U.S. Bureau of Reclamation
Water Conveyance Systems in the West
Context and Evaluation Guidance

September 2023

Contract W9128F19D0059
Delivery Order W9128F21F0255

BUREAU OF RECLAMATION

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CULTURAL RESOURCES CONSULTING

U.S. Bureau of Reclamation
Water Conveyance Systems in the West
Context and Evaluation Guidance

Final Report

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1.0 Project Overview

1.1 Objectives

In 2021, NDN Companies, Inc. (NDN) and Brockington and Associates, Inc. (Brockington) were contracted to prepare a historic context of water distribution infrastructure assets owned by the U.S. Bureau of Reclamation (Reclamation) in the western United States. This work was performed under a United States Army Corps of Engineers (USACE) Omaha District Contract (W9128F19D0059, Delivery Order F0255). The Bureau of Reclamation has jurisdiction over more than 8 million acres of land in 17 western states. It manages 180 reclamation-related projects, which include 8,116 miles of canals, drains, and ditches along with thousands of related features from large, imposing dams to small water gauges that facilitate and measure flow to individual farms. Many of these features have reached or will soon reach 50 years of age, making them eligible for consideration for listing in the National Register of Historic Places (NRHP). Therefore, this context is intended to assist consultants, agency cultural resources managers, and other individuals who would be evaluating or managing historic-age Reclamation assets under the National Historic Preservation Act (NHPA). While Reclamation constructed large dams and reservoirs as components of their extensive projects, this study (as per the Scope of Work) concentrates only on the conveyance systems and their functional components.[1] The Bureau of Reclamation originally began to develop this historic context in support of a proposed Program Comment for water infrastructure assets with the Advisory Council on Historic Preservation (ACHP) for future NHPA Section 106 compliance. The proposed Program Comment is no longer being pursued by Reclamation; however, the context was deemed a worthy endeavor and the work continued. These assets generally include:

- **Diversion Structures**, including diversion dams, weirs, pumping stations, or pump houses.
- **Conduit Structures**, including main canals, lateral canals, sublateral canals, wasteways or drains, flumes, siphons, tunnels, piping systems, and other conveyance features.
- **Flow Control Devices**, including headgates, checks, turnouts, distribution boxes, drops, and chutes.
- **Measuring Devices**, including Parshall flumes, modified Parshall flumes, stilling wells, measurement weirs, weir boxes, flow meters, and gauges.
- **Cleansing Devices**, including trash racks and sand traps.

1.2 Methodology and Research

This project began with the development of a Work Plan, approved by the Reclamation technical reviewers. This Work Plan included an outline and detailed discussion of the proposed archival research materials and repositories. The Work Plan served as a general guide throughout the context's completion but was modified as dictated by the research. As this context covered 17 states, and given the logistical limitations of accessing a diversity of repositories as well as closures due to COVID-19 during the early contract period, all research was conducted remotely. Nevertheless, the project historians reviewed an extensive amount of primary and secondary literature. Reclamation provided a collection of scanned materials including

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[1] David P. Billington, Donald C. Jackson, and Martin V. Melosi, *The History of Large Federal Dams: Planning, Design and Construction in the Era of Big Dams* (Denver: U.S. Department of the Interior, Bureau of Reclamation, 2005) provides an extensive context and evaluation criteria for large dams.

photographs, pamphlets, project completion reports, engineering manuals, and previous cultural resources studies to name a few. The National Archives and Records Administration (NARA) has a growing collection of online materials, which covers Reclamation projects, as well as NRHP listings and materials. Staff reviewed those records along with Historic American Building Survey (HABS) and Historic American Engineering Record (HAER) documents on the Library of Congress online collections page. Staff also contacted many of the western State Historic Preservation Offices (SHPOs), which provided either materials or access to materials. Project staff also made use of Reclamation webpages for specific project histories and information. Additionally, staff reviewed webpages for contractors that provided a substantial collection of written and photographic materials relevant to their work on Reclamation projects.

This context is divided into six chapters and three appendices. Chapter 1 provides a project overview. Chapter 2 presents a broad overview of the history of the Bureau of Reclamation. Chapter 3 includes a discussion of technological and geographical challenges presented to the agency during the construction of their vast infrastructure system. Chapter 4 provides brief histories of 16 separate systems, selected to provide a variation in terms of geography, size, and location. Chapter 5 includes a detailed pictorial listing of water infrastructure assets to give the reader a visual understanding of how the systems appear in the field and operate. Chapter 6 includes a discussion of NRHP criteria and evaluation considerations. The document concludes with a bibliography and a series of appendices. These include known NRHP listings, HABS/HAER documentation, and relevant state documents for further reference.

1.3 Acknowledgements and Contributions

Many individuals contributed to the successful completion of this document. At the Bureau of Reclamation, Mr. Joe Giliberti (Federal Preservation Officer) helped frame the overall outline of the context and offered insight into how it will be used as a cultural resources' evaluation tool. Dr. Andrew H. Gahan, Senior Historian, provided his expertise, helped locate documents and images, and offered reviews on the draft documents. At NDN, Ms. Shawna Newman (President) led the contract effort and Ms. Samantha Murphy served as Project Manager. Also at NDN, Mr. Ryan Enger initially served as Project Manager and assisted with archival research. At Brockington, Senior Historian Mr. Charles F. Philips, Jr. also conducted archival research and served as the document's primary author. Ms. Patricia Stallings, Senior Historian, conducted technical peer review and assisted with architectural components of the report. Ms. Meagan Brady edited and produced the report.

1.4 Summary, Conclusions, and Data Gaps

This context attempts to synthesize a vast amount of research and material and makes broad conclusions regarding system and component evaluation. In summary, there are several issues field investigators and agency managers must address when evaluating the systems and components. First, no two projects are alike. Structures may have the same function but otherwise may appear very different in the field, particularly in size. This narrative is not a substitute for good archival research. Reclamation maintenance is always ongoing and alterations for improvement are constantly occurring. Reclamation project completion or annual reports should be consulted; district office personnel are also a source of information. These individuals often understand what historic features remain and what components have been altered. Investigators must identify the changes that will affect the water system's ability to convey its historic integrity.

Reclamation has a varied inventory of projects. These include small works such as Lewiston Orchards in Idaho that irrigate approximately 5,000 acres. It also includes much larger projects, such as Minidoka, also in Idaho, that encompasses more than 1,000,000 acres. Obviously, the fundamental function of storing and making water available at the correct time is identical for both projects. However, the complexity of fulfilling that responsibility is far greater with one than the other.

The function of the structure is the determining factor for correct identification within the conveyance system. For example, a main canal is the main canal in all projects. However, the size and location can vary widely, depending on geography and hydrology needs. Main canals can be 60 to 100 feet wide or 6 to 10 feet wide. A main canal in a small project might be comparable in size to a small sublateral canal in another. Similarly, a Parshall Flume has the same application in all projects. A Parshall Flume might measure the water flowing into a lateral 30 feet wide or be combined with turnout to perform multiple tasks when measuring water flowing from a sublateral canal into a farmer's ditch 3 feet wide. Both are methods of measuring water use.

Archival work must precede field inspections. The field technician must understand what structures they may encounter in the field and what has changed over time. Project completion reports, annual histories, and engineering drawings provide a baseline of information. In addition, interviews with district staff will help determine the extent of alterations over time, and importantly, identify any significant historic engineering components. For example, Reclamation staff can provide information on conversion of open canals to piped canals, broad automation of gates and gauges, the presence of any engineering components that may represent unique engineering solutions for a particular project or represent rare surviving examples of a type of component (e.g., wooden flumes).

Reclamation systems constantly change, and the alterations may themselves meet the 50-year criteria and contribute to a system's eligibility. For example, a project for an earthen main canal built in 1934 and lined in 1964 might still be eligible, since the modification is over 50 years old. However, it is also important to consider whether that change occurred during a designated "period of significance" for which the system is considered eligible. Generally, substantial modifications less than 50 years old have a negative impact on the feature's ability to exhibit historical integrity, and the accumulation of modifications will also degrade the system's eligibility. For example, a wooden lateral headgate built in 1920 replaced by a concrete and steel headgate in 1990 will likely have a negative impact on the ability of the lateral to retain historic integrity. Certainly, the replacement of open canals and laterals with buried concrete piping when the piping does not follow the original alignment will also have an impact on historic integrity as to design, feeling, and location.

The functionality of the structure determines its identity within a conveyance system. We attempted to explain all major structural components of a Reclamation conveyance system. However, engineering changes and new applications may present the investigator with what appears to be an unrecognizable feature. For example, a water flowmeter installed in 1947 adjoining a headgate to measure water distribution from a lateral to a sublateral may have been upgraded to an inground digital device in 2010. The digital device is performing the exact same function as the flowmeter. However, the investigator will need to assess if the digital device reduces the ability of the structural system to exhibit historical integrity. Automation is proceeding rapidly throughout the agency's infrastructure and will continue to challenge field investigators in assessing a systems' integrity.

In addition, investigators may encounter other peripheral items such as habitation sites, hydroelectric plants, substations, transmission lines, administration and operations buildings, bridges, treatment plants, and fish passages. Such items were not covered under the current scope of work and are not considered integral components of the water control system itself but may represent potentially important features either individually or as groups. Some contexts for these resource types are already available, but others have not been extensively studied. While these features are briefly discussed as needed within this context, investigators may need to consider and research these items separately, or Reclamation may consider future contexts to further our knowledge of the assets.

To further agency management, one of this project's goals was to quantify, or at least attempt to summarize, the extent to which Reclamation systems and assets have been evaluated and documented. There have been over 60 NRHP listings and approximately 180 HABS/HAER recordation projects, in addition to numerous historic resources reports, contexts, and inventoried assets in state databases. While this report doesn't provide a comprehensive listing of every recorded Reclamation asset or water conveyance feature, it does provide a robust sampling of irrigation-related resource types. Given the increasing age of the Reclamation system, its assets, and the increasing Section 106 undertakings to address maintenance, upgrades, and rehabilitation, this information can be used to inform development of a Programmatic Agreement (PA). Example PA stipulations may include selecting representative project "systems" for HABS/HAER documentation or the development of a standardized historic resources inventory system.

2.0 Historical Overview of Reclamation Conveyance Systems

2.1 Introduction

In the first half of the nineteenth century, the United States expanded, more than doubling its land mass.[2] With the 1803 Louisiana Purchase, 1821 Florida purchase, and the 1848 Mexican Cession, along with the acquisition of Texas, the country grew by 67 percent, adding two-thirds of its land area (excluding Alaska). Yet, with the exception of western California, parts of the Oregon territory, and the Mormon settlement in Utah, most of it remained the "Great American Desert" and "unfit for civilization" well into the nineteenth century.[3] Settlement west of the 100th meridian did not proceed until after the Civil War. The 100th meridian roughly marks the dividing line between the arid and humid regions of the United States. The western half of the U.S., what surveyor and explorer John Wesley Powell called in 1879 "the arid region," encompasses 17 states or parts of states that receive on average, with some exceptions, 20 inches or less of rainfall per year.[4]

Though the "Great American Desert" was much more than that, the name stuck, and the public perceived the region as environmentally and economically unviable without some form of irrigation. Except for parts of California and Oregon, little was done by the Federal Government to encourage settlement until the Civil War. Prior to that time, the development of lands east of the Mississippi River was often the object of congressional squabbling and fighting over what was then called "internal improvements," usually limited to public canals, roads, and harbor improvements. By the end of the nineteenth century, irrigation development came to be seen by its proponents as a "legitimate internal improvement that the Federal Government should assume," and that Congress was under "obligation to make water available for western public domain" because without water the land was useless.[5]

Despite a history of federal support for harbors, transportation, and land settlement, the idea of massive, federally sponsored land reclamation via irrigation needed the idealism of the early Progressive Movement to make it a reality. It also required an activist and western-identified president in Theodore Roosevelt to help lift the idea from boosters, programs, pamphlets, speeches, and congressional lobbying into law. Finally, it was pushed along by increasing strength in the western representation in the U.S. Senate. Between 1889 and 1902, seven western territories had achieved statehood, with three more following in the first two decades of the twentieth century. With increasing senate support, aggressive lobbying by President Roosevelt, and having solved the financial cost and the right-of-way issues, Congress passed the Reclamation Act of 1902, and the Secretary of the Interior established the U.S. Reclamation Service (later

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[2] This chapter presents a brief overview of the Bureau of Reclamation. For a more detailed history, see William D. Rowley, *The Bureau of Reclamation: Origins and Growth to 1945. Volume 1* (Denver, Colorado: Bureau of Reclamation, U.S. Department of the Interior, 2006), and Andrew H. Gahan and William D. Rowley, *The Bureau of Reclamation: From Developing to Managing Water, 1945-2000. Volume 2* (Denver, Colorado: Bureau of Reclamation, U.S. Department of the Interior, 2012). Both are available on the agency's webpage: https://www.usbr.gov/history/.

[3] The Oregon Territory originally included the current state of Washington. See Gahan and Rowley, *Developing to Managing Water*, 55.

[4] J.W. Powell, *Report on the Lands of the Arid Region of the United States With a More Detailed Account of the Lands of Utah with Maps* (Washington, D.C.: Government Printing Office, 1879).

[5] Rowley, *Origins and Growth*, 52.

the Bureau of Reclamation). In March 1903, the Secretary of the Interior authorized Reclamation's first five projects.

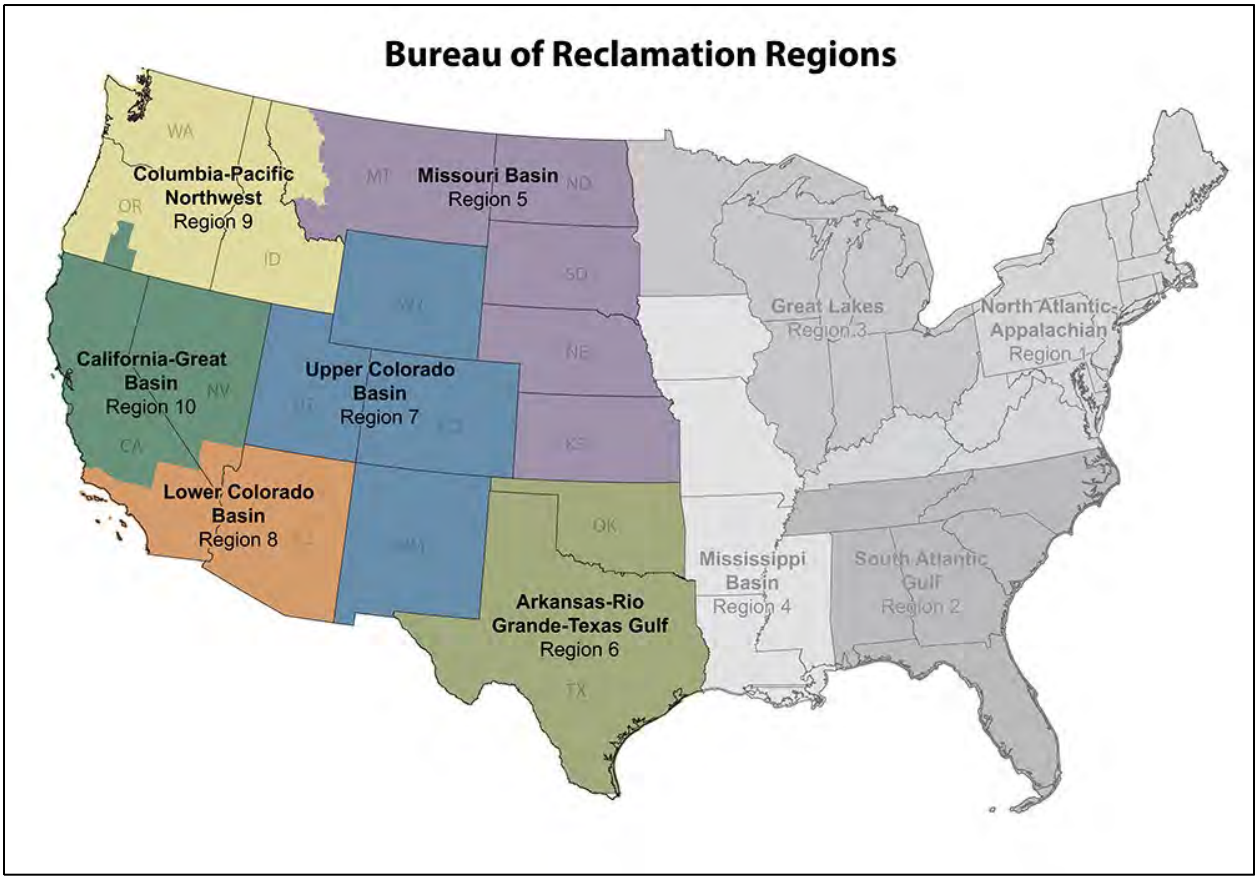

Figure 2.1 Current regions of the Bureau of Reclamation in the western United States covered by the Reclamation Act of 1902.[6]

2.2 Foundation and Early Projects (1902-1918)

Throughout much of the nineteenth and well into the twentieth century, Thomas Jefferson's view of the "land and small freehold farmers" became the "mainstay of American democracy" in the minds of many thinkers.[7] This ideal of the citizen-farmer had deep roots in the eighteenth century. As the second half of the nineteenth century unfolded, this ideology, along with that of America's "Manifest Destiny," generated the development of government plans to settle the American West. Keeping with its goal towards internal improvements, after 1861 Congress embraced the railroad as a key to western development. In 1862 and 1864, the National Railway Acts gave large land grants and loans to private efforts to build the first transcontinental railroad. One of the most popular congressional acts of the Civil War period was the Homestead Act of 1862, which gave 160 acres of public lands to any person willing to settle and improve

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[6] Bureau of Reclamation, "Reclamation Offices, Addresses and Contacts," https://www.usbr.gov/main/offices.html [accessed October 2022].

[7] Rowley, *Origins and Growth*, 48.

it.[8] The act was very effective in settling the Midwest, but generally failed to draw settlers further west due to the absence of water and the presence of Native American Plains tribes.

During the post-Civil War period, Congress made other efforts to encourage the settlement of western lands. First, the U.S. Army effectively subjugated the indigenous Plains tribes. With the Indian threat successfully removed during the 1870s and 1880s, Congress sought to encourage settlement with a series of legislative acts. In 1973 it passed the Timber Culture Act that gave up to an additional 160 acres of lands to settlers for planting trees. The Desert Land Act of 1877 allowed settlers to homestead up to 640 acres at a low cost if irrigation works were built. This latter legislation represented the first effort to provide federal support for irrigation development, though it merely gave larger amounts of inexpensive land and not funding. In one last effort to encourage settlement, Congress passed the Carey Act of 1894, which granted federal lands to the states for the states' sponsorship of irrigation development.

Meanwhile, government-sponsored surveyors produced a number of studies that provided a greater understanding of the "arid" West. These studies and surveys showed "enthusiasm" over the potential for fulfilling the American agrarian ideal but were usually mixed with an equal amount of "caution" about the many potential problems.[9] As early as 1864, Scientist George P. Marsh had reported on the potential for irrigation. Working on his own, John Wesley Powell, who eventually became director of the United States Geological Survey (USGS), published his report on the arid regions of the United States and the potential for irrigation in 1878. In 1888, Congress authorized the USGS to study the hydrography of the arid regions in the West.

Political leaders pushed irrigation as one of the "panaceas" for solving the slow development and economic woes of the new western states.[10] Senator William M. Stewart and Congressman Francis Newlands of Nevada, and Francis Warren of Wyoming, among others, had grown up in a climate of "boosterism" and were impatient for the advantages that irrigation would bring to their states. They lobbied for irrigation development but often had disparate views as to how that was to be implemented. Writers such as William Ellsworth Smythe popularized the sentimental promises of agricultural life and provided a Jeffersonian theme to the irrigation movement.

The boosters' voices were magnified by the economic depression of the 1890s. Initiated by the Panic of 1893, the economic downturn hit the western mining states particularly hard. As the decade progressed, new congressmen began proclaiming the benefits of a national irrigation policy. Eastern states began to pay more attention as they too faced economic stagnation in the early 1890s, along with a rising tide of immigration and a corresponding rise in poverty. The West was seen as a "new frontier that offered opportunity," a solution for the "growing complexities and problems" that the economic trends "of urban industrialization inflicted upon the nation."[11]

To achieve this, Congress needed to solve the issue of ownership and cost of the irrigation works and find a dynamic leader. The first issue seemed to have been resolved by the Mining Acts of 1866 and 1872 that granted rights of way across public lands to carry water. Numerous private efforts to irrigate also developed in the post-Civil War Period. However most, though not all, failed due to limited capital investment or lack of engineering expertise. Promotional societies in the western states were formed,

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[8] Rowley, *Origins and Growth*, 49.

[9] Ibid., 61.

[10] Ibid., 70-71.

[11] Ibid., 73.

brochures published, and lobbyists pressured Congress to act. By the end of the decade, the railroads also called for a federal irrigation effort, recognizing the economic advantages that irrigation could bring such as new towns and railroad stops.

The new century provided an atmosphere of change, what historians would later call the Progressive Era (1900-1920). Progressivism found its expression in more equitable labor laws, greater democracy in political life, conservation of natural resources, improvements in roads and bridges for automobiles, breaking up the monopolies, public efforts to deal with social issues, and use of the scientific method for solving a wide range of societal problems. In international relations, Progressives looked to influence the world through the U.S. military power and technological and engineering expertise. The building of the Panama Canal was the primary showcase of this latter claim. For the American West, Progressivism meant irrigation development. Both Progressives and irrigation advocates saw the federal effort to transform the West into a "garden" as a natural next step in American agriculture.[12]

Theodore Roosevelt became the leader for the development of the arid West. After assuming the presidency in 1901 following the death of William McKinley, one of Roosevelt's earliest acts as chief executive was signing the Reclamation Act of 1902.[13] The act led to the establishment of the U.S. Reclamation Service within the USGS.

Figure 2.2 President Theodore Roosevelt at the dedication of the Theodore Roosevelt Dam on the Salt River Project in Arizona in 1911.[14]

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[12] Rowley, *Origins and Growth*, 85.

[13] Ibid., 100.

[14] Bureau of Reclamation, "A Century of Cooperation: Reclamation and Arizona," https://www.usbr.gov/lc/phoenix/AZ100/1900/yuma_project.html [accessed February 2023].

The new law laid out one of the "most important programs of internal improvement ever attempted by the federal government."[15] The act established a reclamation fund from the sale of public lands in the 16 western states and territories (Texas was added as a Reclamation state in 1906). These funds were to be used to pay for the construction of primary water storage and distribution networks for irrigation systems. Water users were then required to repay the construction costs within 10 years at no interest and were responsible for operation and maintenance costs. The idea was that these funding mechanisms would create a revolving fund to allow irrigation expansion to be self-perpetuating with no need for congressional support through appropriations. Theoretically no federal funds would be used to build irrigation projects, which was the act's main selling point.

In keeping with earlier land legislation, the Reclamation Act limited the amount of land receiving water from a federal project to 160 acres. It was thought that this limitation would prevent the monopolization and speculation of project lands and distribute benefits to a greater number of settlers. The Secretary of the Interior also had the authority to establish land holdings eligible for project water, and often these were less than 160 acres. Reclamation would manage, operate, and maintain the systems until the construction costs were repaid, and then turn over operations to the water users. The Federal Government would retain ownership of all project facilities. To ease concerns over increasing federal oversight of western water development, the act mandated the Federal Government respect and adhere to individual state water laws and water rights, which was far easier said than done.[16] The breadth of the project was clear; the U.S. Government effectively committed itself to an unlimited number of projects as determined feasible by the Secretary of the Interior. Similar to the way the railroads had spurred development, Reclamation and its extensive projects was to be a conduit for opening even more lands. In March 1903, the Secretary of the Interior authorized construction of Reclamation's first five projects.

The first to begin construction was the Truckee-Carson Project in Nevada, later renamed the Newlands Project in honor of Senator Francis Newlands.[17] The Milk River Project in north-central Montana was coordinated with the Bureau of Indian Affairs and the Government of Canada to share the river that ran through both countries and the Blackfeet Indian Reservation. Project construction was delayed until a formal agreement between the Canadian and U.S. governments was reached.[18] The Sweetwater Project (later called the North Platte Project) delivers irrigation water to more than 300,000 acres along the North Platte River in Wyoming and Nebraska.[19] The Uncompahgre Project is a trans-basin project in west-central Colorado that transports water from the Gunnison River to supplement the Uncompahgre River.[20] The Salt

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[15] Rowley, *Origins and Growth,* 100.

[16] For more information on the 1902 Reclamation Act, see Richard K. Pelz (editor), "The Reclamation Act," in *Federal Reclamation and Related Laws Annotated*, Volume I, (Washington, D.C.: United States Government Printing Office, 1972), 31-89.

[17] For more information about the Newlands Project, see Wm. Joe Simonds, "Newlands Project," (Denver: Bureau of Reclamation History Program, 1996), https://www.usbr.gov/projects/pdf.php?id=142.

[18] For more information about the Milk River Project, see Wm. Joe Simonds, "Milk River Project," (Denver: Bureau of Reclamation History Program, 1998), https://www.usbr.gov/projects/pdf.php?id=136.

[19] For more information about the North Platte Project, see Robert Autobee, "North Platte Project" (Denver: Bureau of Reclamation History Program, 1996), https://www.usbr.gov/projects/pdf.php?id=145.

[20] For more information about the Uncompahgre Project, see David Clark, "Uncompahgre Project," (Denver: Bureau of Reclamation History Program, 1994), https://www.usbr.gov/projects/pdf.php?id=203.

River Project in the Salt and Verde river valleys in central Arizona includes the massive Theodore Roosevelt Dam and Powerplant. It is often touted as Reclamation's first multiple purpose project.[21]

By 1907, the Reclamation Service had not only become an independent agency within the Department of the Interior but had 25 projects under construction. Some of these early projects included the Minidoka Project authorized in 1904. This project now irrigates nearly 1,000,000 acres in the Snake River basin in Idaho and Wyoming. It involved building three dams and reservoirs along with an extensive distribution system that included two very large main canals.[22] Approved in 1907, the Sun River Project, along the north and south forks of the Sun River and Willow Creek in Montana, covers more than 90,000 acres of irrigatable land. The project involved nine canal systems and a drainage system. At the Sun River Project as well as on other early projects, Reclamation also discovered that drainage issues were to become major issues.[23] Another early project was the Strawberry Valley Project planned to irrigate 45,000 acres of Strawberry Valley along Spanish Fork River in Utah. This project was the first to transfer water from one river basin to another via the Strawberry Tunnel. The 1908 project was also one the earliest projects to incorporate a powerplant as part of the initial work.[24]

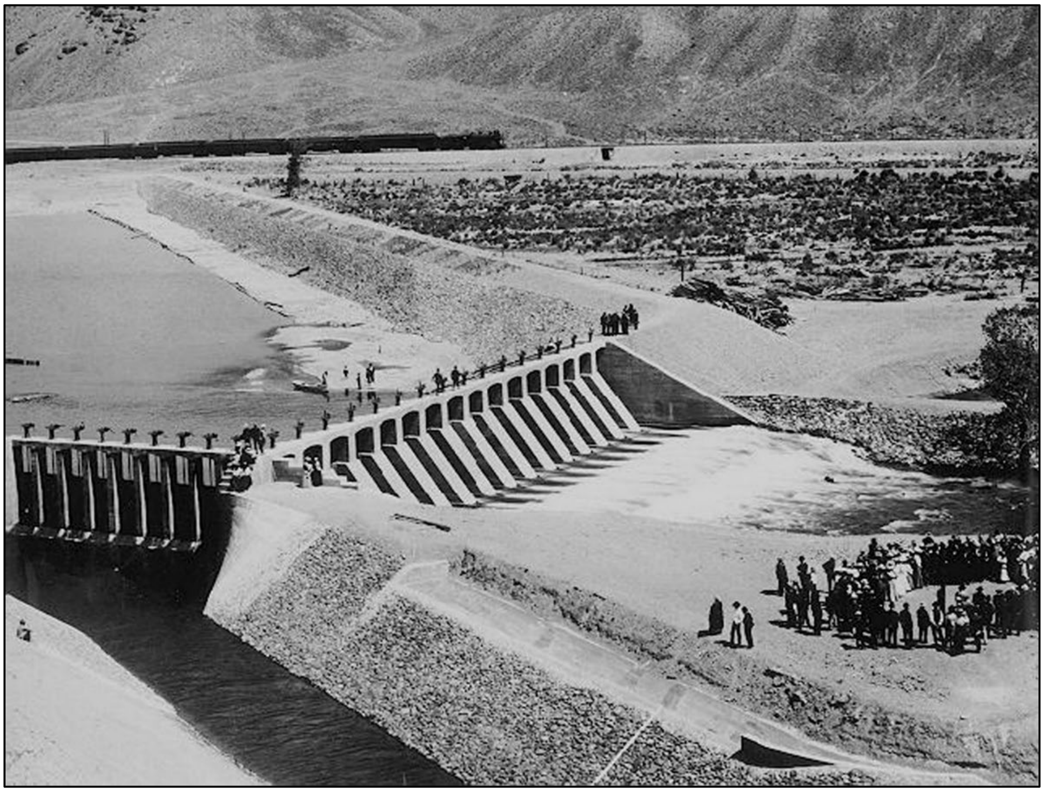

Figure 2.3 Dedication of the Derby Diversion Dam completed by Reclamation in 1905 on the Truckee River in the Newlands Project (courtesy of Bureau of Reclamation).

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[21] For more information about the Salt River Project, see Robert Autobee, "Salt River Project," (Denver: Bureau of Reclamation History Program, n.d.), https://www.usbr.gov/projects/pdf.php?id=183.

[22] For more information about the Minidoka Project, see Eric A. Stene, "Minidoka Project," (Denver: Bureau of Reclamation History Program, 1997), https://www.usbr.gov/projects/pdf.php?id=137.

[23] For more information about the Sun River Project, see Robert Autobee, "Sun River Project," (Denver: Bureau of Reclamation History Program, 1995), https://www.usbr.gov/projects/pdf.php?id=198.

[24] For more information about the Strawberry Valley Project, see Eric A. Stene, "Strawberry Valley Project," (Denver: Bureau of Reclamation History Program, 1995), https://www.usbr.gov/projects/pdf.php?id=197.

It did not take long for problems with the reclamation program to arise. Proponents soon began to realize they may have initiated too many projects too soon. Revenues from the sale of public land never seemed to catch up with project spending. Markets for products proved slow to develop and did not appear as robust as the boosters had professed. Finally, though many settlers had a farming background, many new landowners were unfamiliar with irrigation agriculture. Combined, these issues began to reveal serious problems with the Reclamation program.[25]

As Reclamation began work on these large construction projects, it soon encountered a number of agricultural, social, and economic barriers. By 1911, Director Frederick H. Newell acknowledged that farmers were unable to pay the large construction costs for the western projects, despite "Leniency Acts" that permitted deferring payments.[26] Since hydroelectric power was seen as an important byproduct of the irrigation systems, selling electricity became another avenue for paying the construction costs. In 1906, Congress passed the Town Sites Power and Development Act, which allowed Reclamation to supply water and electricity to government town sites. This became a boon to early project development by making revenues from hydroelectric powerplants available to offset construction costs. Unknowingly at the time, the act established Reclamation's core mission: water and hydroelectric power development and delivery.[27]

Other unanticipated obstacles required Reclamation to modify its approach as it endeavored to contend with unforeseen problems. Soil science at the time was rudimentary and led to a myriad of problems. Some structures were built on soils that were unstable, and projects were developed on lands that could not support agriculture. However, drainage became a major concern, requiring the installation of drain systems to remove excess water from irrigated fields to prevent waterlogging. The installation of drains caused controversy between Reclamation and water users over who was going to finance them, straining their relationship. Reclamation was harshly criticized for not testing the drainage on lands they sought to improve. Farmers and water districts argued that Reclamation was negligent in their engineering investigations. Director Newell and Reclamation advocates responded by arguing that the farmers did not possess the "mettle and determination to succeed."[28] Disputes such as these compounded Reclamation's funding problems, and in 1909, Congress launched investigations of Reclamation. Despite both spirited defense and criticism, Congress was disinclined to eliminate Reclamation and its projects. In the end, Congress authorized another $20 million loan for Reclamation, adding to the original $52 million fund appropriated to start the reclamation program that was nearly exhausted.[29]

Reclamation also faced a barrage of legal issues not covered by the Reclamation Act. The complexities of western water laws were a primary issue. Of the legal issues, the most complex and difficult to resolve was the development of water on interstate streams. This issue pitted state against state and inadequately defined the Federal Government's role. Reclamation argued that the government had preeminent rights to regulate water on interstate streams. Western states countered and resisted efforts to such all-sweeping authority. While the Federal Government had some control in the development of interstate streams, usually for navigation and flood control purposes, state governments and courts were reluctant to grant any authority to the Federal Government when it came to irrigation development. In *Kansas v. Colorado* (1907),

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[25] Rowley, *Origins and Growth*, 155-157.

[26] Ibid., 171.

[27] For more information on the Town Site Power and Development Act, see "Town Sites Power and Development Act" in Pelz, *Federal Reclamation and Related Laws Annotated*, Volume I, 109-113.

[28] Rowley, *Origins and Growth*, 156.

[29] Ibid., 156.

the Supreme Court "curbed the ambitions" of Reclamation by requiring them to negotiate for water rights but did not challenge the constitutionality of Reclamation. [30]

Without question, the first and most difficult problem faced by Reclamation was repayment. Irrigators balked at the way Reclamation computed construction costs, and the 1902 act did not adequately address ongoing operations and maintenance (O&M) expenses.[31] In the first projects between 1905 and 1911, Reclamation legislation, beginning with the Minidoka Project, assigned all O&M expenses to the project. Thus, the expenses fell on the water user associations and, ultimately, the individual farmers. By 1911 farmers had sued in court, claiming the law did not specify who was to pay. Although Reclamation won the lawsuit at the Supreme Court level, it remained a point of contention between it and the users for decades.[32] Farmers found themselves laboring under repayment costs that added to the debt they incurred to prepare lands for irrigation.

With irrigators either refusing or unable to pay, Reclamation found itself in financial difficulties as funds were drawn down but not replenished. The water user associations were not shy about letting their congressional representatives know their feelings. Congress sympathized and sought additional means for raising funds to boost the Reclamation fund. In 1911 Congress passed the Warren Act, which authorized Reclamation to sell excess water from its reservoirs to Carey Act lands. It also allowed Reclamation to charge for the storage and transit of non-project water. This provided an additional flow of funds to replenish the initial investment incurred by Reclamation. However, the additional income was inadequate to resolve the funding shortfall. Congress added other revenue streams to bolster the Reclamation fund. In 1917, Congress declared that federal royalties from potassium mining be deposited into the Reclamation fund, and in 1921, funds from the Mineral Leasing Act were also deposited into the fund.[33]

Financing the 27 projects initiated by Reclamation from 1903 to 1928 took all the creativity, energy, and diplomacy the agency could muster. Nevertheless, Reclamation had reasons to be proud of its work as it neared its 10th anniversary in 1913. Real estate values had increased, as had business activity in the West. The population had grown by 51 percent, and Oklahoma (1907), New Mexico (1912), and Arizona (1912) had joined the United States. These three states were Reclamation states and added to the West's political power in Congress. Reclamation, with an infrastructure of substantial dams, reservoirs, and distribution systems, could rightfully claim some credit for these benefits. However, Congress continued to be concerned with the broad scope of Reclamation authority and the return on its multi-million-dollar investment.

In 1914, Congress, continuing to recognize payment issues for these large construction projects, passed the Reclamation Extension Act that increased the repayment period from 10 to 20 years.[34] This helped farmers by substantially reducing their payments. It also gave reassurance to Reclamation that the debt could eventually be repaid. The Extension Act also made a number of other significant changes to Reclamation, as well as adding more congressional oversight. The act removed the Secretary of the Interior's authority to identify and construct projects. The act also required each new project to be fully approved with funds appropriated by Congress. In addition, Reclamation was permitted to turn over O&M responsibilities to water users' associations prior to receiving full payment for the project. This gave local

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[30] Rowley, *Origins and Growth*, 151.

[31] Ibid., 154-155.

[32] Ibid., 155.

[33] Ibid., 163.

[34] Ibid., 181.

districts better control of their expenses, an opportunity they hoped would reduce costs. Reclamation continued to hold title of these elaborate systems, but local districts would manage and operate them. This provided an opportunity for the farmers to better organize their resources through the water users' associations and water districts to further the improve the distribution and marketing of farm products. Finally, the act called for federal aid in financing a system of agricultural extension agents associated with land grant colleges. Each county in the country would receive a federally funded County Agent, whose primary job was to promote agricultural knowledge within the communities and among the farmers. By so doing, Congress reinforced their commitment to Reclamation and the need for modernizing its practices.[35]

Figure 2.4 An auger digging a drainage ditch on the North Platte Project in Montana in 1917. Reclamation quickly discovered that drainage could be as serious a problem as not enough water.[36]

Figure 2.5 An orange grove in the Salt River Valley near Phoenix, 1908 (courtesy of Bureau of Reclamation).

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[35] Rowley, *Origins and Growth*, 181-186; see also "Reclamation Extension Act," in Pelz, *Federal Reclamation and Related Laws Annotated*, Volume I, 186-200.

[36] Rodney G. TeKrony, Glenn D. Sanders, and Billy Cummins, "History of Subsurface Drainage in the Bureau of Reclamation." In *Bureau of Reclamation: History Essays from the Centennial Symposium*, Volume 2, pp.153-194 (Denver, Colorado: Bureau of Reclamation, 2008), 168.

Markets for irrigation-produced foods expanded after the Act of 1914, not as a result of the legislation, but rather from a demand for goods during World War I. From 1914 to 1919, higher prices for farm products, especially staples, benefited the farmers and silenced much of the criticism of the agency. Congress also passed the Federal Farm Loan Act, which established a banking system for funding farmers through local associations. Cries for lower farm borrowing costs had been a mainstay of the Populist movement since the 1890s, and the new legislation brought relief for millions of indebted farmers. This made for simpler and more advantageous terms, and overall lower costs.[37] However, this improved outlook by both farmers and Reclamation was short-lived. After the war's boom period ended, demand for crops declined and the economic outlook on Reclamation projects became precarious. Congress responded by passing a number of repayment relief measures from 1921 through 1923. In addition, as the 1920s progressed, few new projects were initiated and a new, largely conservative government limited public interest in federal intervention and investment. The growth in private business and the ongoing public criticism of Reclamation, compounded by an increasing farm indebtedness crisis, restricted Reclamation's efforts to complete and maintain their existing projects for most of the next decade.

2.3 Slowdown of Work and New Leadership (1919-1928)

The 1920s began with a cost-conscious, conservative backlash after years of Progressive-era politics. Though it did not completely eliminate new reclamation projects, over the 1920s the Federal Government contracted large expensive projects at home and an isolationist sentiment emerged. However, not all projects for Reclamation were halted. Congress authorized a few new projects during the 1920s, including the Vale and Owyhee projects in Oregon.[38] The most important project authorization was for the Boulder Canyon Project in 1928. This project marked a distinct transformation in the development of western waters and the Bureau of Reclamation. Reclamation's influence would impact western water development as the U.S. suffered through the Great Depression later in the 1930s. The Boulder Canyon Project, in particular, constructed the largest dam ever built in the U.S. and opened up new fields of endeavor for Reclamation. New opportunities arose to expand Reclamation's mission with the marketing of Boulder (Hoover) Dam's hydroelectric power, the use of Lake Mead as a recreational site, and a greater emphasis toward providing water for municipal and industrial (M&I) purposes. It was the beginning of a new era for Reclamation that would introduce the multiple-purpose concept for the dams and reservoirs originally built for irrigation.

The decade would also see another, more impactful, effort to bring the Reclamation Service and the reclamation program on a sounder economic foundation. These efforts would result in the complete reorganization of the Reclamation Service, infusing it with new leadership and a new mission. In addition, there was evidence that the priorities and purposes of water development in the West were shifting. As urban centers showed signs of greater growth, demands for water and power increased, and Reclamation responded to these changing conditions.

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[37] Rowley, *Origins and Growth,* 198-202.

[38] For information about the Vale Project, see Timothy A. Dick, "Vale Project," (Denver: Bureau of Reclamation History Program, 1993), https://www.usbr.gov/projects/pdf.php?id=204; for information about the Owyhee Project, see Eric A. Stene, "Owyhee Project," (Denver: Bureau of Reclamation History Program, 1996), https://www.usbr.gov/projects/pdf.php?id=149.

In the early 1920s, two significant events ushered in this new beginning in western water development. Reclamation released the Fall-Davis Report in 1922, proposing the construction of a large dam and an All-American Canal on the lower Colorado River. The dam would help prevent flooding along the river and stabilize water deliveries to farms in California's Imperial Valley. The report's major, and somewhat novel, selling point was that the dam's construction would be paid for by hydroelectric power revenues. Under contract with the Imperial Irrigation District, the Reclamation Service had been conducting investigations to seek a suitable dam site and to survey the route of an All-American Canal. Frequent flooding and valley diversion works in Mexico convinced both the district and Reclamation of the need for a flood control dam and a more reliable delivery system. Shortly after the report's release, the Swing-Johnson Bill was introduced in Congress to authorize the plan.

Reclamation's investigations and the ensuing introduction of legislation caught the attention of the other states that shared the waters of the Colorado River. In 1922, concern also arose throughout the basin with the Supreme Court's decision in *Wyoming v. Colorado*, a dispute between the two states over the waters of the Laramie River. Of importance to the Colorado River basin states was the court's ruling that the doctrine of prior appropriation applied regardless of state lines on interstate streams. However, the Swing-Johnson bill implied that California could appropriate the river's entire flow. In early 1922, representatives of the seven basin states met in Santa Fe, New Mexico, and agreed to and signed the Colorado River Compact. Unable to agree on individual state allotments, the Compact divided the waters of the Colorado River between the upper basin—Wyoming, New Mexico, Colorado, Utah—and the lower basin—Arizona, Nevada, and California. The Compact allowed Congress to consider and debate what became known as the Boulder Canyon Project Act. Finally, the Colorado River Compact remains one of the keystone documents for the management of Colorado River water resources, and a fundamental piece of what is referred to as "the law of the river."[39]

Despite the excitement and focus on Colorado River development, the Reclamation Service was still unable to put the reclamation program on a sound financial footing. In 1923, Secretary of the Interior Herbert Work established a blue-ribbon commission to examine the constant problems surrounding Reclamation and federal irrigation development in the West. Under the moniker of the Fact Finder's Commission, commissioners visited projects and conducted hearings throughout much of 1923. Their subsequent report called for many recommendations to the reclamation program in order to place Reclamation on a more secure economic foundation. Following the release of the report, Congress passed what became known as the Fact Finder's Act in 1924. The act instituted major reforms of the reclamation program, including mandating the need for detailed planning studies, classifying project lands determining repayment fees, and requiring settler experience and capital. It was an attempt to repair the insufficiencies in the 1902 Reclamation Act and established many program requirements still in use today.

These changes culminated in the reorganization of the Reclamation Service. Of particular note, the entire leadership of the Reclamation Service was let go, including Director Arthur P. Davis. On May 10, 1923, Secretary of the Interior Herbert Work renamed the Service to the Bureau of Reclamation and named David W. Davis as its first commissioner. However, Davis's stint as commissioner was short-lived, and in 1924, Dr. Elwood Mead became commissioner. From 1924 to 1936, Mead fought for and ultimately

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[39] Rowley, *Origins and Growth,* 241-247; for a detailed study of the Colorado River Compact, see Norris Hundley, Jr., *Water and the West: The Colorado River Compact and the Politics of Water in the American West* (Berkeley: University of California Press, 1975).

successfully restored congressional and public confidence in the agency and its mission. He then led it to its new role as one of the "world's preeminent builders of massive water projects."[40]

Mead initially sought to reform the reclamation program and lobbied Congress for passage of the Omnibus Adjustment Act of 1926. The legislation called for a more careful classification of land productivity within Reclamation projects. Importantly for farmer-owners, it ordered a reassessment of land values and reduced and set up better financing terms for construction cost repayment for the water districts or associations. The law established more stringent requirements for qualifying farmers by Reclamation, as well as providing advisors to organize cooperatives for supplying equipment and marketing the farm products for the water users' associations. As a result of these changes, construction costs on Reclamation projects dropped nearly $14 million by 1928, quieting much of the water users' and public discontent. Nonetheless, almost one-third of Reclamation lands were still being farmed, not by farmer-owners, but by farmer-tenants with speculators as absentee owners.[41] Commissioner Mead found this unacceptable to the original goal of the Reclamation Act. Mead also concentrated on improving the life of farmers on irrigation land and improving the land's profitability. He argued persuasively before Congress that Reclamation was not a failure. By 1926, Reclamation had brought 143,000 new settlers onto 24 government projects on western desert lands. In addition, the Reclamation projects drew nearly 300,000 new town dwellers. He pointed out that Nevada was likely saved as a state in the 1920s because of the economic benefit of the Newlands Project.[42] Mead ultimately led Reclamation through the early stages of the transformation that completely realigned water development in the American West.

Figure 2.6 Elwood Mead, Commissioner, April 1924 - January 1936, sitting at desk (courtesy of Bureau of Reclamation).

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[40] Norris Hundley quoted in Rowley, *Origins and Growth*, 235.

[41] Rowley, *Origins and Growth,* 258-259.

[42] Ibid., 265.

Despite the troubles plaguing Reclamation, farmers across the United States struggled during the 1920s. After World War I ended, prices almost immediately fell and markets overseas, especially in Europe, evaporated. Many farms went into bankruptcy and foreclosure. This was especially true in the southern United States with the loss of cotton crops due to the boll weevil. In 1927, the Mississippi Valley was ravaged by a devasting flood; the region felt the reverberations for years, particularly from the massive outmigration of African Americans, who were the primary labor source in the region.[43] Meanwhile, the farmers' problems were masked by the growth of cities and urban jobs, along with an expanding stock market that seemed to signal uninterrupted prosperity for the country. Beginning in 1920, businesses prospered in an era sometimes referred to as the "Roaring Twenties." However, the stock market crash of October 1929 and the resulting economic depression that followed quickly brought the balance of the country into the financial troubles that farmers had wrestled with for most of the decade.

