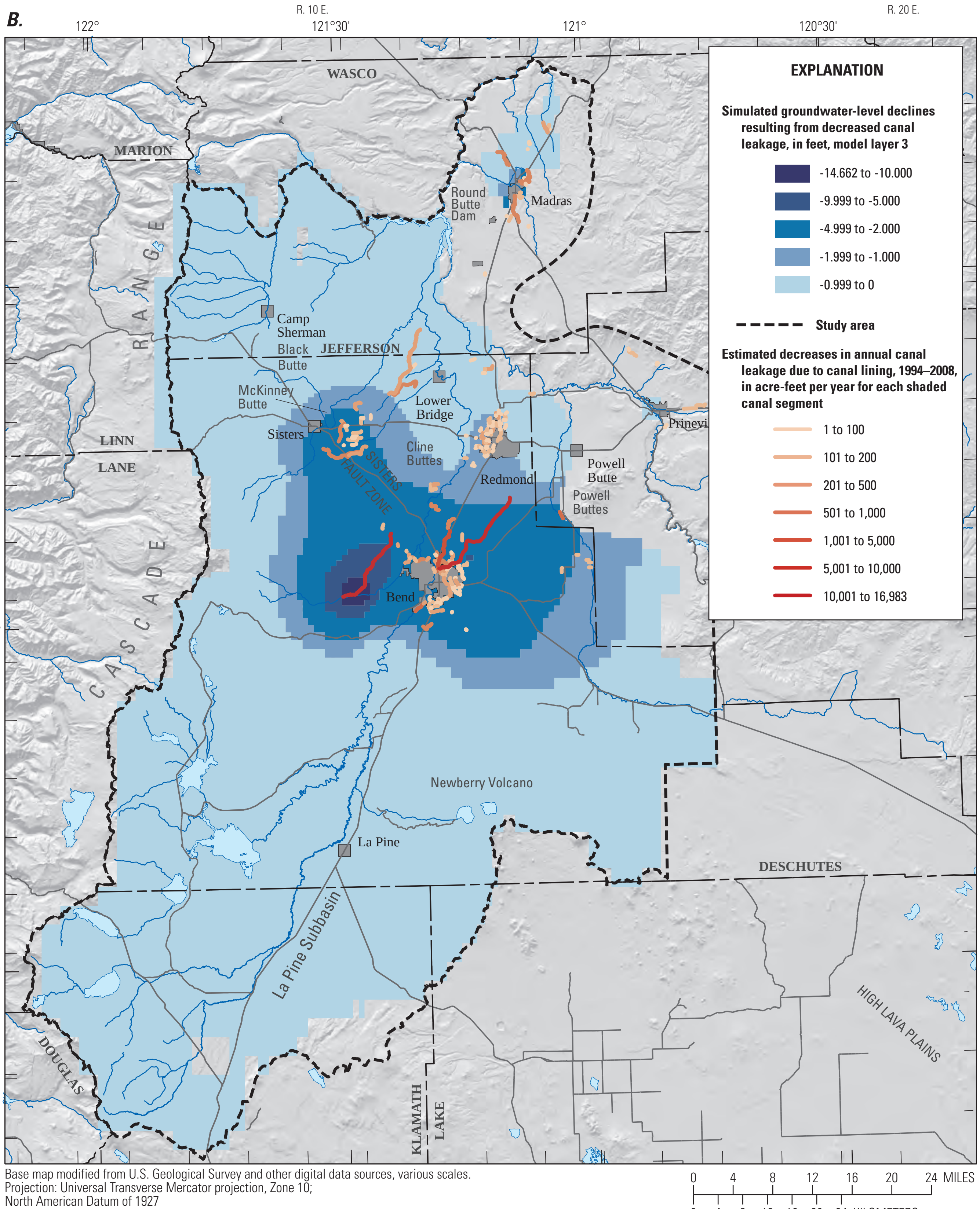

Figure 28.—Continued

Source: Gannett 2013

Tables

Table A: Identified OWRD GIS Observation Wells Located within 1.4 miles of the PBC.