Political wrangling over the Boulder Canyon Project began as soon as the legislation was introduced, primarily due to its costs and Arizona's backing out of the 1922 Compact. Congressional approval of the compact was tied into the legislation along with lower basin annual allotments: 4.4 million acre-feet to California, 2.8 million acre-feet to Arizona, and 300,000 acre-feet to Nevada. Arizona refused to accept lower basin allotments and fought to prevent passage of the act. Nevertheless, Congress ignored Arizona's concerns, allowed for a six-state compact ratification, and passed the Boulder Canyon Project Act in December 1928. Arizona finally agreed to and signed the Colorado River Compact in 1944.

Figure 2.7 The completed Boulder (Hoover) Dam, initiated in 1929 and completed in 1935, the largest dam in the world at that time.[44]

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[43] Rowley, *Origins and Growth*, 269-270.

[44] Ansel Adams, "Photograph of the Boulder Dam from Across the Colorado River," 1941. Available on the National Archives Catalog website, https://catalog.archives.gov/id/519837, NARA ID 519837 [accessed August 2023].

This legislation not only authorized construction, using congressional appropriations to pay for the dam and canal, but also directly permitted the sale of hydroelectric power to help defray the dam's construction costs. Additionally, the act permitted the sale of water for M&I purposes to growing cities in southern California. Finally, the dam was seen as a flood control project along the Colorado River watershed, thereby adding another non-reimbursable benefit to the overall project development. By the end of the decade, Reclamation officials took encouragement from its new multipurpose programs and looked to "new constituencies in urban water and power consumers and downstream communities protected from floods."[45] These multi-use projects increased during the Great Depression. Congress' embracement of the multi-purpose concept revealed inherent weaknesses of the 1902 Reclamation Act. As the multiple purpose concept gained ascendency, the homemaking ideology of the past began to recede.

2.4 Bureau of Reclamation During Depression and War (1929-1945)

The Great Depression provided new opportunities for the Bureau of Reclamation. By 1941, when the U.S. entered World War II, Reclamation had become "the mightiest federal agency in the American West."[46] Its great dams, reservoirs, and irrigation works gave the U.S. the industrial power and agricultural supplies to lead a world war, and support both its own 10-million-person military and feed and supply our allies. The completion of Boulder Dam was such an engineering feat that one presidential advisor noted, "For after Boulder Dam, nothing, however fanciful, seems impossible."[47] Between 1928 and 1945, Reclamation began some of the most substantial terrain-altering projects on earth, including the Grand Coulee Dam in the Columbia River Basin, the Colorado-Big Thompson Project in Colorado, and perhaps the most ambitious of all, the Central Valley Project in California. These projects would celebrate American technology, logistics, and ingenuity. At the same time, project construction provided thousands of jobs to hard-pressed Americans stripped of financial resources by the Great Depression.

In October 1929, the U.S. stock market crashed and plunged the economy into a recession that soon became a depression. The economy slowly began to improve following the inauguration of Franklin D. Roosevelt in March 1933. Roosevelt's myriad of new agencies first invested funds into the American financial and economic system. This "pump priming," as it was often called, was meant to initiate private investment, not take it over. However, the effort polarized the divide between supporters of an activist governmental involvement (i.e., those who supported Roosevelt's New Deal and similar programs in the future) and those who felt the government should remain a passive player and allow the system to fix itself. They argued that private enterprise would eventually resolve the problems created by the Depression without spending hundreds of millions of dollars.

Roosevelt's plans also included using federal agencies, such as the Bureau of Reclamation, as a primary tool for providing jobs to unemployed workers. At the same time, the government would initiate some of the most complex water projects ever attempted. Initially using funds from the Works Progress Administration (WPA) and the Public Works Administration (PWA), the government spent millions of dollars on schools, public facilities, parks, highways, and irrigation projects, particularly the construction of large dams, reservoirs, and canals. Most dam projects, including many by the USACE, contained a hydropower component as well as other authorizations. For example, the Boulder Dam not only held water for agricultural irrigation but also provided hydroelectric power, served as a water source for urban areas,

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[45] Rowley, *Origins and Growth*, 282.

[46] Ibid., 307.

[47] Harry Hopkins quoted in Rowley, *Origins and Growth*, 307.

and aided in flood control efforts for the lower Colorado River region. The level of funding provided to Reclamation revealed the extent of the Roosevelt administration's investment in the agency. During the New Deal, funding for the Bureau of Reclamation sky-rocketed from an average of $8.9 million a year in 1932 to an average of $52 million a year afterwards. Meanwhile in the Denver Office of the Chief Engineer, employment expanded from 200 to 750 personnel.

For Reclamation, still primarily focused on irrigation, the large dam projects were a public example of the Roosevelt administration's fight against the Depression and their own ability to plan, manage, construct, and run large multipurpose projects. Reclamation, which was even questioned by Roosevelt's administration in the early months of the New Deal, found itself "the instrument of construction" during the Great Depression. The New Deal focused on three major river valleys for power generation, flood control, and irrigation. These were the Columbia, the Missouri, and the Tennessee. Reclamation did much of the work on the first two and designed dams for the third.[48] Both Reclamation Commissioners Mead and John C. Page saw that these multiple resource projects garnered much larger public support and ensured work for the agency for the foreseeable future. By the end of World War II, although still holding fast to their irrigation mission, Reclamation officials recognized that multiple use projects would be its future. Additionally, as the Columbia River basin and Missouri River projects would later reveal, Reclamation would share large dam and reservoir building, though not the irrigation mission, with its rival agency, the U.S. Army Corps of Engineers.[49]

By 1938, Commissioner Page reported to the Secretary of the Interior that 14 water control "storage dams" had been completed in the previous five years of the New Deal. That same year, Congress added conservation as a mission to Reclamation; this had been discussed but not implemented until the construction of Grand Coulee Dam on the Columbia River. The scope of Grand Coulee rivaled that of Boulder Dam. It also had an adverse effect on the Columbia River salmon runs (with salmon having to swim upstream to reproduce) and had the potential to destroy the local salmon industry. Congress responded with the Mitchell Act of 1938 to conserve fishery resources on the river.[50] Though the interest was not necessarily an environmental cause (that would come much later), Congress was concerned about the business and financial impacts of fragmenting the salmon runs. Nonetheless, it was the first time Reclamation needed to consider "devices for the protection and improvement of feeding and spawn conditions for the fish."[51] Not only did Reclamation consider the impact on the natural world, but the 1938 Act that authorized Reclamation to protect the fish on the Columbia River also led to the establishment of the U.S. Fish and Wildlife Service. Supporters of the legislation hoped it would serve as an example of how man "could manage his planet by making use of his intelligence and knowledge when it subordinates his otherwise reckless desire to ravish his natural resources."[52]

In Colorado, Reclamation began the Colorado-Big Thompson Project, a major undertaking in the 1930s and 1940s. The Colorado-Big Thompson Project is a trans-basin diversion bringing Colorado River water from the western slope of the Rocky Mountains to the dryer eastern slope underneath the Continental Divide. The Alva B. Adams Tunnel, located beneath the Rocky Mountains National Park, was not only a

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[48] Rowley, *Origins and Growth*, 312.

[49] Ibid., 401.

[50] Oregon Encyclopedia, "Mitchell Act (1938)," Accessed April 2023, https://www.oregonencyclopedia.org/articles/mitchell_act_1938_/#.ZCrihvbMK3A.

[51] Rowley, *Origins and Growth*, 339.

[52] Ibid., 339.

political success for Reclamation, but one of its greatest engineering tests in what was called "a massive reordering of nature."[53] Authorized in 1937, work on the tunnel and the western side dams began shortly afterward. The project was briefly halted for World War II in 1942, but the Adams Tunnel was eventually completed in 1944. When the entire project was completed in 1953, the tunnel, which served as part of the main canal, brought water to several hydroelectric powerplants and 720,000 acres of irrigatable lands. Other projects initiated by Reclamation in the 1930s included the completion of the Milk River and Minidoka projects in Montana and Idaho, respectively, and the Kendrick Project in Wyoming.[54]

Figure 2.8 Grand Coulee Dam was completed in 1941 and was even larger than the Hoover Dam.[55]

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[53] Rowley, *Origins and Growth*, 347.

[54] For information about the Colorado-Big Thompson Project, see Robert Autobee, "Colorado-Big Thompson Project," (Denver, Colorado: Bureau of Reclamation, 1996); Daniel Tyler, *The Last Water Hole in the West: The Colorado-Big Thompson Project* (Boulder: University Press of Colorado, 1992); for information about the Kendrick Project, see Leisl A. Klajic, "The Kendrick Project (Casper-Alcova)," (Denver: Bureau of Reclamation History Program, 2000), https://www.usbr.gov/projects/pdf.php?id=128 [accessed August 2022].

[55] United States War Department, "Washington – Grand Coulee Dam," 1941. Available on the National Archives Catalog website, https://catalog.archives.gov/id/68151565, NARA ID 68151565 [accessed August 2023].

Despite the extensive irrigation work planned and initiated in the 1930s on the Columbia and Colorado rivers and elsewhere, the largest project of all would begin in California's Central Valley. It originated as a state project in the 1920s to serve the region's extensive farms. The project also carried out several other missions. It was to bring water to growing southern California cities and replenish groundwater in the San Joaquin-Sacramento River Delta in northern California. The project involved at least three major dams, development of hydroelectric power, and the irrigation of up to 3,000,000 acres. By far, it was the largest project to be considered by Reclamation and included the majority of California's productive agricultural lands. The Great Depression collapsed California's ability to finance the project, and the state appealed to the Federal Government for help in 1933.[56] The 1935 Emergency Relief Appropriations Act included funding for completing the project with California's approval. The Central Valley Project (CVP) became Reclamation's largest irrigation project. Construction began on the Contra-Costa Canal in 1935 and on the large Shasta Dam in 1936. The dam was completed in 1945 and work on the project would continue for another 20 years.[57]

Reclamation was involved in several plans developed by the Roosevelt administration to improve the life of American farmers. However, some efforts failed. In the New Deal, the United States Department of Agriculture's (USDA) Resettlement Administration attempted to resettle famers on 90,000 acres of Reclamation lands in Wyoming, South Dakota, Idaho, and Oregon. The planning proved overly optimistic, and the Resettlement Administration soon lost interest in the project with only 4,441 families obtaining new lands.[58]

However, other innovative efforts were more successful. The Civilian Conservation Corps (CCC) and its army of laborers proved a valuable contribution to numerous Reclamation projects. These included the All-American Canal of the Boulder Canyon Project, the Boca Dam on the Little Truckee River in California, the Moon Lake Project in Utah, the Uncompahgre Project in Colorado, and the Kendrick Project in Wyoming to name just a few. CCC workers labored on the large western Reclamation projects for most of the 1930s. America's entrance into World War II in December 1941 brought numerous changes to the New Deal projects. The CCC labor force was disbanded and most Reclamation construction projects were paused until the end of the war. However, the Shasta Dam on the Central Valley Project and the Adams Tunnel on the Colorado-Big Thompson Project were two exceptions. These two projects were permitted to continue due to the potential hydroelectric power they could generate for the war effort. Nonetheless, construction largely stalled in 1941 and for the duration of the war, after which Reclamation saw its mission expand.

The slowdown in construction activities did not mean that the Bureau of Reclamation was inactive. Reclamation leadership used this time to plan for the future and study prospective projects to construct once the war ended. Reclamation engineers ventured throughout the West looking for opportunities to expand development of water resources. In considering multiple purpose projects, Reclamation began looking at entire river basins as a whole to efficiently integrate project planning. A prime example of this change was congressional authorization of the Pick-Sloan Missouri Basin Program (PSMBP) in the Flood Control Act of 1944. It represented a massive plan for the largest drainage system in the West. The PSMBP

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[56] Rowley, *Origins and Growth*, 343.

[57] Eric A. Stene, "Central Valley Project: Overview," (Denver: Bureau of Reclamation History Program), https://www.usbr.gov/projects/pdf.php?id=253; Norris Hundley, Jr., *The Great Thirst: Californians and Water, a History* (Berkeley: University of California Press, 2001), 247-275; Billington, Jackson, and Melosi, *Large Federal Dams*, 301-344.

[58] Stene, "CVP Overview"; Hundley, *The Great Thirst*; Billington, Jackson, and Melosi, *Large Federal Dams*, 317-318.

was a joint effort of the USACE and Reclamation. The USACE was responsible for flood control and navigation on the Missouri River's mainstem, while Reclamation oversaw irrigation and power development along the Missouri River's main tributaries. Hydropower development was a major component of the program, along with providing M&I water, fish and wildlife enhancement, and recreation. Ultimately, Reclamation constructed 32 projects, or units, during the twentieth century. Pick-Sloan projects opened 3 million acres of land for irrigation and produced 2.5 million kilowatts of installed capacity.[59]

In 1943, Reclamation underwent another significant change that reflected its future focus on river basin development. Reclamation created seven autonomous regional offices to better serve a diversifying customer base. The formation of the regional offices provided a closer and more intimate relationship with water users and power customers. As a result of this reorganization, Reclamation underwent other transitions; project planning became a regional responsibility and all policy and political functions moved to Washington, D.C.[60]

Figure 2.9 Vale Project. New settlers under Veteran's Homestead entry on new land. Alfred Fincher, nine days after arrival, with temporary camp set on homestead (courtesy of Bureau of Reclamation).

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[59] Toni Rae Linenberger, "Overview: Pick-Sloan Missouri Basin Program," (Denver: Bureau of Reclamation History Program, 1998), https://www.usbr.gov/history/ProjectHistories/PSMBP%20OVERVIEW.pdf; Gahan and Rowley *Developing to Managing Water*, 531-549.

[60] Gahan and Rowley, *Developing to Managing Water*, 553.

2.5 Reclamation and the Big Dam Era (1945-1961)

The end of World War II in September 1945 closed 16 of the most transformative years in American history, characterized by depression and war. As the United States was the only industrialized country untouched by the physical impact of the war, the U.S. emerged as the financial, technical, and military leader abroad. At the top of the United States' construction and logistical expertise was the Bureau of Reclamation. Though the war curtailed many projects, the impact of Reclamation's work was widely recognized for supplying food and power, and the industrialization and urbanization of the West on an unprecedented scale. That industrialization played a major role in making the U.S. the "arsenal of democracy" and winning a two-ocean war over fascism. Reclamation looked forward to reengaging its mission with more river basin planning, greater irrigation projects created by large dams and reservoirs, hydroelectric power, and supplying water to growing cities in a dry, arid region.

Reclamation's impact over the next 25 years was felt in every locality where it built dams, dug canals, and maintained laterals and ditches to manage water for the millions of new residents in the West. The Bureau of Reclamation had come out of the Depression and the war with a vastly enhanced reputation with both Congress and the American public. The troubles and controversies associated with the early years of the Reclamation Service dissipated as the multiple purpose concept provided sounder economic foundations for project development. Reclamation had formed strong alliances in Congress and had the support of politically savvy water users' associations that helped form what some political scientists refer to as an "iron triangle."[61]

By the 1970s, this powerful alliance weakened as a new "environmental ethos" arose among average Americans that questioned some of the large water project's alterations to the natural world. During the 1960s, Congress began to legislate that all federal agencies had to adapt their plans and programs with environmental considerations. These new regulations resulted in rising costs, and along with greater public involvement and scrutiny, led to a slowing construction pace. In addition, the postwar economic boom was showing signs of slowing down. The social programs of the Kennedy and Johnson administrations, along with the increasing cost of the War in Vietnam, meant that federal funds were becoming scarce. In 1976, this decline, along with growing and costly environmental considerations, was only magnified by the failure of the Teton Dam on Reclamation's Teton Project in Idaho. The dam failure was soon followed by President Jimmy Carter's 1977 famous "hit list" of large water projects, which questioned the financial aspects and environmental effects of federal water projects of the USACE, Tennessee Valley Authority (TVA), and Reclamation.[62] The report called for the elimination or restructuring of Reclamation projects. This ideological shift in American culture away from the "utilitarian conservation," that is the "use of natural resources to the fullest extent for the benefit of society," to a mindset of making minimal alterations to the environment had a tremendous impact on water resources development projects.[63]

With the end of World War II, the Bureau of Reclamation's construction program began an era of intense activity that would last well into the 1970s. Fueled by fears of a return to Depression-era conditions, the Federal Government initiated a period of public work efforts to keep the economy moving while industries returned to peacetime production. Reclamation turned its attention to projects that had been halted due to the war. For example, Reclamation resumed work on three projects in particular that involved

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[61] For more information about "iron triangles," see Daniel C. McCool, *Command of the Waters: Iron Triangles, Federal Water Development, and Indian Water* (Tucson: University of Arizona Press, 1994).

[62] Gahan and Rowley, *Developing to Managing Water*, 820-838.

[63] Ibid., xlviii.

river basin systems with extensive engineering demands: the Colorado-Big Thompson, Columbia Basin, and Central Valley projects.

One of Reclamation's first goals was the completion of the Columbia Basin Project's irrigation works. The irrigation phase of the Columbia Basin Project was reminiscent of the early years of the Reclamation Service in that new lands were being prepared, along with new opportunities for families to make a home in the West. Reclamation touted that the project would service over one million acres, and returning veterans would receive preferential treatment in selecting farms. In 1952, Reclamation began the delivery of irrigation water, although construction of water conveyance facilities continued until the early 1960s. Despite Reclamation's goal, the project fell short of its one million acres; however, it does serve 671,000 acres and supplies water to 5,400 farms. By the 1960s, Reclamation turned over operation of the irrigation lands to the three irrigation districts.[64]

Reclamation's second goal was to begin work on the Davis Dam and powerhouse. This was to be a crucial part of hydropower development along the lower Colorado River, fulfilling the United States' commitments to Mexico based on the 1944 water treaty. In 1950, Reclamation completed construction of Davis Dam along the lower Colorado River. Additionally, Reclamation soon proceeded on other projects, such as the ongoing work on the Colorado-Big Thompson. In 1947 alone, Reclamation awarded contracts for the completion of Granby Dam and Horsetooth Reservoir Dam. Work began in earnest on associated units of the PSMBP. For example, in 1946, Reclamation began construction on Kortes Dam in Wyoming, the first Pick-Sloan unit built. The dam was completed in 1951.[65]

Despite Reclamation's feverous construction pace, long-term issues concerning reclamation law continued to arise. As the CVP irrigation features began to come online, enforcement of the 160-acre land limitation became a contentious item. Historically, Reclamation had been somewhat inconsistent on enforcing the requirement. Congress had waved the rule on the Colorado-Big Thompson Project and in the Humboldt Project in Nevada. Reclamation Commissioner Michael Strauss saw an opportunity to return the agency to its commitment to social reform and the family farm ideal. Thus, he refused to budge on the 160-acre limit for water deliveries from government facilities. He primarily sought to reduce monopolistic tendencies and speculation and resurrect the agency's commitment to the welfare of small family farms.[66] Valley agricultural interests and their political representatives vehemently opposed the rule.

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[64] Paul C. Pitzer, *Grand Coulee: Harnessing a Dream* (Pullman, Washington: Washington State University Press, 1996), 267-290; Wm. Joe Simonds, "The Columbia Basin Project," (Denver: Bureau of Reclamation History Program, 1998), https://www.usbr.gov/projects/pdf.php?id=88 [accessed August 2023]; Gahan and Rowley, *Developing to Managing Water,* 670-681.

[65] For more information about Davis Dam, see Toni Rae Linenberger, "Parker-Davis Project," (Denver: Bureau of Reclamation History Program, 1997), https://www.usbr.gov/projects/pdf.php?id=153 [accessed August 2023]; for information about the Kortes Unit, see Wm. Joe Simonds, "The Kortes Unit: Oregon Trail Division, Pick-Sloan Missouri Basin Program," (Denver: Bureau of Reclamation History Program, 1996), https://www.usbr.gov/projects/pdf.php?id=168 [accessed August 2023].

[66] Gahan and Rowley, *Developing to Managing Water*, 555.

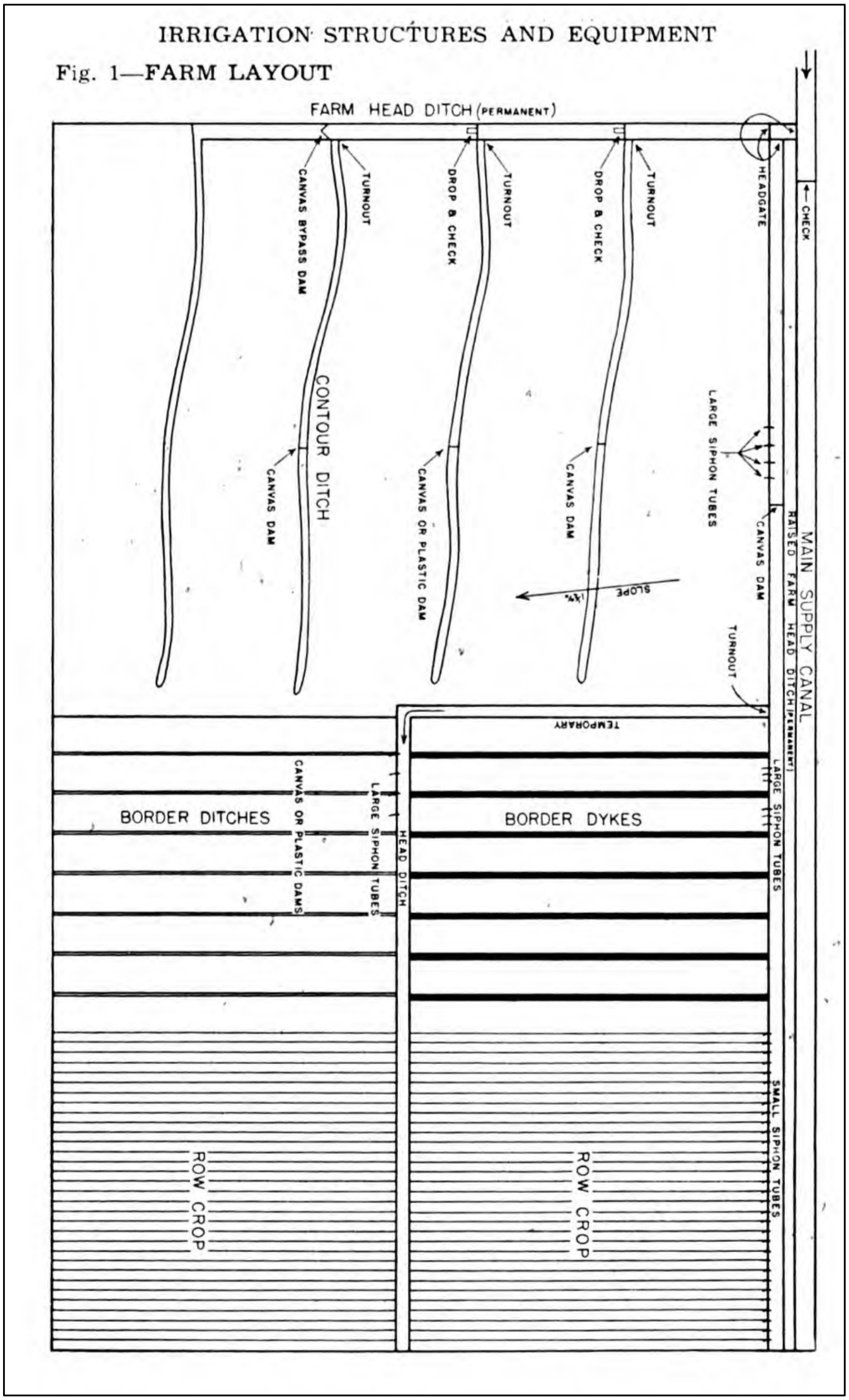

Figure 2.10 A typical irrigation structure design illustrating how water is drawn off a main supply canal or lateral into a farmer's adjoining ditch, then siphoned into the crop fields.[67]

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[67] H.L. Dusenberry and O.W. Monson, *Irrigation Structures and Equipment* (Bozeman, Montana: Montana State College Extension Service, 1951).

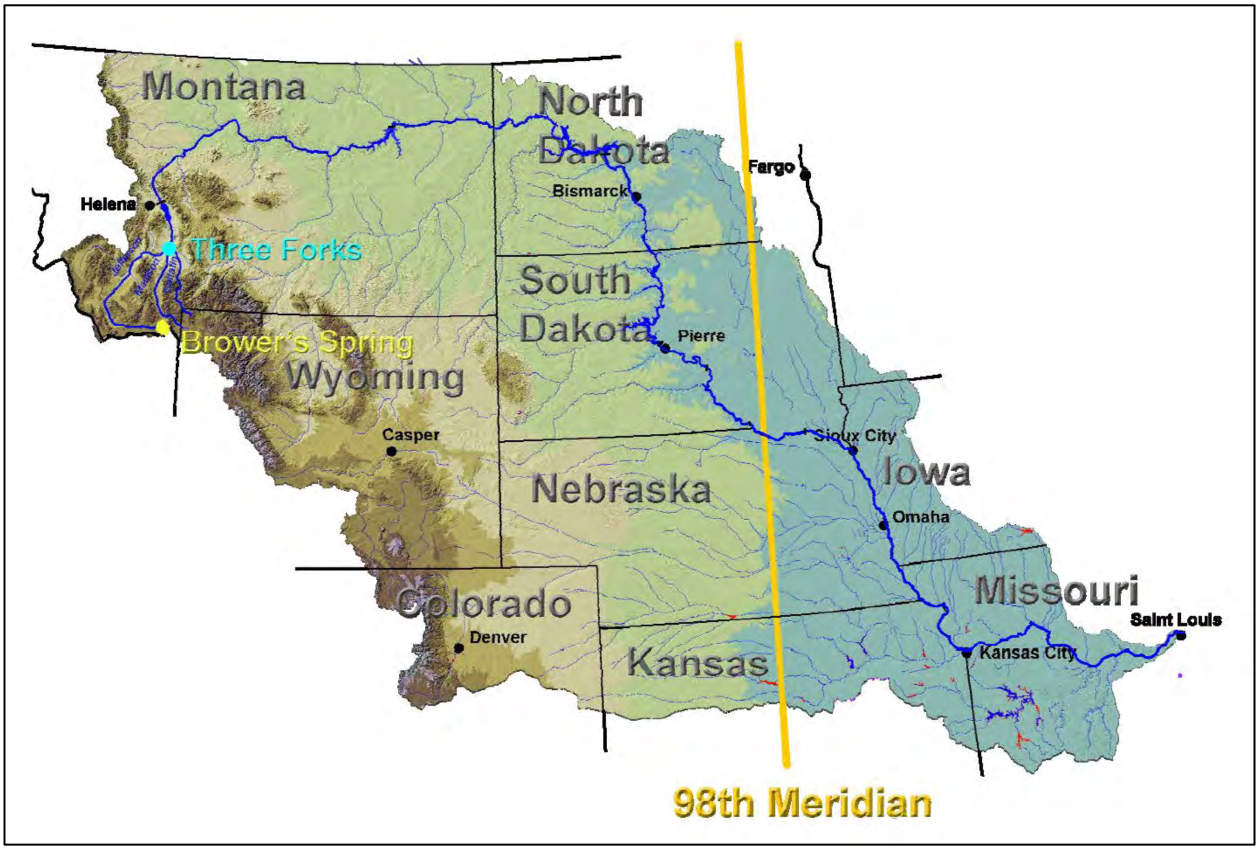

Figure 2.11 Area of the PSMBP, which covers 10 states from the Mississippi River to western Montana, illustrating the size of some projects (courtesy of Bureau of Reclamation).

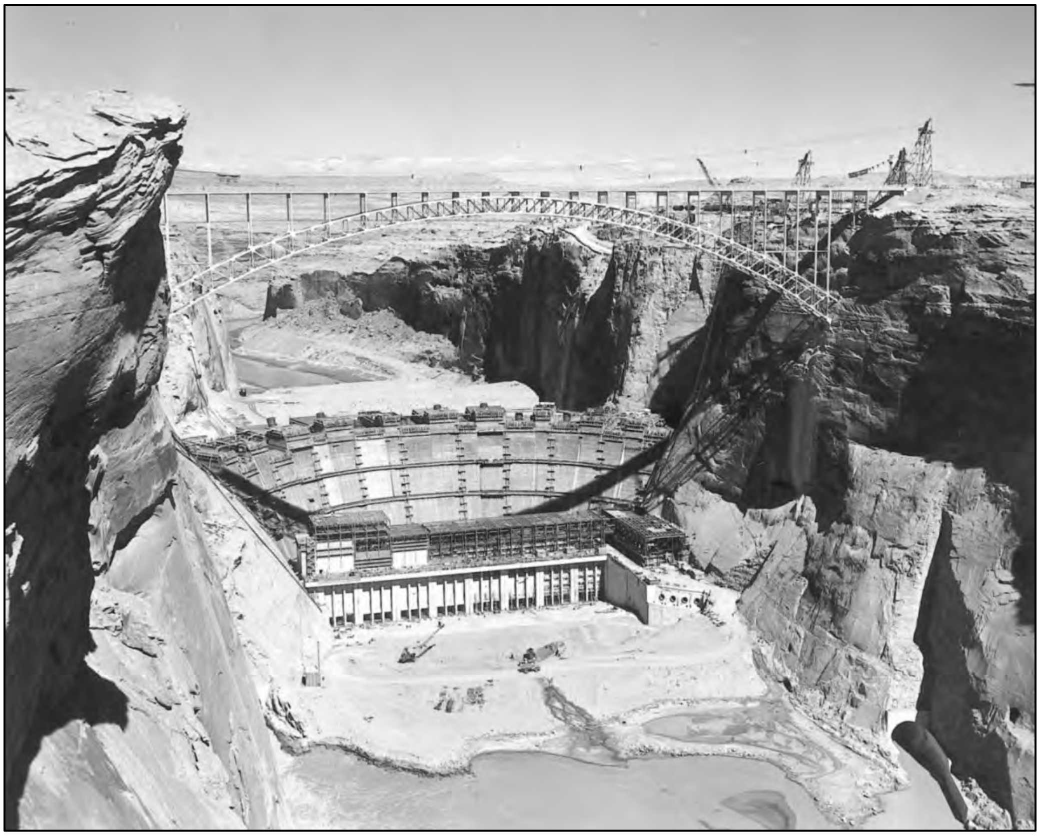

Figure 2.12 One of the larger structures built during the Big Dam Era was the Glen Canyon Dam in the Upper Colorado River Basin Project (courtesy of the Bureau of Reclamation).

Large land holdings in California had historic roots. Large land grants in the state dated back to Colonial Spanish occupation and its large land grants during the eighteenth century. American immigrants incorporated this legacy, laid out under the Spanish and Mexican governments in the early nineteenth century, to their own plans for land development. Larger corporations assumed the same position in the late nineteenth and early twentieth centuries, and by the time Reclamation began construction of the CVP in 1937, "a model of corporate agriculture was firmly entrenched."[68] Despite strong support from labor, social activists, old New Dealers, a sympathetic press, labor unions, Town Hall programs, and persuasive arguments by popular personalities and politicians, the effort failed in the end. This was largely because the press, in an effort to support Reclamation's position on family farms, made it appear that Reclamation was "breaking up" the large holdings and "attacking established and legitimate business interests."[69] The U.S. Army Corps of Engineers, which also shared in some of the work done in the CVP, were under no such limitations on their projects. To some, it made them an attractive alternative when decisions about project development were considered in California. Nevertheless, Congress routinely supported the 160-acre rule and made sure that any irrigation works associated with USACE projects fell under reclamation law. With or without the acreage limitation, the CVP commanded attention. In Congress' 1948 Reclamation budget, the CVP alone accounted for $40 million of the $198 million annual budget.

Reclamation's answer to the 160-acre farm limitation controversy was "technical compliance." By the early 1950s, this principle allowed the agency to expand its definition of "family farm" to include extended families (each person eligible to hold 160 acres), groups, and corporations, particularly with regard to the acreage being purchased or held in the irrigation district. This put Reclamation in a position of becoming increasingly "identified with commercial agriculture, not the family farm."[70] Yet, the law was not eliminated and proved partially effective. Its inclusion as an option on Reclamation projects weeded out speculators and tended to restrict the concentration of monopolies of large landowners. A closer look at the CVP shows that though farmers and groups could acquire more than 160 acres, most farms purchased as irrigation project land from Reclamation were under 160 acres. Additionally, the small landowners needed large landowners to help pay project costs. A kind of truce muted criticism from both sides. After the mid-1950s, technical compliance settled the issue for Reclamation.[71]

Another issue that lingered throughout the New Deal era and became apparent in the postwar period was the debate between public versus private power. The Hells Canyon Dam proposal was another large federal Reclamation investment that encountered intensive opposition from private power interests, local communities fearing loss of control to the central government, and what was a "budding environmental interest" concerned about the salmon industry in the Northwest.[72] The project on the Snake River was a planned hydroelectric power, flood control, and irrigation works in southern Idaho. Ultimately, Congress rejected Reclamation's proposal and approved a plan by the Idaho Power Company to build three smaller dams in lieu of one very large dam at Hells Canyon. The compromise brought the needed power and water to the region without the overarching federal control of the Snake River Valley. Although the environmental groups were defeated in that dams were built, they were not the size of the original Hells Canyon Dam.

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[68] Gahan and Rowley, *Developing to Managing Water*, 644.

[69] Ibid., 646.

[70] Ibid., 654.

[71] Hundley, *The Great Thirst*, 262-271; Ibid., 643-660.

[72] Ibid., 667.

In the 20 years following World War II, Reclamation became an extension of the American foreign policy agenda, especially during the geo-political Cold War. In territories and in Latin America, Reclamation served as consultants in intergovernmental agreements regarding irrigation and water control projects. A parade of foreign engineers visited Hoover Dam and other Reclamation facilities to observe the project construction and return to their own country with ideas for water management issues. After the War, requests for U.S. advice and support came from countries as diverse as India, Palestine, Australia, Greece, Brazil, and especially China. China in particular offered the greatest opportunities as it sought to build the Yangtze Gorge (sometimes called the Three Gorges) Project in what would have been larger dams than Hoover and Grand Coulee. However, the coordination collapsed when Communist forces, under Mao Zedong, took control of mainland China in 1949.

Though work in China ended, Reclamation expanded their influence throughout the world. One official laid out Reclamation's rationale for international cooperation, stating that it would:

(1) enrich opportunities for Reclamation to learn and teach,
(2) operations would open outlets for foreign trade, and
(3) foreign activities gave U.S. officials greater understanding of all kinds of problems throughout the world. [73]

Reclamation made strides in many new countries such as Ceylon (today Sri Lanka) and India that already had a long history of using irrigation for food production. Also, in the 1950s and 1960s, Reclamation assisted Australia with a trans-mountain water diversion project. The Snowy Mountain Scheme was based on the Colorado-Big Thompson Project tunnel work. The U.S. military involvement in Southeast Asia led Reclamation engineers and agents to study the Mekong River Delta for the Pa Mong Irrigation Project. Although Reclamation was able to give advice on dams and reservoirs along with irrigation works in Malaysia and Thailand, efforts on the Lower Mekong River did not materialize. The Communist takeovers in 1975 of Laos, Cambodia, and South Vietnam ended all efforts. Interestingly, an early study by Rand Corporation of dams and irrigation works in Laos found a disconnect between the social benefits of large construction works and the works themselves. For example, in Laos, they found that Laotian farmers did not necessarily accept the irrigation benefits from the dams. In this case, it reaffirmed a similar problem in the U.S. with irrigation as a single-purpose project. The level of investment could not be supported by the users and the benefits they derived. In other words, irrigation projects with large dams and reservoirs could not be supported by irrigation alone.

2.6 The Rise of Environmentalism and the End of the Big Dam Era (1961-1980)

America's postwar economic growth allowed more Americans to get out and enjoy the nation's natural wonders. Those experiences helped to produce a greater awareness of and appreciation for the management of public lands and natural resources. Thus, American views on conservation gradually changed during the postwar period and reached a critical point in the late 1960s and early 1970s. Meanwhile, Reclamation, as well as the USACE and other great project builders in the West, held to the original Progressive ethos that "scientific management of natural resources [is] for the greatest good of all"[74] This included altering natural

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[73] Gahan and Rowley, *Developing to Managing Water*, 592.
[74] Ibid., 792.

water resources for irrigation, flood control, and hydroelectric power generation. The new environmentalism looked at natural resources as important natural and scenic sites that provided immense benefits in their natural state. Although there had been calls for an updated view of America's natural resources, Rachel Carson's book, *Silent Spring*, published in 1962, defined the threats more carefully as coming from pesticides. The new environmentalism was interested in promoting much more than reducing the use of deadly chemicals in the natural world. An earlier Reclamation project was an example of this growing activism. The Colorado River Storage Project was substantially altered when proposed dams that would have flooded sections of Dinosaur National Monument were withdrawn from congressional consideration in 1956.[75]

Congress continued to fund large dam projects throughout the 1960s but met with increasing resistance. The Central Utah Project (CUP) illustrates how the agency's projects were held up during this period of enhanced environmental concern. The project was one of the first to encounter fallout from the new National Environmental Policy Act (NEPA) passed by Congress in 1969. It was 1975 before Reclamation satisfied the NEPA regulatory requirements and the project could continue. The project was not only one of the first to encounter substantial environmental opposition, but one of the first to include claims by Native American tribes, specifically the Utes, over their water rights. The courts had concluded that the infringement of any of those previously held rights would have to be mitigated by the U.S. Government. The slow development of promised benefits from Reclamation to the Utes led to a lawsuit by the tribe in the 1970s. More time was required before the Reclamation won their case in court with the Utes. Nonetheless, the compliance with NEPA and unsatisfied Native American claims slowed the project to a crawl by the early 1980s. The time extensions drove the price of the project far beyond its original estimates of $324 million in 1966 to more than $1.1 billion by 1978. The failure to complete the CUP in a timely manner coincided with other events that would cause extensive changes in both Congressional financing and Reclamation planning for the future, and ultimately brought the Big Dam Era to an end in the 1970s.[76]

During the 1960s, a new consideration of Native American peoples, particularly in the American West, grew in importance. Largely overlooked except as a labor force, the Native American population began drawing attention from Reclamation over two large water projects, the Colorado River Storage Project in 1956 and again with the CUP in 1968. However, only one project, the Navajo Indian Irrigation Project, was authorized for a specific group of Native Americans in 1962. Even then, it was tied to a non-Indian project, the San Juan-Chama Project, which was designed to provided M&I water to the Albuquerque, New Mexico, area. Despite legal victories, Native American tribes still had difficulties with Reclamation. Throughout its history, Reclamation's approach to Indian rights had been similar to that of the U.S. Government in general. That is, Reclamation generally, "favored non-Indian projects over those benefiting Native Americans and did little to protect or develop Indian water resources."[77]

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[75] Many studies have been directed toward the rise of the environmental movement and the Bureau of Reclamation. See Jared Farmer, *Glen Canyon Dammed: Inventing Lake Powel and the Canyon Country* (Tucson: University of Arizona Press, 1999); Mark W.T. Harvey, *A Symbol of Wilderness: Echo Park and the American Conversation Movement* (Seattle: University of Washington Press, 1994); Russell Martin, *A Story that Stands Like a Dam: Glen Canyon and the Struggle for the Soul of the West* (Salt Lake City: University of Utah Press, 1999); Gahan and Rowley, *Developing to Managing Water*, 690-700.

[76] Gahan and Rowley, *Developing to Managing Water,* 778-791.

[77] Ibid., 724.

However, this began to change in the early 1960s. In 1908, the Supreme Court had ruled that Indian tribes held a reserved water right that had come into effect when the Federal Government created reservations. This "reserved right" had a priority over most non-Indian water rights because most reservations were created prior to Anglo-American settlement, and they remained in effect whether or not the tribe(s) had put that water to beneficial use. In Indian law, this is what is known as the Winters Doctrine. From 1908 to the 1960s, the doctrine was largely ignored by the Federal Government, state governments, non-Indian water interests, and the Bureau of Reclamation. Reclamation's apathy toward Indian water development was Reclamation's self-interest: whites could pay for the projects, while Native American projects often did little to boost the Reclamation fund. Reclamation's disinterest led the Office of Indian Affairs to establish its own irrigation construction agency in 1913. The Indian Irrigation Service managed all Native American water resources development but was often underfunded and unable to keep up with tribal water needs. In the 1963 *Arizona v. California* case, the Supreme Court strengthened the "Winters Doctrine" by ruling that the Indian reservations were entitled to enough water to irrigate "practically all irrigable acres." The opinion strengthened Indian rights to water, and tribes began asserting greater control over water resources development on reservation lands.[78]

Despite the newfound power Native American tribes had garnered through the Supreme Court's decision, development of Indian waters remained an arduous process. The Navajo Indian Irrigation Project (NIIP) revealed the kind of delays and, ultimately, successes that could be encountered. In the NIIP, Reclamation committed to a 135-million-dollar project that included the dam, a main canal, two significant tunnels, and several smaller tunnels to reclaim 110,000 acres of reservation land. Squabbling between the Bureau of Indian Affairs (BIA) and Reclamation caused a three-year delay. Legislation required that all NIIP funding proceed through the BIA budget process. Indian Affairs appropriations routinely fell short of project needs, and the tribe lagged in its ability to obtain enough money for Reclamation to complete the project. By 1988, the U.S. Government had spent $450 million on the project that consisted of an all-sprinkler irrigation system for 60,000 acres of reservation land. The Navajo, for their part, had formed the Navajo Agricultural Products Industry to manage the NIIP and was generating a $2 million profit for its members. Taking what they were given by Reclamation, they showed they could be successful when organized and working for their own people. The battle over Native American water rights revealed a growing weakness within the "iron triangle," threatening to unravel a partnership that had been formed over 30 years. Shrinking water resources, along with a larger number of claimants, tested the alliance's cohesiveness.[79]

Much has been written on the growth of American environmentalism in the 1960s and 1970s, and the impact of new legislation on agencies such as Reclamation. Throughout these decades, advocates of the new environmentalism fought Reclamation on several high-profile topics, including the failure to protect Rainbow Bridge National Monument and failing to stop construction for the Glen Canyon Dam on the Colorado River and for the Third Powerplant at the Grand Coulee Dam. However, environmental groups and the public at large gave widespread support to preservation efforts and pushed Congress to pass the Wild and Scenic Rivers Act in 1968. Only a few days later, the same Congress passed the Colorado River Basin Project Act, for which Reclamation had strongly lobbied. However, the construction of large dam projects would soon come to an end. In the early 1970s, Congress passed NEPA and created the

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[78] Gahan and Rowley, *Developing to Managing Water*, 724-725.

[79] Ibid., 740; see also Leah Glasser, "Navajo Indian Irrigation Project," (Denver: Bureau of Reclamation History Program, 1998), https://www.usbr.gov/projects/pdf.php?id=141 [accessed August 2023].

Environmental Protection Agency (EPA).[80] By the end of the decade, Reclamation and the USACE were grappling with an entirely new environmental ethos, one that identified a gulf between the large builders and the vocal environmentalists. One author put it succinctly: "water resource projects now came under unprecedented scrutiny on the basis of water shortages, pollution, and environmental deterioration."[81] Lawsuits, mitigation of damages to the environment, new wildlife protection laws, and public demands over the general destruction of the natural world drove costs increasingly higher.

Figure 2.13 Map and scenes from the Navajo Indian Irrigation Project managed by the Navajo Agricultural Products Industry.[82]

The passage of the NEPA legislation was followed by a string of other environmental laws in the first half of the 1970s. Further, two events in the mid-1970s would have substantial impacts on federal agencies and large irrigation projects in the future, and Reclamation was at the center of both. In 1961 and 1964, Congress approved the Teton Basin Project in southeastern Idaho. The project's primary feature was Teton Dam (originally called the Fremont Dam) on the Teton River, a tributary of the Snake River. The project was to provide water to irrigate 111,000 acres in addition to flood control and hydroelectric power. The

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[80] Gahan and Rowley, *Developing to Managing Water*, 799-801.

[81] Ibid., 802.

[82] Stanley Pollock, "Navajo Indian Irrigation Project managed by the Navajo Indian Agricultural Projects Industry," published online at the Ruth Powell Hutchins Water Center webpage at Colorado Mesa University, 2014, https://www.coloradomesa.edu/water-center/ [accessed October 2022], 7.

project, like many others, was held up by environmental lawsuits in the early 1970s, especially the construction of the dam. The dam was completed in the fall of 1975, and Reclamation began filling the reservoir the following spring. On Saturday, June 5, 1976, the dam failed and washed away 4 million cubic yards of embankment, burying the power and pumping plants and causing a catastrophic flood downstream.[83] The wall of water completely destroyed two towns and damaged others. The flooding also threatened American Falls Dam further downstream on the Snake River. President Gerald R. Ford declared the six-county region a disaster area. At least 11 people and 13,000 head of livestock were killed, and crop and home damages exceeded $300 million (in 1976 dollars). The dam was not rebuilt, though most of the irrigation system was repaired.[84] Today, it stands as one of the worst dam failures in U.S. history.

Figure 2.14 Despite passing the Wild and Scenic Rivers Act only a few days earlier on September 30, 1968, President Lyndon Johnson signed the Colorado River Basin Project Act, a project questioned by environmental groups.[85]

The congressional and departmental investigation that followed the disaster determined that the design's flaw was the failure to protect impervious core material in the dam that allowed erosion to start.[86] Reports also questioned Reclamation's policies and procedures that led to drastic reforms. Reclamation's Safety of Dams Program was initiated, and contracting responsibilities shifted from the Office of the Chief

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[83] Eric Stene, "Teton Basin Project," (Denver: Bureau of Reclamation History Program, 1996), 10, https://www.usbr.gov/projects/pdf.php?id=199 [accessed August 2023].

[84] Ibid., 12.

[85] Jack L. August, Jr., "Hydropolitics in the Far Southwest: Carl Hayden, Arizona, and the fight for the Arizona Central Project." In *Bureau of Reclamation: History Essays from the Centennial Symposium*, Volume 2, pp. 593-613 (Denver, Colorado: Bureau of Reclamation, 2008), 602.

[86] Stene, "Teton Basin Project", 12.

Engineer to the regions. Employee morale was at an all-time low, and the calamity foreshadowed major revisions in the perception of water resources development in the American West.

Not long after the Teton disaster, Reclamation encountered another change to the political environment. In 1976, Jimmy Carter was elected president and his administration developed what the press termed the "hit list," a report of water resource projects considered to be environmentally questionable and too expensive. Along with the Bureau of Reclamation, the "hit list' targeted projects of the USACE and TVA. Carter was motivated by a deep concern over dam safety from the Teton Dam failure. He also attacked Reclamation for its federal subsidies, citing the Garrison Diversion Unit as an example where farmers paid only $77.00/acre against a federal investment of $1,992.00 per acre.[87] It was common knowledge that reclamation irrigation projects were only viable because of the sale of hydroelectric power and water to communities, but Carter's point was that Reclamation projects benefitted only a special interest group. Essentially, Carter's attack was against "the culture of federal water resource development as an archaic spoils system that must come to an end."[88] While future Congresses continued to approve large water projects for the Bureau of Reclamation, change had come. During the 1980s and 1990s, the Bureau of Reclamation turned more towards water management and less on large-scale construction activities.[89]

Figure 2.15 The catastrophic failure of the Teton Dam on June 5, 1976, on the Teton Valley Project.[90]

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[87] Gahan and Rowley, *Developing to Managing Water*, 834.

[88] Ibid., 836.

[89] Ibid., 837.

[90] Bureau of Reclamation, "Teton Dam," 1976. Photograph available online, https://www.usbr.gov/pn/snakeriver/dams/uppersnake/teton/7.html [accessed August 2023].

2.7 Reclamation in the Post-Teton Period (1980-2000)

By the last decade of the twentieth century, Reclamation services extended to 5 million acres of irrigated farmland with an additional 6 million obtaining supplemental water. This amounted to about 25 percent of the irrigated farmland in the U.S., which generated an estimated $4.4 billion in agricultural revenue.[91] Additionally, Reclamation was a primary generator of electrical power in the West. Despite these successes, the agency faced significant challenges following the Teton Dam failure and the financial repercussions from Carter's "hit list." Congressional critics continued to examine program benefits and posed fiscal constraints on all federal agencies. A more fiscally conservative government, along with environmental opposition, finally brought the Big Dam Era to a close in the early 1980s. Demographic changes, cultural changes, and political power shifts in the West forced Reclamation to reexamine the economies of scale for their project planning in the latter decades of the twentieth century.[92]

Reclamation Commissioner R. Keith Higginson (1977-1981) instituted a "New" Bureau of Reclamation that pursued environmental concerns and paid more attention to public input. [93] However, several events illustrated ongoing difficulties. In 1979, the Bureau changed its name to "Water and Power Resources Service," which was reversed in 1981 back to Bureau of Reclamation. The inconsistency by top Government officials created confusion both inside and outside the agency. Secondly, and even more importantly, was the 160-acre family farm issue. Due to urbanization in the West, economies of scale made small family farms less economically viable, and environmental activists argued the subject was an unnecessary diversion away from more important issues. Despite intense criticism, Congress adjusted the maximum acreage from 160 to 960 acres in the Reclamation Reform Act of 1982. Along with acreage increase, the act removed the residency requirement, essentially eliminating the cornerstone of federal reclamation in the American West.[94]

By the end of the 1980s, water utilization loomed as an even larger issue. Droughts and new demands from multiple entities forced Reclamation into transition. New burgeoning urban and industrial areas, recreational use demands on water storage, and environmental activists demanding more allocation of water for fish and wildlife protection all "[sped] up the Bureau of Reclamation's transition from a construction agency to a water management agency."[95] For example, in 1987, approximately 85-90 percent of water was distributed for agriculture. By the mid-1990s, large allocations were being diverted for Native American reservations, public water systems, and endangered species issues; as much as 25 percent of the water resources were used for wildlife preservation alone. Competing uses of a limited resource (water in a largely arid region) continues to dominate discussions at the federal, state, and local levels. [96]

As the agency entered the twenty-first century, water management became the primary focus of Reclamation. Although construction continued, projects became smaller. Federal requirements demanded that beneficiaries pay a higher share of the costs. This change in cost sharing reduced the size and scope of future Reclamation work. In short, the era of large-scale federal construction projects had ended. In 2005, the agency clarified the needs for the western United States in their *Water 2025* bulletin, acknowledging that the Federal Government's role in water management had changed dramatically since the 1970s. It also

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[91] Gahan and Rowley, *Developing to Managing Water*, 839.

[92] Ibid., 839.

[93] Ibid., 847.

[94] Ibid., 858.

[95] Ibid., 859.

[96] Ibid., 869, 876.

recognized that “growing urban communities, agriculture, Native American tribal communities, and the environment all exert a claim on the limited water resources.”[97] Finally, the report recognized that state and local governments would have a leading role in the development and use of those resources. However, the report concluded that solving water use issues in the West would rest with the various states, and only “collaboration” could end “bitter disputes” that inhibited an equitable distribution.[98] Now into the twenty-first century, water management continues as a crucial topic, highlighted by severe droughts, floods, and the impacts of climate change.

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[97] Gahan and Rowley, *Developing to Managing Water*, 899.

[98] Ibid., 901.

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3.0 Geographical Challenges

3.1 Introduction

John Wesley Powell traveled to parts of the western states from 1877 to 1878, surveying and observing its geography and climate for the U.S. Geological and Geographical Survey. His observations, and those of three other surveys, helped lay the groundwork for much of the irrigation development that followed in the late nineteenth and early twentieth centuries. Powell first categorized the West into three geographical regions and recommended the government work to form water user associations with which to contract for water distribution. He carefully noted that only small portions of the lands in the arid states were "available for agriculture; they require, in general, drainage or irrigation for their redemption."[99] Despite his own findings, he was somewhat doubtful of the potential for useful irrigation in many sections of the region, stating that within the "Arid Region only a small portion of the country is irrigatable [*sic*]."[100] He recognized that most irrigation was possible primarily on the "lower irrigatable lands" along the floodplains of rivers and creeks.[101] Powell's work is considered important not only because he was an early proponent of irrigation, but because his study provided the geographical foundation for U.S. reclamation policy and law.

Much of the water control infrastructure managed by the Bureau of Reclamation is driven by geography. The region covered by the 1902 Reclamation Act included all of the United States west of the 100th Meridian. This area was further defined by John Wesley Powell as a line, more or less following the Meridian from a point "60 miles west of Brownsville [Texas] on the Mexican border to a point 50 miles east of Pembia, [North Dakota] on the Canadian border."[102] An extensive area covering four-tenths of the United States (excluding Alaska), this region includes all or part of the states of Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Idaho, Washington, Oregon, and California.[103] With some exceptions, rainfall in this "arid" region averages 20 inches per year or less.

The American West, labelled in the 1850s as the "Great American Desert," and formally called by John Wesley Powell the "Arid West," was not considered valuable for settlement due to the absence of sufficient water. When debating the expansion of slavery and the Compromise of 1850, Daniel Webster noted that it was not necessary to restrict slavery in these regions since the "Great American Desert barred the advance of plantation agriculture and slavery; and the 'Ordinance of Nature' stood in the way."[104] With the exception of the coastal areas of the Puget Sound in Washington, the Willamette Valley in Oregon, and parts of coastal California, most of the land was seen as unproductive.[105]

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[99] Powell, *Lands of the Arid Region*, vii.

[100] Ibid., 6.

[101] Ibid., 6.

[102] Ibid., 11.

[103] Gahan and Rowley, *Developing to Managing Water*, 55.

[104] Ibid., 55.

[105] Ibid., 55.

Figure 3.1 Powell's "arid regions" and drainage districts.[106]

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[106] J.W. Powell, *Eleventh Annual Report of the Director of the United States Geological Survey, 1889-1890. Part II: Irrigation* (Washington, D.C.: Government Printing Office, 1891).

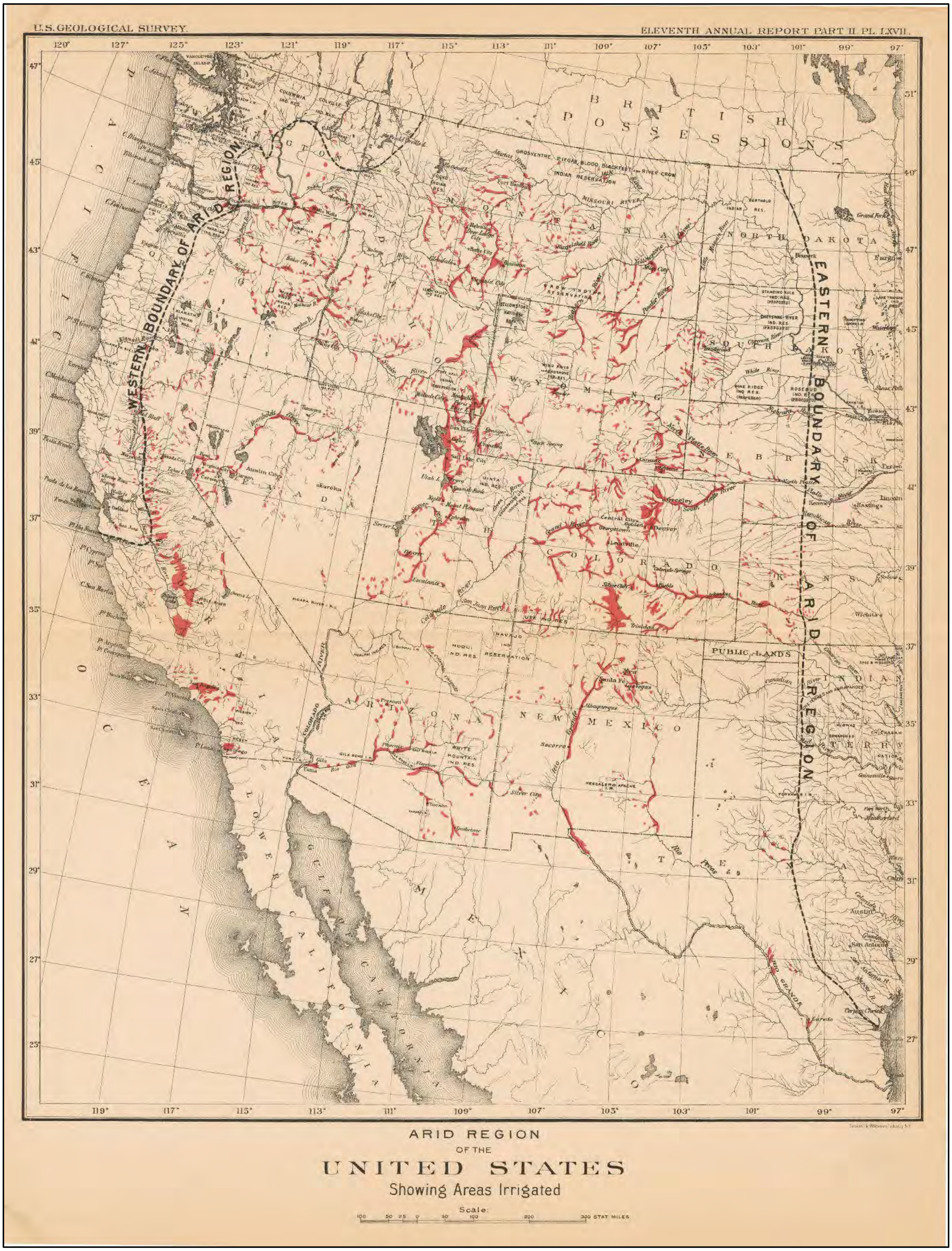

Figure 3.2 Powell's "arid regions" showing existing irrigated lands.[107]

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[107] Powell, *Eleventh Annual Report*.

However, the Mormons who settled in Utah in the late 1840s proved the opposite. By religious commitment, community cohesiveness, and industrious enterprise, they demonstrated how irrigation could be used to cultivate arid lands.[108] The key to their success was their willingness to work together for the benefit of the community. Mormon leaders and followers were willing to submit to established authorities with a common ownership for the general welfare of the community.[109] In the 1870s, Powell also noticed an agricultural community in Greeley, Colorado, where farmers worked together to develop successful irrigation.[110] Generally, however, between the Spanish Colonial Period and the 1880s, no successful large-scale irrigation works were established within the region.

3.2 The American West Before Irrigation

Since the late eighteenth century, the American ideal of the agrarian farm and the farmer-citizen was widely considered the crucible of American Democracy. This ideal had its critics, including Alexis de Tocqueville, who found that farmers in the new United States were far more commercially driven and looked upon their crops and livestock as commodities from which to derive wealth. Nonetheless, the myth spurred the efforts of irrigation proponents in the latter part of the nineteenth and early twentieth centuries. They lobbied for the Federal Government to fund irrigation development and believed that millions of untapped irrigated lands in the West held the potential for thousands of farms to relieve the increasingly crowded eastern cities. In short, proponents believed irrigation to be both an economic and social experiment.

In his study, Powell stressed that the eastern lands, being excessively humid, had almost inexhaustible fertility. He went on to say, "the agricultural capacity of the United States will eventually be largely increased by the rescue of these [western] lands from their present valueless condition."[111] Powell's study of western geography was one of the first comprehensive investigations that proposed potential irrigation, though he thought it unwise to attempt dry agriculture where rainfall did not average more than 20 inches a year and was unevenly distributed.[112]

Powell did recognize, however, certain geographical exceptions. The northwestern coast, including Washington, Oregon, and northern California received up to 80 inches of rainfall, driven by Pacific current winds. However, these Pacific-induced wetlands ended at the Cascade Mountains.[113] Powell also viewed California as its own geographical anomaly due to its sheer size. The central and northern portions of California possessed unequal distribution of rainfall. These areas had an extensive rainy season (December to April) but could also be subject to intense droughts. Finally, he also found portions of eastern Washington and Oregon and northern Idaho as having reliable water sources and, thus, a good potential for irrigation. These areas contained streams coming down from the mountains and emptying into wider flood plains that made irrigation easier. On the eastern range of the arid lands, Powell observed that due to the timing of rainfall, there was an opportunity for successful dry farming. Eastern Kansas, Nebraska, and the Dakotas receive 20 inches of rain regularly. The rain falls heaviest in these regions in the spring, summer, and autumn during the growing season, and thus could produce crops. However, in the southernmost parts

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[108] Gahan and Rowley, *Developing to Managing Water*, 56.

[109] Powell, *Lands of the Arid Region*, 57.

[110] Ibid., 11.

[111] Ibid., viii.

[112] Ibid., 2.

[113] Ibid., 1.

of the West, especially in Texas and Oklahoma, rain does not fall in those months and dry farming is not consistently successful.

As early as the 1870s, Powell noted that farmers in some areas attempted to irrigate from the local creeks and rivers. This was particularly true in northern California, centered around the San Francisco Bay area.[114] He also noted that a few other areas, such as the Mormon settlements around the Great Salt Lake, were attempting to irrigate on a local level.

3.3 Powell's Three Regions

Powell broke this varied "arid region" of the West into three general categories. Despite many later studies, and subdivisions of his classifications, Powell's study still forms the foundation of irrigation work in the West. Powell identified the upper regions as marked by the growth of timber with mountains and jagged peaks. The higher plateaus and mountains located in that region contain stands of timber and are marked irregularly by local conditions. The timber areas are found at lower altitudes in the southern mountains, versus at higher altitudes in the northern mountains. Some scattered forests are located below the timber regions; these are usually pines and cedars and are not good for construction. Timber in the upper regions of the mountains include pine, spruce, and fir. Humidity and temperature were the key factors in the area.[115] In his study, Powell focused a great deal of attention on Utah, where he found that the forests dominated 23 percent of the land area, which was typical for the arid region in general.

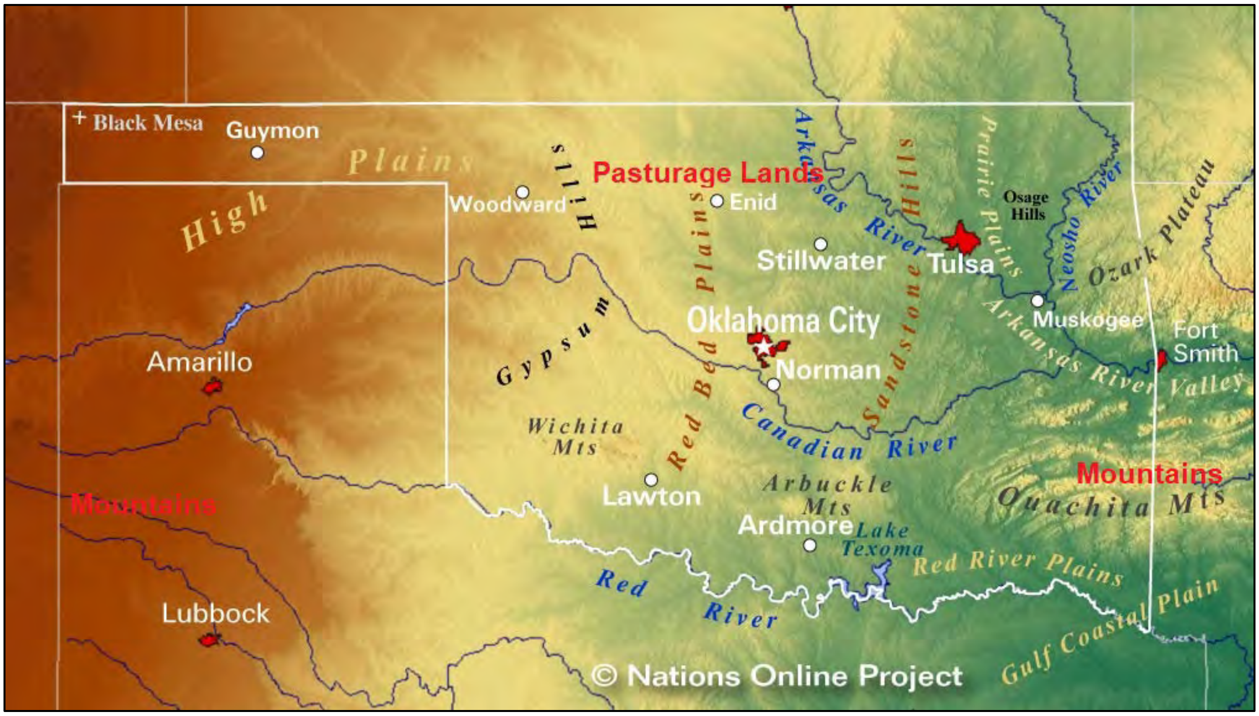

Figure 3.3 Map illustrating the three regions of Oklahoma: mountains in the east and west, pasturage lands in the center, and river valleys.[116]

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[114] Powell, *Lands of the Arid Region*, 5.

[115] Ibid., 14-15.

[116] Nations Online Project. *Topographic Regions of Oklahoma Map*, 2018, https://www.nationsonline.org/oneworld/map/USA/oklahoma_map.htm [accessed February 2023].

Upper region timber is regularly beset with fire, especially during times of drought, which in turn thins the timber. Though the droughts are relatively infrequent, this region receives greater rainfall. The forests grow best in the marginal area where rainfall is more consistent and is between 20 to 24 inches. In certain local mountainous regions, the trees grow further down the mountains and are protected from fires by the rocky lands that offer little purchase for grasses and shrubs, which is where fires usually start. Powell thought "Fire is the primary reason forests do not grow on the great prairies." In his report, he observed that fires were often set by the Native Americans. Since Powell, other observers identified other climatic causes for the grasslands as well. Another phenomenon of the region are patches of forest that grow on alluvial cones. Rivers flowing out of mountain canyons into valleys or basins carry materials that form circular-shaped wetlands, which then spread out to cone-shaped areas (alluvial cones).[117]

Powell called the second region "pasturage lands," today referred to as Basin lands or the Great Basins.[118] These areas, marked by high prairie grasslands and plateaus, and are often scoured by river courses. The mountain streams, creeks, and rivers sometimes form deep gorges and canyons, of which the Grand Canyon, formed by the Colorado River, is the most notable example. These pasturage lands contain districts called "country rock," and steep hills are sometimes called "the Bad Lands" of the Rocky Mountain Region. These badlands are characterized by towering cliffs and a landscape of bare rock. Despite the presence and quantity of water in the pasturage region, Powell considered most of the rivers unusable for irrigation, though later many of them would be dammed and used.[119] The grasses that grow are of better quality in the northern portions than in the south, where it was of little value. The region also includes a true desert area, including the Mohave Desert and Death Valley. This is particularly true in southern California, Nevada, southern Arizona, and New Mexico, with the grasslands improving as one heads north.[120] Powell suggested that these higher regions could be used by herdsmen in summer months.

The third section Powell observed included valleys formed by rivers and creeks with wide floodplains that were excellent for irrigation. These existed in every state, spread all over the region from the Lower Rio Grande Valley in Texas to the Willamette Valley in Oregon and the Milk River Valley in Montana. Many of the early Reclamation projects were taken over from existing local efforts to irrigate these valleys. Powell considered the smaller rivers and creeks in this third section more suitable for irrigation. However, he carefully qualified his opinion, stating that the smaller rivers were capable of irrigation only if they could carry the right volume necessary for the floodplain surrounding the waterways.[121] He acknowledged that generally, water storage was needed to support the irrigation effort. In some locations and at certain times, too much water could be a problem. In this case storage was needed to contain flooding, and drainage was needed to remove excess alkaline-laden waters.

Powell illustrated the amount of irrigatable land available in the states. In Utah alone, he estimated that there was more than 1.4 million acres of irrigatable land.[122] He observed that this same amount was available for each of the states west of the 100th Meridian. His targeted lands were generally separate from the timberlands, with pasturage fitting in between. While most observers anticipated that the sandy river valley

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[117] Powell, *Lands of the Arid Region*, 15-16.

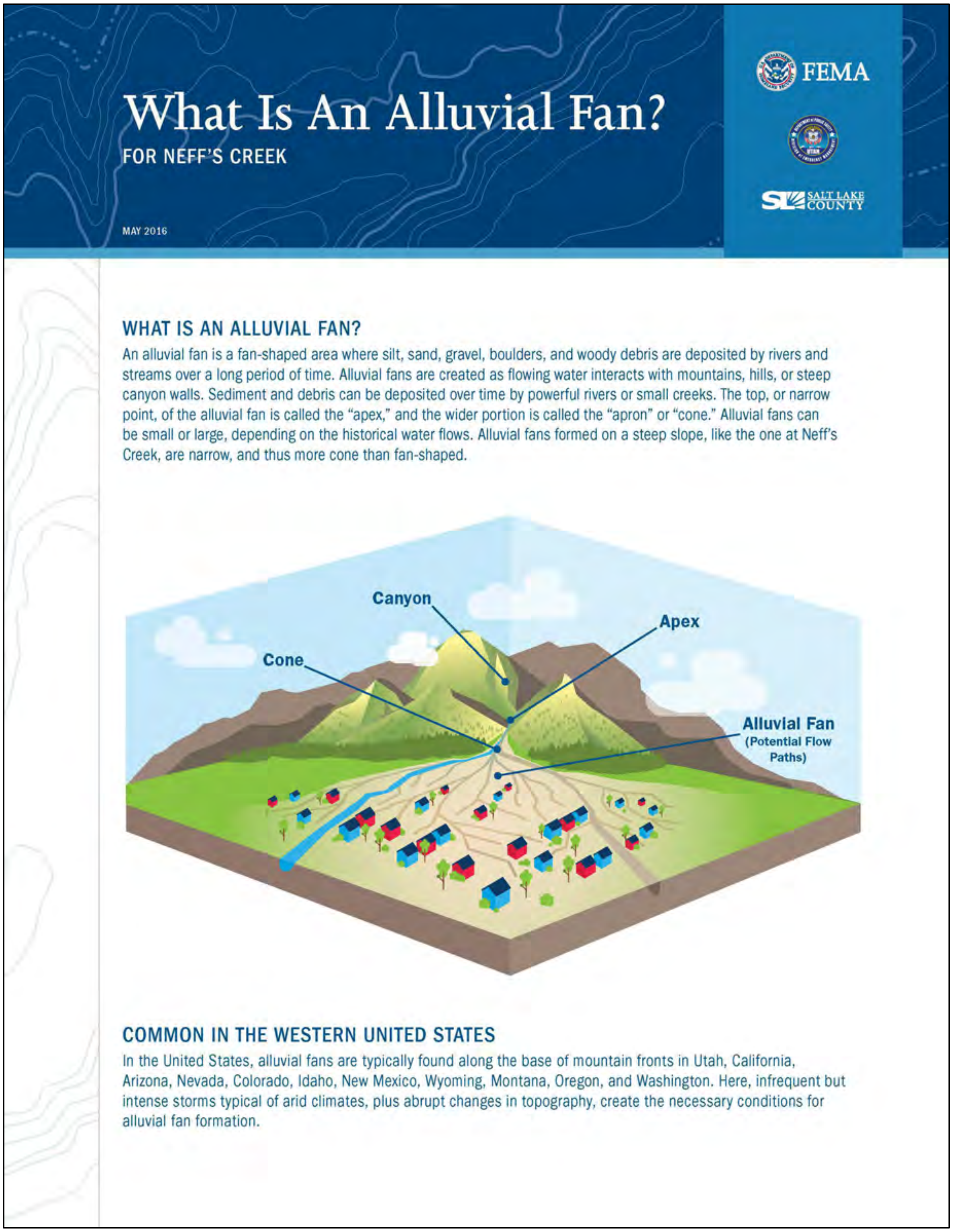
[118] Ibid., 18.

[119] Ibid., 19.

[120] Ibid., 19.

[121] Ibid., 7.

[122] Ibid., 7. Powell also noted that the land represented less than 2.8 percent of the land area in Utah.



FEMA

SALT LAKE COUNTY

What Is An Alluvial Fan?

FOR NEFF'S CREEK

MAY 2016

WHAT IS AN ALLUVIAL FAN?

An alluvial fan is a fan-shaped area where silt, sand, gravel, boulders, and woody debris are deposited by rivers and streams over a long period of time. Alluvial fans are created as flowing water interacts with mountains, hills, or steep canyon walls. Sediment and debris can be deposited over time by powerful rivers or small creeks. The top, or narrow point, of the alluvial fan is called the "apex," and the wider portion is called the "apron" or "cone." Alluvial fans can be small or large, depending on the historical water flows. Alluvial fans formed on a steep slope, like the one at Neff's Creek, are narrow, and thus more cone than fan-shaped.

COMMON IN THE WESTERN UNITED STATES

In the United States, alluvial fans are typically found along the base of mountain fronts in Utah, California, Arizona, Nevada, Colorado, Idaho, New Mexico, Wyoming, Montana, Oregon, and Washington. Here, infrequent but intense storms typical of arid climates, plus abrupt changes in topography, create the necessary conditions for alluvial fan formation.

Figure 3.4 FEMA schematic showing a typical alluvial cone or fan created by water runoff where timber will often grow in lower areas of region.[123]

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[123] Federal Emergency Management Agency, Salt Lake County, Utah, *What is an Alluvial Fan? For Neff's Creek,* May 2016, https://slco.org/contentassets/908d08705b834358a5261a60a0aab9f2/neffs_sheet2.pdf [accessed February 2023].

soils were good for irrigation, they generally believed that the pasture lands were sterile. However, Powell noted that the pasturage lands could be suitable for agriculture if they were properly supplied with water.[124] Finally, he observed that some locations in the pasture region had natural springs that did not begin in the mountains. These, if the water flow was sufficient, could supply enough water for irrigation. A good example of this is the Sam Solomon Springs at the Balmorhea River in West Texas.

Figure 3.5 Cattle grazing in Lusk, Wyoming, 1936.[125]

3.4 The Great River Basins

Reclamation used six major river systems in the West for its foundation of irrigation. Dams built on these river systems would lead to extensive irrigation projects that encouraged settlement and the development of western agriculture. With the exception of several rivers in East Texas and the Sacramento/San Joaquin River system in California, nearly all the interior branches, creeks, and rivers in the region empty into one of these systems. Among these, the Missouri River System, the Red River System, and the Arkansas River System empty into the Mississippi before they reach the Gulf of Mexico. The Columbia River System empties into the Pacific Ocean in Washington State, and the Colorado River System in its natural state empties into the Gulf of California at Baja California. Today it ends several miles north of its former mouth at the Gulf of California. Finally, the Rio Grande flows southeast into the Gulf of Mexico and forms the border between the U.S. and Mexico.

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[124] Powell, *Lands of the Arid Region*, 10.

[125] Arthur Rothstein, "Cattle grazing. Lusk, Wyoming," photograph, July/August 1936. Available at https://www.loc.gov/item/2017761021/ [accessed August 2023].

Reclamation has subdivided its administrative regions to generally correspond to these river systems, although some exceptions exist. Table 3.1 shows the subdivision of the west Reclamation regions, their associated river system, and the states covered by the individual river system.[126] A brief discussion of each system, beginning with the Missouri System, is presented below.

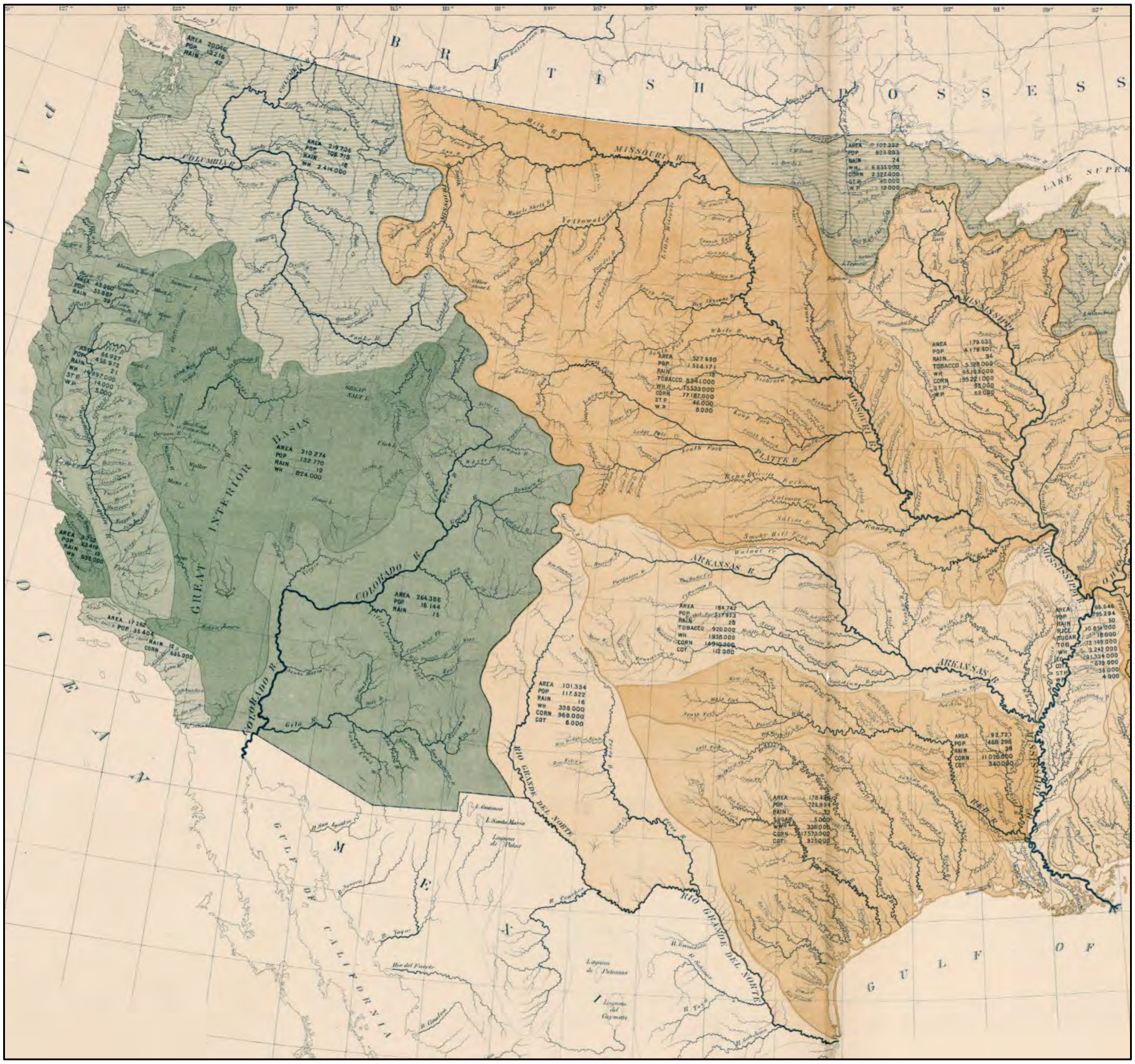

Figure 3.6 River systems in the western United States.[127]

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[126] These assignments do not perfectly match with the rivers systems. For example, the Missouri River system actually covers parts or all of 10 states and a Canadian Province. As another example, northern California is served by several smaller river systems, including the Sacramento-San Joaquin River system that flows directly from the mountains into the Pacific at or around the San Francisco Bay. Also, east Texas, east of the 100th Meridian, has a number of smaller rivers that form in the western mountains and flow southeast to the Gulf of Mexico.

[127] United States Census Office (Francis Amasa Walker). 9th Census, 1870. "Statistical atlas of the United States based on the results of the ninth census 1870 with contributions from many eminent men of science and several

Table 3.1 Subdivision of the West into the Reclamation regions and river systems.

Region	**River System**	**Reclamation assigned states covered by this system**
Region # 5 Missouri Basin	Missouri River System	Montana, North Dakota, South Dakota, Nebraska, Kansas
Region # 6 Texas Gulf Region	Arkansas-Rio Grande	Texas, Oklahoma, New Mexico, Colorado
Region # 7 Upper Colorado Basin	Upper Colorado River System	Wyoming, Colorado, New Mexico, Utah
Region #8 Lower Colorado Basin	Lower Colorado River System	California, Nevada, Arizona
Region # 9 Pacific Northwest	Columbia River System	Washington, Oregon, Idaho, Montana
Region #10 California-Great Basin	Sacramento-San Joaquin	California, Nevada, Oregon

The Missouri River System

The Missouri River System is the longest in the United States, measuring 2,619 miles from its headwaters near the town of Three Forks, Montana, to where the river empties into the Mississippi above St. Louis. It covers a drainage area of 529,000 square miles, including nearly 10,000 square miles of Canada. The Missouri drainage system covers all of Nebraska, most of Montana, Wyoming, North and South Dakota, and parts of Missouri, Kansas, Iowa, Colorado, and Minnesota. Some large subsidiary branch rivers include the Yellowstone, Little Missouri, Platt, Republican, Kansas, and James rivers.[128]

Arkansas-Rio Grande River System

At 1,469 miles long, the Arkansas River is a tributary of the Mississippi. It begins near Leadville, Colorado, and flows eastward to empty into the Mississippi River on the Arkansas border southeast of Pine Bluff, Arkansas. The river basin has 170,000 square miles across seven states including Colorado, New Mexico, Texas, Kansas, Oklahoma, Missouri, and Arkansas. Some well-known tributaries include the Canadian, Cimarron, Neosho, and Beaver rivers. The river has three distinct sections, including fast-flowing mountain rivers that widen, and a large floodplain in Oklahoma and Texas. In eastern Arkansas, the Arkansas River becomes a more traditional eastern river, flowing through flatter forest lands before emptying into the Mississippi.

The Rio Grande is an international river forming a boundary and large drainage basin for both the U.S. and Mexico. It begins in the San Juan Mountains of southern Colorado on the Continental Divide at Stony Pass. It flows 1,990 miles south/southeast to the Gulf of Mexico at Boca Chica on the Mexican/U.S. border. The basin covers 355,500 square miles and the river forms the southern border of Texas with Mexico. In the U.S., it traverses southern Colorado, central New Mexico, and southern Texas. In Mexico, it passes through the states of Dorango, Chihuahua, Coahilla, Nueva Leon, and Tamaulipas. Well-known subsidiary rivers of the system include the Pecos, Devils, San Juan, Conchos, and Salado rivers, the last three being located in Mexico. The river covers approximately 11 percent of the continental U.S. and, due to droughts in the region, the river is sometimes so dry it cannot reach the Gulf of Mexico.[129]

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departments of the government." New York: Julius Bien, lithographer, 1874, https://www.loc.gov/item/05019329/ [accessed February 2023].

[128] For a more detailed discussion, see USACE Northwest Division, "Missouri River Basin," available at https://www.nwd-mr.usace.army.mil/ [accessed January 2023].

[129] Rio Grande International Study Center, "About the Rio Grande." Available at https://rgisc.org/about-the-rio-grande/ [accessed January 2023].

From a regional management perspective, Reclamation also includes the Red River and its tributaries within this system. The Red River, which deposits into the Mississippi, has a large drainage basin that stretches more than 1,360 miles west to east. It forms on the eastern side of New Mexico where the Tierra Blanca Creek begins and runs to the Mississippi River at the Mississippi/Louisiana border. Its drainage basin covers more than 65,000 square miles and stretches across northern Louisiana, southern Arkansas, southeast Oklahoma, and northern Texas into eastern New Mexico. Well-known subsidiary rivers include the North Fork, the Wichita, the Saline, and the Ouachita.

The Columbia River System

The Columbia River is 1,200 miles long and stretches from southeastern British Columbia, Canada, near the town of Invermere and empties into the Pacific Ocean near Astoria, Oregon. It runs north, south, and west before reaching the Pacific. A subsidiary river, and nearly as large as the Columbia, is the Snake River. It begins in the mountains of northwestern Wyoming and flows west and north to an intersection with the Columbia River near Kennewick, Washington. The river basin covers 285,000 square miles and covers parts of Washington, Montana, Idaho, Wyoming, and small portions of northern Utah and Nevada. It also covers the southeastern section of British Columbia. Prior to work by the USACE and Reclamation, the river produced the world's largest run of salmon, with as many as 30 million per year.[130]

The Colorado River System

The Colorado River System is 1,450 miles long and passes through seven states and a portion of northwestern Mexico. It begins at the Continental Divide in the Rocky Mountains of Colorado and stretches through gorges, pastoral landscapes, desert canyons (including the Grand Canyon), buttes, mesas, and 11 National Parks. Prior to the U.S. and Mexico agreeing on water distribution in 1944, the river emptied into the Gulf of California in Baja California, Mexico. It passes through the states of Wyoming, Utah, Colorado, New Mexico, Arizona, California, and Nevada before entering Mexico near San Luis on the Sonora and Baja California line. The basin covers 260,000 square miles, or about eight percent of the continental U.S. Some of its well-known subsidiary rivers include the Green, San Juan, Little Colorado, Virgin, Verde, Salt, and Gila rivers. Due to the reclamation and dam work, the river no longer empties into the Gulf of California, except under flood conditions.[131]

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[130] American Rivers, "Pacific Northwest: Columbia River," available at https://www.americanrivers.org/river/columbia-river/ [accessed February 2023].

[131] U.S. Geological Survey, "Colorado River Basin Focus Area Study." October 16, 2018. Available at https://www.usgs.gov/mission-areas/water-resources/science/colorado-river-basin-focus-area-study [accessed February 2023].

3.5 The States of the Arid West

Colorado

Colorado is consistent with the western geography laid out by Powell. The state contains eastern Great Plains, river valleys, and mountains with timber ranges. Approximately 10 to 12 inches of rain falls annually in the eastern prairies, while the San Luis Valley receives as little as five inches. However, the mountains usually absorb up to 50 inches of rain/snowfall per year, which results in runoff in the spring and summer. After Reclamation distributed water from the mountainous west into the eastern prairies, the eastern part of the state was largely settled beginning in the last half of the twentieth century. Canals and ditches made the plains irrigatable, which produced growth in many of Colorado's eastern cities.[132]

In the 1850s, mining and water control technology developed by Gold Rush participants in California spread eastward into Colorado. Therefore, much of the early Reclamation irrigation technology found its earliest expression in these two states and, with some limitations, to the Mormon settlers in Utah. Colorado was one of the first states to practice reclamation. Early miners and settlers dug canals and ditches for their mines, towns, and water-powered mills. Even before Reclamation began work in Colorado, by 1900 settlers had irrigated as much as 1,000,000 acres using small, localized irrigation works. By 1950, with the added Reclamation systems, Colorado had surpassed 3.2 million acres of irrigated lands.[133]

California

California has a Mediterranean climate, with most rainfall occurring in the winter and spring, and little in the summer and autumn. Rainfall differs between northern and southern California. Taken as a whole, California is considered semi-arid, and the state is dependent on winter snows in the eastern mountains to provide runoff in the spring and summer to water the valleys below for agriculture.[134] Despite the lack of rainfall at times, the state, particularly northern California, also suffers from floods. Compared to other western states, California had the unusual experience of developing cities prior to extensive agriculture, primarily as a result of the 1849-1850 gold rush that lured thousands of settlers to the state. Thus, cities such as San Francisco, Sacramento, and Los Angeles emerged early.[135] However, small farms still made up a substantial portion of the state, especially in the areas away from the immediate coast. Figure 3.8 presents a geomorphic topographic map of California showing the Great Valley between the Sierra Nevada and Coastal Mountains.

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[132] Michael Holleran, *Historic Context for Irrigation and Water Supply Ditches and Canals in Colorado* (Denver: University of Colorado, 2005), 7.

[133] Ibid., 8. "Pioneer ditches," as they are sometimes called in Colorado, are merely the first generation of ditches in any locality. A "farm ditch" served a single user or farm, "mutual ditches" served more than one, and a "ditch company" was a group operating a ditching system or irrigation water flowing works. The "ditch rider" managed the ditch, making sure the headgate and lateral gates were operating correctly, removed debris from the ditches, and looked for problems. Holleran, *Historic Context*,12-13.

[134] JRP Historical Consulting Services (JRP) and California Department of Transportation (CALDOT), *Water Conveyance Systems in California* (Sacramento: California Department of Transportation, 2000), 3.

[135] Ibid., 4. Los Angeles was founded as a town during the Spanish Colonial Period.

Figure 3.7 Map of the states of the “Arid West” with the major geographical areas noted.

Northern California also has the relatively unusual problem of sometimes grappling with too much water. Storm-fed rivers periodically rampage down narrow gorges and spread water across coastal plains and inland valleys.[136] The Central Valley, a seasonal wetland, is considered the agricultural breadbasket of the state. Prior to reclamation, the Sierra snowmelt fed the valley, with any surplus drained through the Sacramento-San Joaquin River Delta.[137] Therefore, the valley would occasionally flood.

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[136] JRP and CALDOT, *Water Conveyance Systems,* 4.

[137] Ibid., 4.

In California, reclamation efforts resulted in contentious arguments over water rights. "Riparian Rights," derived from English Common Law, gave residents living adjacent to water exclusive and non-transferable rights. Conversely, "Prior Appropriation" rights, derived from Spanish law and more common in arid lands, allowed the first users the right to divert water and have priority regardless of who owns the land later. Within California, this argument was exacerbated by the geographical diversity between the well-watered northern half of the state and the heavily populated, but dryer, south.

California is divided by two sets of mountains. The most notable features of the western set include the Cascades on the western side of the state, stretching north from Northern California into Oregon and lower Washington, and the Sierra Nevada, which runs down the eastern side of the state from southern Oregon to the Mohave Desert in the south. Runoff from the mountain streams of the Sierra Nevada provides much of the state's water. A second, eastern set of coastal ranges extends from the Klamath Mountains in the northwestern part of the state to the Peninsular Ranges south of Los Angeles that extend south into Baja California. Between the two sets of ranges lies California's Great Central Valley, which stretches about 25 to 60 miles wide from the Klamath Mountains in the north to the Tehachapi range south of Bakersfield. The Central Valley dominates California's agricultural lands, and therefore was targeted by both Reclamation and the state for irrigation. [138] It is the location of Reclamation's largest irrigation project, the CVP, that began after World War II and would ultimately water more than 3 million acres.

Oregon

Oregon's landscape is characterized by two mountain ranges, the Cascades and the Klamath, between which is the Willamette Lowland, one of the most fertile valleys in the West. The Columbia Plateau, stretching east of the Cascades, includes the Snake River and Burnt River systems, which provide irrigatable lands. To the southeast is the basin and range region, extending north from California. The Columbia River basin is one of the largest river basin projects that Reclamation undertook. In Oregon, that involved the use of the Snake River and its subsidiaries in the eastern part of the state. Reclamation also completed substantial work in the Willamette Valley along the Deschutes River, and along the Rouge River in the basin and range region in the southwest part of the state.

Washington

Washington is divided into two regions by the Olympic Mountains in the coastal areas and the Cascade Mountains that extend north from California, Oregon, and into central Washington. West and south of the Olympic Mountains are temperate rain forests, with natural harbors and timber forests. The northwestern corner of the state includes Puget Sound, which borders Canada. East of the Cascade Mountains are semi-arid pasturage lands, also called Basin lands, with a typical eastern prairie climate like other western states. The Columbia Plateau is located in the central/southern region in the Basin lands. In this area, the Columbia, Snake, and Yakima rivers feed much of the state's substantial irrigated agricultural lands.

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[138] JRP and CALDOT, *Water Conveyance Systems,* 73-74.

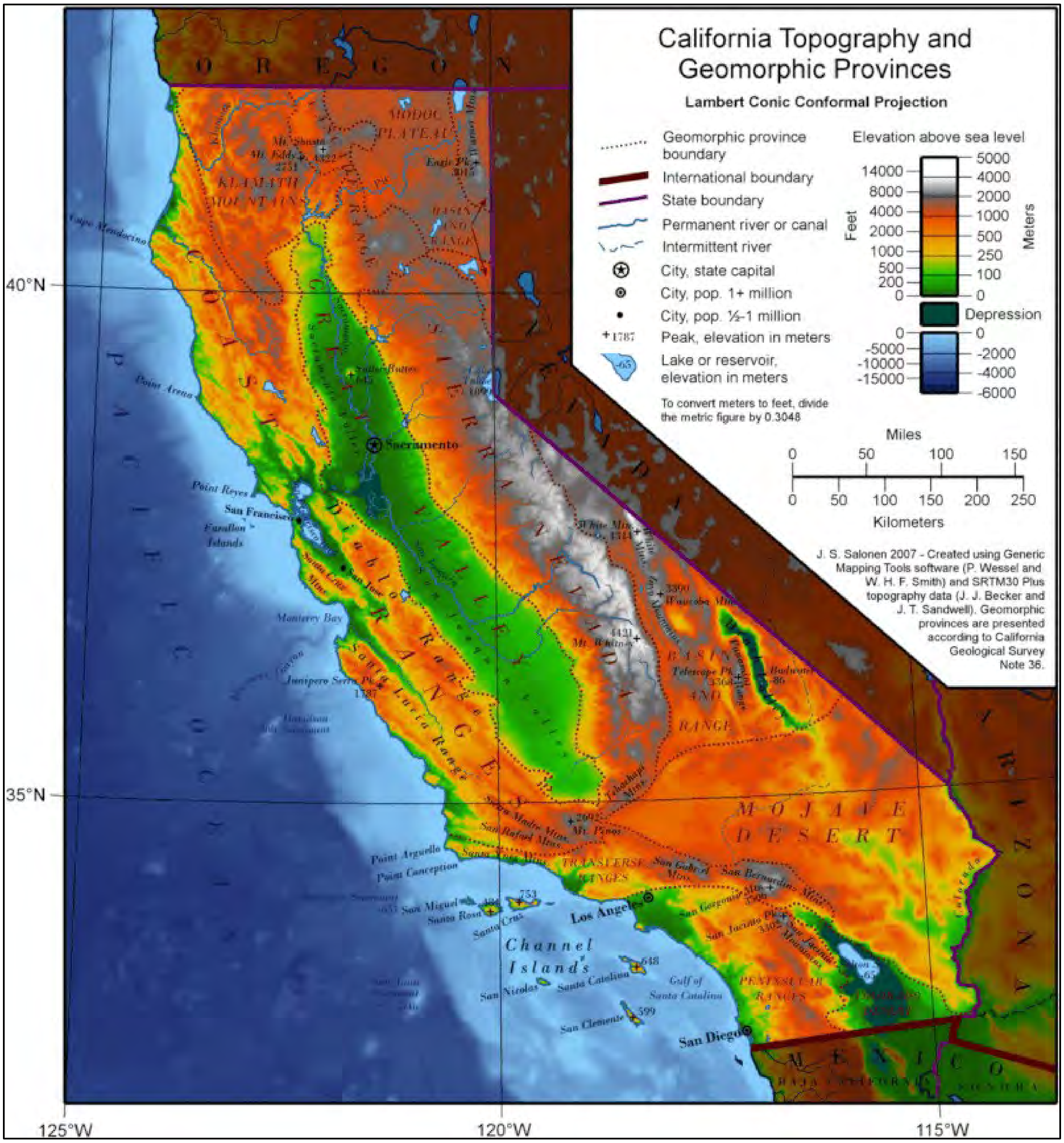

Figure 3.8 A map of California with the Central Valley and other important geographic regions.