					Location (lat/long)					oldest								most recent		water level decrease		
PBC EIS Segment Area	OWRD GIS Well Type	Well Log ID	Well Name	Location (approx to PBC)	lat	long	Well Depth (feet)	Hydrograph	# of WL measures	WL depth (feet)	date	WL depth (feet)	date	WL depth (feet)	date	period 1994 to 2008 data?	period post-2008 data?	WL depth (feet)	date	most recent - oldest	approx number of years	Notes
Rivers Edge	**current obs well**	DESC 52907	City of Bend	1.32 mi NW Pilot Butte to PBC entry	44.062556	-121.28695	1140	yes	14	786.00	2/15/2000	788.40	3/25/2013	786.00	3/18/2019	no	yes	781.95	**3/20/2023**	-4.05	23	Well drilled 3/24/00
Rivers Edge	non-current obs well	DESC 8499	City of Bend	1.32 mi. Adjacent to DESC 52907	44.062673	-121.28716	1065	no	3	731.00	8/17/1993	750.00	8/25/1993			no	no	725.13	*10/26/1993*			Well drilled 8/17/93
Rivers Edge	non-current obs well	DESC 5029	Dunlap	1.02 mi NW of north end of lined PBC. Near river.	44.09278	-121.31245	186	no	3	177.00	2/18/1972	119.25	5/17/1978			no	no	119.90	*3/17/1994*	-57.10	22	Well drilled 1/20/72
Rivers Edge	**current obs well**	DESC 5045	USFS Bend Pine Nursery	0.84 mi east of Empire Ave crossing.	44.0911	-121.26305	1057	yes	58	701.50	10/11/1979	718.91	3/2/1995	734.46	6/15/2010	yes	yes	754.94	**2/17/2023**	53.44	28	Well drilled 2/16/77
Rivers Edge	non-current obs well	DESC 471	Clausen	0.9 mi west of NW corner NE 18th alignment	44.11064	-121.29706	745	yes	4	504.00	2/17/1972	506.00	1/19/1973	585.00	10/24/1974	no	no	350.00	*7/27/1977*	-154.00	5	Well drilled 2/20/72; deepened 1/73, 5/74, 10/74. Original well had much lower WL.
Deschutes Mkt	non-current obs well	DESC 461	Kent	1.13 mi east of PBC crossing BNSF RR	44.130448	-121.24876	655	no	2	590.00	3/28/1989					no	no	581.45	*10/27/1993*	-8.55	4	Well drilled 3/28/89
Deschutes Mkt	**current obs well**	DESC 57132	Hocker	0.55 mi east near Deschutes Market Rd	44.11808	-121.25489	710	no	2	641.00	10/27/2005					no	yes	653.52	**3/1/2022**	12.52	17	Well drilled 10/27/05
Deschutes Mkt	non-current obs well	DESC 4436	MGM Investments	0.59 mi east of west side Grande Loop	44.15499	-121.2477	620	yes	4	465.00	4/12/1978	502.00	9/27/1978			no	no	494.14	*3/22/1994*	29.14	16	Well drilled 4/14/78
Deschutes Mkt	non-current obs well	DESC 4413	Haley	0.03 mi west of PBC on Gift Road	44.18115	-121.2543	510	yes	15	452.46	12/1/1993	453.68	11/9/1994	460.69	3/19/1996	yes	1 wl	470.48	6/10/2009	18.02	16	Well drilled 2/8/78
Deschutes Mkt	non-current obs well	DESC 4320	Devereaux	0.02 mi west of PBC north end 73rd St	44.18475	-121.2547	235	yes	17	207.00	5/14/1984	197.11	8/31/1994	199.20	12/20/1996	yes	1 wl	197.26	6/12/2009	-9.74	25	Well drilled 5/14/84
Deschutes Mkt	non-current obs well	DESC 8612	Smith	0.36 mi west of PBC near SW corner of 74th Ln	44.18975	-121.2614	430	no	2	391.00	10/4/1993					no	no	408.66	*1/12/1994*	17.66	1	Well drilled 9/23/93
Veterans Way	**current obs well**	DESC 55844	Juniper Golf Course	0.78 mi east middle of Juniper Golf Course	44.2302	-121.19412	605	yes	14	360.00	3/1/2010	352.96	3/2/2015	354.12	3/15/2019	no	yes	381.00	**1/1/2023**	21.00	13	Well drilled 11/25/03
Veterans Way	non-current obs well	DESC 3982	Redmond Village Mobile Park	0.19 mi SE of PBC near SW Ben Hogan Dr corner	44.2373	-121.2011	466	yes	10	256.00	6/14/1974	381.00	3/12/1998	376.30	3/31/2003	close 2005	no	376.29	3/23/2005	120.29	31	Well drilled 6/14/74
Veterans Way	non-current obs well	DESC 3981	Redmond Village Mobile Park	0.03 mi SE of DESC 3982	44.2371	-121.200477	472	yes	24	362.44	4/10/1979	367.36	8/2/1993	375.45	4/11/2002	close 2005	no	379.60	3/23/2005	17.16	26	Well drilled 7/19/74
Veterans Way	**current obs well**	DESC 51967	Deschutes Cty Fair & Expo	0.69 mi east of SW Airport Way crossing	44.23632	-121.18445	607	yes	5	362.00	5/28/2005	368.50	3/22/2011	370.00	3/4/2020	no	yes	386.62	**3/15/2022**	24.62	17	Well drilled 5/22/88; deepened 5/28/05
Veterans Way	non-current obs well	DESC 407	City of Redmond	0.43 mi well south of Umatilla Park	44.248668	-121.20345	765	yes	17	362.00	5/25/1985	380.80	3/11/2011	387.10	3/1/2019	yes	yes	388.60	**3/1/2021**	26.60		Well drilled 5/25/85
Veterans Way	non-current obs well	DESC 3879	City of Redmond	0.47 mi west of PBC in Kalama Bicentennial Park	44.2666	-121.18575	452	yes	20	265.00	2/14/1975	293.00	3/7/2011	297.40	3/1/2018	yes	yes	302.20	**3/1/2021**	37.20	46	Well drilled 2/14/75
Veterans Way	**current obs well**	DESC 3931	Kitchell [DESC 63587 Westendorf]	0.93 mi west Redmond Memorial Cem	44.2509	-121.21541	787	no	4	500.00	8/1/1979	575.00	8/25/2022	501.70	7/31/2019	no	yes	511.33	**9/1/2022**	11.33	43	Well drilled 8/1/79; deepened 8/25/22
Redmond	non-current obs well	DESC 55853	City of Redmond	0.52 mi east of PBC near west side Redmond airport	44.253	-121.1743	855	yes	14	336.00	12/22/2003	345.30	3/1/2012	354.00	3/1/2019	no	yes	358.90	**3/1/2021**	22.90		Well drilled 12/31/03
Redmond	non-current obs well	DESC 3949	Redmond Industrial Park Inc.	0.5 mi east of PBC near west side Redmond airport	44.2568	-121.1725	390	yes	96	295.00	3/30/1979	310.71	7/1/2003	322.00	12/17/2013	yes	yes	325.00	7/27/2016	30.00		Well drilled 9/27/93; abandoned 7/28/16
Redmond	non-current obs well	DESC 3952	City of Redmond	0.91 mi east of PBC west side Redmond airport	44.25499	-121.16399	740	yes	9	314.00	12/14/1983	312.92	3/2/1994	385.00	3/7/2001	close 2005	no	381.00	3/1/2005	67.00		Well drilled 12/14/83; abandoned 1/26/07
Redmond	non-current obs well	DESC 3951	City of Redmond	0.91 mi east of PBC west side Redmond airport	44.25397	-121.16405	801	yes	18	310.00	5/18/1987	317.00	2/29/2008	353.00	3/1/2018	yes	yes	363.00	**3/1/2021**	53.00		Well drilled 5/18/87
Redmond	**current obs well**	DESC 3880	Juniper Golf Course, Inc (Lions Lake)	0.3 mi east SW Kalama & SW Indian Aves	44.26569	-121.1691	358	yes	9	268.00	1/23/1978	310.11	12/7/2021	312.26	10/3/2022	yes	yes	314.25	**7/18/2023**	46.25	45	Well drilled 1/23/78. Near piped section of PBC
Redmond	non-current obs well	DESC 57788	City of Redmond	0.7 mi east of PBC at NW Dogwood Ave	44.2799	-121.15497	860	yes	13	326.00	12/13/2006	331.30	3/11/2011	332.70	3/1/2019	no	yes	335.60	**3/1/2021**	9.60	15	Well drilled 12/14/06
Redmond	non-current obs well	DESC 3853	City of Redmond	0.67 mi west of PBC at NW Maple Ave	44.29052	-121.18159	300	yes	20	168.00	7/15/1969	183.99	3/7/2011	202.00	3/2/2017	yes	yes	207.30	**3/1/2021**	39.30	52	Well drilled 7/15/69
Redmond	non-current obs well	DESC 3723	North Rim Subdivision	0.63 mi west of PBC SW of Quince Park	44.2978	-121.1821	297	yes	32	235.00	2/7/1972	228.31	9/7/1994	233.43	6/7/1996	no	no	233.00	*3/18/1998*	-2.00	26	Well drilled 2/8/72
King Way	non-current obs well	DESC 223	Sager	0.98 mi NW of PBC north of N canal blvd & NE Yucca Ave	44.3169	-121.16956	300	no	2	255.00	11/9/1990					no	no	251.70	*8/5/1993*	-3.30	3	Well drilled 11/9/90
King Way	non-current obs well	DESC 2739	Britten	1.17 mi east of north end of PBC project end	44.3131	-121.11705	290	no	2	270.00	5/10/1980					no	no	237.12	*8/5/1993*	-32.88	13	Well drilled 5/10/80