Idaho

Idaho is separated to the east by the Rocky Mountains. The state is divided by the Snake River floodplain, which stretches east to west across the state's lower section before forming part of the northwest boundary of the state. Numerous mountain rivers come from the south to the north and empty into the Snake River, Idaho's dominant drainage. The Snake River floodplain contains most of the state's irrigation land. The balance of the state contains the high and low timber mountains.

Montana

The western part of Montana is characterized by the Rocky Mountains, where the Missouri River begins. East of the Rockies, the northern Great Plains stretches eastward toward the Dakotas. The western mountain region of the state receives approximately 40+ inches of rain, while the eastern, more arid region receives on average about 20 inches. Nearly 70 percent of the state is forested. Montana is crossed by the Missouri River and its host of subsidiary rivers such as the Milk, Yellowstone, and Powder rivers. The Missouri, being the largest and most important for irrigation purposes, extends from west to east through the state. Along with the Missouri, the Milk, Yellowstone, and Beaverhead rivers in the east and the Bitterroot River in the western mountains support irrigation systems.

Wyoming

Wyoming has four distinct regions: The Great Plains, the Southern Rocky Mountains, the Middle Rocky Mountains, and the Great Basins. The Great Plains are in the northeast part of the state and consist of plains with low hills and isolated buttes. South of the Great Plains are the Southern Rocky Mountains. The Middle Rocky Mountains stretch through the central, western, and northwestern parts of the state. Between the mountains are the Great Basins that spread out along broad river valleys, mostly in the central part of the state. The Great Plains and the Basins form the region's most available lands for irrigation. Rivers such as the Big Horn, North Platte, Belle Fourche, and Green rivers traverse these two regions and contain irrigation systems.

Nevada

Nevada has the most arid climate with the lowest precipitation in the United States. It has three mountain ranges, and a part of the Mohave Desert is located within its boundaries. The Columbia Plateau is located in the northeast and is known for its canyons and ridges, with grassland prairies in the far north near Idaho. The glacier-formed Sierra Nevada Mountains lie on the western edge of the state. Primary natural lakes in the state include Lake Tahoe, Walker Lake, Topaz Lake, Pyramid Lake, and Ruby Lake. Lakes Mead, Havasu, and Mohave were created along the Colorado River for irrigation and hydropower purposes. East of the Sierra Nevada Mountains is the Great Basin region with buttes and flat-topped mountains. Nevada's primary rivers are found in the Basin region in the eastern part of the state. In this area, the Truckee, Carson, and Humboldt rivers all contain floodplains with irrigation works.

Arizona

Arizona has three primary regions: the Colorado Plateau in the northeast, a Basin and Range section in the southwest and central parts of the state, and a small transition zone between these two larger sections. The Colorado Plateau is a flat, semi-arid region known for its brightly colored sedimentary rock and canyons. This is best exemplified by the Grand Canyon, the Painted Desert, and the Petrified Forest. The Colorado River runs through this plateau and down the western side of the state. The transition zone contains both mountain ranges and valleys. The Basin and Range region is marked by steep mountain ranges and deserts. The Colorado River drains nearly the entire state and consists of many branches including those used for irrigation such as the Salt River, the Verde River, the Little Colorado River, and the Gila River, all located in the Basin and Range region.

New Mexico

New Mexico consists of four land regions: the Great Plains, the Colorado Plateau, the Rocky Mountains, and the Basin and Range region. The southern Great Plains region is located within the eastern third of the state and is marked by prairies and canyons cut by rivers. The eastern edge of the Great Plains is called the High Plains and has steep escarpments and rocky formations. To the northwest is the Colorado Plateau, which the state shares with Arizona and Colorado. It consists of wide valleys, canyons, cliffs, and mesas, and the Continental Divide runs through this region. The Rocky Mountains form in the north/central section and the Basin and Range region forms south of the Rocky Mountains. Although the Rio Grande and the Pecos are two primary rivers, the San Juan River, a tributary of the Colorado, puts the western part of New Mexico in the Colorado river basin. Irrigation is located along these river valleys as they traverse the Colorado Plateau and the High Plains.

Texas

Texas is the largest state of the contiguous U.S. and is divided into four primary regions including the Coastal Plains, North Central Plains, High Plains, and Basin and Range regions. The Gulf Coastal Plains link the eastern part of the state to the other southern states in the U.S. and are characterized by brackish water inlets, bays, and barrier islands. Within the Coastal Plains section is the coastal prairie and pine woods with the Lower Rio Grande Valley in the south and west. These floodplains form the primary irrigation areas for the state. Behind the Coastal Plains lies the North Central Plains, a largely treeless region with rolling prairies and strips of forested lands. Northwest of the North Central Plains are the High Plains of northern Texas. Western Texas contains the Basin and Range region, which the state shares with many of the other western states. This region contains mountains and valleys, and the Lower and Middle Rio Grande form the southwestern border with Mexico. The state contains a number of important rivers, the Rio Grande being the largest and the location of most irrigation efforts. However, most irrigation projects along the Rio Grande in Texas are privately held and only a portion of them have Reclamation investment. The Sabine and Red rivers form state borders, and numerous other rivers, such as the Brazos, Guadalupe, Trinity, and Colorado (not the same as the Colorado further west) that form in West Texas and the Rocky Mountain regions drain through Central and East Texas to the Gulf of Mexico. The state has many irrigation projects, but Reclamation's projects are primarily along the river systems that drain into the Gulf of Mexico.

Oklahoma

Oklahoma has a number of regions; some researchers count as many as 10 regions, but those include the drainage basins of the Red and Arkansas rivers. In the northwestern corner, the state contains the semi-arid High Plains, with a rolling flat landscape and intermittent canyons. The southwestern part of the state contains partial plains with small mountain ranges and is home to the location of most irrigation lands in the state, with Reclamation projects along the Red, Washita, and Canadian rivers. Most of central Oklahoma is covered by prairie and woodlands. Finally, the eastern third of the state contains the Ozark Mountains, which rise in elevation from west to east. The state has more than 200 dams and reservoirs that store water for a variety of uses, including irrigation.

Kansas

Kansas is known for its flat, wide-open prairies with gradual elevation changes from the lower eastern part of the state to the west where higher elevations occur. Western Kansas, though defined as flat terrain, has the highest elevations in the state and is considered High Plains. East of west Kansas are the more rugged sections of the state, though still categorized as plains, and include the Badlands and areas of Central Kansas with deep canyons and steep cliffs. This central section is home to the Smoky Hills, Red Hills, Flint Hills, and the Arkansas River Valley. A number of other branches of the Arkansas River cut through the north/central section of the state, creating river valleys. Tall grass prairies begin in this region and stretch into eastern Kansas. On the southeastern side of the state are the rich, alluvial plains, more closely related to the fertile areas in the Eastern U.S. Despite that, most Reclamation projects are located in the north/central region in the plains section along branches of the Arkansas River such as the Kansas, Solomon, and Smokey Hill rivers.

Nebraska

Nebraska is subdivided into two primary geographic sections: the dissected Till Plains and the Great Plains. The dissected Till Plains are gently rolling hills, fertile floodplains, and rich farmland. This section is served by the creeks and rivers of the Platte and Missouri river systems, especially in the north/central area. The Great Plains section is marked by rough, hilly sections and flat prairies. The southeastern portion of central Nebraska gets enough rainfall to permit dry farming, but most of the western part of the state has limited rainfall like the other western states. North of the Platte River is the Sand Hills portion of the Great Plains, an area noted for large sand dunes but also containing grasslands for grazing. Nebraska contains High Plains in the Great Plains section, north and west of the Sand Hills, where there are also the Badlands. Reclamation projects are generally located in the Great Plains section of the state and are fed by the Platte, Republican and Niobrara river systems, which flow from west to east and drain into the Missouri River.

South Dakota

South Dakota contains three primary geographical sections including prairies, timber mountains, and the Black Hills. The eastern and central sections are marked by prairies that include fertile farmland and natural and manmade lakes. Western South Dakota is marked by timber mountains and Badlands, with deep canyons and steep cliffs. The Badlands are located in the southwestern portion of the state known as the Black Hills. The climate in western South Dakota is semi-arid and the Missouri River watershed drains the entire state. Branches of the Missouri that also drain large portions of the state include the James, Big Sioux, Cheyanne, White, and Belle Fourche rivers. Most of these rivers are in the central section of the state. Most irrigation lands are in the western part of the state, east of the timber mountains along the Cheyenne, Belle Fourche, and Grand river floodplains.

North Dakota

Like its sister state, North Dakota consists of three primary regions: the Red River Valley, the Drift Prairie, and the Missouri Plateau. The Red River Valley is dominated by the Red River and is a flat floodplain running along the eastern border of the state and spreading into Canada and Minnesota. It contains the best farmland and is extremely fertile. The section runs from about 10 miles wide in the southeast to 40 miles wide at the Canadian border. The Drift Prairie is a higher prairie region, or pasturage lands as Powell would identify them. This region is covered with grasslands and wildflowers and contains the eastern half of the state that is not part of the Red River Valley. The Drift Prairie is about 75 miles wide at the South Dakota border, but more than 400 miles wide at the Canadian border. The Missouri Plateau, located west of the Drift Prairie, is a hilly, rocky area that is not as fertile as the Drift Prairie. North Dakota also has a large section of the Badlands in the southwestern part of the state. The central and western parts of the state are semi-arid to arid. Reclamation irrigation projects are located within the Missouri Plateau along the Missouri River, and its subsidiaries in the southern part of the state.

Utah

Utah consists of two large regions subdivided by the southern Rocky Mountains. The mountains divide the state from the northeast to the southwest. There are two primary drainage systems, the Colorado and the Great Basin. The southeast contains the Colorado Plateau, the state's portion of the Colorado River, and Lake Powell, an artificial lake created by the Glen Canyon Dam built by Reclamation. The northwest section of the state is dominated by the Great Salt Lake and was the site of early European-American settlement. Some of the first successful irrigation efforts in the American Period were initiated in this section by Mormon settlers in the nineteenth century. This section of the state is within the Great Basin watershed. The state includes a small portion of the Columbia River basin in the northwest corner. The Great Basin watershed does not drain into the sea; rather, it drains into inland lakes such as the Great Salt Lake. Most irrigation is located within the Great Basin or along the Colorado River.

3.6 Engineering the Conveyance Systems: Challenges and Technology

Beginning in 1902, the Bureau of Reclamation would ultimately develop 180 projects irrigating 18 million acres of land across this vast and varied western landscape. When the agency was in its infancy, Chief Engineer Arthur Powell Davis noted that:

> the projects undertaken [by Reclamation], unlike the early simple diversions upon valleys adjacent to the headworks, involved, on the contrary, expensive storage works, high diversion dams, difficult tunnels, or long, expensive canal work on side hills, where large investment was necessary before any water was brought to the land.[139]

While engineers drew on previous experience, they quickly adapted to address much larger and complex issues.

In addition, Reclamation was required by law to directly negotiate with water user cooperatives or irrigation companies. These organizations owned the land around the planned canals and would engage with the government by accepting the water, paying for its usage, and billing and collecting fees for the end users. According to the federal legislation, once the investment costs were repaid, Reclamation would transfer management of the systems to the associations. In some cases, Reclamation owned the lands and built the systems from the beginning. However, in many situations, such as with the Salt River Valley Water Users Association, the CVP, and the Lower Rio Grande Project, the Federal Government purchased the local associations' water conveyance systems and assumed ownership of their projects. Reclamation improved the projects using updated technology and new, heavier equipment that enlarged the scope of the project. Additionally, with federal management came federal funding. In most of the projects, particularly those in Arizona, Nevada, Washington, and South Dakota, irrigation not only brought federal action into

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[139] Arthur Powell Davis, *Irrigation Works Constructed by the United States Government* (New York: John Wiley & Sons, Ltd., 1917), 2.

the states, but water sales from the reservoirs and hydroelectric power facilitated development. Indeed, in the case of Arizona, irrigation on projects such as that on the Salt River Project contributed directly to its statehood in 1912.[140]

Used for railroads and mining, steam locomotion and power brought tremendous change to the West by the 1880s.[141] Steam power quickly became adapted for other equipment uses. For example, by the end of the century, California gold miners used steam power to wash and filter raw materials.[142] The technology was easily adapted for the construction of irrigation projects in the form of tractors, scrapers, and other earth-moving equipment. In the late 1930s, the railroads again pioneered the key technological advancement of diesel locomotives, which quickly found expression in construction equipment.[143]

By the early twentieth century, these innovations sped the pace of construction. Railroads could bring in supplies on temporary lines. Improved electrical-powered equipment reduced manpower needs. Powerful draft animals pulled scrapers and other heavy equipment to inaccessible areas. Improvements in the quality of mortar and concrete substantially contributed to the construction success of irrigation projects. As dams soon incorporated hydroelectric powerplants, electric power was used to drive derricks, dredges, trams, and concrete mixing plants as well as other equipment used for building the canals and ditches. Other interesting engineering innovations came from overseas such as the silt-cleaning design, pioneered by the British in India and incorporated into Laguna Dam on the Yuma Project in 1905.[144]

3.6.1 Early Project Engineering and Innovation, 1902-1917

As with most new innovations and governmental investments, the early years of federal involvement were represented by innovation, trial and error, mistakes and successes, and the usual budgetary underestimates and overruns. The Reclamation Service was no exception. Despite lengthy efforts at planning and studies, irrigation remained an inexact science for the first two decades of the twentieth century. For example, Reclamation struggled with the use of proper materials for dams and canals, and pioneered innovative uses of concrete. The wear and tear from the western environment posed a constant problem, drainage costs became an unexpectedly costly challenge, and repayment by irrigation alone remained elusive. However, the cost of hydroelectric power development was soon returned, and Reclamation found that selling power was an important source of revenue when irrigation repayments lagged. Reclamation officials and engineers remained determined in their mission and by the 1920s had established their work as permanent on the agricultural, social, and political landscape. Cost efficiency remained a challenge for the Reclamation project managers.

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[140] James W. Steeley and Dennis Gilpin, *Lifeline to the Desert, Water Utilization and Technology in Arizona's Historic Era, 1540-1960.* A report prepared for the Arizona State Historic Preservation Office (SWCA Environmental Consultants, Arizona, 2004), 100.

[141] Ibid., 5-6.

[142] Another engineering contribution miners made to irrigation was the "miner's inch." Miners measured water using the "miner's inch," measuring it by speed and depth. In miner lingo, 1 inch equals 11.22 gallons; Ibid., 10.

[143] Ibid., 18.

[144] Ibid., 8.

Figure 3.9 Theodore Roosevelt Powerplant (courtesy of Bureau of Reclamation).

3.6.2 Cost Efficiency

As with most large government projects, Reclamation almost immediately encountered a variation between projected and actual costs. For these early projects, officials had no previous experience of such large-scale projects and often underestimated the cost. Moreover, the country experienced an economic depression in the 1890s, which skewed prices downward. The new estimates were made when the country was entering a period of inflation, and therefore the years 1903 to 1908, in which most of the early construction work was done, were concurrent with a railroad construction boom and reconstruction of the City of San Francisco after the 1906 earthquake, in addition to a corresponding expansion of construction work throughout the West. Canals and ditches made the plains irrigatable, which produced growth in many of Colorado's eastern cities.[145]

The Bureau of Reclamation's work was based on "on a large-scale ideas and methods in hydraulic construction."[146] By the time the U.S. entered World War I in 1917, Reclamation had begun, or partially completed, 25 projects in 16 western states. By the end of 1923, it had invested $200 million on those 25 projects, double its initial $100 million allocation by Congress. It also supplied water for nearly 2 million acres of formerly arid lands in all 16 states.[147] Chief Engineer Davis noted that:

> the engineering features of the Reclamation Service presented greater difficulties than most large works because of their variety and wide distribution throughout the Western United States. However, most of the features and structures were challenging due to the size of the operations, both the dams and reservoirs so frequently covered, but canals and ditches also. The cost, timing, and complexity was

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[145] Holleran, *Historic Context*, 7.

[146] Davis, *Irrigation Works*, 2-4.

[147] Ibid., 4.

> increased by the addition of powerplants, that ended up being a primary source of revenue for the irrigation projects.[148]

One early example was the Salt River Project, which involved the 1,000-foot-long Granite Reef Diversion Dam, and two main canals leading from the dam on either side of the river. The diversion dam was 26 feet high, cresting at 20 feet above low water, and had 18 regulator gates, with each sluice gate weighing 30,000 pounds.[149] The two main canals, the larger Arizona Canal on the north side and the smaller South Side Canal, serviced 127,000 and 80,000 acres, respectively. A second smaller diversion canal was built 24 miles downriver; the Granite Reef Diversion Canal diverted water into two previously built main canals, the Salt and Maricopa canals. The Arizona Canal has two substantial drops where small powerplants were added to generate electricity. The South Side Canal has a single drop 12 miles down from its head that includes another small powerplant. Later in the 1940s, the Salt River Project was enlarged when the Verde River, a subsidiary river, was brought online via the Horseshoe Dam; this increased the number of irrigated fields.

The Salt River Project illustrates the early changes in water distribution. The head that supplied the water flowed 10 cubic feet per second (cfs). In the beginning, one 24-hour period of water was supplied to every farm every eight days: one day of water and seven days without. However, due to the farmers' needs, the method was changed in 1912. Reclamation management began supplying water at any time with notice, as opposed to earlier pre-set times. The one-in-eight-day rotation was used only in extremely hot weather or during a drought, when multiple demands required it. The cost of the water depended on the time that it flowed to the end users at the pre-measured amount. A headgate with a measuring device at each farmer's tap point on the sublateral canal ensured the proper flow. Time was then calculated based on opening and shutting time of the headgate. Figure 3.10 shows a view of the L-line lateral in the Newlands Project. The end users were satisfied with the new arrangement that gave them more flexibility in their crop planting.

Sublateral canals also illustrate Reclamation's efforts to change older irrigation methods. In the Salt River Project, a new sublateral canal was added so that only one measurement device was necessary for each irrigator. The previous existing lateral systems were wood, often dilapidated or in poor condition, and inefficient. Each end user had taken water for each field directly from the main canal. For example, if a farmer had four fields, he used four heads and four questionable measuring devices. Reclamation established a sublateral where each farmer took all allocated water from a single point, thereby requiring only one measurement device for each farm. Reclamation was also able to enlarge the earlier system and substitute concrete structures for wood, which minimized maintenance costs. They also installed waste ditches to remove excess water, a new unplanned development in itself.[150]

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[148] Davis, *Irrigation Works*, 4.

[149] Ibid., 26.

[150] Ibid., 37.

Figure 3.10 A c1912 photograph of the L-line lateral (Newlands Project, Nevada), a part of the water distribution system, under construction.[151]

Another example of extensive engineering was the Minidoka Project in Idaho and Wyoming. Reclamation planned a dam and storage facility, and irrigation works for up to 200,000 acres of lands along the Snake River. The Minidoka Dam created the reservoir and contained the headworks for the main canal, located on the north side of the river. As with many of the earlier systems and nearly all the later irrigation projects, a hydroelectric component was included with the dam. The powerplant included a 10,000-horsepower electric generation system and 31 miles of 33,000-volt power lines.[152] The flat terrain on the north side of the river required the distribution works to be raised above the surrounding land. The use of gravity, while facilitating the irrigation of 70,000 acres on one side of the river, was insufficient. The project required construction of two primary pumping plants, which further lifted the water from the main canal into two sublateral canals for irrigation of large sections on the north side of the river. Reclamation also installed a number of small "scoop wheel" plants to lift water 3 to 5 additional feet from the sublaterals into individual farmers' fields for final distribution.[153]

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[151] Rowley, *Origins and Growth*, 7.

[152] This provided additional income for the project, and in time, helped offset poor irrigation revenues.

[153] Davis, *Irrigation Works*, 144-146.

Figure 3.11 Scoop wheel electrically operated. 60% efficient. Lifting water 3 1/2 feet, to irrigate 800 acres, 1914 (courtesy of Bureau of Reclamation).

As with other projects, Reclamation also installed a number of wastewater ditches at Minidoka. The north side flat terrain demanded the installation of a ditch to collect large amounts of unneeded runoff water. Distribution of water on the north side of the river was continuous, but on the south side, more pumping stations were needed to move the water across the flat terrain. This limited the delivery of water to one day in eight, similar to the early Salt River Project.

The sheer size and scope of these early projects, along with Federal Government involvement, are what set the Reclamation projects apart. At Minidoka, for example, the dam and reservoir cost $509,683, in addition to $1,157,000 for the electric pumping plants, power generators, and transmission lines. The 108 miles of open drainage lines added another $622,000 in costs to the $1.190 million cost for the main canals and laterals. By the end of 1917, when most of the initial work was completed, Reclamation had spent $3.5 million on the Minidoka Project.[154] This cost would be dwarfed, however, by Reclamation's expansion of the project in the 1930s to more than 1,000,000 acres, seven dams, 1,600 miles of main canals, and 4,000 miles of laterals.[155]

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[154] Davis, *Irrigation Works*, 151.

[155] Stene, "Minidoka Project."

Table 3.2 Listing of the first 18 projects initiated by the Reclamation Service through 1923.

Project Name	**Location of Project**	**Year initiated**	**Canals and Laterals**	**Other Key Irrigation Elements**	**Status Today**
Salt River Project	Arizona	1903	Arizona-38.5 miles long; New Crosscut-3.5 miles long; South Canal-10.1 miles long; Grand Canal-22.3 miles; Eastern Canal-14.5 miles long; Consolidated Canal 18.4 miles long; Tempe 9.3 miles long. 924 miles of laterals and 250 miles of drains. See McDonald and Bailey 2017 for details 205,000 acres of irrigation	Granite Reef diversion dam-1000' long with a sluiceway settling basin with 18 intake gates; Joint Head Diversion Dam (off project and also drainage collection point for recycling water. Syphons serve as spillways at the key points.	Main Canals-no change in length, change is in urbanization; Irrigation below 65,000 acres
Yuma Project	Arizona and California	1904	Main Canal Ca.(80'bottom) side-10 miles; Indian Reservation head pic on p. 45 Davis. On AZ side, is the Yuma Valley Canal, subdivides after one mile to East and West canals-16.5 miles long. The East Canal has 10 laterals taking water to the individual farmers.	1000' Pressure tunnel for the main canal under Colorado River-14 diameter, picture Davis, p. 47. On both sides of the river there is a levee system to prevent the river from flooding and move down the river, 70 miles, from the tunnel to the Gulf of California (picture p. 51). Also 80 miles of open drains planned but by 1918 only 27 miles constructed.	
Orland Project	California	1907	South Canal on Stoney Creek. No checks on the South Canal. North Canal is very simple and laterals and along with the canals aggregate to 200 miles. Most laterals were concrete lined.	Big Stoney Creek Diversion Dam and Canal to supplement reservoir. Drops had a notched weir. 1400 structures of various kinds in the system.	
Grand Valley Project	Colorado	1912	North side canal was concrete lined canals, tunnels, using siphons and flumes (3) and is 43 miles long and 38' bottom width.	Lifts 50-75 feet to bring water up to 11,000 acres. Asbury Creek Siphon, Coal Creek Siphon, culverts and bridges and a simple drainage system.	

Project Name	**Location of Project**	**Year initiated**	**Canals and Laterals**	**Other Key Irrigation Elements**	**Status Today**
Uncompahgre Project	Colorado	1903	Gunnison tunnel is 5.8 miles 10' wide; Diversion dam is rock and crib weir; South Canal is 11.5 miles long and concrete lined and earthen with 10' drop at the portal (photo p. 87); Happy Canyon Wooden Flume in Main canal. 110 canals (laterals) of more than 500 miles; Montross and Delta Canal enlarged by BOR includes a 35-foot drop. by 1920 438 miles of canals had been built. Loutzenheizer Canal and California Ironstone Canal are iron piped canals.	South Canal has several drops with concrete lined chutes and a wooden flume. Large 1,100 siphon (24" diameter) carrying water across the Uncompahgre River to the West Canal. Seileg Canal has a collapsible, weir-framed damn and timber headworks. Garrett Mesa Siphon 8,560' long.	One of the oldest Reclamation projects, the Uncompahgre Project contains one storage dam, several diversion dams, 128 miles of canals, 438 miles of laterals and 216 miles of drains.
Boise Project	Idaho and Oregon	1905	Main Canal is 32 miles long 580 miles of canals and laterals completed by 1918. Lateral called the Mora High Line continues on from end of main canal and five concrete turnouts. Indian Creek diversion is concrete diverting weir with iron waste gates in it. main Canal is also a feed canal feeding Deer Flat Reservoir with water not used in the irrigation along the way. Deer Flat Reservoir and Arrowrock Reservoir were backups to the Boise Reservoir.	Three turnouts in the main canal Five, eight and Ten Mile. Hubbard Reservoir serves as a backup to Boise reservoir. Steel flume that crosses Eight Mile Creek.	
Minidoka Project	Wyoming and Idaho	1904	North and South Canals; Norths side canal is on flat terrain, so waters raised at Diversion Canal to put into North Canal which is above the landscape. Large losses due to seepage. Clay and sage brush mattresses used to minimize.	Pumping plants play a major role in more than 1/2 acres irrigated. Reinforced concrete plants at lower end of canal pumps water average 64 up. North side Minidoka has an extensive drainage system. Also, wind erosion is a severe problem and solved by use of sage brush plants and a large amount of riprapping. More than 108 miles of drains built at Minidoka as part of the system.	

Project Name	Location of Project	Year initiated	Canals and Laterals	Other Key Irrigation Elements	Status Today
Huntley Project	Montana	1905	No storage units on this project. Several (2,800') reinforced concrete tunnels in the main canal.	Pryor Creek flood control flume. Two pumping plants at a 36' drop east of the project. Custer Coule superpassage flume (p. 161). A number of concrete drainage culverts installed in project. Six miles of open drains and 27 miles of tiled or lined drains.	
Lower Yellowstone Project	Montana and North Dakota	1904	Diversion Dam is a rock-filled weir with timbers and steel. Very large main canal with 11 headgates and pine supports.	Linden creek concrete flume 12' wide and 152' long and Burns Creek Conduits.	
North Platt Project	Wyoming and Nebraska	1903	Whalen Diversion Dam and North side Interstate Canal and South side Fort Laramie Canal (25 miles long with three tunnels 8,550') with two sluice gates each (drawings of each pp. 183)	Project contains additional high and low line canals on both sides and a number of laterals. (Spring Canyon Flume Photo p. 195); Rawhide Pressure Conduit on interstate Canal (photo p. 196). 22 miles of drains, open and closed. Flight of drops photo page 197. The project has 806 miles of canals.	
Truckee Carson (Newlands) Project	Nevada	1903	Already have info on this project will skip here		
Carlsbad Project	New Mexico and Texas	1907	Main Canal (14 miles lined) has three spillways. No. 1 spillway has distinctive wells to support tunnels	Main Canal concrete flume; Dark Canyon Pressure Pipe; drainage system has 13 miles of drains including 9 miles of open drains.	
Hondo Project	New Mexico	1904	three low concrete diversion dams lead to main canal. Project was a failure due to the failure of the reservoir to retain water. Project is used only when rains permit.	four lateral canals that contain multiple concrete drops.	Project abandoned by Reclamation, 1915

Project Name	Location of Project	Year initiated	Canals and Laterals	Other Key Irrigation Elements	Status Today
Rio Grande Project	New Mexico and Texas	1906	Leasburg Diversion Dam is concrete weir; Mesilla Diversion dam has a moveable crest, a flood control function with canal heads on each side of the river. Franklin Canal has unique cylinder drop (photo 252) concrete lined with all concrete structures.	Sluiceway at the diversion dam to clear the headgates of mud.	The water system for this narrow oasis features Elephant Butte and Caballo Dams, six diversion dams, 141 miles of canals, 462 miles of laterals, 457 miles of drains, and a hydroelectric plant.
Umatilla Project	Oregon	1905/1923	Umatilla Diversion Dam, and Feed Canal (concrete lined) to Cold Springs Reservoir (photo p. 255). Actual head contains a sluice gate to reduce silt in the canal. Three Mile Falls Diversion dam on west bank of the river.	Concrete drop into the Cold Springs Reservoir. Concrete chute and stilling basin in the Feed Canal prior to arrival at the Cold Springs Reservoir. Most canals and laterals were lined and use of concrete pressure pipes due to terrain. Later many of the canals and laterals left unlined were later lined to prevent seepage. Picture of a pipe drop, p. 264 along laterals. About 10 miles of open drains and about 1.5 miles of enclosed drains to remove water.	
Klamath Project	California and Oregon	1906	Main Canal with six-gated concrete headgate in Klamath Lake (photo p. 275) and is concrete lined and a tunnel. South Branch [lateral] Canal branches off at the 9-mile point. At the Poe Valley there is another major lateral. Lost River Diversion [Raised] Dam (photo p. 274).	Lost River Flume on the Poe Valley Canal. Poe Valley Lateral and branches. Lost River Power Canal.	

Project Name	Location of Project	Year initiated	Canals and Laterals	Other Key Irrigation Elements	Status Today
Belle Fourche Project	South Dakota	1903	Feed Canal from Belle Fourche River to Owl Creek Storage facility. Diversion Dam to Feed Canal. North Canal on north side of Belle Fourche River. South Canal on the south side of the river (45 miles long).	Semi-circular concrete weir and Crow Creek overflow weir. Indian Creek Flume (1300' long galvanized steel on wood bents) and Indian Creek Spillway. Lower end baffles at the lower end of Indian Creek Flume. South Canal Siphon over the Belle Fourche River. Steel grizzly on siphon. Pressure pipes carry the South Canal across the Anderson and Whitewood Creek draws.	
Strawberry Valley Project	Utah	1906	Spanish Fork Diversion Dam concrete overflow weir with concrete sedimentation basins. Trail Hollow and Indian Creek Feed Canals add waters to the reservoir. Strawberry Tunnel delivers water through the Wasatch Mtn. range to Diamond Creek, tributary of the Spanish Fork. High Line Canal--extension of the Power Canal.	Main Line Branch Drop Chute and Goshen Pass Iron Pressure Pipe. Goshen Valley Lateral.	
Okanogan Project	Washington State	1905	concrete Diversion Weir is 10 miles downstream on the Salmon River from the dam (photo p. 319). Main Canal is concrete lined.	Two small drops in main canal to water powered power plants. Most of the laterals were concrete lined (photo p. 322). View of the orchards is quite impressive p. 320	
Yakima Project	Washington State	1905	Tieton Unit Main Canal was concrete lined and 12 miles (9.8 miles of lined canal; 2 miles of tunnel; with several tunnels). Diversion Dam and headgates consist of reinforced concrete and a low crib with six 6x6 gates; Sunnyside Unit main canal 83 miles	Wagon Road was a primary feature on Bumping Lake Dam and town of Naches City. Tieton Unit has five wasteways; 225 miles of canal; 52 miles of various piping and lined canal; 14.6 miles of wood and metal flumes. Sunnys side contains , 442 miles of laterals, more than 6,300 canal structures including 38.6 miles of concrete, metal, or wooden flumes. this includes numerous drops, culverts, and turnouts. Included is Zillah wasteway and Sunnyside inverted siphons.	

Project Name	**Location of Project**	**Year initiated**	**Canals and Laterals**	**Other Key Irrigation Elements**	**Status Today**
Shoshone Project	Montana and Wyoming	1904	Reinforced concrete Corbett Diversion Dam, tunnel and Garland Canal.	Drainage works on the project included 47.7 miles of covered drains	
Milk River Project	Montana	1903	Not listed as having started yet.		

The Salt River Project also quickly revealed problems with drainage issues and the cost to repair them. Previously, the localized efforts along the Salt River sometimes permitted excess water to build up, causing inundation and the loss of crops. When the water did not build up, the excess water was drained off and no effort was made to reuse it. Reclamation not only improved drainage ditches at the lower ends of the farmers' fields but collected the runoff and recycled it back into the main canal for reuse further downstream. This was another of the early projects where Reclamation engineers quickly learned that agriculture required good drainage as much as good irrigation,[156] and that a good drainage system could recycle critical water. It also presented the agency with unplanned components of their projects and increased costs.

3.6.3 Concrete

The most critical component of large-scale reclamation was concrete, or more specifically the Portland cement compound. In the last two decades of the nineteenth century, especially beginning in the 1890s, Portland cement concrete underwent refinement through the use of the rotary kiln, which made production more efficient. By 1902, roads, homes, larger commercial buildings, and apartments were constructed with steel-reinforced concrete. In 1904, architects successfully constructed a 16-story high rise with concrete. By this time, the Reclamation Service was ready to use the material for its planned dams and canal linings.[157]

Another innovation advanced by Reclamation was the use of prestressed concrete. Prestressed concrete is a method of manufacturing concrete products by using a prestressed steel strand inside the concrete, thus reinforcing it with tensioned steel to add strength. By the 1920s, the use of prestressed concrete was becoming common on large structure projects.[158] Prestressed concrete would later be used for road and railroad bridges. Reclamation tended to use them on large siphons, flumes, and other water distribution features.[159]

In Reclamation systems, one particularly notable example of concrete's use was the bifurcation of the Colorado River on the Yuma Project. For this application, Reclamation engineers settled on a water transferring design, which became known as the Colorado River Siphon. Created in 1905 to 1912, it permitted water to flow from the river to California irrigation fields through the California Canal. The excess water from those fields was then rerouted back under the riverbed to Arizona to the Arizona Canal where it was again used for irrigation. This was one of the first examples where Reclamation made use of a

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[156] Davis, *Irrigation Works*, 149-151.

[157] Portland Cement in its current form was first manufactured in the 1860s, and the cement was a key ingredient for concrete. It was also used by itself as a sealant and mortar for the dams and linings of the canals and laterals planned by Reclamation. When mixed with aggregate, sand, and water, it produced concrete.

[158] Steeley and Gilpin, *Lifeline to the Desert*, 14.

[159] Ibid., 9.

concrete siphon to move water completely underneath a natural riverbed.[160] It illustrates both the innovative use of concrete by the agency and the types of challenges their engineers overcame.

Figure 3.12 Yuma Project. Colorado River Siphon; looking down Arizona shaft 55 feet below surface at night, 1910 (courtesy of Bureau of Reclamation).

By the 1930s and 1940s, concrete began to replace earthen, open, main and lateral canals by lining the bottoms and sides. Later in the 1960s, concrete piping, which had been available in small-scale designs since the earliest construction projects, began to replace open canals, laterals, and ditches. Massive concrete tunnels were also critical parts of systems, such as the Alva B. Adams Tunnel on the Colorado-Big Thompson Project, the multiple tunnels in the Kendrick Project, and the Gunnison Tunnel on the Uncompahgre Project. Concrete linings appeared in the 1930s to help improve maintenance and as a water conservation method. Such projects as the Phantom Lake Spring in the Balmorhea Project in Texas, the Sun River Project canals and new laterals in Montana, and the rehabilitation of laterals on the Umatilla Project in Oregon are examples of water conservation efforts.

The installation of concrete piping, especially in the southernmost climes such as Texas, Arizona, California, and New Mexico, helped eliminate evaporation and address seepage issues. This process increased substantially in the latter twentieth century. Piping in places like south Texas has been so thoroughly used on formerly earthen main canals, sublateral canals, and ditches that little remains water above ground. For example, in the Hidalgo County Irrigation District in the Lower Rio Grande Project area,

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[160] Steeley and Gilpin, *Lifeline to the Desert*, 16; Davis, *Irrigation Works*, 2-4.

all but 78 of the 400 hundred miles of once-open canals have been converted into underground pipelines or aboveground enclosed pipe flumes since the 1950s.[161]

Figure 3.13 The first bucket of concrete ready to be poured on the Arrowrock Dam site on the Boise River. James Munn, spt of const.; A.B. Mayhew, assist. resident engineer; Frank Crowe, shift boss who later worked at Hoover Dam, Shasta Dam, and Deadwood Dam; John Beemer, inspector; and C.H. Paul, resident engineer, 1912.[162]

3.6.4 Depression Era Project Engineering (1930-1942)

Although a second wave of Reclamation construction began in the late 1920s, the agency entered its golden era of construction during Franklin D. Roosevelt's New Deal (1933 to 1942). Large-scale construction for the Grand Coulee and Boulder dams, the Columbia Basin Project, and the Colorado-Big Thompson Project dwarfed earlier work. The CVP in California planned to irrigate nearly 3 million acres, and the Colorado Big Thompson Project transported water across the Continental Divide under the Rocky Mountains National Park. The engineering demands were massive and numerous based on the scale of land transformation being wrought by Reclamation.

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[161] Lila Knight, *A Field Guide to Irrigation in the Lower Rio Grande Valley,* a report prepared for the Texas Department of Transportation, Environmental Affairs Division (Buda, Texas: Knight & Associates, 2009), 223.

[162] Rowley, *Origins and Growth*, 17.

During this period, Reclamation completed Grand Coulee Dam in 1942. At 550 feet high and 5,223 feet long at the time of its construction, it was the largest dam on earth.[163] Though the dam was one of the most complicated engineering feats completed by the United States, the irrigation features that were planned were nearly as impressive and initially proposed to bring water to a planned one million acres in the Columbia Basin. However, construction of the irrigation features was not initiated until after World War II, as progress on nearly all reclamation projects was postponed due to the war. After the war, Reclamation completed an extensive array of irrigation works in the basin, including several equalizing reservoirs, dozens of pumping plants, and hundreds of miles of lined and unlined main and lateral canals.[164] Even with that infrastructure, a substantial portion of the project was never completed due to the lack of farming interest. The number of farmers attracted to the project fell far short of the projected number needed to make the project successful.[165]

New Deal funding allowed the expansion of several existing projects, such as the Kendrick Project (first known as the Casper-Alcova Project) on the North Platt River in Wyoming, among many others. The Kendrick Project, initially estimated at $20 million, involved two dams and reservoirs, two powerplants, six substations, and main canals, laterals, and ditches to irrigate 66,000 acres. Like most New Deal projects, the main canals and laterals were concrete lined. One, the 59-mile-long main Casper Canal, included six concrete-lined tunnels, carrying water at 1,200 feet per second at a depth of nearly 10 feet.

Irrigation projects were not solely for agricultural production. Arizona residents soon found that water from irrigation could be used for municipal needs. Reclamation engineers developed a method of funneling water from the Verde River to Phoenix as early as the end of World War I by using a wooden pipe. By 1940, the domestic water system made the area a primary defense establishment, which was timely for the United States' entry into World War II, and "forecasted the post-war residential development" that emerged afterward.[166]

In the earliest years of federal irrigation, nearly all the Reclamation projects undertaken were abandoned, unsuccessful, private or state efforts. Usually, the local financing ran out and the Federal Government assumed ownership, planning, and construction to complete the work. In other cases, the projects were so complex that promoters showed little or no interest in them. Large-scale funding and large-scale engineering were the answers, and only the Federal Government could supply both.[167]

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[163] Bureau of Reclamation, "Grand Coulee Dam Statistics and Facts," available at: https://www.usbr.gov/pn/grandcoulee/pubs/factsheet.pdf [accessed February 2023].

[164] Simonds, "Columbia Basin Project," 30-31.

[165] Gahan and Rowley, *Developing to Managing Water*, 682.

[166] Steeley and Gilpin, *Lifeline to the Desert*, 2.

[167] Ibid., 4.

Figure 3.14 Large, lined canal of the Columbia River Irrigation project taken in the 1940s as it was being constructed.[168]

Table 3.3 Listing of Reclamation projects initiated or expanded during the 1930s.

Project Name	Location of Project	Year initiated	Canals and Laterals	Other Key Irrigation Elements	Status Today
Boulder Canyon Project	Arizona and California	1934	Imperial Diversion Dam and desilting works; All American Canal (80 miles) and the Coachella Canal [lateral] (123 miles)		
Parker Davis Project	Arizona and California	1934	Parker Diversion Dam and desilting works; Colorado River Aquaduct.		

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[168] Rufus Woods, photographer, Rufus Woods Papers and Photograph Collection located at the Central Washington University Library Ellensburg, Washington. Available at https://digitalcommons.cwu.edu/rufus_woods/.

Project Name	Location of Project	Year initiated	Canals and Laterals	Other Key Irrigation Elements	Status Today
Uncompahgre Project	Colorado	1937 completed	Taylor Park Dam	Other improvements included enlargement, lining, and smoothing portions of the Gunnison Tunnel, constructing concrete and steel structures to replace some of the worn-out wooden structures in the privately constructed irrigation systems, relining portions of the canals; constructing a drainage system to relieve and prevent waterlogging of land.	see earlier summation
Humboldt Project	Nevada	1935	Rye Patch Dam	No irrigation, just dam and reservoir. Irrigation works were privately built	
Carlsbad Project	New Mexico	1936	Sumner Dam; East Canal (20 miles long) and Southern Main Canals (21 miles long)		Today 137 miles of laterals with 95 miles lined and balance unlined. 41 miles of main canal with 9 miles lined and 32 miles of drains
Rio Grande Project	New Mexico and Texas	1936	Caballo Dam	Today physical features include: 6 diversion dams, 139 miles of canals, 457 miles of laterals, 465 miles of drains, and a hydroelectric powerplant. Dam was predominately a flood control project.	Dam is a regulating facility to allow more efficient production of the Elephant Butte Powerplant upstream.
Vale Project	Oregon	1926/1938	Agency Valley Dam and Harper Diversion Dam; Vale Main Canal is 74 miles long with three concrete-lined tunnels; Bully Creek Extension of project included dam and feeder canal.	Irrigation laterals and canals were reworked and completed in 1935. Drainage canals were 57 miles. Little Valley Siphon puts water in Little Valley Canal, lateral of the main canal. Bully Creek Feeder Canal and Siphon	Note that some unusual settlement agreements were made with BOR and districts to discourage speculators. May be work looking at.
Burnt River Project	Oregon	1935	Unity Dam	BOR handles only the dam. Irrigation is by local districts. No BOR work other than the storage dam.	

Project Name	Location of Project	Year initiated	Canals and Laterals	Other Key Irrigation Elements	Status Today
Hyrum Project	Utah	1933	Hyrum Dam and Hyrum Flume; Hyrum Mendon Canal (14 miles long); Hyrum Feeder Canal (unlined);	Hyrum Wasteway; Hyrm Pump plant penstock; Hyrum siphon (1000'); Hyram Mendons Canal has several flumes	Completed work in 1936 is the same today with improvements such as more concrete lining and also work on the canal flumes.
Moon Lake Project	Utah	1935	Moon Lake Dam; Yellowstone and Duchesne Feeder canals.	project only involved limited BOR work on storage dam and feeder canals.	Project remains the same. CCC built large sections of the Feeder Canals and Midview Dam
Ogden River Project	Utah	1934	Pine View Dam; Ogden-Brigham Canal (non-irrigation canal--water supply to Ogden Utah) 24.2 miles; South Ogden Highline Canal (5.2 miles of concrete-lined canal and 35-mile of pressure pipe);	Ogden Canyon Conduit (Siphon); both canals contain trash racks to prevent debris from entering the system. The Ogden Brigham Canal contains a Venturi Flume at the head of the canal. Equalizing reservoirs along the Highline canal.	CCC workers work on the project from 1935 on
Riverton Project	Wyoming	1920/1936	Bull Lake Dam and Wind River Diversion Dam; Wyoming Canal (62.4 miles long) and Pilot Canal (38.2 miles)	Riverton Wastesway Additional new canals and laterals to serve new lands. Laborers called camp "Shacktown" Some work done by the CCC.	(125 lined balance unlined). Drainage system 644 miles of drains (382 miles closed pipes) Pavilion Laborers Camp near Riverton.
Kendrick Project	Wyoming	1935	Alcova Dam and Seminoe Dam and Casper Canal (59 miles long)	Irrigation not completed until 1946. Siphons, highway and farm road bridges and many additional features and measuring devices- most not built until after WW II.	190 miles of laterals and sublaterals; 41 miles of drains.
Upper Colorado Basin Project	Colorado	1938	Fruitgrowers Dam	No irrigation, just dam and reservoir.	
Columbia River Project	Washington	1932	Only production was the Grand Coulee Dam and Lake Franklin D. Roosevelt, and the Hydroelectric power plant.	No irrigation prior to 1945 due to World War II.	

3.6.5 Post War Project Engineering (1945-1980)

Constructed by the Bureau of Reclamation, the CVP represented the largest reclamation project in the United States, eventually irrigating more than 3,000,000 acres, or one sixth of the agency's total 18,000,000 available acres. The engineering of water storage and distribution represented some of the most significant and difficult efforts in the U.S. Although work began on the Contra Costa Canal in 1937, most work on the project was halted until World War II's conclusion in 1945. Construction of the Shasta Dam was allowed to continue throughout the war, as it was to supply hydroelectric power for the war's production effort. The project was primarily an irrigation project, but like many projects after the 1930s, it contained authorizations for hydroelectric power, water supply, flood control, navigation on the Sacramento River, recreation, and fish and wildlife preservation.[169] The project was divided into eight divisions,[170] some of which are further divided into units. Engineers had to grapple with all the terrain changes, water needs, long range movement of large amounts of water, and thousands of local users. Additionally, though most distribution was gravity-fed, allocation required pumping stations and pumps to move the water over, around, and through hillier terrain. The project was so complex that water removed from the San Joaquin River for the Friant-Kern Canal had to be placed back into the river from the Sacramento River via the Delta-Mendota Canal.