Bold font date indicates a post-2020 date.

Italic font date indicates a pre-2000 date.

Table B: Identified WRD GIS Observation Wells Located within 1.4 miles of the PBC - Groundwater Levels from 1994 through 2008.

							Select Water Levels													
							oldest		2004 through 2009 period						most recent			oldest to most recent water level decrease		Notes
									1994 Period		2009 Period		1994-2009 Period							
PBC EIS Segment Area	**OWRD GIS Well Type**	**Well Log ID**	**Well Name**	**Location (approx to PBC)**	**Well Depth**	**# of WL measures**	**WL depth (feet)**	**date**	**WL depth (feet)**	**date (1994?)**	**WL depth (feet)**	**date (2009?)**	**Period 1994 thru 2008 data?**	**1994 thru 2008 change in WL**	**period post-2008 data?**	**WL depth (feet)**	**date**	**most recent - oldest**	**approx number of years**	
Rivers Edge	**current obs well**	DESC 5045	USFS Bend Pine Nursery	0.84 mi east of Empire Ave crossing.	1057	58	701.50	10/11/1979	717.64	**5/31/1994**	733.91	3/11/2009	yes	-16.27	yes	754.94	**2/17/2023**	53.44	28	Well drilled 2/16/77
Deschutes Mkt	non-current obs well	DESC 4413	Haley	0.03 mi west of PBC on Gift Road	510	15	452.46	12/1/1993	454.64	**3/16/1994**	470.48	6/10/2009	yes	-15.84	1 wl	470.48	6/10/2009	18.02	16	Well drilled 2/8/78
Deschutes Mkt	non-current obs well	DESC 4320	Devereaux	0.02 mi west of PBC north end 73rd St	235	17	207.00	5/14/1984	197.11	**8/31/1994**	197.26	6/12/2009	yes	-0.15	1 wl	197.26	6/12/2009	-9.74	25	Well drilled 5/14/84
Veterans Way	non-current obs well	DESC 3982	Redmond Village Mobile Park	0.19 mi SE of PBC near SW Ben Hogan Dr corner	466	10	256.00	6/14/1974	386.00	3/26/1997	376.29	3/23/2005	1997-2005	9.71	no	376.29	3/23/2005	120.29	31	Well drilled 6/14/74
Veterans Way	non-current obs well	DESC 3981	Redmond Village Mobile Park	0.03 mi SE of DESC 3982	472	24	362.44	4/10/1979	367.25	**3/2/1994**	379.60	3/23/2005	1994-2005	-12.35	no	379.60	3/23/2005	17.16	26	Well drilled 7/19/74
Veterans Way	non-current obs well	DESC 407	City of Redmond	0.43 mi well south of Umatilla Park	765	17	362.00	5/25/1985	365.04	1/31/1995	387.44	4/8/2009	yes	-22.40	yes	388.60	**3/1/2021**	26.60		Well drilled 5/25/85
Veterans Way	non-current obs well	DESC 3879	City of Redmond	0.47 mi west of PBC in Kalama Bicentennial Park	452	20	265.00	2/14/1975	269.00	3/26/2001	288.10	4/8/2009	2001-2009	-19.10	yes	302.20	**3/1/2021**	37.20	46	Well drilled 2/14/75
Redmond	non-current obs well	DESC 3949	Redmond Industrial Park Inc.	0.5 mi east of PBC near west side Redmond airport	390	96	295.00	3/30/1979	301.37	**3/2/1994**	317.34	1/30/2009	yes	-15.97	yes	325.00	7/27/2016	30.00		Well drilled 9/27/93; abandoned 7/28/16
Redmond	non-current obs well	DESC 3952	City of Redmond	0.91 mi east of PBC west side Redmond airport	740	9	314.00	12/14/1983	312.92	**3/2/1994**	381.00	3/1/2005	1994-2005	-68.08	no	381.00	3/1/2005	67.00		Well drilled 12/14/83; abandoned 1/26/07
Redmond	non-current obs well	DESC 3951	City of Redmond	0.91 mi east of PBC west side Redmond airport	801	18	310.00	5/18/1987	328.95	**9/9/1994**	321.05	4/8/2009	yes	7.90	yes	363.00	**3/1/2021**	53.00		Well drilled 5/18/87
Redmond	non-current obs well	DESC 3853	City of Redmond	0.67 mi west of PBC at NW Maple Ave	300	20	168.00	7/15/1969	154.00	3/8/2001	183.99	4/7/2009	2001-2009	-29.99	yes	207.30	**3/1/2021**	39.30	52	Well drilled 7/15/69

Notes:

Median period 1994 thru 2008 wl depth change all 12 wells	-15.97
Average period 1994 thru 2008 wl depth change all 12 wells	-16.59
Median period 1994 thru 2008 wl depth change in 6 wells w/ 1994-2009 data	-15.91
Average period 1994 thru 2008 wl depth change in 6 wells w/ 1994-2009 data	-18.69

Table C: Identified WRD GIS Observation Wells Located within 1.4 miles of the PBC - Groundwater Levels from 2009 through 2023.

							Select Water Levels										
							oldest		2009 Period		2009 through 2023 Period		most recent 2023 Period		Oldest to most recent water level decrease		
PBC EIS Segment Area	**OWRD GIS Well Type**	**Well Log ID**	**Well Name**	**Location (approx to PBC)**	**Well Depth**	**# of WL measures**	**WL depth (feet)**	**date**	**WL depth (feet)**	**date (2009?)**	**period 2009 to 2023 data?**	**Period 2009 thru 2023 data?**	**WL depth (feet)**	**date**	**most recent - oldest**	**approx number of years**	**Notes**
Rivers Edge	**current obs well**	DESC 52907	City of Bend	1.32 mi NW Pilot Butte to PBC entry	1140	14	786.00	2/15/2000	786.00	3/12/2009	yes	4.05	781.95	**3/20/2023**	-4.05	23	Well drilled 3/24/00
Rivers Edge	**current obs well**	DESC 5045	USFS Bend Pine Nursery	0.84 mi east of Empire Ave crossing.	1057	58	701.50	10/11/1979	733.91	3/11/2009	yes	-21.03	754.94	**2/17/2023**	53.44	28	Well drilled 2/16/77
Deschutes Mkt	**current obs well**	DESC 57132	Hocker	0.55 mi east near Deschutes Market Rd	710	2	641.00	10/27/2005	641.00	10/27/2005	2005-2022	-12.52	653.52	**3/1/2022**	12.52	17	Well drilled 10/27/05
Veterans Way	**current obs well**	DESC 55844	Juniper Golf Course	0.78 mi east middle of Juniper Golf Course	605	14	360.00	3/1/2010	360.00	3/1/2010	2010-2023	-21.00	381.00	**1/1/2023**	21.00	13	Well Drilled 11/25/03
Veterans Way	**current obs well**	DESC 51967	Deschutes Cty Fair & Expo	0.69 mi east of SW Airport Way crossing	607	5	362.00	5/28/2005	368.50	3/22/2011	2011-2022	-18.12	386.62	**3/15/2022**	24.62	17	Well drilled 5/22/88; deepened 5/28/05
Veterans Way	non-current obs well	DESC 407	City of Redmond	0.43 mi well south of Umatilla Park	765	17	362.00	5/25/1985	387.44	4/8/2009	2009-2021	-1.16	388.60	**3/1/2021**	26.60		Well drilled 5/25/85
Veterans Way	**non-current obs well**	DESC 3879	City of Redmond	0.47 mi west of PBC in Kalama Bicentennial Park	452	20	265.00	2/14/1975	288.10	4/7/2009	2009-2021	-14.10	302.20	**3/1/2021**	37.20	46	Well drilled 2/14/75
Veterans Way	**current obs well**	DESC 3931	Kitchell [DESC 63587 Westendorf]	0.93 mi west Redmond Memorial Cem	787	4	500.00	8/1/1979	501.70	7/31/2019	2019-2022	-9.63	511.33	**9/1/2022**	11.33	43	Well drilled 8/1/79; deepened 8/25/22
Redmond	**non-current obs well**	DESC 55853	City of Redmond	0.52 mi east of PBC near west side Redmond airport	855	14	336.00	12/22/2003	342.90	4/9/2009	2009-2021	-16.00	358.90	**3/1/2021**	22.90		Well drilled 12/31/03
Redmond	**non-current obs well**	DESC 3951	City of Redmond	0.91 mi east of PBC west side Redmond airport	801	18	310.00	5/18/1987	321.05	4/8/2009	2009-2021	-41.95	363.00	**3/1/2021**	53.00		Well drilled 5/18/87
Redmond	**current obs well**	DESC 3880	Juniper Golf Course, Inc (Lions Lake)	0.3 mi east SW Kalama & SW Indian Aves	358	9	268.00	1/23/1978	312.26	10/3/2022	2021-2023		314.25	**7/18/2023**	46.25	45	Well drilled 1/23/78. Near piped section of PBC
Redmond	**non-current obs well**	DESC 57788	City of Redmond	0.7 mi east of PBC at NW Dogwood Ave	860	13	326.00	12/13/2006	330.00	3/17/2010	2010-2021	-5.60	335.60	**3/1/2021**	9.60	15	Well drilled 12/14/06
Redmond	**non-current obs well**	DESC 3853	City of Redmond	0.67 mi west of PBC at NW Maple Ave	300	20	168.00	7/15/1969	183.99	4/7/2009	2009-2021	-23.31	207.30	**3/1/2021**	39.30	52	Well drilled 7/15/69