Figure 3.15 Contra Costa Canal. Lining operations on canal, 1948 (courtesy of Bureau of Reclamation).

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[169] U.S. Department of the Interior, Water and Power Resources Service, *Project Data* (Denver, Colorado: United States Government Printing Office, 1981), 168-169.

[170] Those divisions were the Pit River Division, American River Division, Delta Division, Friant Division, Sacramento River Division, San Felipe Division, West San Joaquin Division, and the Shasta/Trinity River Division.

As just one example within the system, the Friant-Kern Canal, completed in 1951, conveys water from the Friant Dam on the San Joaquin River to the Kern River southwest of Bakersfield, California. The canal stretches nearly the entire length of the Central Valley, measuring approximately 450 miles. It was originally planned to be concrete lined, but up to 25 miles of it was left earthen.[171] It was built as a side hill canal that had to cross at least three wide stream valleys and traverse through clay soils with substantial rock outcroppings until it cut through more sandy soil. Additionally, near Kings River the canal had to cut through a ridge that rose 85 feet above the canal bed.[172] Other obstacles such as the Kings Riverbed and rail lines demanded such adaptations as a 24-foot 3-inch tube siphon to carry the water 5 feet below the riverbed and underneath the rail line. More than 500 separate and varied control or conveyance structures had to be planned into the canal. These included such features as overchutes, drainage inlets, turnouts, and irrigation crossings, not to mention the engineers had to navigate road crossings and various utility lines.[173] In perspective, it was only a single part of the massive system.

Figure 3.16 Friant-Kern Canal, 1962 (courtesy of Bureau of Reclamation).

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[171] Wilbur A. Dexheimer, Grant Bloodgood, and Fred A. Seaton, *Friant-Kern Canal Technical Record of Design and Construction* (Denver, Colorado: Bureau of Reclamation, 1958), 1-2.

[172] Dexheimer, Bloodgood, and Seaton, *Canal Technical Record*, 1.

[173] Ibid., 3.

In 1946, Reclamation assumed control of the Lewiston Orchard Project in Idaho. This project provides an example of the complexity of irrigation projects. Reclamation engineers were required to rehabilitate an older, failing irrigation system along the Snake River and Clearwater Creek that provided water to 4,000 acres around the town of Lewiston, Idaho. It involved the replacement of an older diversion dam with a new rock-filled structure, and the replacement of 7,100 feet of a dilapidated wooden flume with a new 30-inch lockjoint concrete piping flume with a self-cleaning concrete sand trap. A second flume was also replaced with a 42-inch concrete pipe siphon. The project involved the replacement of the main irrigation distribution lines with new spiral welded, coal tar enamel coated steel pipe, along with sections that were to be replaced with galvanized piping. Since the project also had a municipal water authorization, a new water treatment plant distribution system was designed that included cement-asbestos and galvanized piping. Complicating the work, the $2.5-million-dollar project was fast-tracked for the upcoming 1949 spring planting season.[174] Part of the expedited solution was the assembly of a temporary pipe-enameling plant next to the project.

Figure 3.17 Lewiston Orchards Project main canal wooden flume being replaced with a concrete flume in 1948.[175]

The Columbia Basin Project also illustrated several complicated engineering feats faced by Reclamation after World War II. In 1946, engineers designed the bifurcation of the Main Canal into a West Canal and an East Low Canal, both massive distribution lines in themselves. The 88-mile long West Canal took nine

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[174] Arthur V. Werner, *Annual Project History—Calendar Years 1947 and 1948—Lewiston Orchards Project*, (Denver, Colorado: Bureau of Reclamation, 1950), 4-5 and 7-8.

[175] Ibid., 13.

years to complete. Its construction included both concrete- and earth-lined sections, a 12,820-foot-long (nearly 2.5 miles) Soap Lake Siphon, the 9,150-foot-long Frenchman's Tunnel, and two additional complex siphons. The East Low Canal began at the bifurcation and traveled 87 miles and included three siphons and a large wasteway. The canal components were both concrete-lined and unlined.[176]

In 1949, engineers added the Soap Lake Siphon, a unique structure, to the project. The 12,900-foot-long pipe was 25 feet in diameter. It was constructed to move 5,100 cubic feet of water per second though the pipe. It included steel-lined concrete pipe and steel plate pipe, both mounted on steel ring girders, steel bearings, and reinforced concrete footers. Part of the siphon was buried under a roadway. It had to include a 60-foot gravel trap at the headgate of the siphon, a concrete headgate, and concrete inlet and outlet piping.

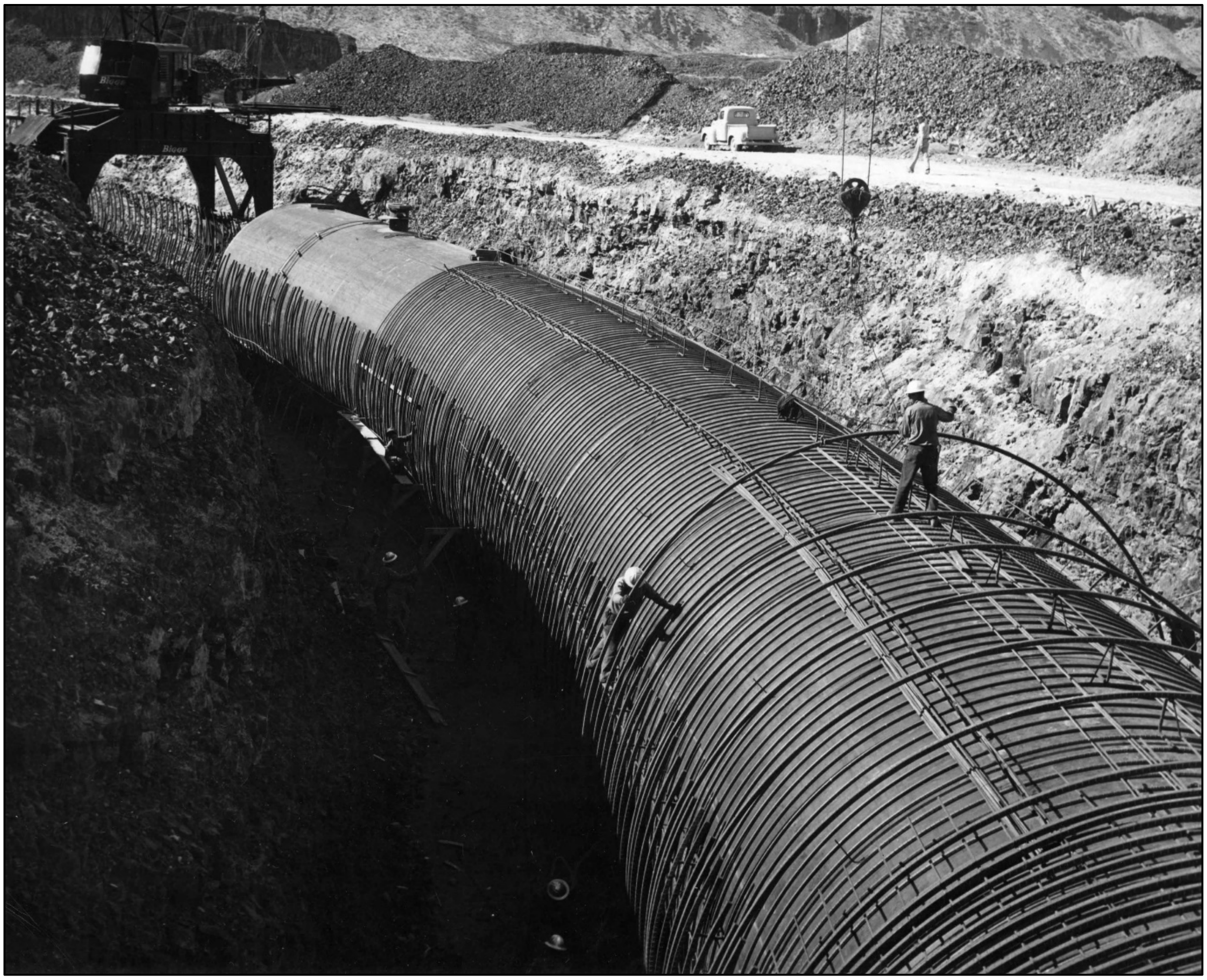

Figure 3.18 A portion of the Soap Lake Siphon steel piping being constructed, along with the reinforcing steel for the concrete portion.[177]

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[176] Simonds, "Columbia Basin Project," 41-43.

[177] H. E. Foss, "Columbia River Basin Project: Dam Construction in the Pacific Northwest: Soap Lake Siphon." 1949. Historical Photographs of the Columbia Basin Project and other dams constructed in the Pacific Northwest, 1933-1965. University of Idaho Library. Online photograph collection, https://www.lib.uidaho.edu/digital/crbp/items/crbp1043.html [accessed January 2023].

In Nebraska, the Bostwick Division Project was authorized in 1944 and construction began in 1948. The project primarily involved irrigating 104,000 acres on the Republican River. Due to the propensity for the Republican River to flood its bottomlands, the Bostwick Division Project contains flood control. The project is divided into the Franklin Unit and the Superior Courtland Unit. The Superior Courtland Unit begins at the Superior Courtland Diversion Dam on the Republican River. The dam is a concrete ogee weir that is 8 feet in height. It pulls water for the Superior Canal that stretches 30 miles eastward along the valley to the Nebraska/Kansas line. By 1957, engineers installed a 6-by-10-foot radial gate in the headworks to pull the 139 cubic feet per second of water necessary to irrigate 5,863 acres. The Superior Canal is a blend of piping, rip rap, and unlined canal. The Superior Lateral contains a number of siphons that were difficult to install and had to be reworked several times. Work was not completed on these until 1968.[178]

A second canal system also begins at the Superior Courtland Diversion Dam. On the south side of the dam, the Courtland Canal, also completed by 1957, contains five radial gates that funnel water at 751 cubic feet per second to serve 63,000 acres, most of it in Kansas. The Courtland Canal and its related systems are 114 miles in length and cross into Kansas at the southeast corner of the Nebraska/Kansas border. The canal has five primary laterals that serve the farmers, including the North, Ridge, White Rock, Miller, White Rock Extension, and Courtland West canals. This project contains four pumping stations to lift water from the canals to the laterals. Other features include the Scandia Diversion Dam and Canal, and the Hardy Canal. The project took eight years to complete. The project begins at the Superior Courtland Diversion Dam and stretches 50 miles to a point 3 miles north of Norway, Colorado.

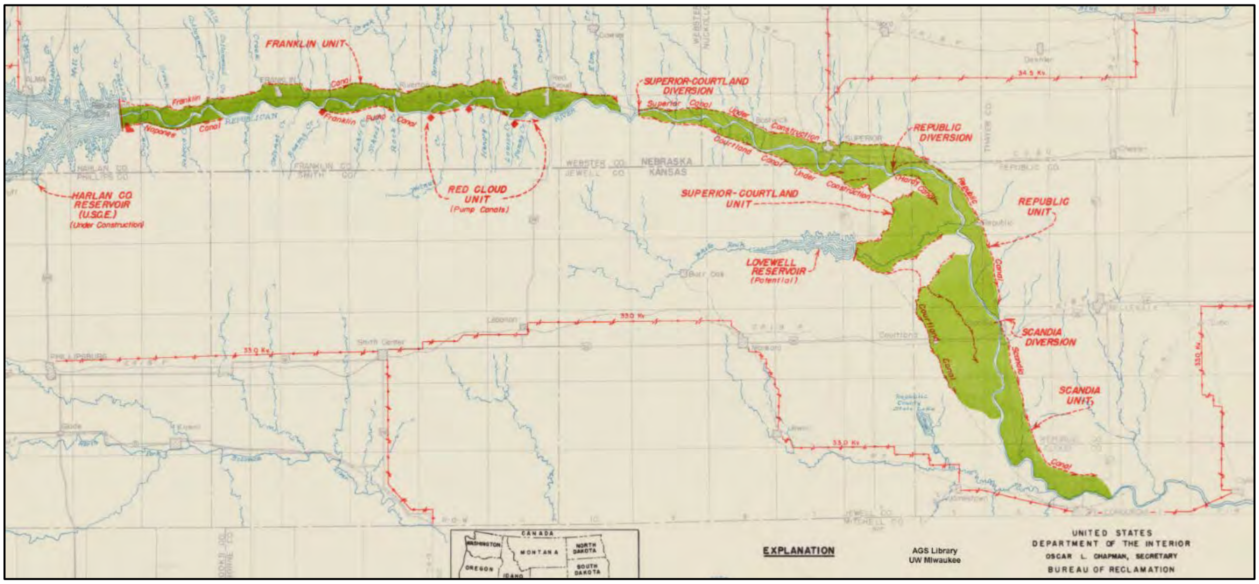

Figure 3.19 Map of the Bostick Division Project in Nebraska and Kansas.[179]

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[178] Keven E. Rucker, "Bostwick Division: Pick-Sloan Missouri Basin Program" (Denver: Bureau of Reclamation History Program, 2009), 24.

[179] University of Milwaukee online map collections, https://collections.lib.uwm.edu/digital/collection/ [accessed December 2022].

3.7 Special Challenges

While some engineering challenges could be anticipated through a study of geography, topography, and hydrology, or simply through previous experience, sometimes the agency encountered random problems. A number of unique problems were addressed by engineers, such as the water flow issue that occurred at the end of flumes, building up silt and sand. Three issues are described below as examples of these types of challenges.

3.7.1 The Yuma Siphon

The Yuma Siphon represented a unique answer to the problem of getting sufficient water to two states, California and Arizona, from the Colorado River at the same time. In 1912, Reclamation engineers developed the Yuma Siphon on the Yuma Project to deliver water from the Colorado River to the California side of the river opposite the town of Yuma, Arizona. Excess water was transported via the siphon from the California side of the river underneath the Colorado River to the Arizona side at the town of Yuma. At Yuma, the siphon bifurcated and delivered water to the East and West Main Canals in the Yuma Valley for irrigation on the Arizona side of the river.[180] The siphon ranged from 17-feet in diameter on the California side to 23-feet in diameter on the Arizona side. It was 1,000 feet in length and could move water at 1,400 cubic feet per second to irrigate fields on both sides of the river. It cost $677,000 to build and opened in 1912. It became the shortest route for moving water where a flume was not possible and permitted the continuous flow of the river southward. At the time of its construction, it was considered an engineering marvel.[181]

3.7.2 Ogden Canyon Conduit (siphon)

Reclamation engineers began construction of the 5-mile-long Ogden Canyon Conduit in 1935. The Reclamation history states that the conduit consisted of a 75-inch-diameter wood stave pipeline delivering water to the Pioneer Powerplant and the irrigation canals near Ogden City in Box Elder County, Utah. The wood stave pipeline was comprised of wood slats bound together with steel bands. Removal of an older pipeline and the excavation for the new pipe began in the summer of 1935, and the placement of the new pipe was finished before the end of that same year. Work continued through the winter, as weather permitted. Falling rock during the winter of 1935/1936 and spring floods damaged the pipe, necessitating repairs. Workers from the Huntsville CCC camp aided in connecting the pipe to one of the systems` tunnels. Completion of the connection on November 20, 1935, finished the conduit construction. The conduit initiates the Ogden-Brigham Main Canal that starts its 25-mile journey to Brigham City at the connection of the wood stave pipe of the Ogden Canyon Conduit and the steel penstock pipes of Pioneer Powerplant.[182]

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[180] Bureau of Reclamation, "Century of Cooperation."

[181] Davis, *Irrigation Works*, 44-47.

[182] Bureau of Reclamation, "Ogden River Project, Construction," https://www.usbr.gov/projects/index.php?id=371 [accessed February 2023].

Figure 3.20 Ogden River Project. Ogden Canyon Conduit, 1935 (courtesy of Bureau of Reclamation).

3.7.3 Water Flow Issues

In the post-war development years, Reclamation engineers coped with several problems, an example of which is water flow issues. In a study published in 1969, Skogerboe et al. reviewed all forms of small water management structures. They observed the kinds of problems and hydrological enigmas that impacted water flow faced by the Reclamation engineers, even after more than 60 years of experience. For example, one kind of engineering problem faced by the engineers involved silt build-up at the downstream end of a flume. This offsets the true amount of discharge, causing an under-evaluation of used water. The 1969 report suggested that the effect of the slope in the free flow and submerged flow ratings of several types of flumes should be determined. The report recommended that time, material transportation costs, and maintenance costs could be saved by installing pre-cast concrete measuring devices instead of cast-in-place devices.[183]

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[183] Gaylord B. Skogerboe, Wynn R. Walker, Brent B. Hacking, Lloyd H. Austin, "Analysis of Small Water Management Structures in Irrigation Distribution Systems (1969)," Reports of the Utah Water Research Laboratory, #78, 21-24. https://digitalcommons.use.edu/water_rep/78 [accessed August 2023].

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4.0 Components of Water Conveyance Systems

4.1 Overview

This chapter presents the typical structures found within a Reclamation conveyance system.[193] Based on the scope of work, and in consideration of the archival research, the structures are divided into six categories typical of the normal division of elements of an irrigation system. Those primary components or structures include:

> **Diversion Structures**, including diversion dams, weirs, pumping stations, or pump houses.
>
> **Conduit Structures**, including main canals and laterals, wasteways or drains, flumes, siphons, piping systems, tunnels, and spillways.
>
> **Flow Control Devices**, including headgates, checks, turnouts, distribution boxes, drops, and chutes.
>
> **Measuring Devices**, including Parshall flumes, modified Parshall flumes, stilling wells, measurement weirs, weir boxes, and flow meters or gauges.
>
> **Cleansing Devices**, including trash racks and sand traps.
>
> **Associated Structures**, including habitation sites; hydroelectric plants, substations, and lines; administration and operations buildings; bridges; treatment plants; and fish passages.

Early Reclamation projects made extensive use of wood, especially in small structures such as turnouts, measuring devices, and flumes. Though concrete was always an option for Reclamation, wood was a primary construction material during the agency's first three decades. Generally, Reclamation transitioned from wood to steel and concrete for many applications in the 1930s and 1940s. After World War II, Reclamation transitioned from steel to concrete, which became the prominent material for irrigation structures through the present day. In more rigorous engineering such as piping, flumes, and siphons, Reclamation uses even stronger prestressed concrete. Most wood diversion dams, headgates, weirs, pipes, turnouts, and other features have been replaced over time with concrete; older cast iron has been replaced with steel, other metals, or concrete. However, many original components survive and are identified in historic archaeological or architectural surveys.

Two examples from Idaho and Nebraska projects illustrate the replacement of wooden features with concrete versions. In 1948, Reclamation replaced the former wooden flume from the Sweetwater Diversion Dam on the Lewiston Orchard Project in Idaho with a concrete flume. As time progressed, much larger projects were attempted. In the late 1970s and early 1980s, Reclamation replaced 109 open ditch laterals and sublaterals on the Cambridge Frenchman Project in Nebraska with concrete piping. Reclamation has determined that, if cost efficient, a good "concrete diversion structure should be designed and installed to save annual maintenance and provide a permanent structure."[194]

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[193] The scope of work for this project specifically excluded main dams and associated features such as power houses. Those structures are covered extensively, with guidance for NRHP consideration, in Billington, Jackson, and Melosi, *Large Federal Dams*).

[194] Dusenberry and Monson, *Irrigation Structures*, 12.

Since the early twenty-first century, Reclamation has increasingly used high-grade plastics for some piping and applications. Little of this work is more than 50 years old and is not covered in this study. Also, digitalization and automation of many Reclamation systems continues at a rapid pace. Like the use of plastics, this study does not review the digitalization of irrigation structures, as those components are not yet 50 years of age.

This study looked at all the components of the Reclamation conveyance system. However, many other structures may be observed during a survey of a Reclamation system. Different features frequently noted by observers are presented in Sections 4.7 to 4.13. These items are not directly part of the conveyance system nor of this study but are presented for the benefit of the researcher.

4.2 Diversion Structures

4.2.1 Diversion Dams

Diversion Dams are built into the main channel of the creek, river, or canal from which water for the system is drawn. They divert the desired amount of water into the main canal for the system, and at the same time, permit surplus or high water to continue downstream without damage to the dam or canal. Early dams were simple rocks, or rocks and brush material, piled across a creek or river. Later, wood, or broken rock and rubble, with concrete diversion dams were built to withstand floods and high water. Most Reclamation projects involved rubble rock, concrete, or some form of reinforced concrete dam, though some early ones may have been constructed of wood. Most restrict water flow and force it either over the top of the dam or into a gated feeder area for withdrawal into the canal. The types of dams used in Reclamation projects are listed below.

4.2.1.1 Concrete Rubble Diversion Dam

This gravity ogee-type dam is built of rubble concrete and permits high water to flow over the top of the dam. It also contains a sluiceway and intake structure to funnel water into the main canal. These can be large or small. An ogee spillway dam is a modified drop spillway and is used in rigid dams like diversion dams. The crest of the spillway is shaped to conform to the lower nappe of a water sheet flowing over an aerated, sharp, crested weir. The weir is added to still the water as it flows over the dam.[195]

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[195] INDWRDAM Water Diplomacy, "Types of Spillways and Classification," https://inwrdam.net/types-of-spillways-and-classification/ [accessed January 2023].

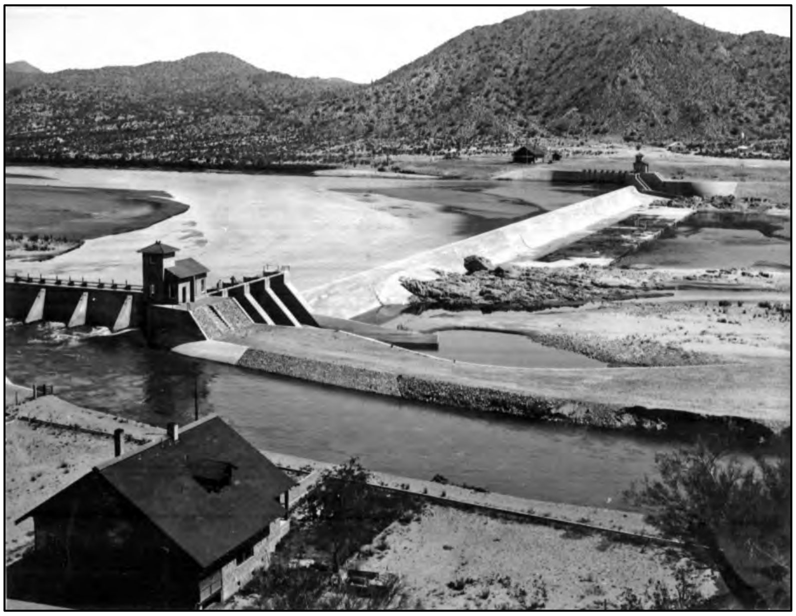

Figure 4.1 Granite Reef Dam, looking southeast from the north side, 1910 (courtesy of Bureau of Reclamation).

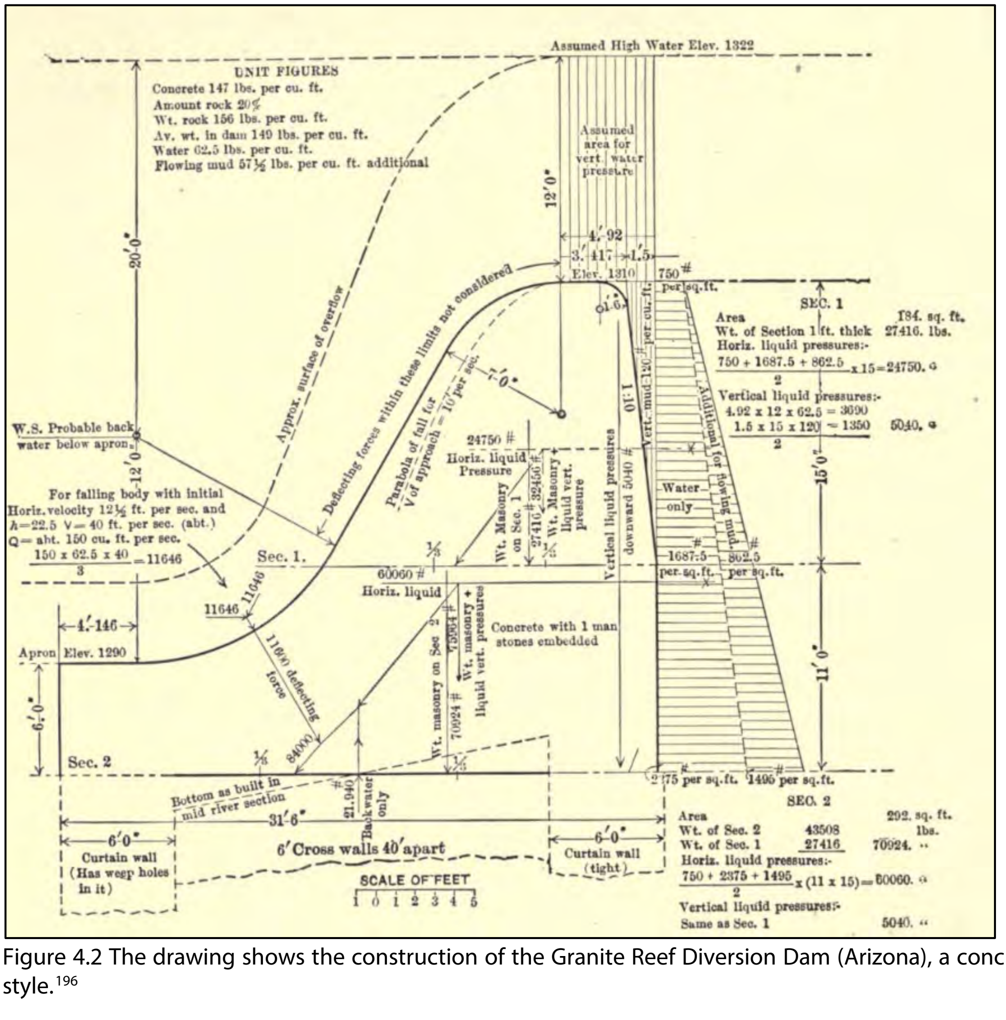

Figure 4.2 The drawing shows the construction of the Granite Reef Diversion Dam (Arizona), a concrete rubble construction style.[196]

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[196] Davis, *Irrigation Works*, 22.

4.2.1.2 Solid Reinforced Concrete Diversion Dam

These diversion dams are constructed of reinforced steel concrete. Like all Reclamation diversion dams, they divert water from the primary source into a main canal. The photo below shows the East Park Feed Canal Diversion Dam in the Orland Project, one example of these larger structures.

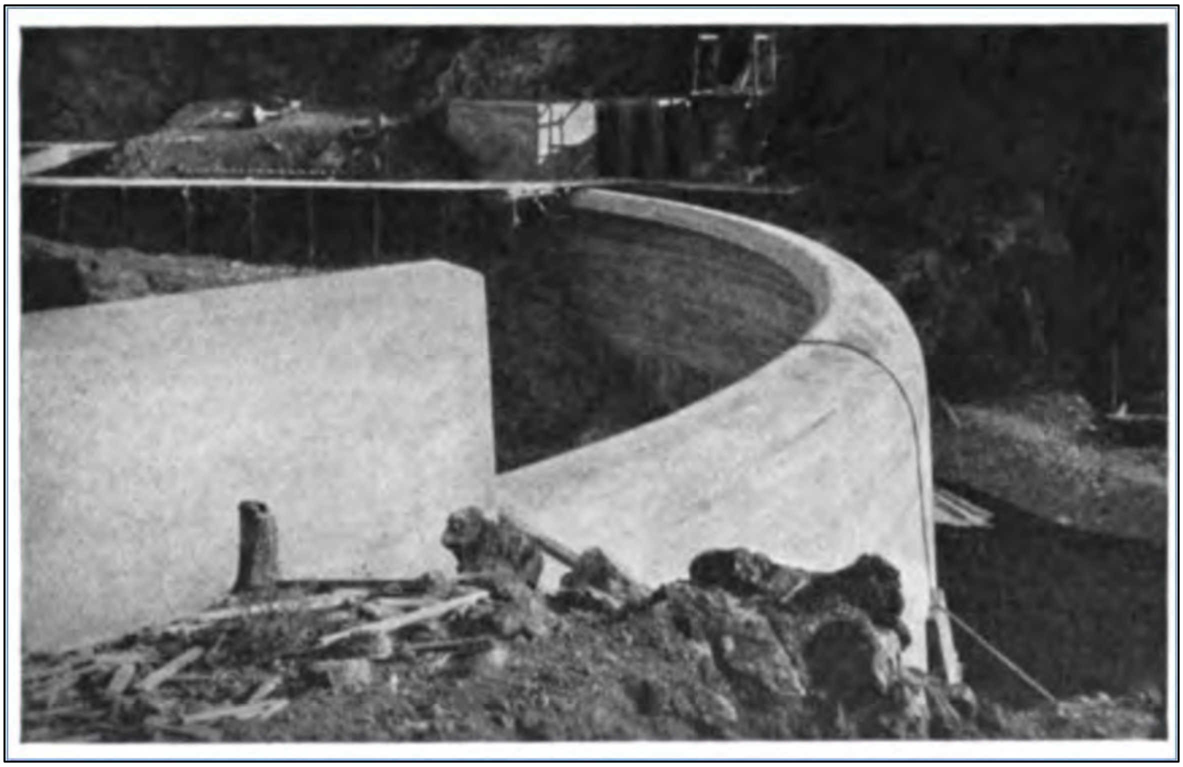

Figure 4.3 East Park Feed Canal Diversion Dam (California) is 100 feet length with a 155 feet crest length, a height of 44 feet. It is 6.5 feet thick at the base and 3.5 feet at the height. It is curved downstream, has headgates for the canal which also has an overflow weir to dispose of surplus water.[197]

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[197] Davis, *Irrigation Works*, 58.

4.2.1.3 Solid Reinforced Concrete Diversion Dam Topped with Movable Overflow Extensions

This type of diversion dam is solid reinforced concrete but has a movable roller extension that can be temporarily raised or lowered to increase or restrict the overflow.

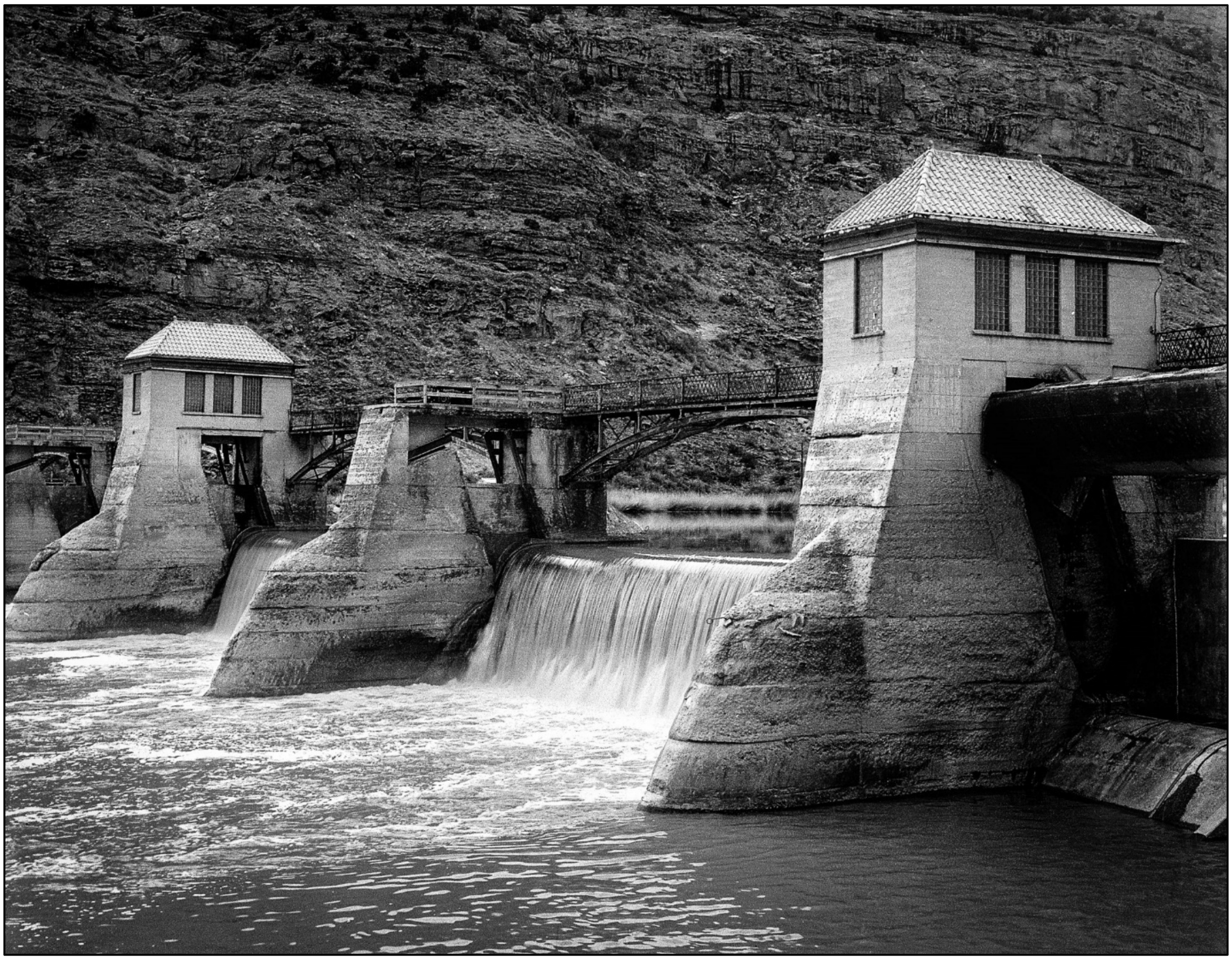

Figure 4.4 Grand Valley Diversion Dam, Grand Valley Project (Colorado). Photo shows the roller portion in place.[198]

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[198] Kate Ryan, "Concerted efforts and partnerships that protect a stretch of river." Colorado Water Trust, June 3, 2020, https://coloradowatertrust.org/2020/06/concerted-efforts-and-partnerships-that-protect-a-stretch-of-river [accessed January 2023].

4.2.1.4 Wooden Pile and Bulkhead Diversion Dam

This type of diversion dam includes a double row of wooden piles driven into the base of the river and attached on both sides with a wooden bulkhead that stretches to about 4 to 10 feet from the top of the water. This style of dam typically includes an apron of large rock on the down-stream side.[199]

Figure 4.5 A wooden pile and bulkhead on the Blue River in the Colorado—Big Thompson Project, Colorado (courtesy of Bureau of Reclamation).

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[199] See "Miller Buttes Diversion Dam, Orland Project", California" in Davis, *Irrigation Works*, 59-60.

4.2.1.5 Rock and Timber Weir Diversion Dam

This type of dam is a rock-filled pile decked with timber to raise the water in order to flow into a canal. Piles (usually round) are driven to attach the decking. The water rises until it tops the dam and flows gently into the canal. These were usually built on early Reclamation Service Projects and were later replaced with concrete-based dams.

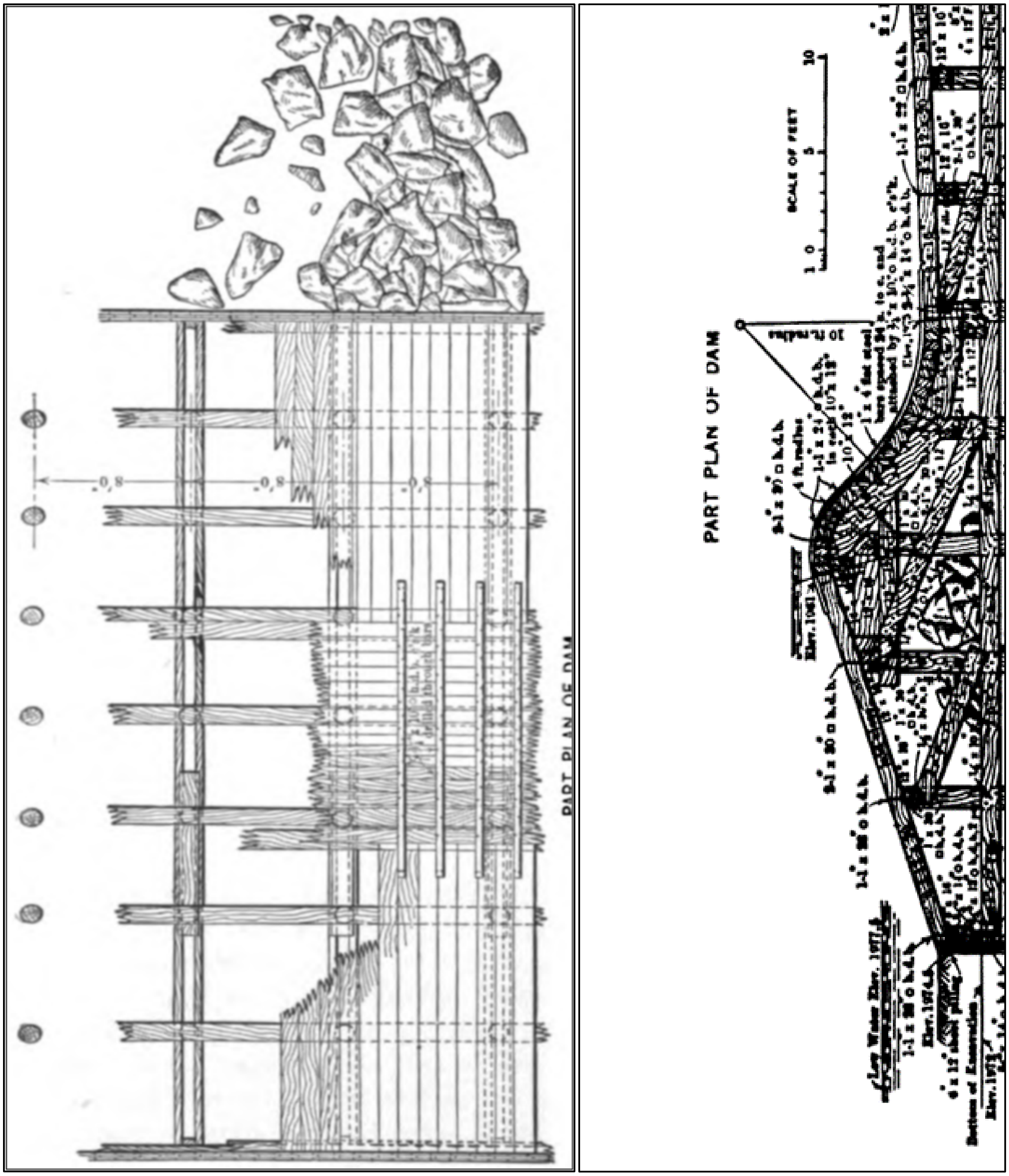

Figure 4.6 This drawing shows the two views of the rock and timber Lower Yellowstone Diversion Dam, Lower Yellowstone Project (North Dakota).[200]

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[200] Davis, *Irrigation Works,* 164.

4.2.1.6 Rock Weir Diversion Dam

This is a very simple method of diverting water by creating a rock pile high enough to force water to rise and be safely diverted into a ditch or canal to funnel it into fields. The authors could not find any examples of this style of dam built by Reclamation; it was a style used in early pre-Reclamation construction. An example of one in Colorado is shown below.

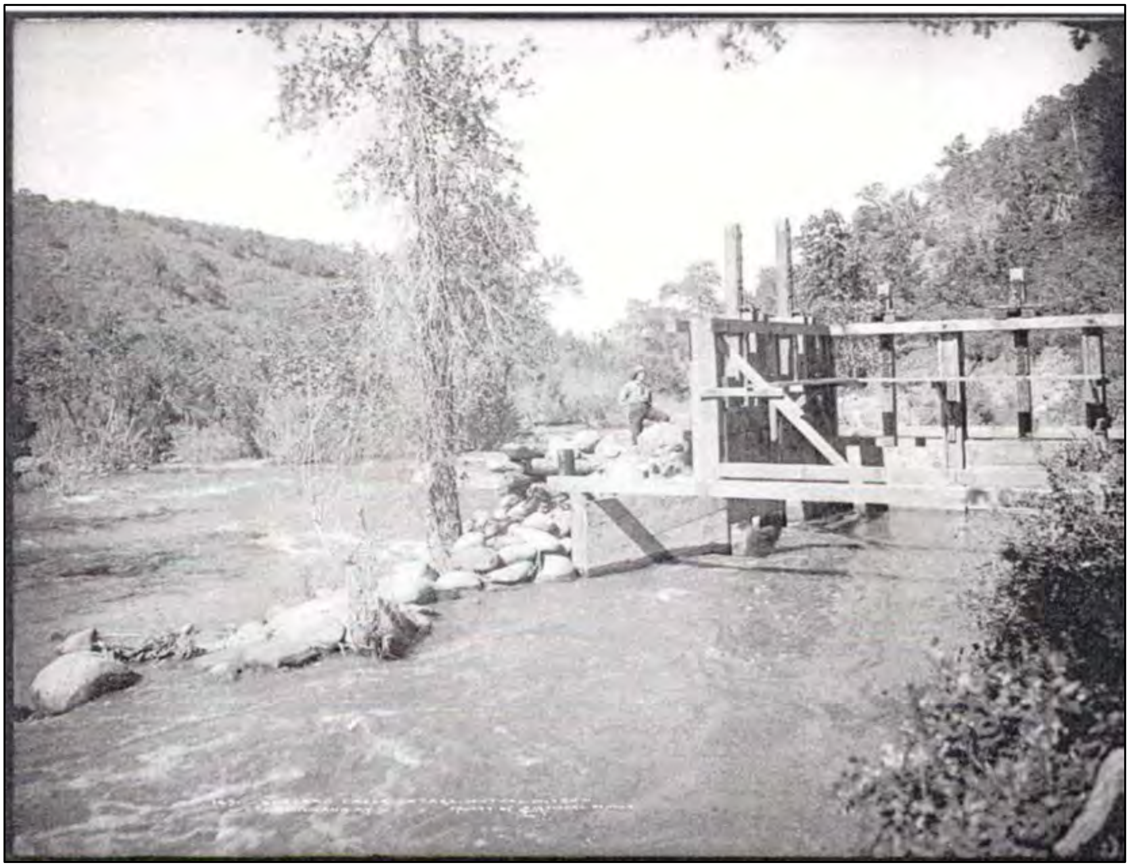

Figure 4.7 In the picture above, the temporary rubble in the stream is diverting the water into the headgate in an early Colorado irrigation effort (Colorado).[201]

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[201] Holleran, *Historic Context*, 57.

4.2.1.7 Rubble with Ogee Spillway and Laid Stone Facing Diversion Dam

This style of diversion dam features random rubble laid in Portland cement, but with a laid stone facing with an ogee overflow spillway. These were usually built on gravel and rock boulders.[202]

Figure 4.8 Boise River Diversion Dam and Powerhouse (courtesy of Bureau of Reclamation).

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[202] Davis, *Irrigation Works*, 97.

4.2.1.8 Brush and Rock Diversion Dam

This dam is always used with local materials, rock, brush, and logs. It is inexpensive and rarely used by Reclamation engineers due to its maintenance upkeep. The authors found no current examples of a brush and rock diversion dam in Reclamation projects. It is constructed of alternate layers of rocks and willows, backfilled with soil, and stepped backwards with each level to provide a stairway effect to the spillway. These are usually seen as remnants of earlier irrigation efforts where Reclamation assumed the project from private owners.

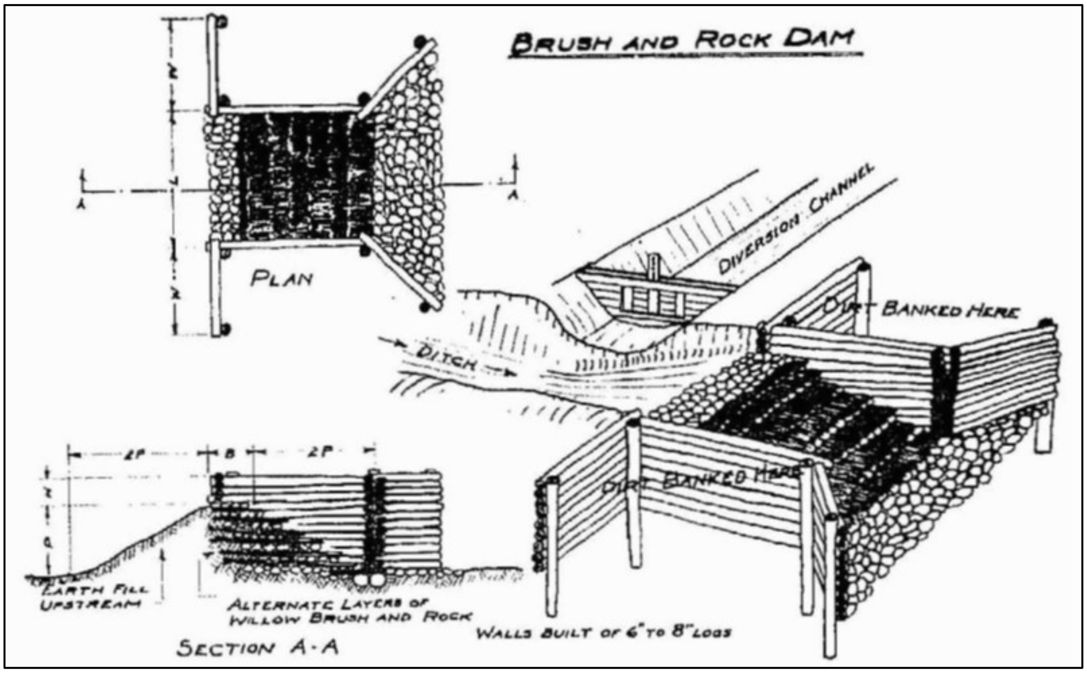

Figure 4.9 The drawing shows three views of this style diversion dam (Montana).[203]

4.2.2 Weirs

Weirs are "used to control grade or water level in rivers or canals, for offtakes [diversion canals], flow gauging, amenity, navigation, etc." [204] There are four different styles of these structures, including orthogonal, curved, diagonal, or labyrinth. Each type of weir contains either movable gates, a notched dam, or a solid dam. The solid and notched dams were usually lower in the water. They allowed water to rise behind it, be channeled into the diversion canal, and the excess water flowed over the top or through the notch and downstream.