Notes:

Median period 2009 thru 2023 wl change -15.05

Average period 2009 thru 2023 wl depth change -15.03

Table D: Identified WRD GIS Observation Wells Located within 1.4 miles of the PBC - Comparison of 1994 thru 2008 Water Levels with 2009 thru 2023 Water Levels

							Select Water Levels				
							1994 thru 2008 data		2009 thru 2023 data		
PBC EIS Segment Area	OWRD GIS Well Type	Well Log ID	Well Name	Location (approx to PBC)	Well Depth	# of WL measures	Data for 1994 thru 2008 period?	1994 thru 2008 change in WL	Data for 2009 to 2023 period?	2009 to 2023 change in WL	Notes
Rivers Edge	**current obs well**	DESC 52907	City of Bend	1.32 mi NW Pilot Butte to PBC entry	1140	14	no		yes	4.05	Well drilled 3/24/00
Rivers Edge	**non-current obs well**	DESC 8499	City of Bend	1.32 mi. Adjacent to DESC 52907	1065	3	no				Well drilled 8/17/93
Rivers Edge	non-current obs well	DESC 5029	Dunlap	1.02 mi NW of north end of lined PBC. Near river.	186	3	no				Well drilled 1/20/72
Rivers Edge	**current obs well**	DESC 5045	**USFS Bend Pine Nursery**	0.84 mi east of Empire Ave crossing.	1057	58	yes	-16.27	yes	-21.03	Well drilled 2/16/77
Rivers Edge	non-current obs well	DESC 471	Clausen	0.9 mi west of NW corner NE 18th alignment	745	4	no				Well drilled 2/20/72; deepened 1/73, 5/74, 10/74. Original well had much lower WL.
Deschutes Mkt	non-current obs well	DESC 461	Kent	1.13 mi east of PBC crossing BNSF rr	655	2	no				Well drilled 3/28/89
Deschutes Mkt	**current obs well**	DESC 57132	Hocker	0.55 mi east near Deschutes Market Rd	710	2	no		2005-2022	-12.52	Well drilled 10/27/05
Deschutes Mkt	non-current obs well	DESC 4436	MGM Investments	0.59 mi east of west side Grande Loop	620	4	no				Well drilled 4/14/78
Deschutes Mkt	non-current obs well	DESC 4413	Haley	0.03 mi west of PBC on Gift Road	510	15	yes	-15.84			Well drilled 2/8/78
Deschutes Mkt	non-current obs well	DESC 4320	Devereaux	0.02 mi west of PBC north end 73rd St	235	17	yes	-0.15			Well drilled 5/14/84
Deschutes Mkt	non-current obs well	DESC 8612	Smith	0.36 mi west of PBC near SW corner of 74th Ln	430	2	no				Well drilled 9/23/93
Veterans Way	**current obs well**	DESC 55844	Juniper Golf Course	0.78 mi east middle of Juniper Golf Course	605	14	no		2010-2023	-21.00	Well drilled 11/25/03
Veterans Way	non-current obs well	DESC 3982	Redmond Village Mobile Park	0.19 mi SE of PBC near SW Ben Hogan Dr corner	466	10	1997-2005	9.71			Well drilled 6/14/74
Veterans Way	non-current obs well	DESC 3981	Redmond Village Mobile Park	0.03 mi SE of DESC 3982	472	24	1994-2005	-12.35			Well drilled 7/19/74
Veterans Way	**current obs well**	DESC 51967	Deschutes Cty Fair & Expo	0.69 mi east of SW Airport Way crossing	607	5	no		2011-2022	-18.12	Well drilled 5/22/88; deepened 5/28/05
Veterans Way	non-current obs well	DESC 407	City of Redmond	0.43 mi well south of Umatilla Park	765	17	yes	-22.40	2009-2021	-1.16	Well drilled 5/25/85
Veterans Way	**non-current obs well**	DESC 3879	**City of Redmond**	0.47 mi west of PBC in Kalama Bicentennial Park	452	20	2001-2009	-19.10	2009-2021	-14.10	Well drilled 2/14/75
Veterans Way	**current obs well**	DESC 3931	Kitchell [DESC 63587 Westendorf]	0.93 mi west Redmond Memorial Cem	787	4	no		2019-2022	-9.63	Well drilled 8/1/79; deepened 8/25/22
Redmond	**non-current obs well**	DESC 55853	City of Redmond	0.52 mi east of PBC near west side Redmond airport	855	14	no		2009-2021	-16.00	Well drilled 12/31/03
Redmond	**non-current obs well**	DESC 3949	Redmond Industrial Park Inc.	0.5 mi east of PBC near west side Redmond airport	390	96	yes	-15.97			Well drilled 9/27/93; abandoned 7/28/16
Redmond	**non-current obs well**	DESC 3952	City of Redmond	0.91 mi east of PBC west side Redmond airport	740	9	1994-2005	-68.08			Well drilled 12/14/83; abandoned 1/26/07
Redmond	**non-current obs well**	DESC 3951	City of Redmond	0.91 mi east of PBC west side Redmond airport	801	18	yes	7.90	2009-2021	-41.95	Well drilled 5/18/87
Redmond	**current obs well**	DESC 3880	Juniper Golf Course, Inc (Lions Lake)	0.3 mi east SW Kalama & SW Indian Aves	358	9			2021-2023		Well drilled 1/23/78. Near piped section of PBC
Redmond	**non-current obs well**	DESC 57788	City of Redmond	0.7 mi east of PBC at NW Dogwood Ave	860	13	no		2010-2021	-5.60	Well drilled 12/14/06
Redmond	**non-current obs well**	DESC 3853	**City of Redmond**	0.67 mi west of PBC at NW Maple Ave	300	20	2001-2009	-29.99	2009-2021	-23.31	Well drilled 7/15/69
Redmond	non-current obs well	DESC 3723	North Rim Subdivision	0.63 mi west of PBC SW of Quince Park	297	32	no				Well drilled 2/8/72
King Way	non-current obs well	DESC 223	Sager	0.98 mi NW of PBC north of N canal blvd & NE Yucca Ave	300	2	no				Well drilled 11/9/90
King Way	non-current obs well	DESC 2739	Britten	1.17 mi east of north end of PBC project end	290	2	no				Well drilled 5/10/80