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[203] Dusenberry and Monson, *Irrigation Structures*, 10.

[204] T. Crawford and J. D. Gosden, "River and Canal Structures," Chapter 11 in Binnie Black & Veatch, *Fluvial Design Guide, R&D Technical Report W109* (Surrey [UK]: Grosvenor House, 2009), available at: https://assets.publishing.service.gov.uk/media/602ea199d3bf7f7220fe10b8/_Fluvial_Design_Guide_Technical_Report.pdf [accessed December 2022].

4.2.2.1 Simple, Masonry (Concrete) Canal Weirs

These weirs come in various sizes and shapes. The example below is a concrete notched weir found on the Belle Fourche Project (South Dakota).[205]

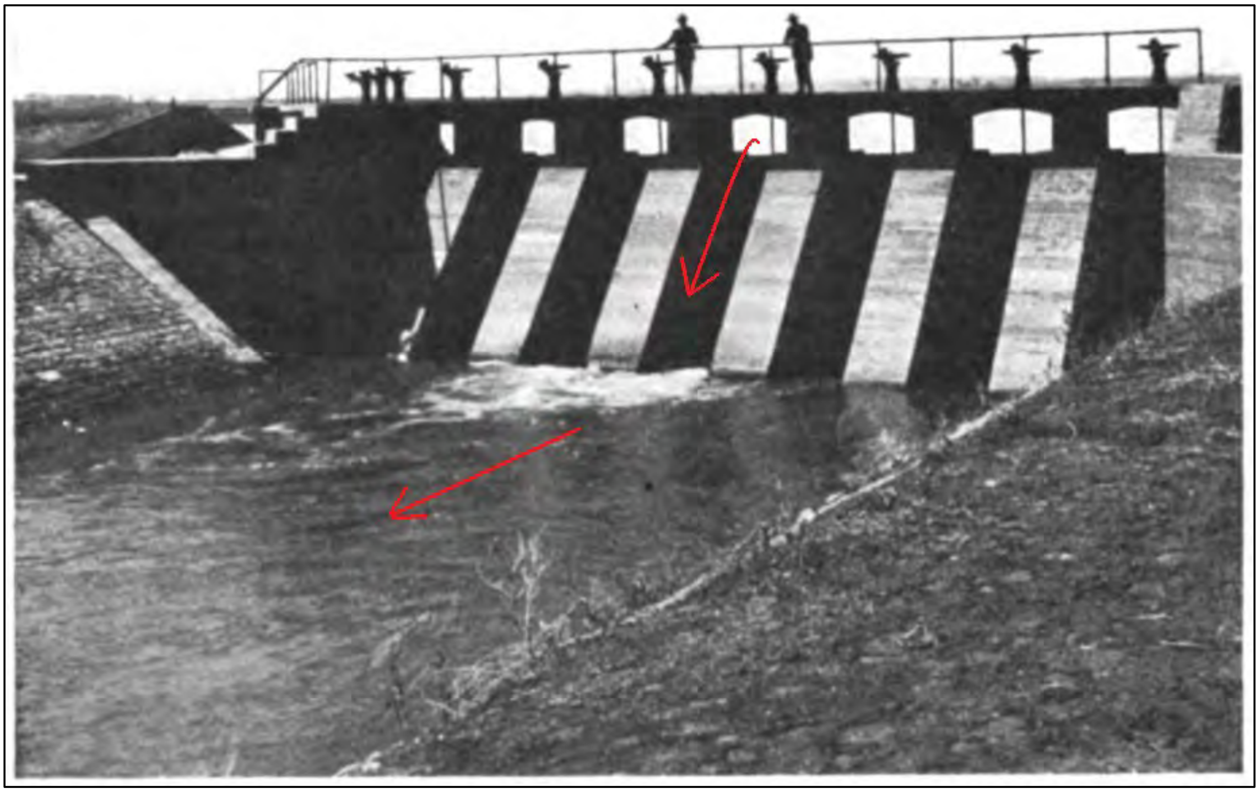

Figure 4.10 An example of a large concrete notched weir is found on the Belle Fourche Feeder Canal, Belle Fourche Project (South Dakota). This weir was designed to maintain proper depth in the canal. It has 3-foot-tall notches through which the water can flow to match the concrete lined canal. Red arrows show the direction of water flow. [206]

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[205] Davis, *Irrigation Works*, 279.

[206] Ibid., 279.

4.2.2.2 Wood-Covered Rock Weir

This type of weir is rock-filled and decked with timber so as to raise the water and funnel it into the main canal. This example is from an early 1900s Reclamation project on the Lower Yellowstone River and concurrently serves as a diversion dam. These are outdated and frequently replaced with concrete or concrete and steel dams, though some may still exist. This would be a type of the more rarely retained resource that investigators may single out for independent recordation.

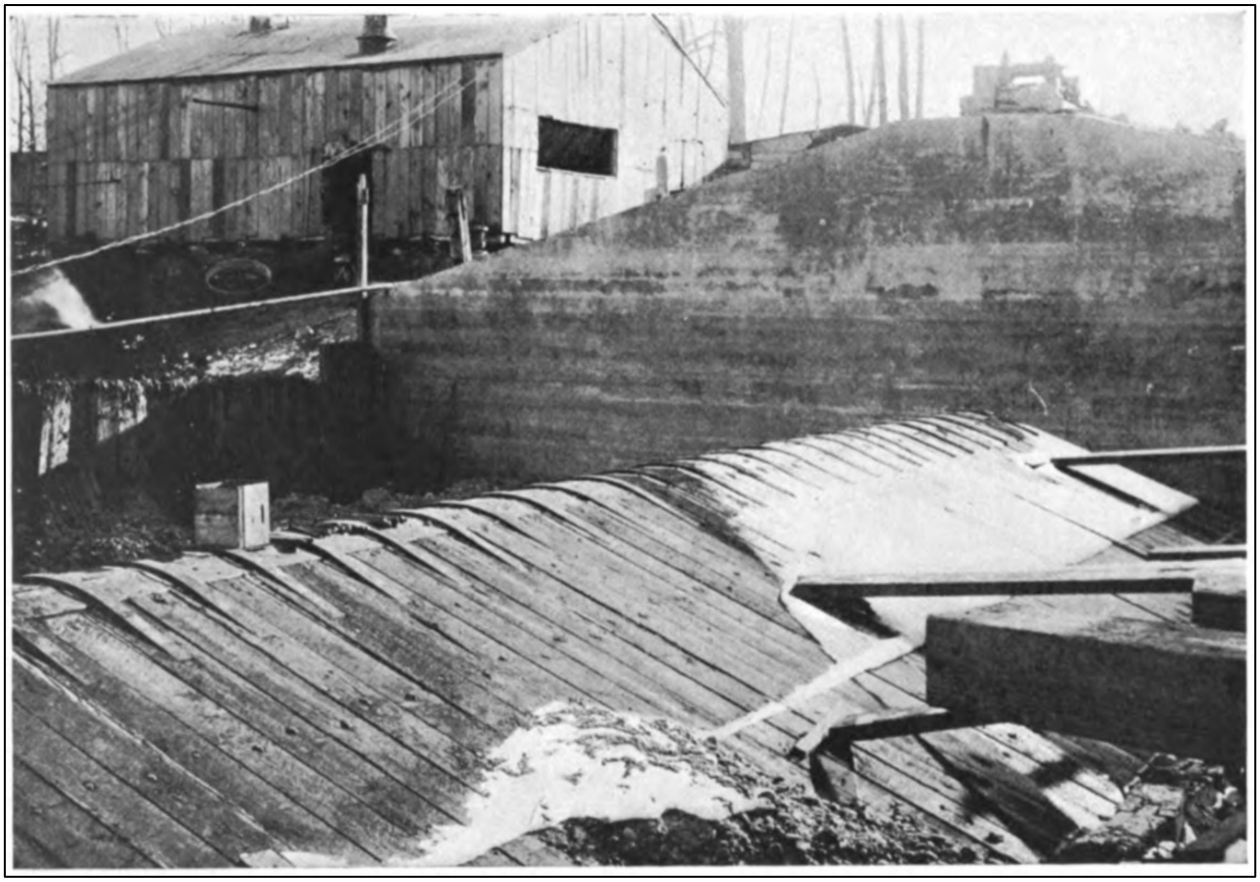

Figure 4.11 Southside abutment of the rock and timber covered diversion on the Lower Yellowstone River (1917), Lower Yellowstone Project (Montana, and North Dakota).[207]

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[207] Davis, *Irrigation Works*, 169.

4.2.2.3 Masonry (Concrete) Weir with Sluice Gates

In this example, the weir is typically below the grade of the canal and has multiple gates that filter out mud and debris from the creek or river. It causes the water to back up gently on the inlet side, thus raising the water so that the turnout can be effectively used to remove water for the fields.[208]

Figure 4.12 Concrete weir with foot bridge on Sutter Butte Main Canal (State of California irrigation project). Note the turnout and orchard in the background.[209]

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[208] Davis, *Irrigation Works*, 280.

[209] Pete Lucero, "Reclamation Releases Environmental Documents on Butte Water District Canal Automation—Thresher Weir Replacement Project," July 14, 2011, Bureau of Reclamation News and Multimedia, https://www.usbr.gov/newsroomold/newsrelease/detail.cfm?RecordID=36723 [accessed February 2023], 9.

4.2.2.4 Wooden Box Weirs

Wooden box weirs are usually used in small canals, laterals, and sublaterals. These are often hand operated and consist of a wooden box with a moveable plank to control or raise the water flow. Due to their size, these are not usually seen on Reclamation projects unless they are in an individual farmer's fields.

Figure 4.13 This photo shows an early wooden box weir method of measuring water by adjusting the water flow through the gate. These are rarely found on Reclamation projects and are long outdated.[210]

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[210] Russell Lee, "Cooperation in wells for irrigation purposes. Mr. Johnson and Mr. Wright, FSA Farm Security Administration clients, standing at the weir box, Syracuse, Kansas." Photograph, August 1939, https://www.loc.gov/item/2017740891/ [accessed August 2023].

4.2.3 Pumping Stations or Pumphouses

Pump stations and pumphouses are typically located next to the lower canal, lateral, or ditch from which they are moving water. They are also used in sprinkler systems and to pump water over long distances in flat terrain. The pumps are usually located in concrete pits below ground level in the buildings. Suction pipes or inlet pipes extend into the lower body of water. Driven by electric motors or internal combustion engines, these lift water from a lower body of water into a higher body of water and deposit it into the irrigation system, directly into a canal, lateral, ditch, or additional piping system. Most stations are run by electric power or natural gas with a diesel or gasoline backup. However, some of the first generation of pumping plants prior to the 1930s relied on steam. Where pumping stations are used at many levels in the irrigation process, such as in the Lower Rio Grande, the first level pumping stations tend to be more elaborate in design than the second and third lift stations.[211] The schematic drawing below shows the primary components of a pumping station.

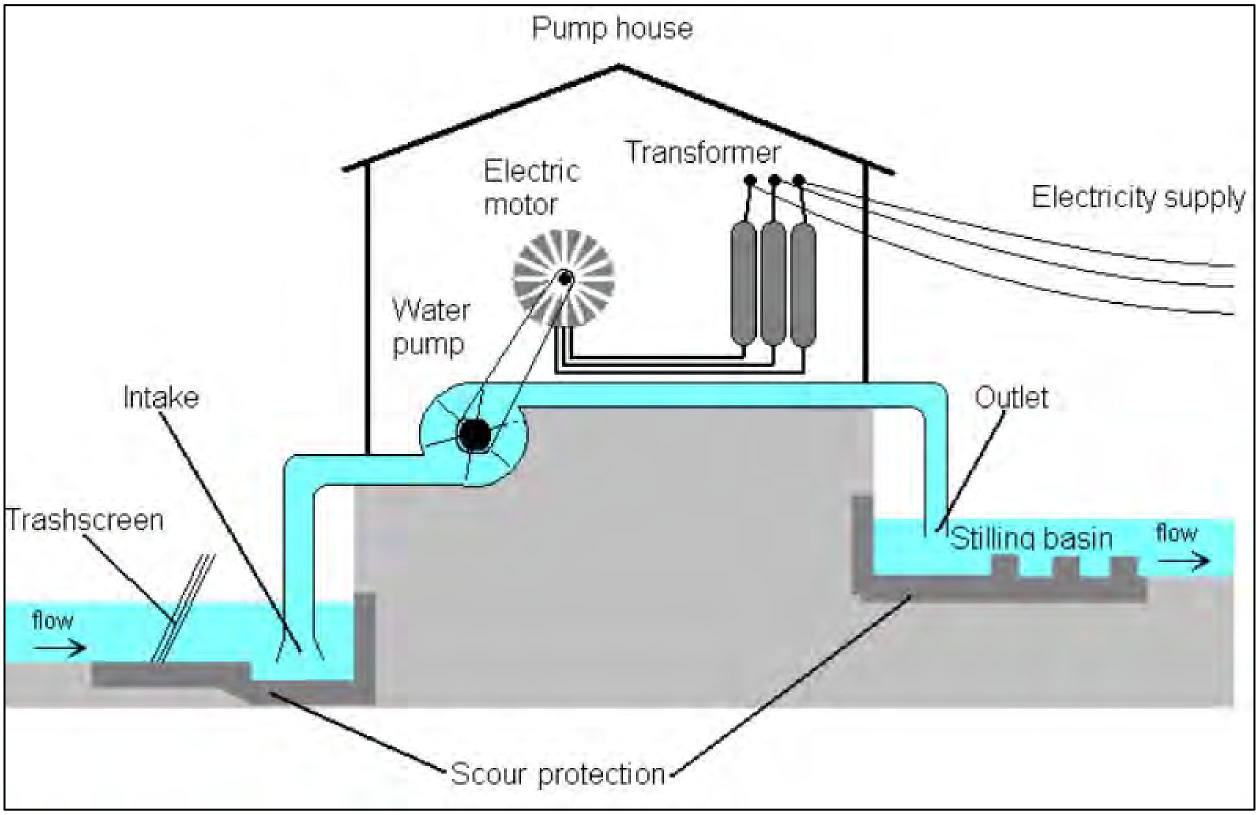

Figure 4.14 In the above drawing, water is drawn from the lower body through an intake (on the left), then through a pump conduit, and deposited into a stilling basin (on the right) where it settles into a higher canal. From there it flows through the canal for use in irrigation fields. [212]

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[211] Lila Knight, *A Field Guide to Irrigation in the Lower Rio Grande Valley* (Buda, Texas: Knight & Associates for the Texas Department of Transportation, 2009).

[212] Crawford and Gosden, "River and Canal Structures."

4.2.3.1 Brick Pumping Stations

Brick masonry structures housed the electric motors or gas-powered engines that raised water from one level to another. The pumps are located below grade and the foundations are usually concrete. A more recent example is the one shown below in the CVP.

Figure 4.15 The Coyote Pump Plant in the CVP (California).[213]

4.2.3.2 Metal Pumping Stations

These pump houses were made primarily of metal, including the roofs, but may have used other materials for the foundations, such as concrete block. Also, there is a wide range of styles from simple sheet-metal buildings (see Figure 4.16) to a structural steel superstructure on a concrete base, as at the Senator Wash Pumping Plant, CVP.

Figure 4.16 Metal pump station in the United Irrigation District, Lower Rio Grande Project (Texas).[214]

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[213] Valley Water, "Coyote Pump Plant," https://www.valleywater.org/coyote-pump-plant [accessed January 2023].

[214] Knight, *Field Guide*.

4.2.3.3 Concrete Pumping Stations

As concrete became more popular in usage, especially after World War II, it became the material of choice for most pumping plants. The pump station shown in Figure 4.17 is an example of a concrete pumphouse with concrete buttresses and steel-framed pivot windows.

Figure 4.17 Concrete pumphouse on the Yakima Project.[215]

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[215] HABS/HAER No. WA-10-1, Library of Congress, Control # WA-0186.

4.2.3.4 Wooden Pumping Stations

These were built during the earliest Reclamation projects and were generally not constructed after concrete became affordable. At least one was noted within the Lower Rio Grande and others may be extant elsewhere. Regardless of exterior materials, all Reclamation-built pump stations had concrete floors.[216]

Figure 4.18 Adams pumping Plant (wood structure) on the Klamath Project, also showing flume and concrete siphon, 1950.[217]

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[216] Knight, *Field Guide*, 109.

[217] Klamath Waters Digital Library, "Adams Pumping Plant, Flume and Concrete Siphon." Photograph, 2023, http://digitallib.oit.edu/digital/collection/kwl/id/2556/rec/1 [accessed August 2023].

4.2.3.5 Uncovered Pumping Stations

The earliest pumping stations had no outer building shell, only a foundation of concrete or brick upon which the pump rested. However, they remained a popular type and are still observable on Reclamation projects, as in the one on the Columbia Basin Project, shown below.

Figure 4.19 Uncovered pumping station on the Columbia Basin Project, Irrigation Division (Washington State), Burke Pump Plant, 1954.[218]

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[218] Bureau of Reclamation, *Columbia Basin Annual History, Vol. XXII* (Washington State, 1954), 272.

4.2.3.6 Pumping Sheds

These consist of pumping equipment placed into a shed or metal building. These are common in the smaller projects but are gradually being replaced with more permanent concrete structures.

Figure 4.20 Pumping shed, Cameron County Irrigation District, #6, Lower Rio Grande Project (Texas).[219]

4.3 Conduit Structures

4.3.1 Main Canals

Canals were a primary component of an irrigation system. Generally, they are divided into three types: main canals, lateral canals, and sublateral canals. Every irrigation system has at least one main or primary canal, and larger projects have more than one. Conveyance systems also contained many lateral and hundreds of sublateral canals as the water is carried to the individual farms. For purposes of this study, many sublaterals and most farming ditches were not built by Reclamation and were not reviewed for this work. The main canal begins at a head works was and usually incorporated into a diversion dam along the primary water body from which water for the system is drawn. In the early period of construction, portions of most canals were left open and unlined. Later, as efficiencies were needed, canals were lined, usually with concrete, though some were lined with brick or stone. In the second half of the twentieth century, all or part of most main canals were lined or piped with enclosed concrete or iron piping. However, some main canals remain unlined and not piped. Figures 4.21 through 4.23 show three unlined main canals. Main canals also frequently include such structures such as tunnels, flumes, siphons, culverts, and chutes, as well as bridges, roads, and other ancillary features to permit travel over the canal.[220]

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[219] Knight, *Field Guide*, 102-103.

[220] Frequently, piping can hide from view the location of the original canal, lateral, or sublateral it replaced. Archival research from blueprints may be necessary to determine its actual location. Additionally, piping can destroy the

4.3.1.1 Open Main Canals

Figure 4.21 The unlined Truckee Main Canal (Nevada) in the Newlands Project was an early Reclamation project. Parts of the canal are still unlined.[221]

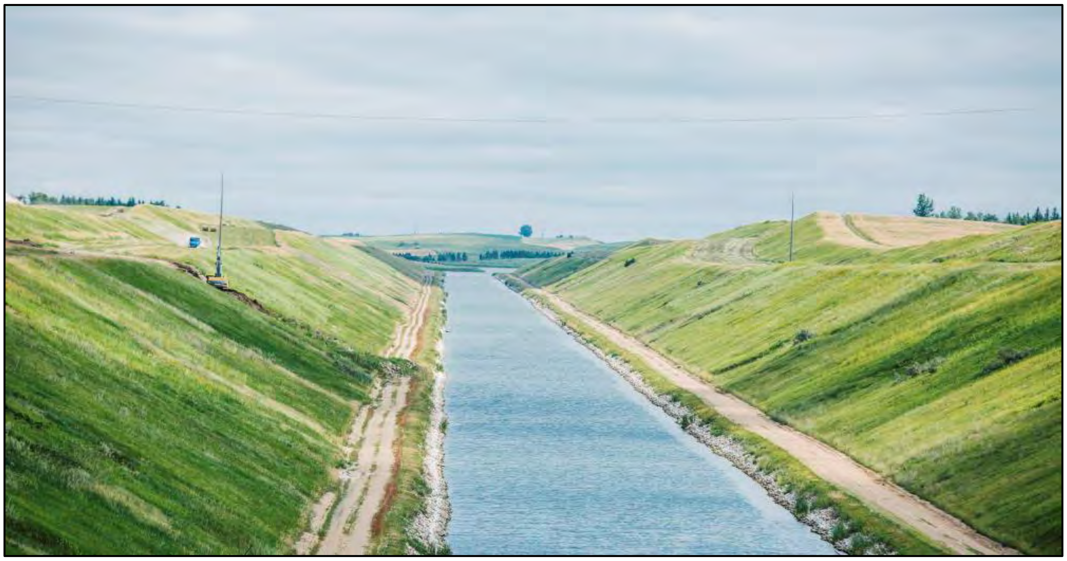

Figure 4.22 The McCluskey Main Canal in the Garrison Diversion Project (North Dakota) is an example of an unlined main canal with rip rap installed to prevent erosion. This canal was completed in the mid-1970s.[222]

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integrity of the historic location, since the new piping may not be placed in the original design of the system (Knight, *Field Guide*, 223).

[221] Amy Alonzo, "Fernley fears future water Shortage as $148M plans to line Truckee Canal move forward," *Reno Gazette Journal*, March 9, 2021, https://www.rgj.com/story/news/2021/03/09/project-line-truckee-canal-forward-fernley-water-shortage/6912613002/ [accessed February 2023].

[222] Garrison Diversion, "McClusky Canal Irrigation," http://www.garrisondiv.org/programs/agricultural_irrigation/McCluskyCanalIrrigation/ [accessed February 2023].

4.3.1.2 Partially Lined Main Canals

Figure 4.23 An unlined section of the All-American Canal (Arizona), partly lined and partly unlined in the Boulder Canyon Project, was completed in 1942 (courtesy of Bureau of Reclamation).

4.3.1.3 Concrete Lined Main Canals

Today, most main canals have some concrete lining. Some were lined during construction, such as the Friant-Kern Canal in the CVP shown in Figure 4.24. Others were built unlined but were later lined as a water conservation improvement.

Figure 4.24 An unlined section of the All-American Canal (Arizona), partly lined and partly unlined in the Boulder Canyon Project, was completed in 1942 (courtesy of Bureau of Reclamation).

Figure 4.25 Main canals can vary widely in width and depth. The lined main canal in the Grant County Irrigation System portion of the Columbia River Basin Project (Washington State) is easily large enough for an automobile.[223]

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[223] H.E. Foss, "Canal lining and construction – car parked in completed section of Main Canal." Photograph, October 1949. Columbia Basin Project, Irrigation Division, Main Canal. University of Idaho Library Special Collections and Archives, https://digital.lib.uidaho.edu/digital/collection/crbproj/id/1296/rec/12 [accessed August 2023].

4.3.1.4 Concrete or Metal Piped Main Canals

Though piped canals were present from the beginning of Reclamation Service work, after World War II concrete became a common construction material. Main canals, laterals, sublaterals, and ditches were piped to preserve water, especially in the southern parts of the West. As previously stated, too much piping can destroy the integrity of design and location on a Reclamation project.

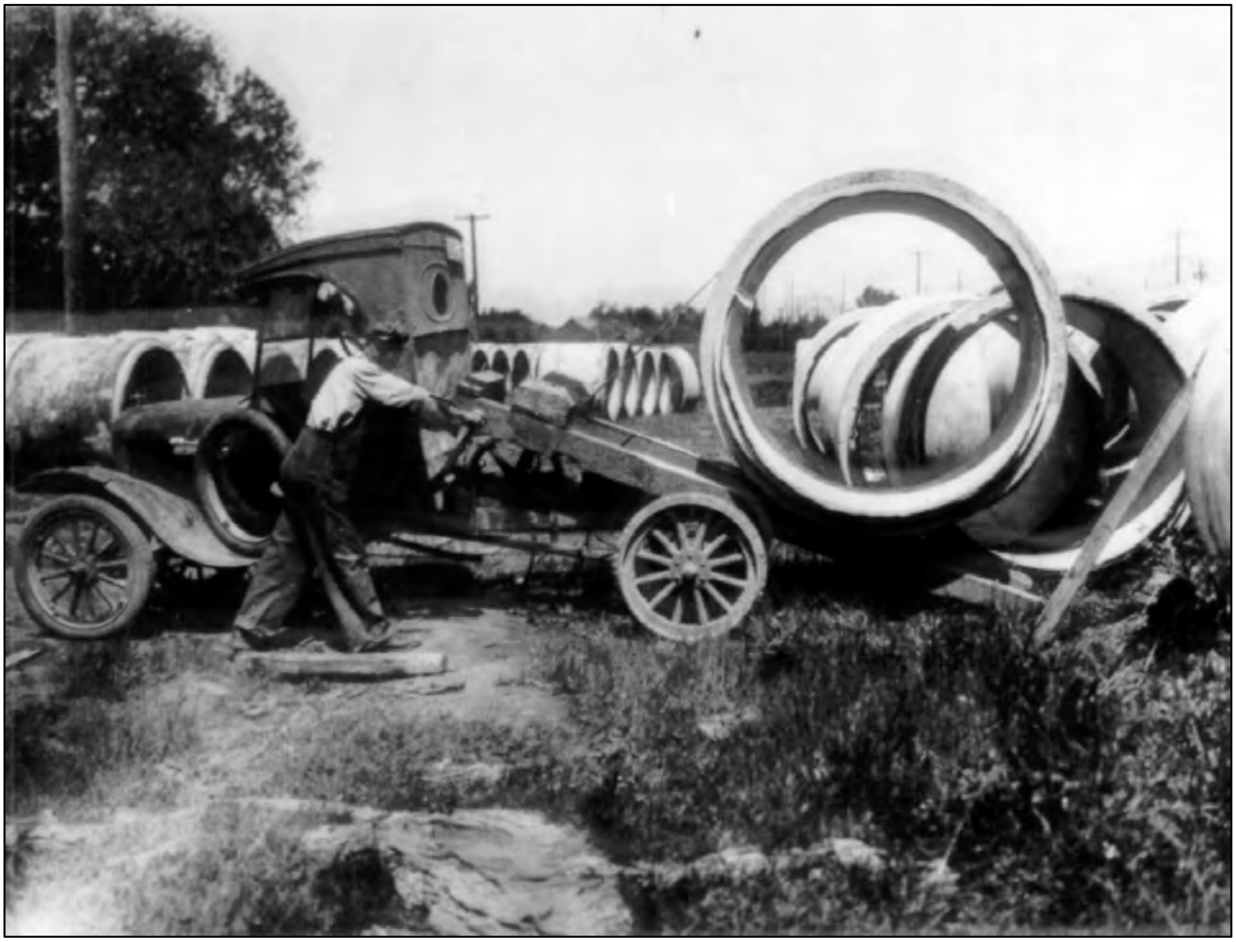

Figure 4.26 Yakima Project. Loading a 60-foot pipe weighing approximately 2.5 tons, 1929 (courtesy of Bureau of Reclamation).

4.3.1.5 Mortared Masonry Facing Main Canal

Masonry or rock facing main canals are relatively rare in Reclamation projects, as concrete serves as the primary means of lining. However, historically, masonry-lined canals were constructed. Figure 4.27 shows a mortared brick-lined lateral canal in the Lower Rio Grande Project dating from the early twentieth century. Such lined canals would be rare in the Reclamation inventory but may remain in non-Reclamation areas.

Figure 4.27 Brick-lined lateral canal in the Cameron County Irrigation District in the Lower Rio Grande Project (Texas).[224]

4.3.2 Wasteways or Drain Lines

Wasteways or drain lines are ditches or canals that carry excess water away from irrigation fields, usually for reuse. Early efforts at irrigation revealed that, though the West was an "arid region," too much water could also be a problem. Reclamation officials quickly saw the need for drains or wasteways in their projects. The Salt River and the Middle Rio Grande projects were good examples of this. Usually, the early wasteways were simple ditches dug to draw off excess or flood waters from the main system. The water was recycled back into the system further downstream. Later, wasteways became more sophisticated, and pumps and siphons became incorporated into the water recycling systems. Today, drainage lines can be open, unlined, lined, or piped. Wasteway systems on some projects include a spillway. The siphon spillway and the side spillway are two types used by Reclamation. Examples of each type of wasteway are given below. A key to knowing the difference between a drain line and other laterals and sublateral canals is the location of the lines in the system.

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[224] Knight, *Field Guide*, 102-103.

4.3.2.1 Earthen Drain Line or Wasteways

The simplest, and still a popular, method of withdrawing water from wet fields is an earthen ditch. Maintenance requirements soon led to lining and piping. However, the open drain line is still used on many, if not all, Reclamation projects.

Figure 4.28 A typical example of an earthen drain in the W.C. Austin Project (Oklahoma).[225]

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[225] Bureau of Reclamation, *W.C. Austin Project*, Oklahoma (Denver Colorado: Bureau of Reclamation, 1947), 23.

4.3.2.2 Concrete-Lined Drain Lines

As drainage and reuse of water became more important to Reclamation, lined wasteways became more common and were often constructed by lining older earthen lines.

Figure 4.29 Concrete-lined section of the Newman Wasteway, Delta Mendota Canal, CVP (California).[226]

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[226] Bureau of Reclamation, *Delta Mendota Canal Recirculation Feasibility Study, Engineering Geologic Evaluation of the Newman Wasteway and Structures* (Sacramento, California: Bureau of Reclamation, Mid-Pacific Region Geology Branch, 2009), Appendix H.

4.3.2.3 Concrete piped drain lines

During the twentieth century, as water became more critical in the West and demand rose, wasteways and drains were piped as a conservation effort. For the purposes of NRHP evaluation, just as piping can destroy the integrity of design and location, too much piping can destroy the integrity of drain lines.

Figure 4.30 Closed drain construction at the Klamath Project, 1973.[227]

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[227] Klamath Waters Digital Library, "Closed Drain Construction – Tule Lake Sump 3." Photograph, February 1973, http://digitallib.oit.edu/digital/collection/kwl/id/4840/rec/103 [accessed August 2023].

4.3.3 Spillways

Spillways are typically associated with large dams. Within an irrigation system, spillways are primarily a wastewater removal structure. There are two common types of spillways used in Reclamation irrigation: the siphon spillway and the side spillway.

4.3.3.1 Siphon Spillway

The siphon spillway is a method of removing large amounts of excess water from a canal or lateral. It operates under positive pressure from the water height. Once primed, it can lift water over a crest and discharge it at a lower elevation. From there it is removed via the wasteway or drain line.

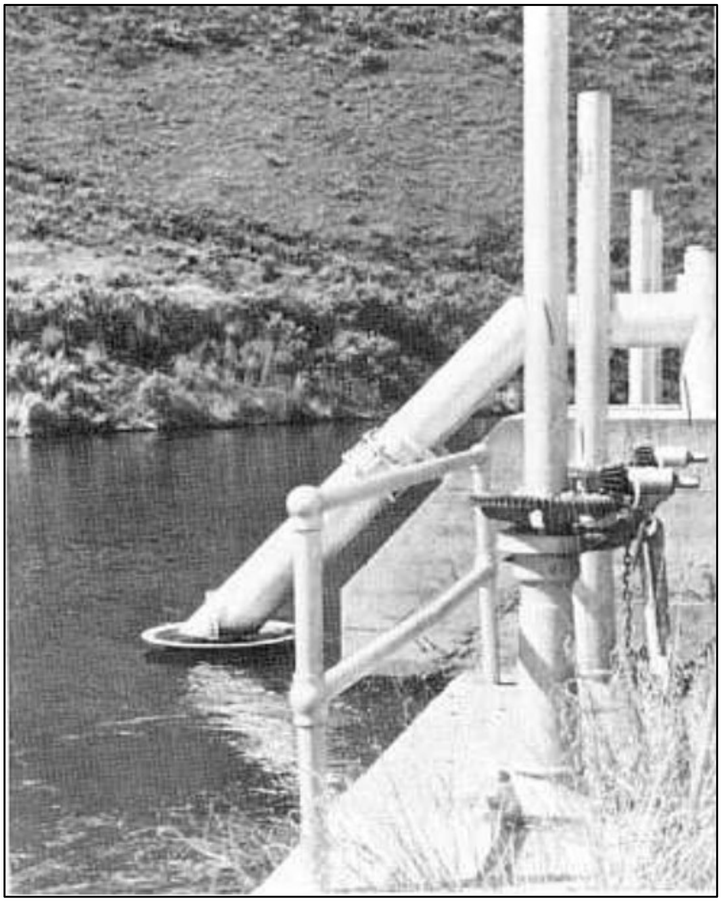

Figure 4.31 A siphon spillway with a siphon breaker pan at the inlet of the siphon.[228]

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[228] A. J. Aisenbrey, Jr., R. B. Hayes, H. J. Warren, D. L. Winsett, and R. B. Young, *Design of Small Canal Structures* (Denver, Colorado: Bureau of Reclamation, 1978), 198.

4.3.3.2 Side Chanel Spillway

Side channel spillways are located along and run parallel to the banks of canals or laterals. As the water rises above the crest, excess water is discharged through the open spillway, drops into a pool, and is carried off into the wasteway channel. These can serve as wasteway turnouts.

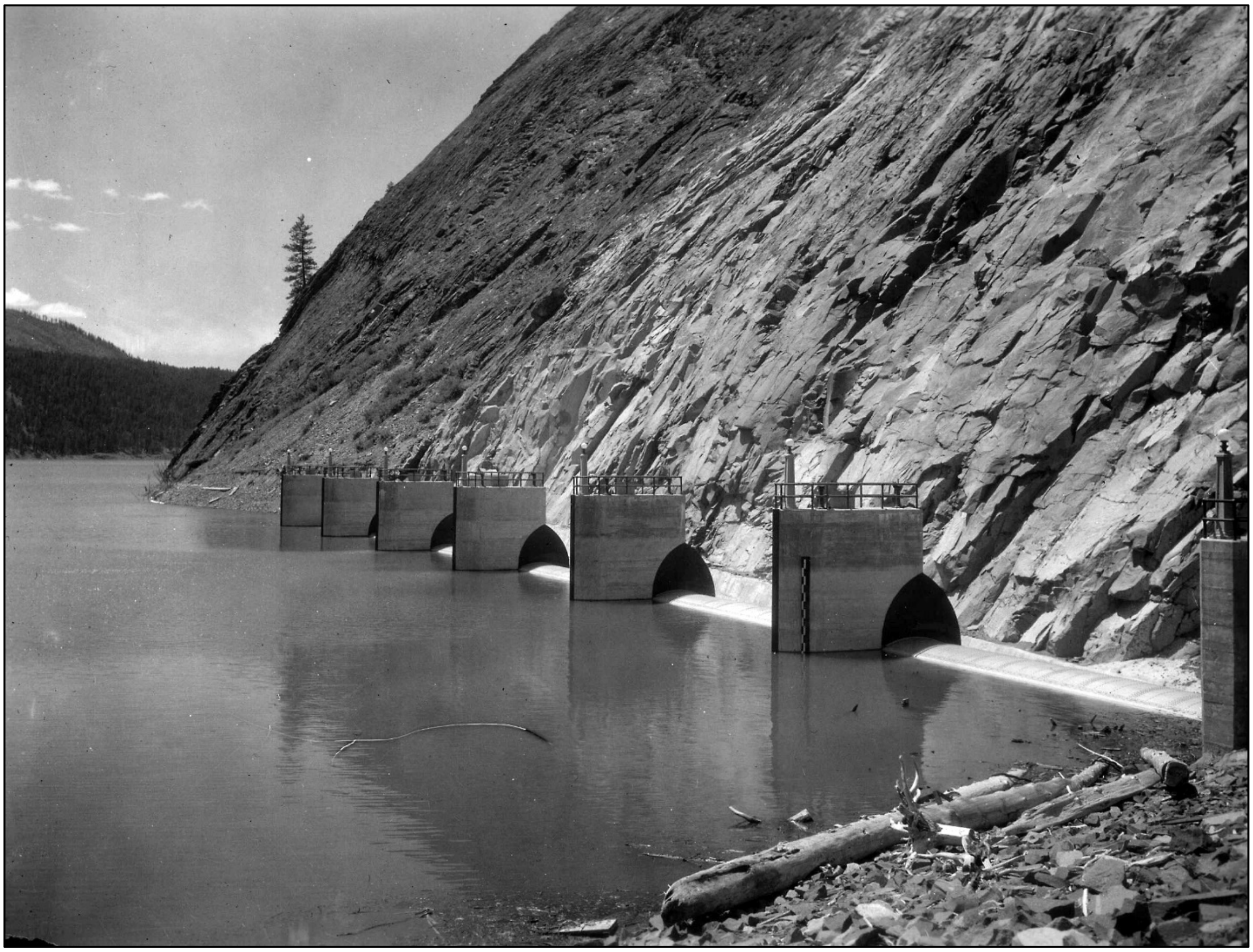

Figure 4.32 An example of a side channel gate and spillway system on the Yakima Project, 1929, Washington (courtesy of Bureau of Reclamation).

4.3.4 Tunnels

Tunnels are used in numerous Reclamation projects and can be long such as the 13-mile Alva B. Adams Tunnel in the Colorado-Big Thompson Project, or smaller such as the main canal tunnels on the Kendrick-Alcova Project, which vary in length. They are usually concrete-lined, but some still exist that contain only wood lining. Tunnels carry water to the main or lateral canals or form a section of the canal. Tunnels underneath features are set on a small grade that permits the water to run safely through to the other side. They may also contain flumes to actually carry the water through the tunnel, but most are free-flowing. Three types are discussed below: solid reinforced concrete-lined, partially lined, and wood-lined.

4.3.4.1 Solid Reinforced Lined Concrete Tunnel

These concrete tunnels can vary in length from less than 100 feet to several miles and are concrete lined throughout. Good examples include the three tunnels in the Grand Valley Project, the Alva B. Adams Tunnel in the Colorado-Big Thompson Project, and the six reinforced concrete-lined tunnels on the Casper Main Canal on the Kendrick-Alcova Project in Wyoming.

Figure 4.33 The entrance to the Alva B. Adams Tunnel on the west side of the Continental Divide in the Colorado Big-Thompson Project (Colorado) (courtesy of Denver Public Library online).

4.3.4.2 Concrete tunnels with partial lining

Rather than being reinforced concrete, tunnels can be simply lined with concrete such as the square trio of tunnels on the South Canal of the Uncompahgre Project on the Gunnison River. In these tunnels, squares of mixed concrete measuring 12 inches thick or more were placed over wood framing. Often, railway tracks are placed in the bottom of the tunnel during construction and left there for maintenance. In partially lined tunnels, not all the walls and ceilings are lined where exposed granite was deemed acceptable.

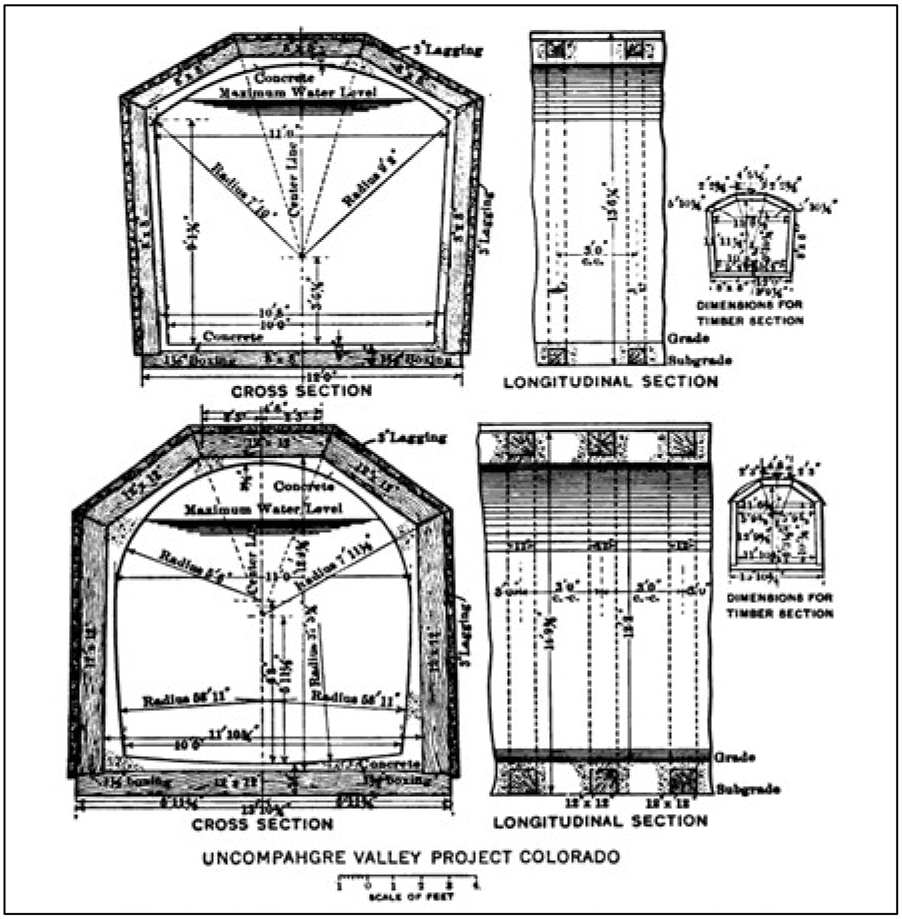

Figure 4.34 This schematic drawing shows the wooden framework and concrete lining for the Gunnison Tunnel in the Uncompahgre Project (Colorado).[229]

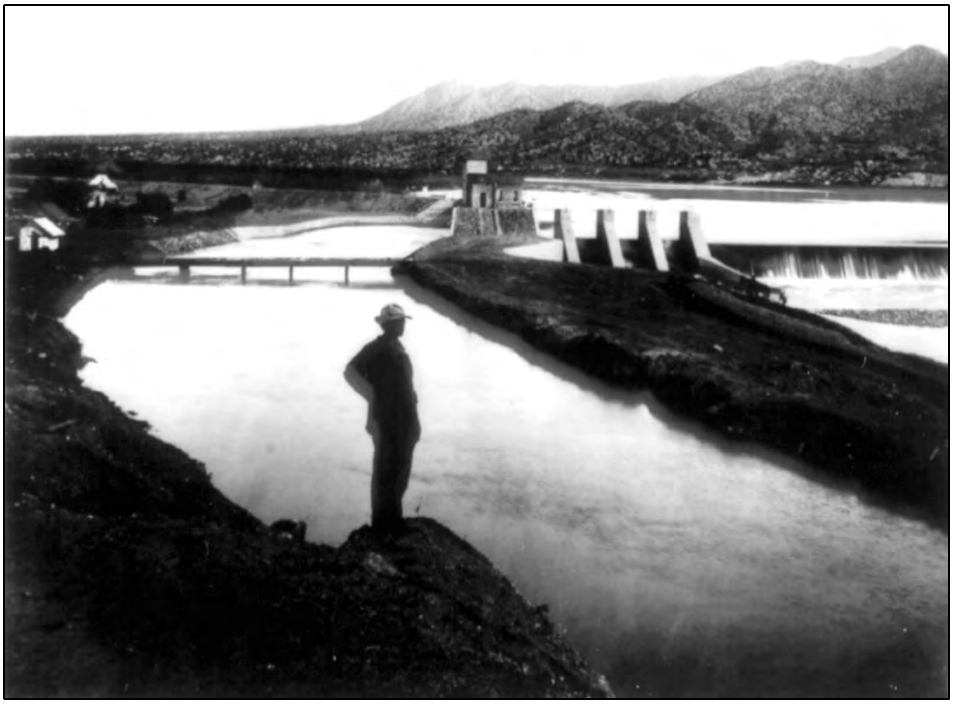

Figure 4.35 Uncompahgre Project. East Portal of the Gunnison Tunnel, 1905 (courtesy of Bureau of Reclamation).

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[229] Davis, *Irrigation Works*, 78.

4.3.4.3 Wood timber-reinforced tunnel

Timber-reinforced tunnels were mostly used in the nineteenth and early twentieth centuries for mining. They are mentioned here only as an example of a type of tunnel. The authors found a few examples of this type of tunnel in Reclamation projects. Wood timber support beams were traditionally used during construction; on wood timber-reinforced tunnels, the beams became the supports for the tunnel. One example is the Pacific Tunnel in the El Dorado Irrigation District in the CVP, California. However, in 2018 the Pacific Tunnel was undergoing renovations, likely replacing the wood with concrete.

Figure 4.36 In need of repair, the wooden Pacific Tunnel inside the El Dorado Irrigation District in the CVP, California, is shown in 2016.[230]

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[230] *Mountain Democrat*, "Pacific Tunnel EIR approved by EID," May 18, 2020, https://www.mtdemocrat.com/news/pacific-tunnel-eir-approved-by-eid/ [accessed February 2023].

4.3.5 Flumes (not measuring devices)

In irrigation projects, flumes carry water over gulches, streams, or other depressions between sections of the canal. They can be used on main, lateral, and sublateral canals. Flumes are structures capable of supporting water moving at a high velocity and are usually short, though some can run several miles. They are similar in form to the Roman Aqueducts, and most are open flumes. They are made of wood, metal, concrete, and concrete and metal pipe. Typically, the wood flume support system is the same material as the flume; wood flumes have wood frames, steel flumes have steel frames, and concrete flumes have concrete frames.

4.3.5.1 Wooden flumes

Like most other structures, wood was used in the early period of the Reclamation Service and most wooden flumes date from before World War II.

Figure 4.37 Wooden Flume # 13 in the Bitter Root Project (Montana) is an excellent example of a flume built in the 1930s and still operational today.[231]

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[231] Kevin Maki, "Wooden flumes still working hard for Bitterroot irrigators," NBC Montana, September 23, 2018, https://nbcmontana.com/news/local/wooden-flumes-still-working-hard-for-bitterroot-irrigators [accessed January 2023].

4.3.5.2 Steel Flumes

Steel flumes have been in service since the earliest Reclamation projects. However, they became more popular during the Depression period, when steel began to replace wood on bridges, flumes, rail line bridges, etc.

Figure 4.38 A steel flume on steel trusses in the Tieton Distribution System on the Yakima Project (Washington State).[232]

4.3.5.3 Concrete Open Flumes

Concrete has been used by Reclamation since the earliest days of the agency. However, it came into popular use on nearly every project after World War II. Concrete flumes were built on new projects and often replace wooden or even metal flumes on older projects.