Notes: Average 2009-2023 wl change -15.97

Average period 1994 thru 2008 wl depth change -16.59

Median 2009-2023 wl change -15.05
Average 2009-2023 wl change -15.03

Table E: Estimated Canal Leakage Decreases PBC Piping Phases

Phase or Segment	Length of project improvements (ft)	Length (Miles)	Estimated Seepage Loss in System (af/year)	Est Seep & Evap Loss per Mile (af/year per mile)	Estimated Seepage and Evaporative Loss in System (af/day)	Estimated Seepage and Evaporative Loss in System (cfs)	Est Seep & Evap Loss per Mile (cfs per mile)
Rivers Edge	19,750	3.7	11,771.80	3,147.09	32.25	16.26	4.35
Deschutes Market	22,000	4.2	8,398.86	2,015.73	23.01	11.60	2.78
Canal	13,850	2.6	8,810.50	3,358.81	24.14	12.17	4.64
Veterans Way	16,650	3.2	8,612.66	2,731.22	23.60	11.90	3.77
Redmond	13,800	2.6	2,023.13	774.07	5.54	2.79	1.07
King Way	11,875	2.2	3,927.07	1,746.10	10.76	5.42	2.41
Total	97,925	18.5	43,544.02	2,347.84	119.30	60.15	3.24

Data Source	COID EIS NEE Analysis Workbook_2023.05.27	Values from "Est Savings Seepage + Op Water" sheet in PBC EIS WaterLossEstimate_2023.03.14. CFS from seepage values used with the sheet's conversion to acre feet formula.	1 cubic foot/second =	1.983471 acre foot/day

11.83 miles NUID canal from river diversion to east side of Pronghorn Club. Detemined using GoogleEarthPro. This is length shown on 2013 USGS Fig28.

10,001 to 16,983 Estimated decrease in annual canal leakage in afy for NUID ~11.83 mile shaded segment shown on 2013 USGS Fig28.

NUID Southern Portion Main Canal Leakeage Estimates (USGS 2013)	canal leakage (afy)	canal leakage rounded (afy)	estimated miles	est canal leakage per mile (afy/mile)	est canal leakage per mile (acre-feet/day per mile)	est canal leakage per mile (cfs per mile)
Lower USGS range	10,001	10,000	11.83	845	2.32	1.17
Upper USGS range	16,983	17,000	11.83	1436	3.93	1.98
Average USGS range		13,500	11.83	1141	3.13	1.58

NUID 11.83 mile canal segment runs east of Rivers Edge and Deschutes Market segments.

13,500 Average estimated decrease in annual canal leakage for NUID ~12 mile shaded segment shown on 2013 USGS Fig28.

1,140 Average of NUID ~11.83 mile est canal leakage per mile

1,125 12 miles of canal with a leakage rate of 13,500 afy.

2,581 Average of Rivers Edge and Deschuted Market est seep & evap loss per mile

2013 Model Fig28 indicates

-68.3 to -50.0 ft decline in Layer 1 in NUID section in/near Rivers Edge phase extending to southern half of Deschutes Market phase. Mid way value from -68.3 to -50.0 = 59.15. Round down 59 feet.

-49.9 to -10.0 ft decline in Layer 1 in NUID section northern half of Deschutes Market phase. Mid way value from -49.9 to -10.0 = 29.95. Round up 30 feet.

-4.99 to -2.0 ft decline in Layer 3 in NUID canal. Decreases to -1.99 to -1.0 ft most north end of simulated NUID canal. Mid way value from -4.99 to -2.0 = 3.5.

Averge 1,200 afy loss per mile of canal divided

Table F: Vertical Hydraulic Conductivity Values Bend and Redmond Areas

Geologic Unit	Unit Symbol (Sherrod et al.	Bend Area		Redmond Area	
		Mean Vert K (ft/d)	Median Vert K (ft/d)	Mean Vert K (ft/d)	Median Vert K (ft/d)
Quaternary Alluvium	Qbn	na	na	na	na
Quateranary Basalt and Andesite	Qbn, Qb, Qba	4.1	3.3	2.3	2.1
Basalt of Awberry Butte	Tbab	4.1	0.15	na	na
Tertiary basalt and andesite	Tbr, Tbdr	na	na	1.1	0.73
All tests		4.3	2.9	1.3	0.86

Multiple of Bend area values to Redmond Values	3.3	3.4

Values are based on infiltration tests completed on City of Bend and City of Redmond underground infiltration controls (UICs).

Sources:
Technical Memorandum, Pollutant Fate and Transport Model Results in Support of the City of Bend UIC WPCF Permit - Groundwater Protectivenss Demonstration and Proposed EDLs, Prepared for City of Bend; Prepared by GSI, September 21, 2011.

Technical Memorandum, Pollutant Fate and Transport Model Results in Support of the City of Bend UIC WPCF Permit - Groundwater Protectivenss Demonstration and Proposed EDLs, Prepared for City of Redmond; Prepared by GSI, September 21, 2011.