Figure 4.39 A concrete C Flume on a concrete pier foundation in the Klamath Project (Oregon and California).[233]

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[232] Davis, *Irrigation Works*, 357.

[233] Foundation Engineering, Inc., "C Flume Replacement," https://nbcmontana.com/news/local/wooden-flumes-still-working-hard-for-bitterroot-irrigators [accessed January 2023].

4.3.5.4 Concrete Pipe Flumes

Concrete pipe has also been used by Reclamation for flumes since the beginning, but use of the material became more popular after World War II. As development in the West demanded more conservation of water, concrete piping, including flumes, became an obvious answer to seepage and evaporation problems. Below is an example of where concrete pipe flumes were used.

Figure 4.40 Concrete pipe flume in Hidalgo County Irrigation District on the Rio Grande Project (Texas).[234]

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[234] Knight, *Field Guide*, 137.

4.3.5.5 Bench Wall Flume

One of the most popular and intrinsically pleasing architectural features of Reclamation is the use of bench flumes. These features, first developed for mining and logging, were easily adapted to Reclamation work. The early flumes were almost exclusively wooden and were attached to rock walls in steep areas where it was necessary to move the irrigation water. Rather than tunneling through rock, the flume was attached to the side of the mountain via a strapping and support system made of wood and metal. Most of these have been replaced by steel flumes and steel supports or removed altogether by Reclamation.

Figure 4.41 Wooden Tieton Bench Flume in the Yakima Project (Washington State).[235]

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[235] Fred C. Scobey, "The Flow of Water in Flumes," United States Department of Agriculture, Economic Research Service, Technical Bulletin #163959 (1933), plate #7.

4.3.6 Siphons

Siphons are closed conduits, such as a pipe or culvert, that carry water under pressure. This allows the siphon to dip below a ditch or other feature's grade. Long siphons replaced trestles to cross ravines or depressions. They are pressurized pipes, usually made of steel, steel-banded wooden staves, or reinforced concrete. Shorter siphons became common at railroad or road crossings. Siphons could cross or go underneath streams and even rivers and can be a substitute for flumes. They are usually considered part of the canal or lateral in which they carry water. Small siphons are frequently used by local farmers to draw water from a lateral into their individual fields.[236]

4.3.6.1 Wooden Siphons

Wood siphons were used in early Reclamation projects but are rarely seen today. Most, like wood flumes and wood headgates, are being replaced by steel and concrete.

Figure 4.42 Wooden Stave Siphon being installed in 1941 on the Yakima Project (Washington State).[237]

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[236] Holleran, *Historic Context,* 64-65.

[237] Bureau of Reclamation, *W.C. Austin Project*, A-260.

4.3.6.2 Metal Siphons

Iron or steel siphons perform the same task as wood stave siphons and have replaced many of the older wooden ones.

Figure 4.43 Looking upstream along Big Thompson River at Big Thompson Siphon, 1967 (courtesy of Bureau of Reclamation).

4.3.6.3 Concrete Siphon

Concrete siphons function the same as wooden or metal ones. Gravity pulls the water under pressure from a higher point to a lower point. Usually, they are used in Reclamation projects to carry water underneath other water beds, across ravines, and through low areas where gravity can be used.

Figure 4.44 A large siphon being constructed to carry water underneath the Friant Kern Main Canal in the CVP (California).[238]

Figure 4.45 Siphon under Patterson Creek on the Delta Mendota Canal, CVP (California) (courtesy of Bureau of Reclamation).

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[238] Friant Water Authority, "About the Friant Kern Canal," 2021, https://friantwater.org/fkc [accessed January 2023].

4.3.6.4 Prestressed Concrete Siphon

Since World War II, Reclamation's use of prestressed concrete has become more common. It results in a structure where steel strands in the concrete are prestressed prior to the concrete's placement in the mold. It produces a very strong concrete product capable of handling the pressures of siphoning large volumes of water.

Figure 4.46 North Fork prestressed concrete siphon on the Strawberry Valley Project (Utah).[239]

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[239] ENR Mountain States, "North Fork Siphon Replacement: Project of the Year Finalist and Best Intermountain Water/Environment Project," 2021, https://www.enr.com/articles/52632-north-fork-siphon-replacement [accessed February 2023].

4.3.6.5 Rubber (usually temporary)

The use of rubber siphons to remove water from sublaterals into farmers' fields is usually done seasonally. Nearly all small siphons are removed by hand after the water accumulated in fields. Figure 4.47 shows a field in the W.C. Austin Project where the farmer has used rubber siphons to bring irrigation water to his crops. Rubber syphons are typically used by the end user or farmer and not Reclamation.

Figure 4.47 Rubber siphons shown removing water from a lateral canal and placing it in the farmer's field. Reclamation rarely uses these siphons; farmers retain them for their fields (W.C. Austin Project, Oklahoma).[240]

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[240] Oklahoma Historical Society, "W.C. Austin Project," https://gateway.okhistory.org/explore/collections/WCAP/browse/?fq=dc_type%3Aimage_photo&start=168 [accessed January 2023].

4.3.7 Piping systems

Piping systems are considered circular, closed conduit systems for conveying water. They are manufactured of several different materials including wood, steel, concrete, and prestressed concrete, among other materials. For irrigation purposes, they can conduct water under roadways, railroad lines, down steep terrain, across depressions, and through canal banks. Closed piping systems have become much more popular in the post-World War II era as water conservation has become a more critical component of western irrigation. Reclamation uses various piping systems made of wood, precast concrete, asbestos cement, and metal. Most piping systems also employ a venting structure to release built-up pressure in the pipes. As with all piping systems used to replace open-air systems, the piping presents not only a locational challenge, with the underground system not easy to observe, but for NRHP evaluation purposes, it presents an integrity issue for the system given that the original open-air system has essentially been destroyed in the areas where piping has been adopted.

4.3.7.1 Wooden Pipe system

Figure 4.48 Wood stave construction on an early irrigation project (California).[241]

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[241] JRP and CALDOT, *Water Conveyance Systems.*

4.3.7.2 Concrete (Precast) Pipe System

Figure 4.49 A photograph of the East Low Canal Section of concrete piping on the Columbia Basin Project (Washington State) in 1950.[242]

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[242] Bureau of Reclamation, *Columbia Basin Annual History, Vol. XVIII, Part 2* (Denver, Colorado: Bureau of Reclamation, 1950).

4.3.7.3 Asbestos Cement Pressure Pipe

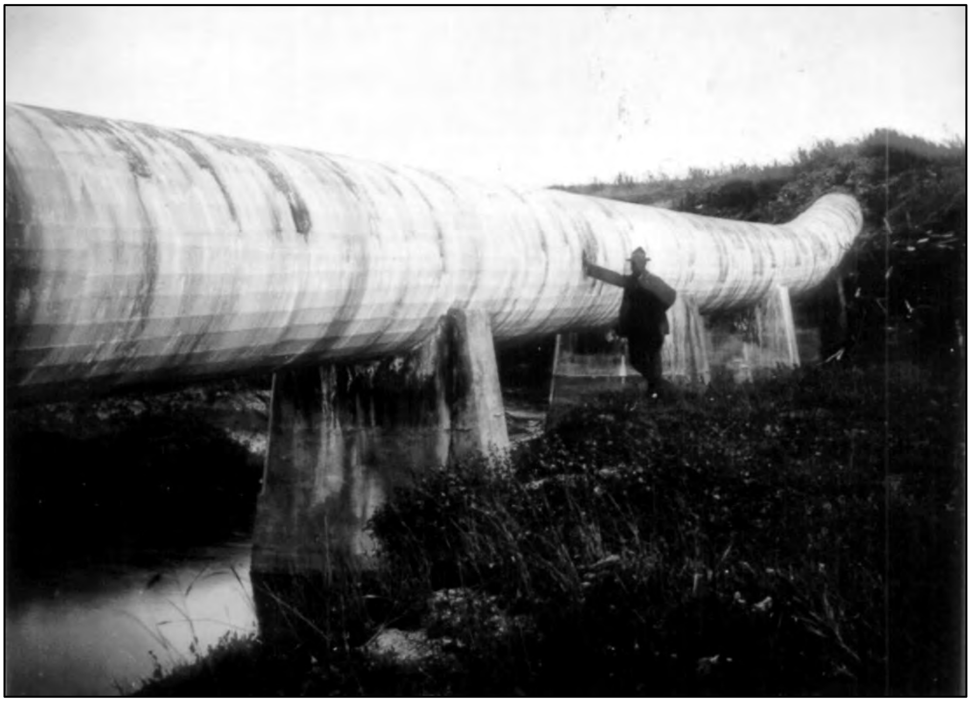

Figure 4.50 Cement pressure pipe on the Sun River Project, Montana, 1908.[243]

4.3.7.4 Steel piping system

Figure 4.51 Steel pipeline being installed on the Lewiston Orchards Project (Idaho).[244]

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[243] Photograph courtesy of the Bureau of Reclamation.

[244] Bureau of Reclamation, *Lewiston Orchards Project, Idaho: Annual Project History – Calendar Years 1949 and 1950* (Denver, Colorado: Bureau of Reclamation, 1952), 14.

4.3.7.5 Vents

Vents are usually concrete and installed in conjunction with concrete piping systems. They help prevent excessive air pressure from building up in the pipelines and destroying the pipes. Usually, they protrude above ground level about two feet, and can be placed up to 500 feet apart. Diversion stands can also serve as vents.

Figure 4.52 The vent is shown on the left. The large pipe protects the diversion stand valve in this Cameron County Irrigation District on Rio Grande Project (Texas).[245]

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[245] Knight, *Field Guide*, 156.

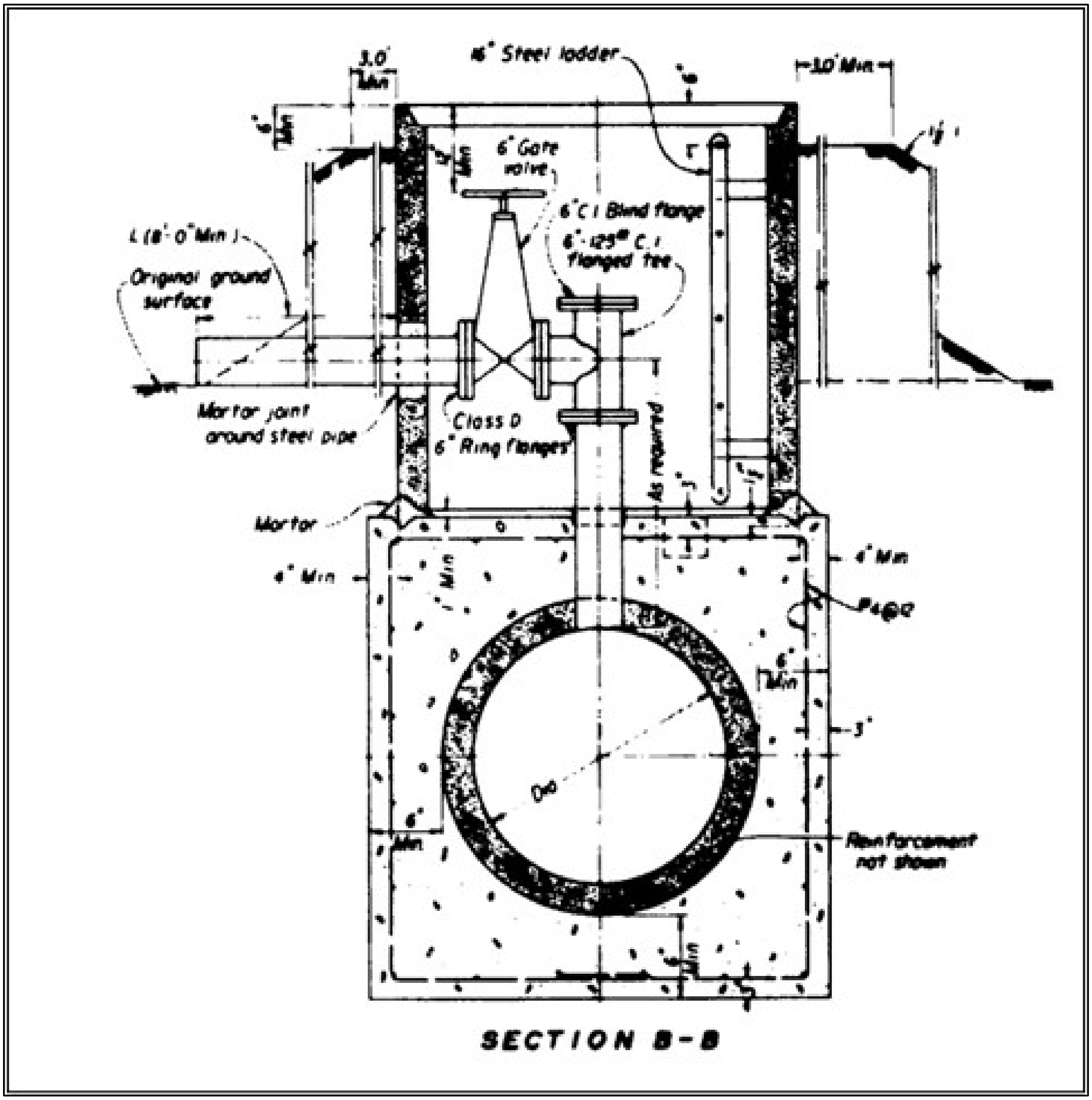

Figure 4.53 Schematic drawing of a vent and its corresponding gate valve to release water inside a concrete pipe.[246]

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[246] Aisenbrey et al., *Small Canal Structures*, 376.

4.3.8 Culverts

Culverts are considered part of the cross-drainage structures. They usually carry drainage water under the canals or laterals and may carry the water under other transportation features such as bridges and rail lines. Since World War II, concrete pipe has been Reclamation's choice for culverts. However, metal culverts are often used to cut costs. Some older projects may still contain wooden culverts but most of these have been replaced with concrete or metal. Culverts may be simple or multi-barreled (as shown in Figure 4.54) and are often precast.

4.3.8.1 Precast Concrete Pipe Culverts

Figure 4.54 A precast concrete pipe culvert being installed on a Reclamation project.[247]

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[247] Aisenbrey et al., *Small Canal Structures*, 204.

4.3.8.2 Precast Concrete Box Culverts

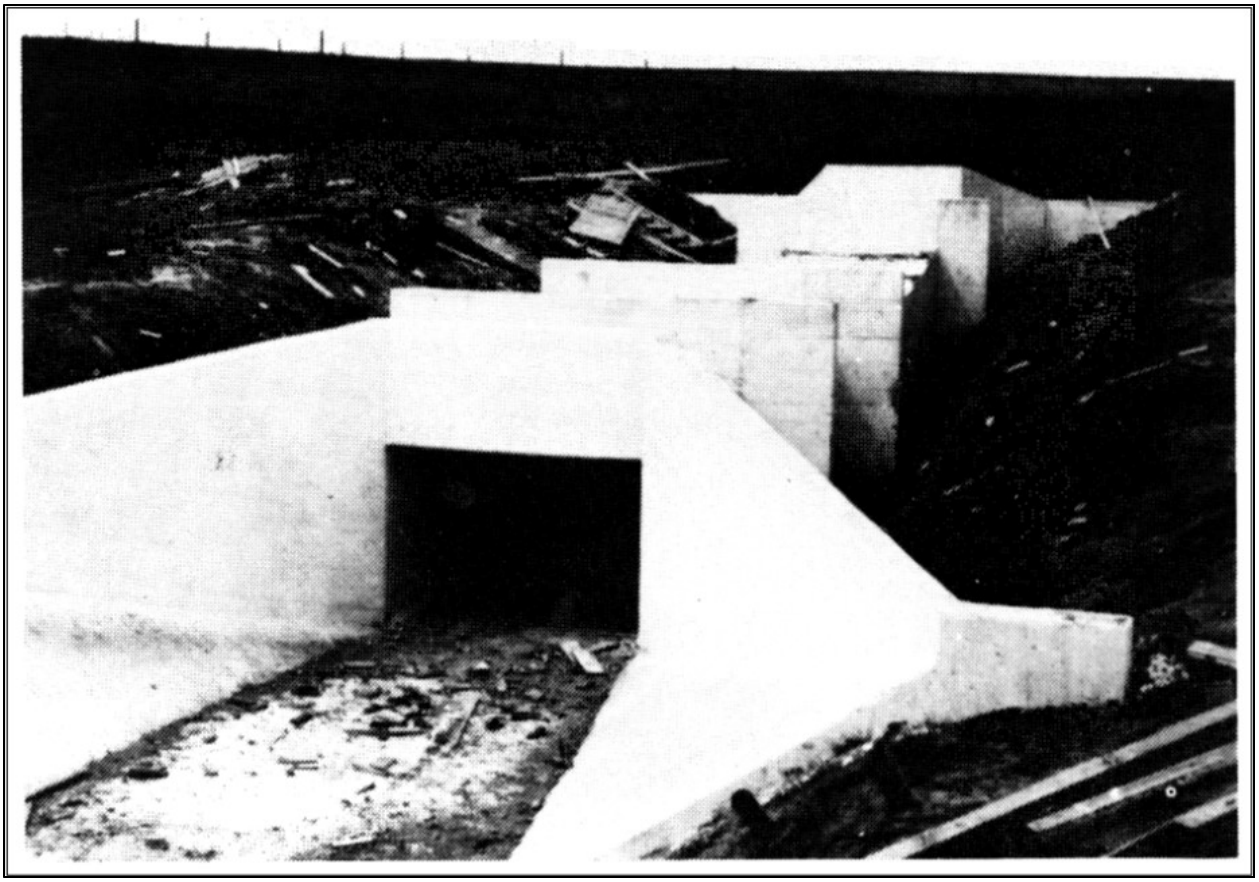

Figure 4.55 A precast concrete box culvert with a percolation collar during installation.[248]

4.3.8.3 Steel Culverts

Figure 4.56 Corrugated steel pipe used at a road crossing on an unknown Reclamation project.[249]

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[248] Aisenbrey et al., *Small Canal Structures*, 204.

[249] Ibid., 361.

4.4 Flow Control Devices

Flow control devices regulate and measure flow rates, dispose of water, trap sediment and debris, and adjust the volume of water passing a particular point in the system. These include turnouts, checks, and gauges. Early Reclamation control devices included some simple wood gates that were manipulated by hand. Over time, those have grown to sophisticated automated concrete and steel checks, turnouts, and water measuring devices. As most digital devices are not yet 50 years old, they will not be covered in this discussion.[250]

4.4.1 Headgates

Headgates are primary feature of the irrigation systems in a dam, canal, or lateral that opens to permit water to flow. On diversion dams, they are opened when there is a demand for water from the farmers. The gates are a critical function of the irrigation system. As with most Reclamation projects, headgates are adapted to local needs; there are as many types of headgates as there are needs. However, this study notes only the types of headgates in wasteways or drains, diversion dams, laterals, and sublaterals that Reclamation built.

4.4.1.1 Headgates on Diversion Dams

Diversion structures usually have headgates that permit water to flow from the primary source into the main canal. Whereas with weirs the water is usually drawn off as it flows over the weir, diversion dams demand a headgate and are usually in the larger systems. As with all headgates, they permit the water to flow safely into the main canal of the irrigation system. The earliest examples were usually wood, but by the mid-twentieth century Reclamation used iron, steel, or concrete.

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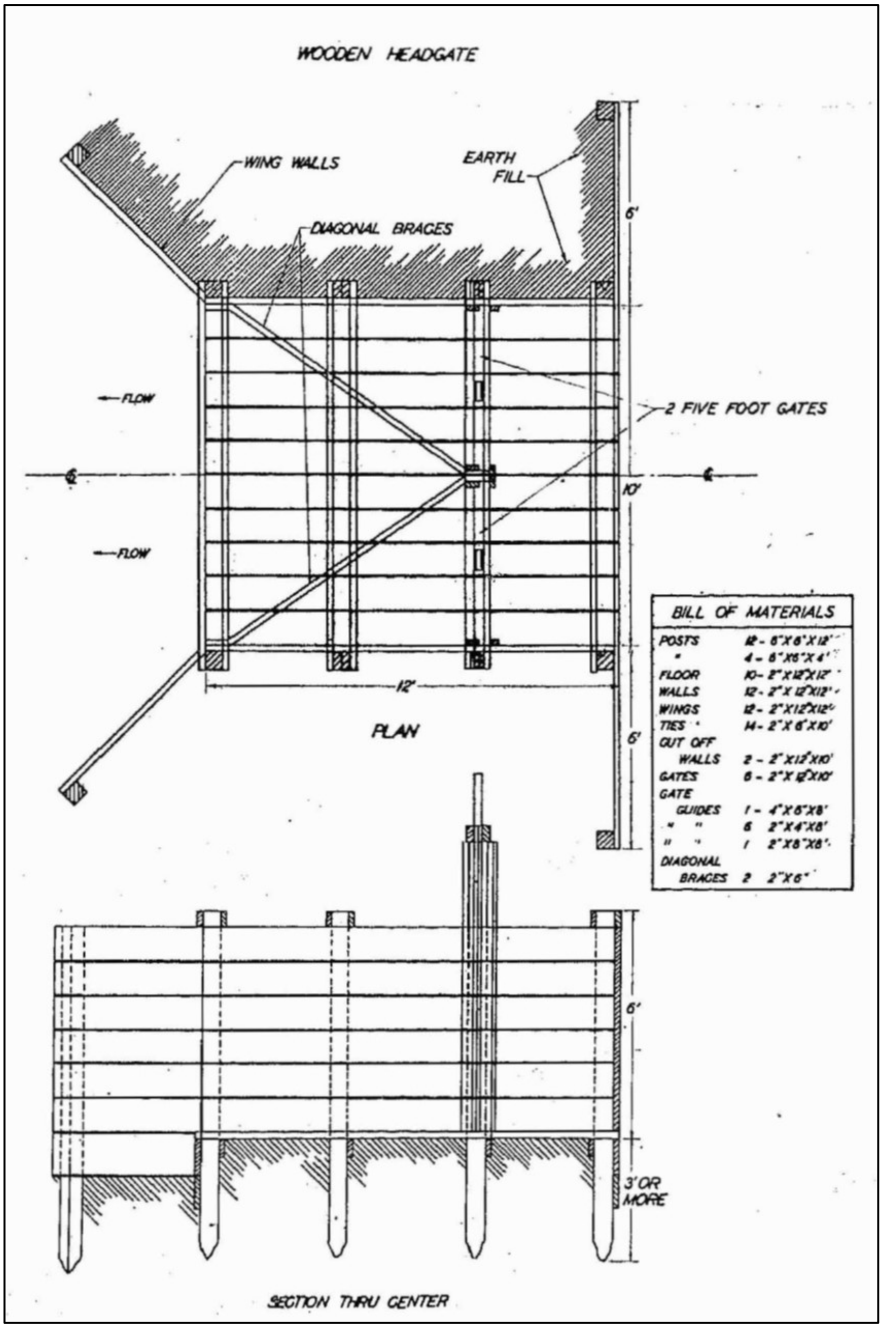
[250] JRP and CALDOT, *Water Conveyance Systems*, 88.

Wooden Headgates

Early Reclamation Service work included the use of wooden headgates. These were eventually replaced by steel gates. Nearly all projects now contain metal gates in the diversion dams. The earliest headgates were controlled by a screw, stem, and handwheel to lift the gates when desired. More recent gates have been moved to automated control and are usually rolled up or down to permit the water to flow through the dam to the canal.



BILL OF MATERIALS	
POSTS	12 - 6"X6"X12'
"	4 - 6"X6"X4'
FLOOR	10 - 2"X12"X12'
WALLS	12 - 2"X12"X12'
WINGS	12 - 2"X12"X12'
TIES	14 - 2"X6"X10'
CUT OFF WALLS	2 - 2"X12"X10'
GATES	6 - 2"X12"X10'
GATE GUIDES	1 - 4"X6"X8'
" "	6 2"X4"X8'
" "	1 2"X8"X8'
DIAGONAL BRACES	2 2"X6"

Figure 4.57 A drawing showing two views of a wooden headgate.[251]

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[251] Dusenberry and Monson, *Irrigation Structures*, 13.

Figure 4.58 Wooden headgate and intake at Sharp's Heading, Imperial Irrigation District, Boulder Canyon Project.[252]

Concrete with Iron Headgates

Though used from the beginning, metal headgates for Reclamation projects became more popular in the 1930s and 1940s.

Figure 4.59 An excellent example of a concrete diversion dam with iron headgates on an unknown Reclamation project (courtesy of Bureau of Reclamation).

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[252] Bureau of Reclamation, *Boulder Canyon Project Final Reports. Part IV: Design and Construction,* Bulletin 6, Imperiam Dam and DeSilting Works (Washington D.C.: Bureau of Reclamation, 1949), 9.

Concrete and Steel Headgates

Since the 1970s, most new headgates, as well as replacements, have been steel gates within concrete structures.

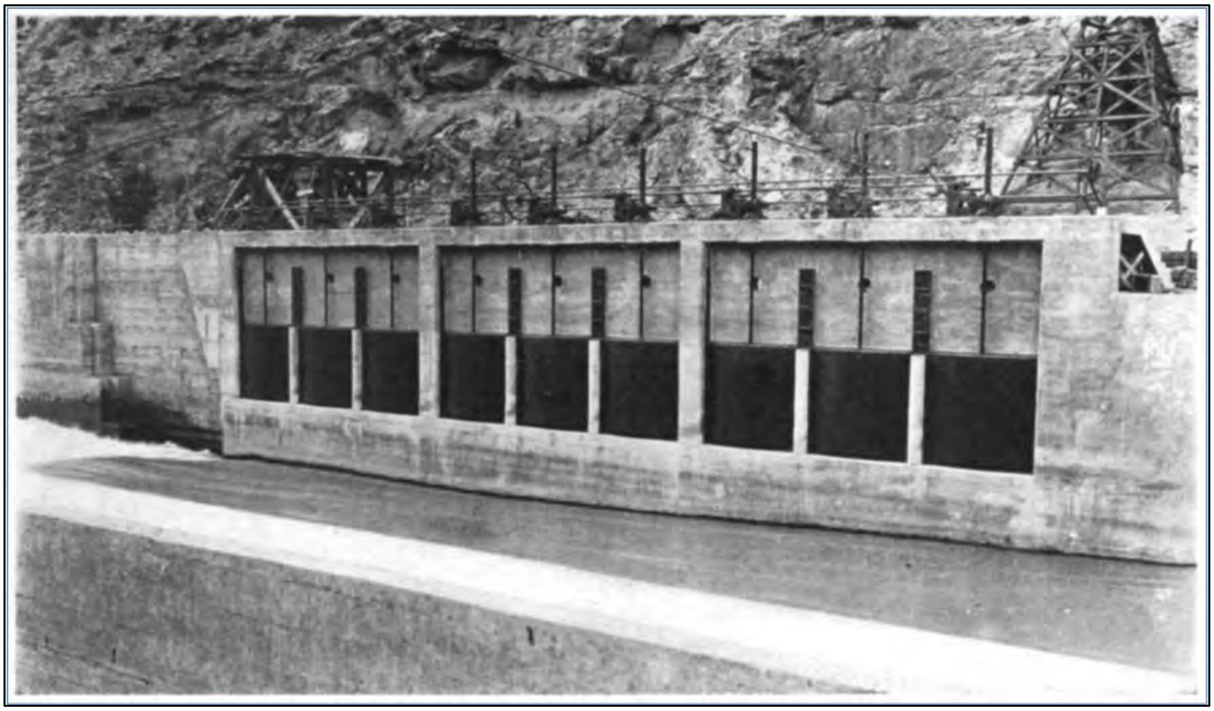

Figure 4.60 Steel headgates with automated controls in the main canal of the Grand Valley Diversion Dam on the Grand Valley Project (Colorado).[253]

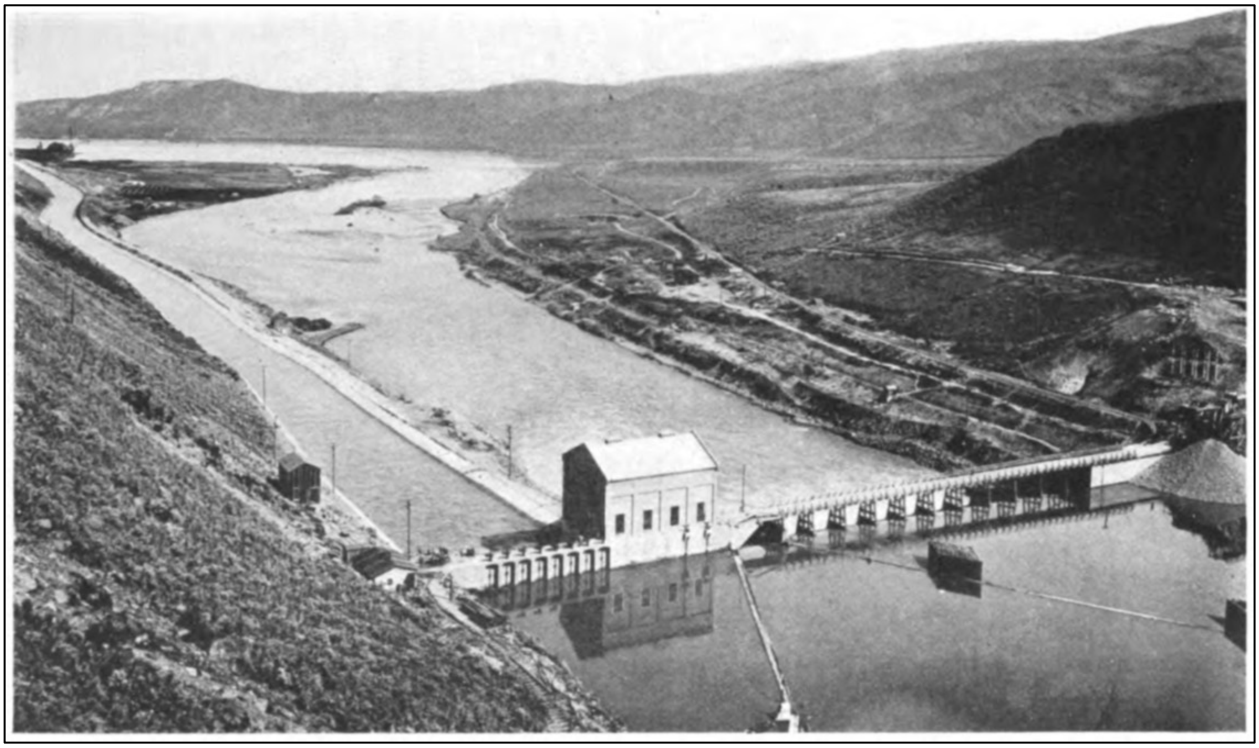

Figure 4.61 Steel headgates of the Boise Project's (Idaho) Main Canal are on the left side of the dam (Idaho).[254]

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[253] Davis, *Irrigation Works*, 67.

[254] Ibid.

Concrete Headgates

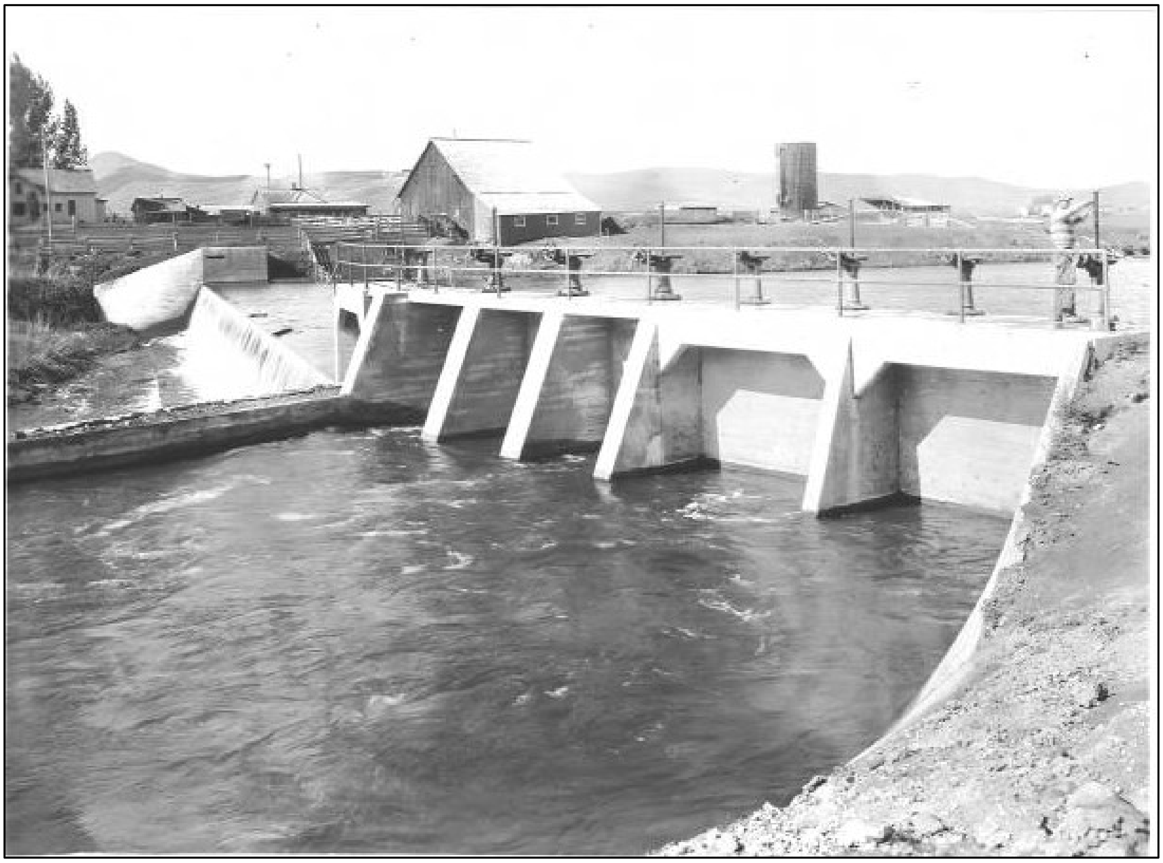

Figure 4.62 Concrete headgates on the Lost River main diversion canal on the Klamath Project (Oregon) (courtesy of Bureau of Reclamation).

4.4.1.2 Headgates on Wasteways or Drain Lines

Waste gates or wasteway headgates allow excess water to flow out of a canal or channel into a secondary drain, usually to be redirected back into the irrigation system. They are conservative in nature and are used when water levels are too high. Typically, the gate is associated with a drop or chute structure and a channel. When in use, they provide an automatic release of excess water and can be used to empty canals. The wasteway outlets are frequently equipped with energy dissipaters, such as baffles, to better control the draining process.

Wood Wasteway Headgate

In early Reclamation projects, headgates could be wood. These were usually replaced over time with concrete or iron gates. However, some remain.

Figure 4.63 A good example of a wooden wasteway gate on the Minidoka Project (Idaho) c1916 (courtesy of Bureau of Reclamation).

Simple Metal or Concrete Drain Lines

The simplest form of drain on a Reclamation project is a drainpipe or line. Usually metal or concrete, they can also be clay. They drain the excess water from the canal into the wasteway when it reaches a certain height.

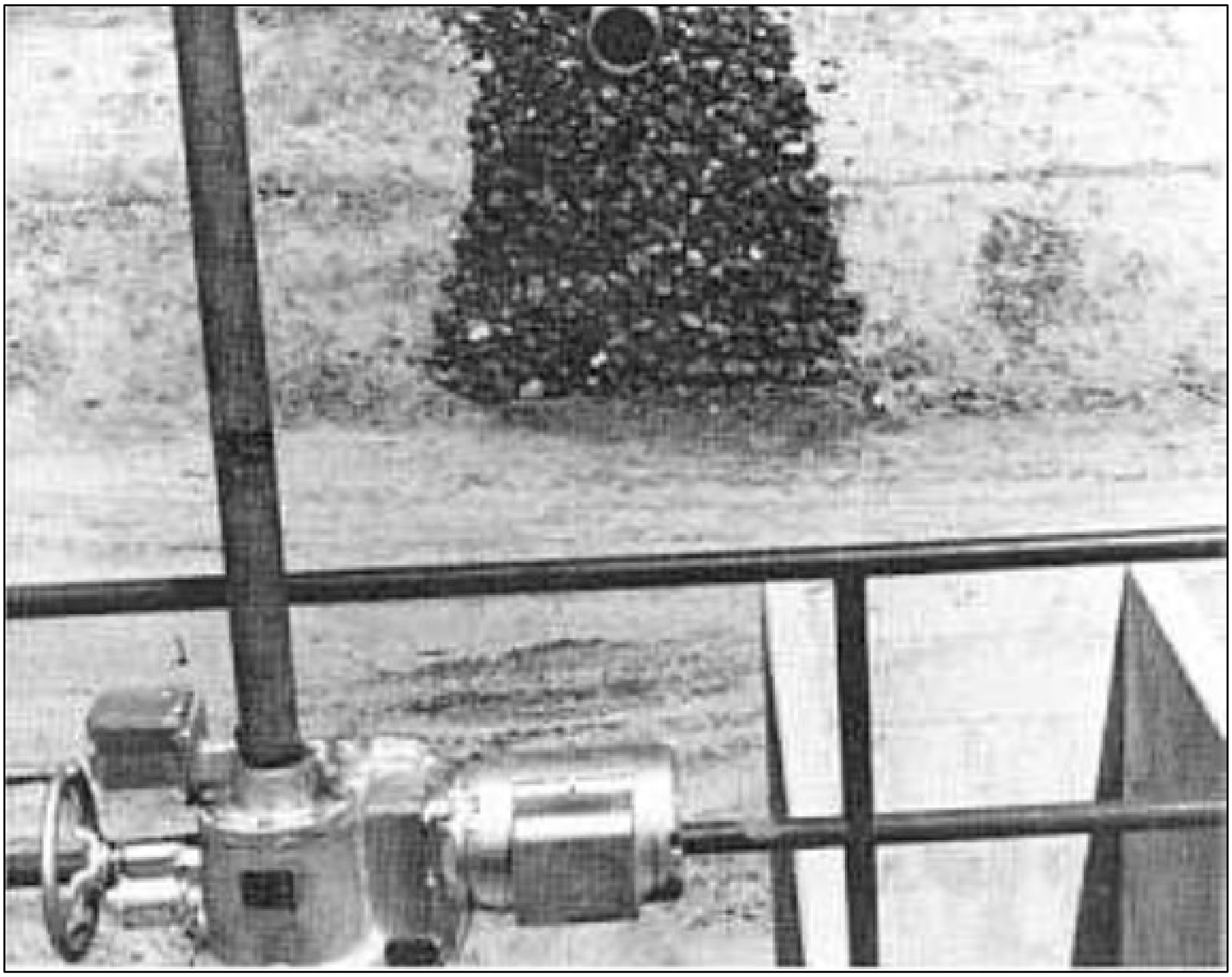

Figure 4.64 The photo shows a metal drain line placed into an earthen canal to drain off excess water in an unknown Reclamation project. This simple system requires no gates but drains water into an adjoining wasteway when the canal water reaches a certain height.[255]

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[255] Aisenbrey et al., *Small Canal Structures*, 231.

Concrete Waste Gate with Cast-Iron Headgate

These gates can be manually raised or automated. Their purpose is to withdraw excess water from the canal or ditch and permit it to flow into a wasteway or ditch for return to the system.

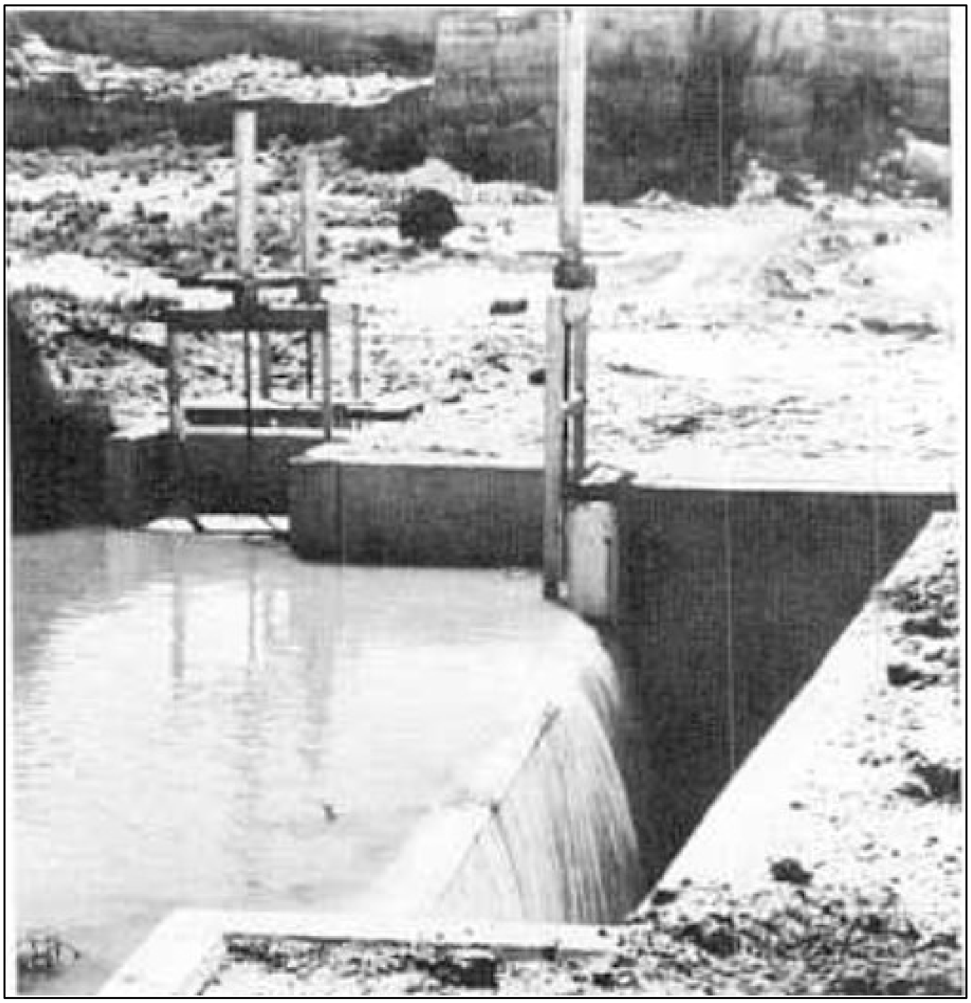

Figure 4.65 This photo shows an example of a concrete and iron gate wasteway gate and spillway. The gate is at the far end of the photograph. This particular style is called the side wastewater gate.[256]

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[256] Aisenbrey et al., *Small Canal Structures.*

Concrete Waste Gate with Concrete Head

These waste gates are concrete and usually automated. Due to their weight and size, they are found on larger projects.

Figure 4.66 Concrete wasteway gate and wasteway on the Friant Kern Canal on the CVP (California).[257]

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[257] Friant Water Authority, "About the Friant Kern Canal."

4.4.1.3 Headgates on Canals and Laterals

Wooden Headgates

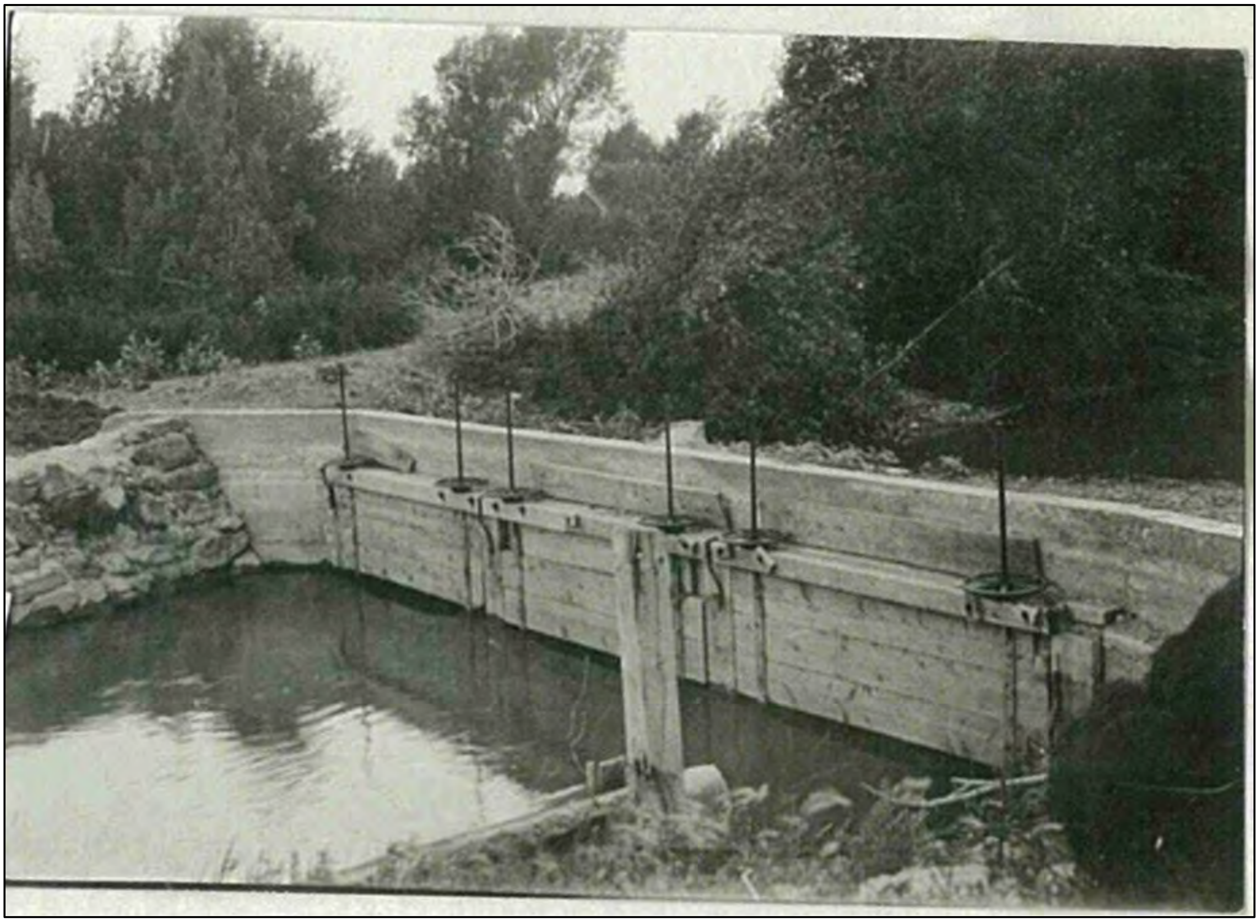

Figure 4.67 An example of a wooden lateral headgate at Lenroot Canal on the Minidoka Project (Idaho).[258]

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[258] Bureau of Reclamation, *Minidoka Annual Project History: Report of Construction and Operations and Maintenance, Volume XI* (Denver, Colorado: Bureau of Reclamation, 1917).

Concrete Structure with Cast-Iron Gates

This common style of gate is found on many Reclamation projects, especially on the lateral and sublateral canals.

Figure 4.68 An example of a concrete turnout with an iron slide gate. The drawing below shows an older version of the same style and use (Texas).[259]

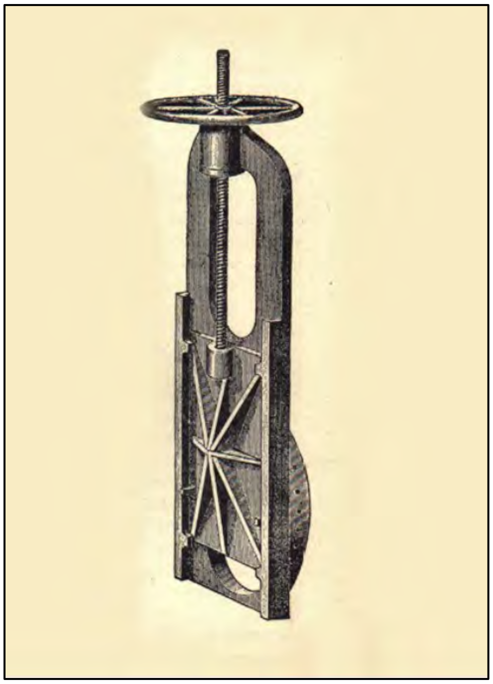

Figure 4.69 A c1895 advertisement for an iron radial gate.[260]

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[259] Knight, *Field Guide*, 151.

[260] Ibid., 151.

Concrete Headgates with Steel Gates

These can be on main canals or laterals and sublaterals. These have replaced wooden and cast-iron headgates on most projects over the past 50 years.

Figure 4.70 Concrete and cast-iron headgate on the Truckee Canal on the Newlands Project (Nevada).[261]

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[261] Steve Ranson, "Water: More precious than gold," *Lahontan Valley News*, October 6, 2021, https://www.nevadaappeal.com/news/2021/oct/06/water-more-precious-gold/ [accessed February 2023].

Concrete Headgates with Concrete Gates

Like the concrete and steel headgates, these gates are usually found on larger projects and often replaced older wooden and iron gates.

Figure 4.71 An example of a vertically hinged concrete headgate in a lateral on an unknown Reclamation Project.[262]

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[262] Crawford and Gosden, "River and Canal Structures," 11.3.1.

4.4.2 Turnouts

Turnouts are devices to permit water to move from a lateral, sublateral, or ditch into an adjacent lateral or ditch. They are made of wood, metal, or concrete, and may be simple hand-operated devices or automated. The floor of the turnout is installed level with the bottom of the lateral or ditch into which the water must flow. Below are examples of a concrete check gate or wall, wood, concrete with concrete gate, concrete with iron gate laterals, and concrete orifice structures.[263]

4.4.2.1 Checks or Check Gate or Check Wall

A check or check gate usually consists of a single wall in a canal or ditch meant to cause the water to rise, permitting the turnout headgate upstream from the flow to withdraw water. Simple ones consist of a single wooden or concrete wall built perpendicular to the canal. They contain a notch through the center that provides for water passage when not in use. Like drops (discussed in Section 4.4.4), the notch can be adjusted either manually or electrically to control the height of the water flow.

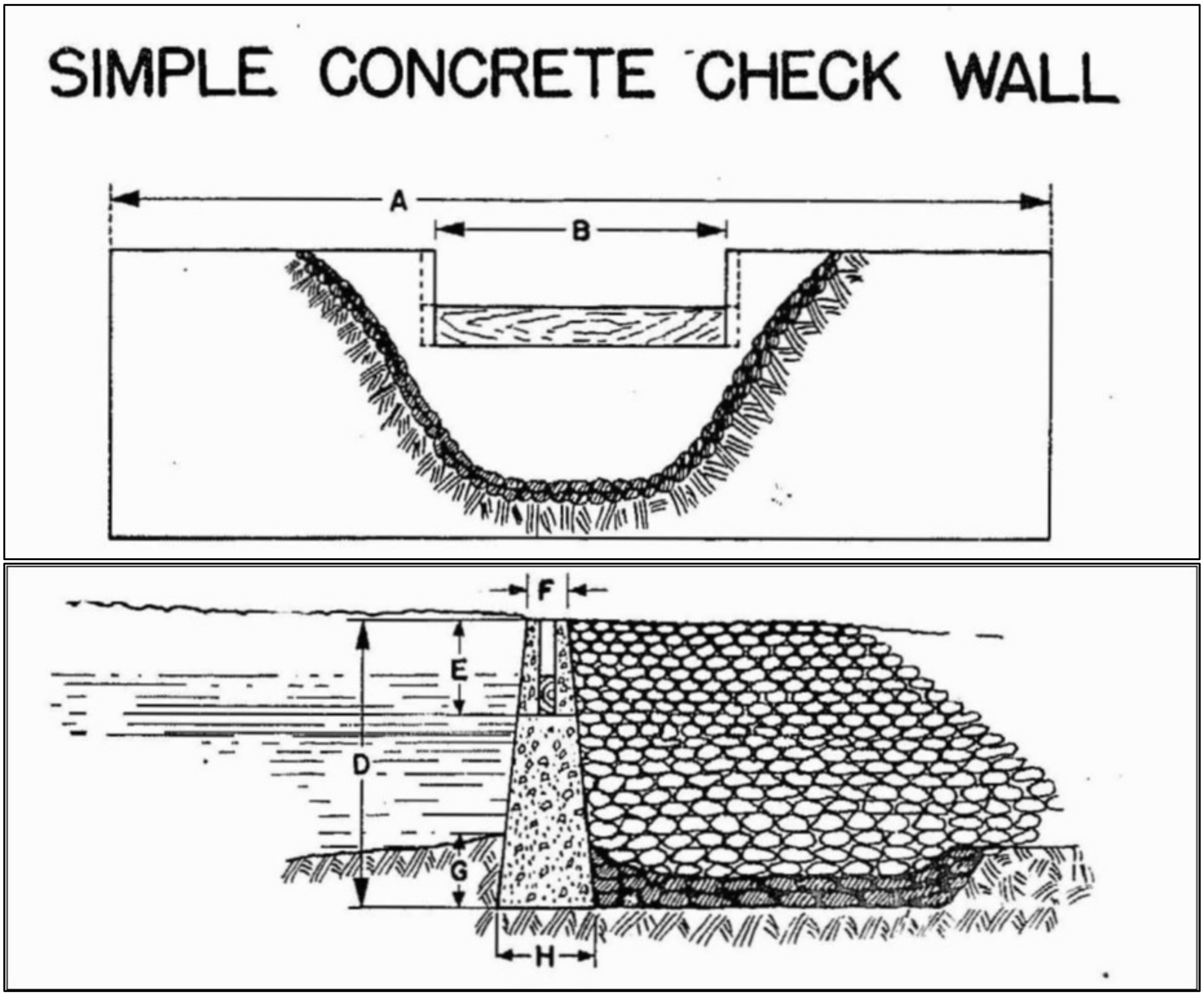

Figure 4.72 A simple concrete check wall that stops the flow of water and permits it to overflow through the notch in the wall. Water backs up and rises on the upstream side, permitting the turnout to withdraw it. A rip rap bottom is used to help still the water at the fall.[264]

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[263] Dusenberry and Monson, *Irrigation Structures*, 20.

[264] Ibid., 15.

4.4.2.2 Wooden Lateral Headgate Turnouts

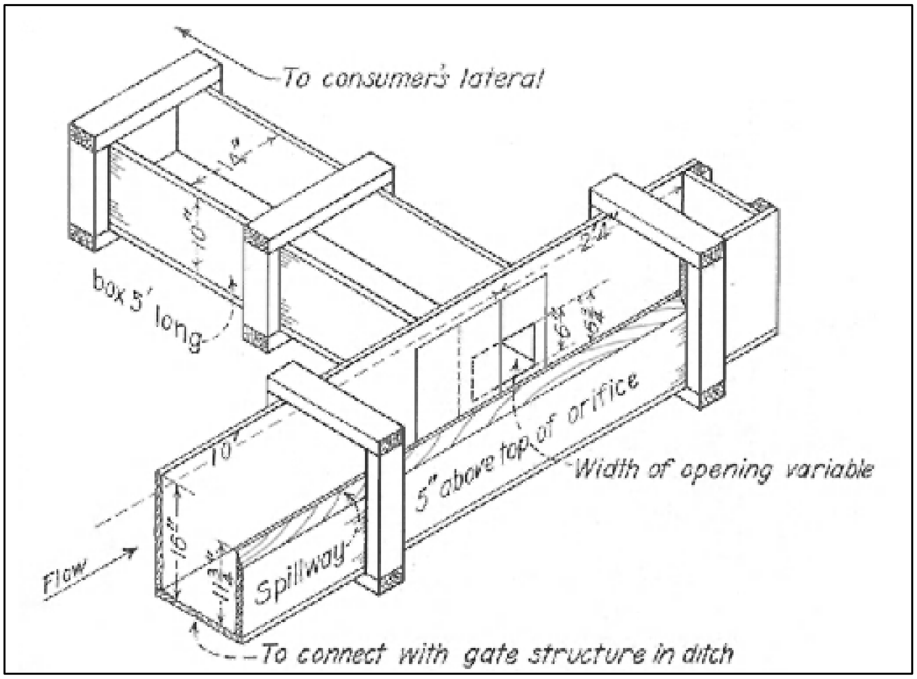

Figure 4.73 Schematic drawing of a standard lateral turnout.[265]

Figure 4.74 Simple hand-operated wooden turnout gate on an unknown Reclamation project (Colorado).[266]

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[265] Holleran, *Historic Context*, 72.

[266] Ibid.

4.4.2.3 Concrete Lateral Headgate Turnout with Concrete Gates

Figure 4.75 Concrete turnout with trash rack that permits water into the field from the lateral canal in an unknown Reclamation project.[267]

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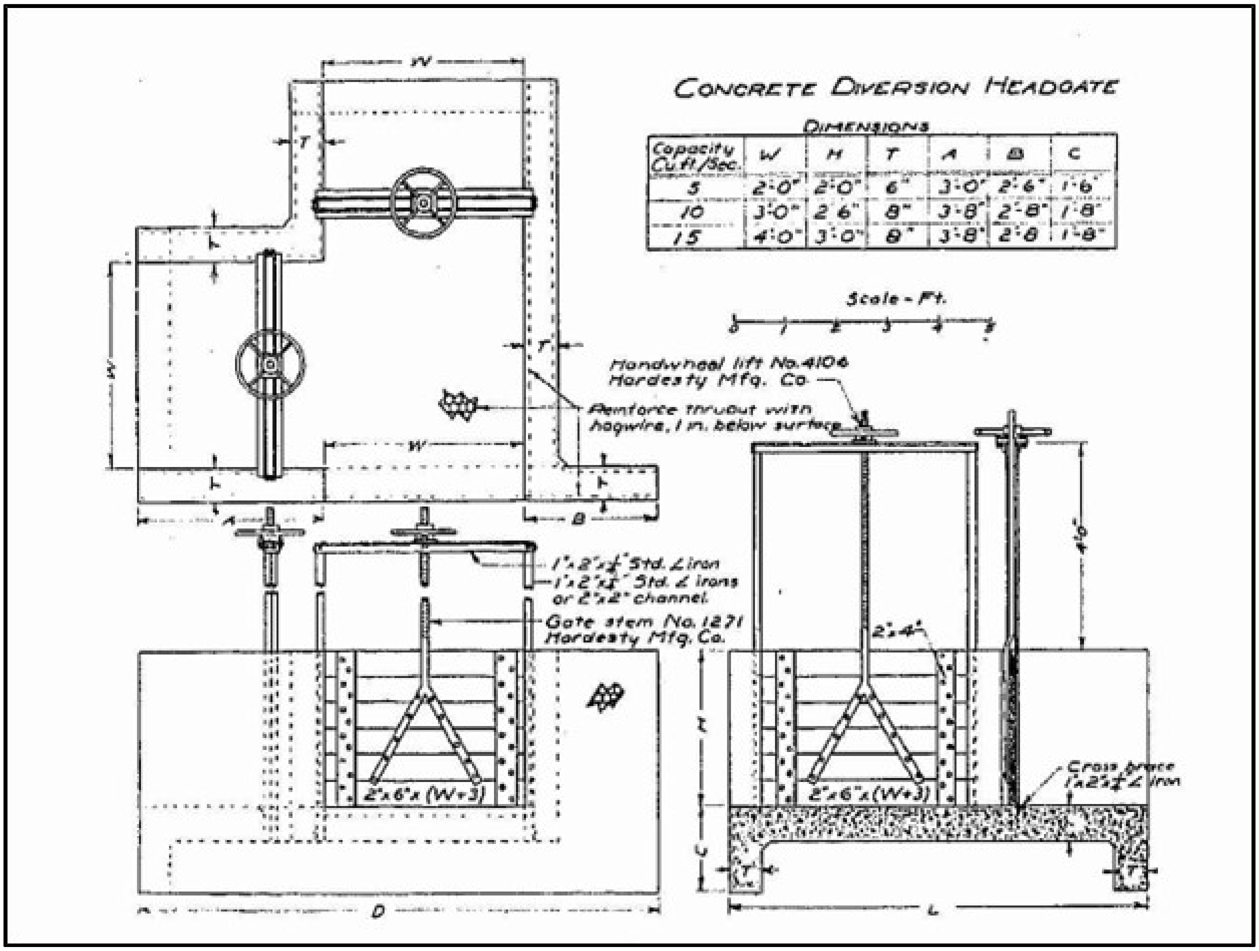
[267] Aisenbrey et al., *Small Canal Structures*, 150.

4.4.2.4 Concrete Lateral Headgate Turnout with Cast-Iron Gate



DIMENSIONS

Capacity Cu.ft./Sec.	W	H	T	A	B	C
5	2'-0"	2'-0"	6"	3'-0"	2'-6"	1'-6"
10	3'-0"	2'-6"	8"	3'-8"	2'-8"	1'-8"
15	4'-0"	3'-0"	8"	3'-8"	2'-8	1'-8"

Figure 4.76 A schematic drawing of a concrete lateral headgate with cast-iron doors.[268]

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[268] Dusenberry and Monson, *Irrigation Structures*, 14.

4.4.2.5 Concrete constant head orifice structure

This device developed by Reclamation both releases water into an adjacent ditch or lateral and measures it at the same time. They have at least two gates. The first gate controls the head of the orifice (or measuring box) and permits water to flow into the orifice or box. The second controls the water depth below the orifice to keep it at a constant value. The size of the orifice can be adjusted as to the amount of water needed. The device can compute the approximate flow of water and determine the amount of water used.

Figure 4.77 Constant Head Orifice Structure with the operator adjusting the headgate.[269]

4.4.3 Distribution or Division Boxes (Head Box)

These boxes, made of metal, wood, or concrete, divide the flow of water within an irrigation canal based on a proportional system rather than an exact measuring system. They are generally outdated, with more accurate electronic measuring systems now available. However, they can be seen on older projects where they have not been replaced. They have removable partitions or valves that permit the flow of water from a lateral into a sublateral or ditch in a precise manner.[270] These would be more commonly made of concrete on Reclamation projects. Two examples are shown in the drawings and photograph in Figures 4.78 through 4.81. In lower areas these can be raised above the ground; Figure 4.81 shows an example of this type of diversion stand.

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[269] Aisenbrey et al., *Small Canal Structures*, 150.

[270] Knight, *Field Guide*, 156.

4.4.3.1 Wood Distribution Box

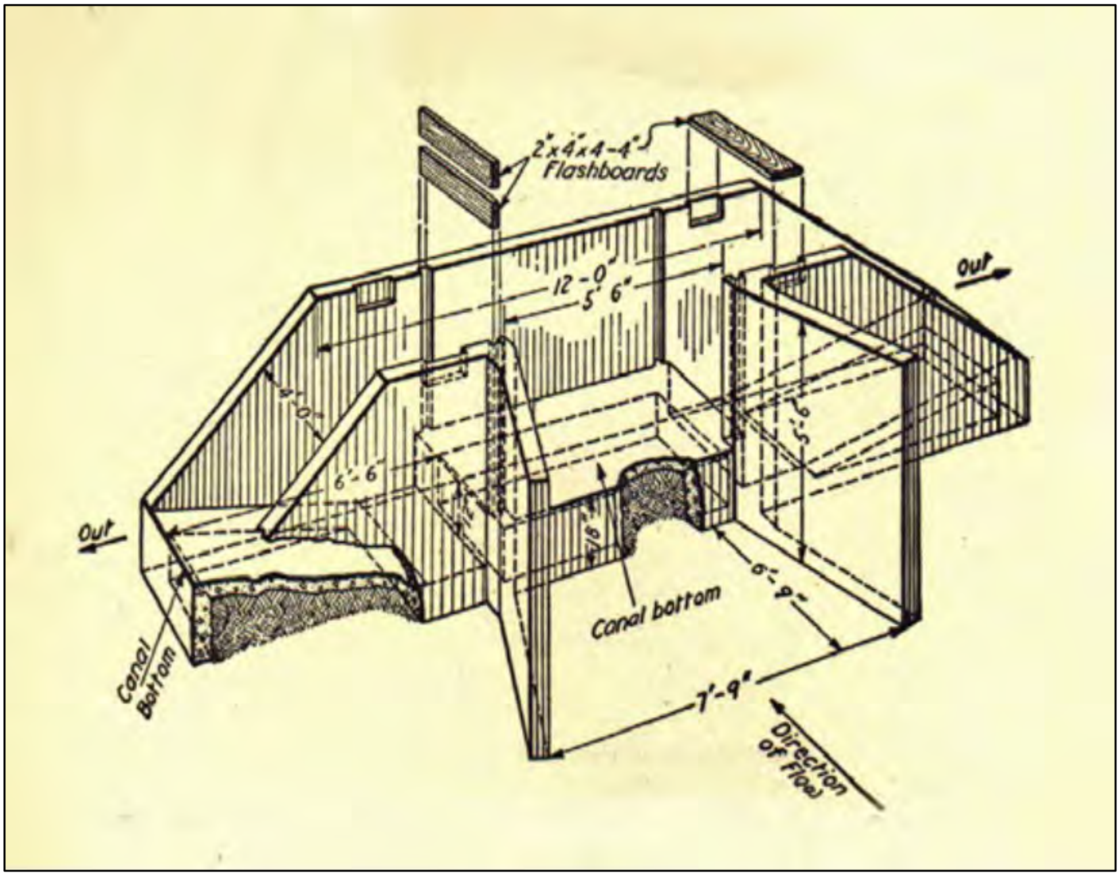

Figure 4.78 Drawing of a wood distribution or division box that divides water into proportional amounts from lateral to sublateral canals and serves as a lateral turnout.[271]

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[271] Knight, *Field Guide*, 164.

4.4.3.2 Concrete Distribution Box

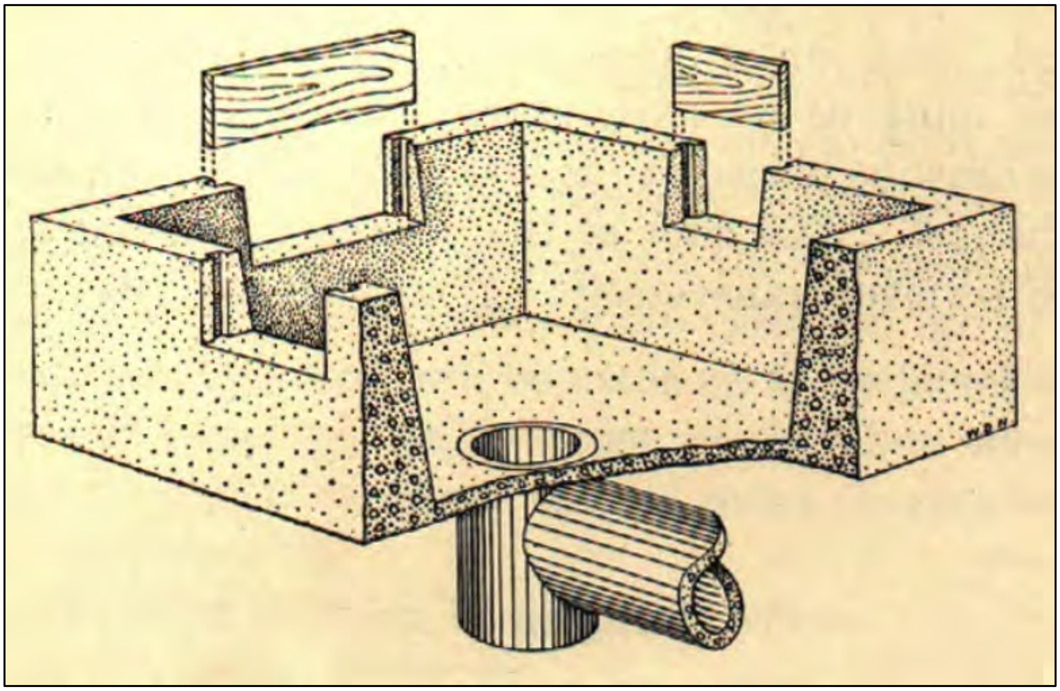

Figure 4.79 Drawing of a concrete division or distribution box employing underground piping subdividing the water into proportional parts. Note that the amount of water for each lateral or ditch is determined by the size of the notch in the wall.[272]

Figure 4.80 Interior of an underground concrete distribution box.[273]

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[272] Knight, *Field Guide*, 156.

[273] Ibid., 157.

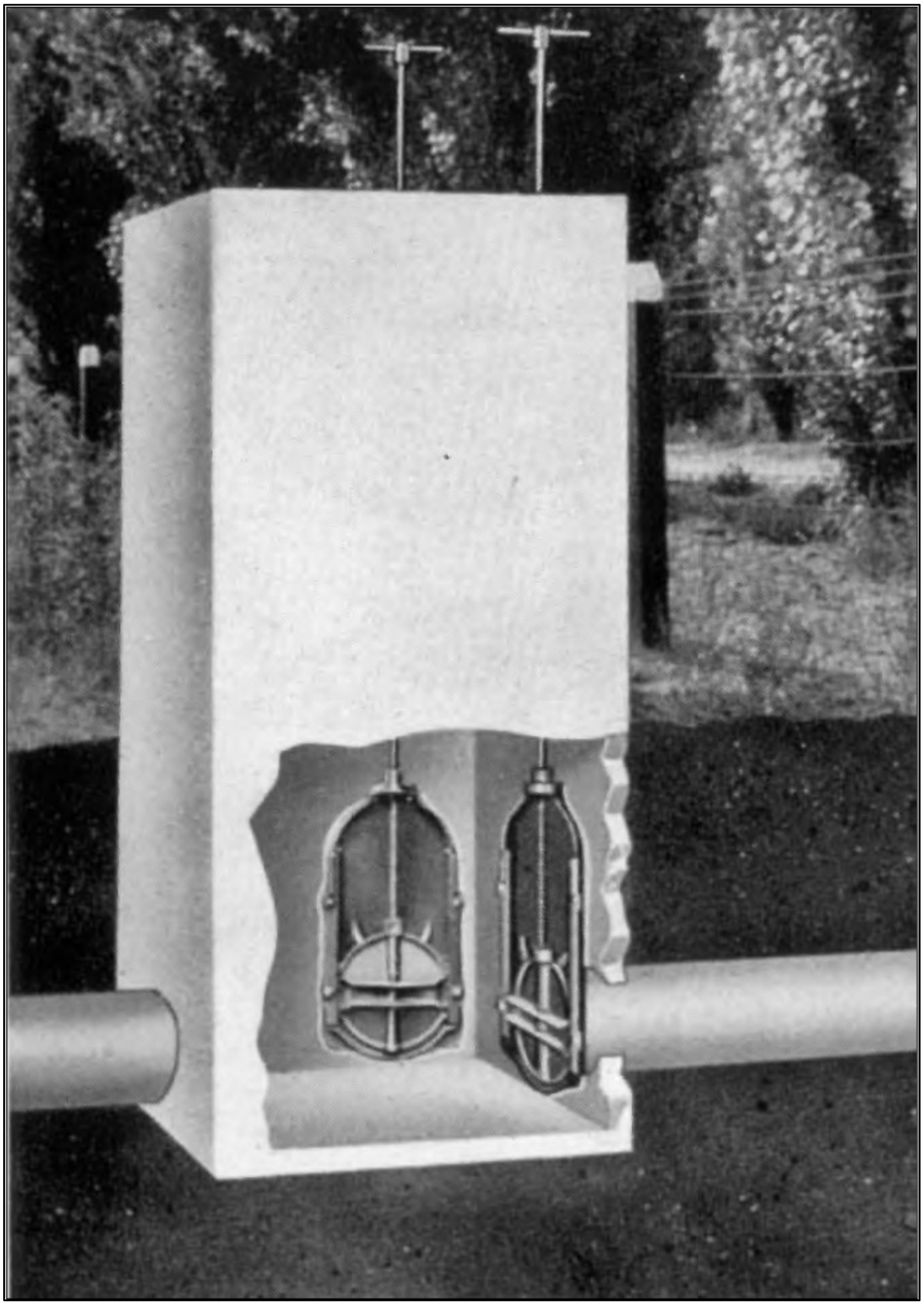

Figure 4.81 A combined photograph and illustration of the lower interior portion of a distribution box, showing how it regulates flow from a canal or lateral to one or more sublaterals. Note that the gate opening valves are at the top of a tall concrete structure, but the functional components are below-grade (Lower Rio Grande Project, Texas). [274]

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[274] Knight, *Field Guide*, 164.

4.4.4 Drops

Drops are used primarily to slow the velocity of water as it drops in elevation and to protect the channel from erosion. They have the added advantage of raising the water level. In that capacity, they act more as a check. The notch in the top permits the water to continue to move at a slower rate and prevent erosion. Most drops have adjustable notches for different levels of flow. Various options to help reduce the turbulence of the drops include baffles, boxes, and aprons that are attached to the downward side. Drops tend to be the simplest and lowest cost to install.[275] Discussed below are wood drops with wooden baffles, reinforced concrete baffle block drops, baffle rock drops, concrete drops with simple aprons, wood drops, and concrete pipe drops.

4.4.4.1 Wood Drops with Wooden Baffles

These baffles are made of local materials, usually wood. There are simpler examples using logs and parts of brush and wood. The latter are rarely used in Reclamation projects as they can be susceptible to flood damage.

Figure 4.82 A wooden drop on the Truckee Carson Project (Nevada).[276]

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[275] Dusenberry and Monson, *Irrigation Structures*, 17-18.

[276] B.A. Etcheverry, *Irrigation Practice and Engineering, Vol. III, Irrigation Structures and Distribution System* (New York: McGraw-Hill Book Co., 1916), 222 Figure C.

4.4.4.2 Reinforced Concrete Baffle Block Drop

These drops include mortaring reinforced concrete baffles into the floor of the drop to reduce agitation created by the falling water.

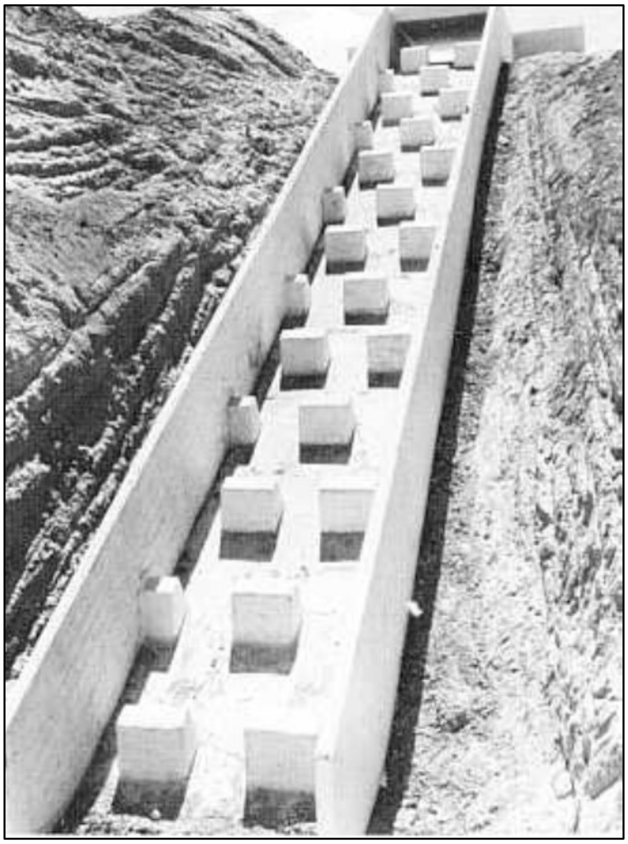

Figure 4.83 Baffles are mortared into the apron of the drop to dissipate the energy of the falling water into the canal, thus reducing erosion and smoothing the delivery of the water.[277]

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[277] Aisenbrey et al., *Small Canal Structures*, 300.

4.4.4.3 Baffle Rock Drop

Mortared rocks into the floor of the drop can produce a similar result as the reinforced concrete baffle.

Figure 4.84 A reinforced concrete drop using rocks as the baffle on an unknown Reclamation project (California).[278]

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[278] State of California, *Drainage Criteria Manual, Vol. 2 Hydraulic Structure*, Urban Drainage and Flood Control District, c2007, https://www.waterboards.ca.gov/rwqcb2/water_issues/programs/stormwater/muni/nrdc/08%20chapter%2008%20structures%202007%20rev.pdf [accessed February 2023], HS-120.

4.4.4.4 Concrete Drop with Simple Apron

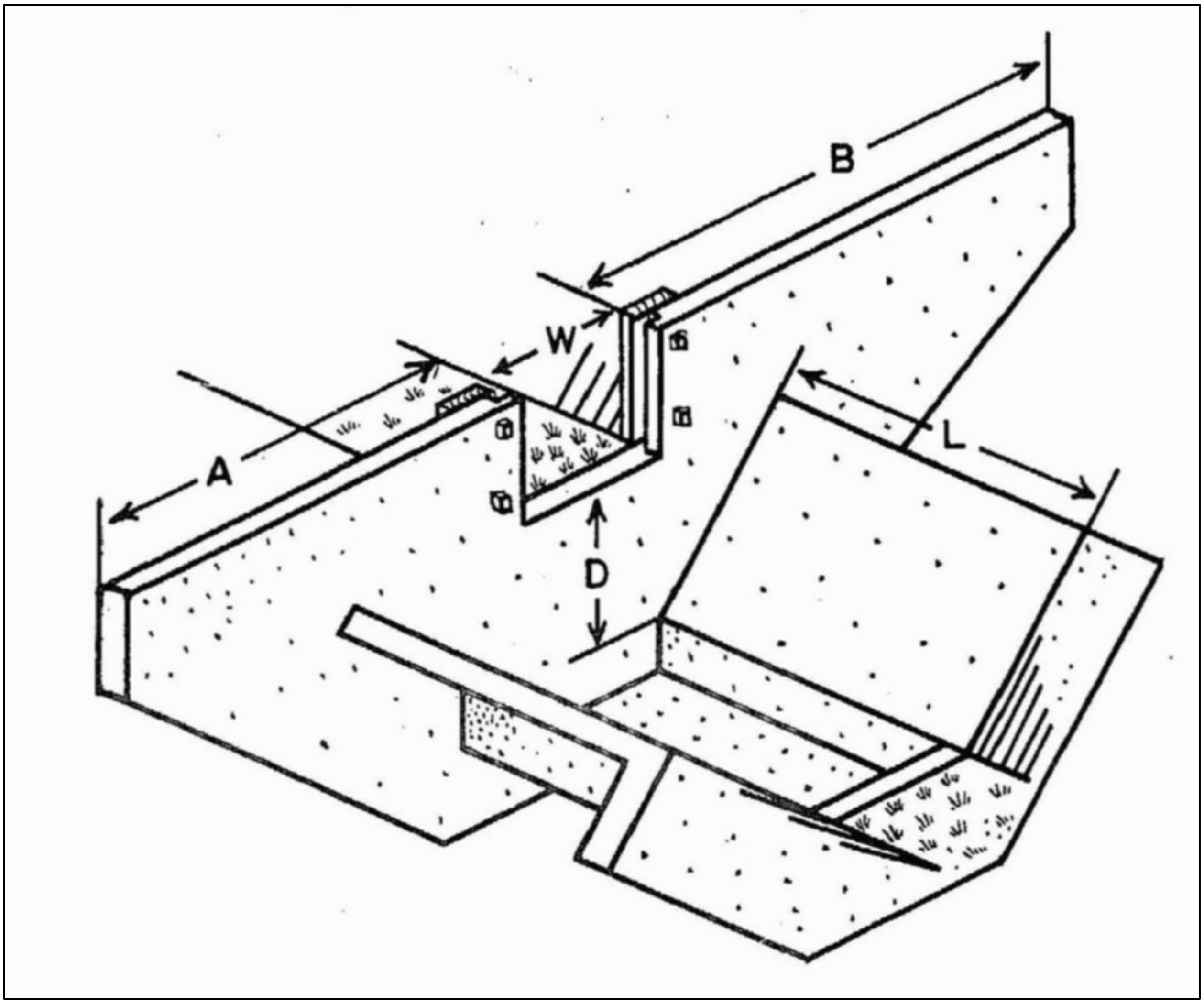

Figure 4.85 This drawing shows a concrete drop with a simple apron to help still the water as it falls through the check notch. The notch is adjustable depending on the height needed by the operator to get water into the turnout gate. However, concrete drops can exclude aprons and other turbulence-reducing features.[279]

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[279] Dusenberry and Monson, *Irrigation Structures*, 16.

4.4.4.5 Wood Drops

Wooden drops are constructed in a similar shape to concrete drops. Most of these are in older systems that Reclamation constructed, as concrete has been the most frequent material of choice since the 1940s.

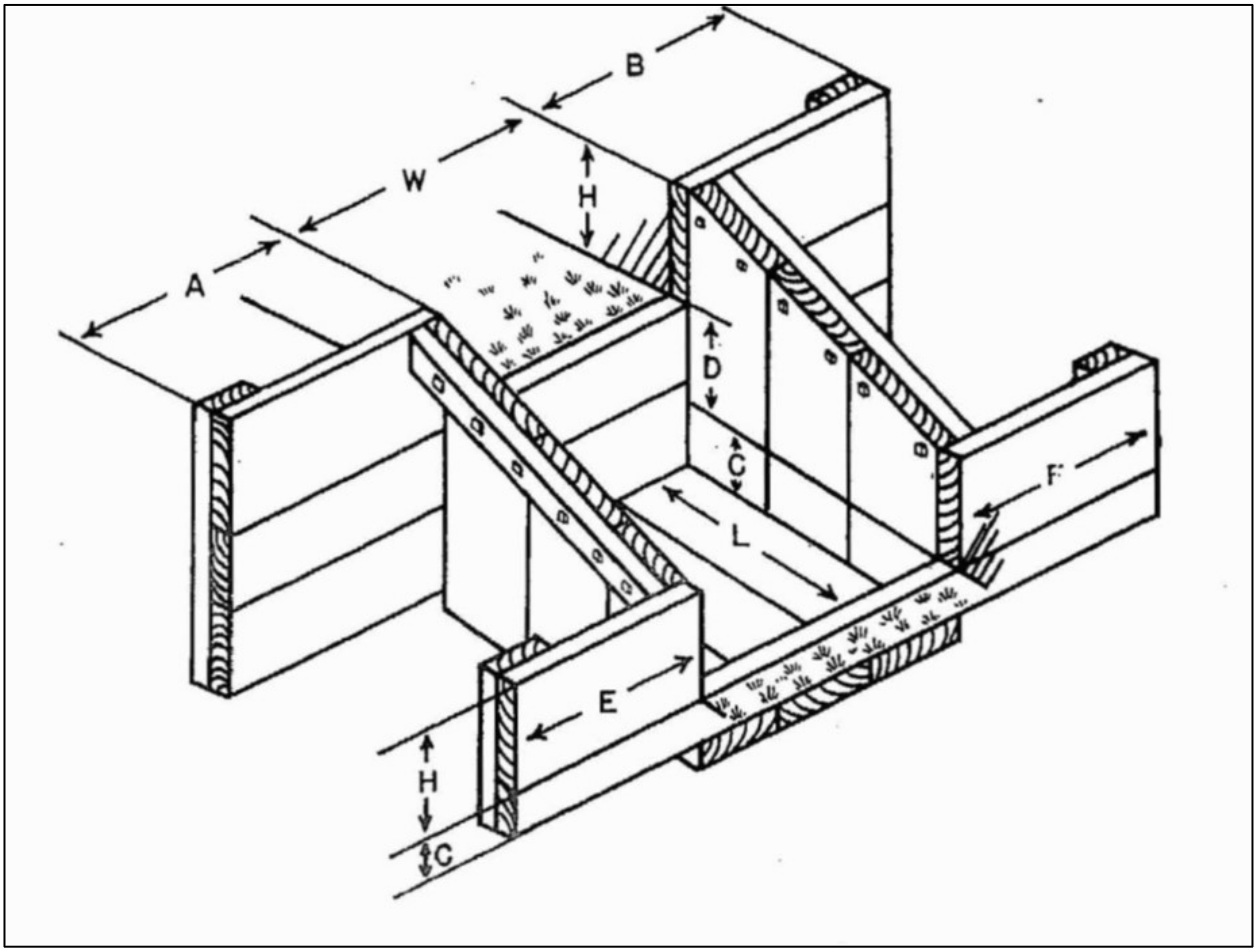

Figure 4.86 Wood drops are constructed in a similar shape to a concrete drop.[280]

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[280] Dusenberry and Monson, *Irrigation Structures*, 18.

4.4.4.6 Concrete Pipe Drops

Since the mid-twentieth century, companies have been pre-manufacturing pipe drops, sometimes called "ready-made drops," for use in irrigation canals.[281] The photograph below shows one type of precast concrete pipe drop.

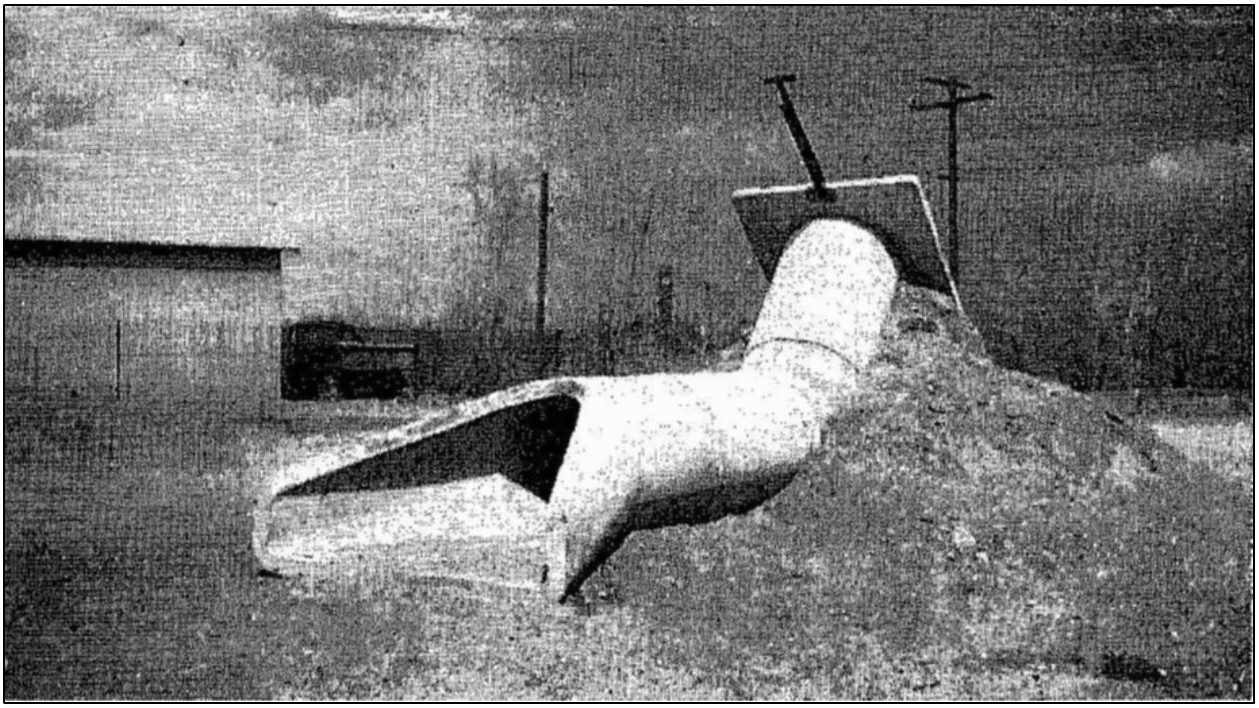

Figure 4.87 A precast concrete pipe drop.[282]

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[281] Dusenberry and Monson, *Irrigation Structures*, 18-19.

[282] Ibid., 19.

4.4.5 Chutes

Chutes are used to convey water from a higher elevation to a lower elevation. They are a type of drop but can accommodate greater changes in grade gradually and over longer distances. Chute structures consist of an inlet, a chute section, an energy dissipater, and an outlet transition. Chutes are usually either wood or concrete and can be open or piped.

4.4.5.1 Wood Chute

Figure 4.88 Example of a wood chute constructed early 1900 as part of irrigation canals in the Uinta Basin, Utah.[283]

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[283] Library of Congress, "Irrigation Canals in the Uinta Basin, Deep Creek Canal, Duchesne, Duchesne County, UT," Photograph, 1968, https://www.loc.gov/pictures/collection/hh/item/ut0374/ [accessed August 2023].

4.4.5.2 Concrete Chutes

Due to the demand for chutes covering long distances, concrete chutes have taken the place of wooden chutes.

Figure 4.89 An open concrete chute on a steep slope.[284]

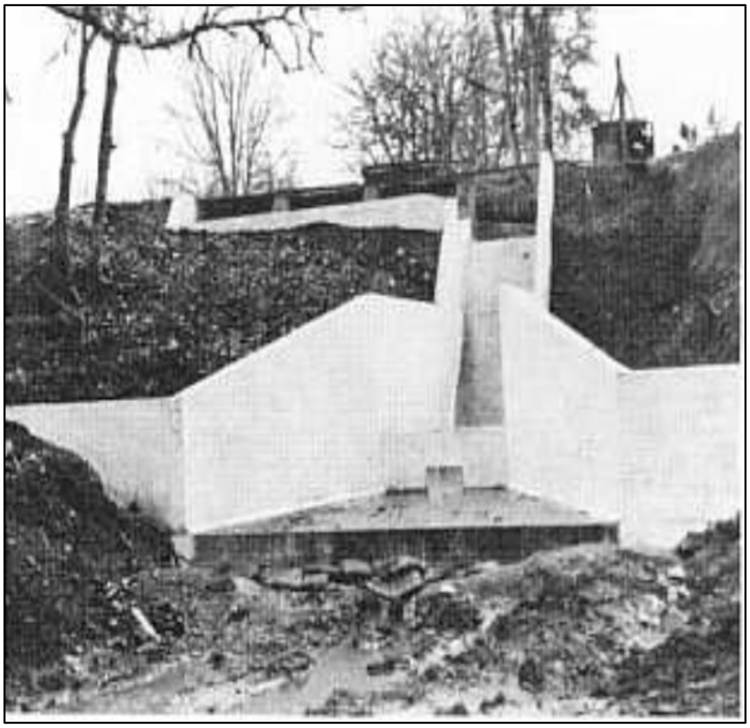

Figure 4.90 The stilling pool and outlet portion of a chute. Note how the check bank requires the water to stop and dissipate, then exit the chute.[285]

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[284] Aisenbrey et al., *Small Canal Structures*, 103.

[285] Ibid., 103.

4.4.5.3 Steel Chute

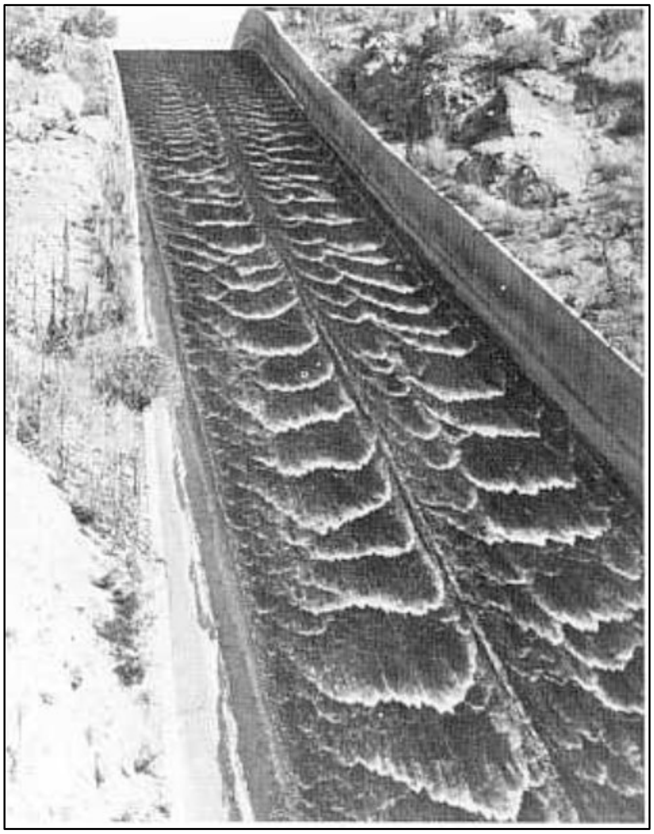

Figure 4.91 An example of a metal chute. This example indicates an unstable flow at a shallow depth.[286]

4.5 Measuring Devices

Measuring devices are critical for irrigation districts to determine farmers' water usage and assess costs. There have been many types of measuring devices used on Reclamation projects over the years. These can generally be subdivided into six categories: Parshall flumes, modified Parshall flumes, stilling wells, weirs, weir boxes, and open flow meters. In a typical irrigation system, measurements of water flow are usually taken at the storage reservoir outlet, the canal headworks, and at lateral and farm turnouts.[287]

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[286] Aisenbrey et al., *Small Canal Structures,* 112.

[287] Ibid., 243.

4.5.1 Flumes

4.5.1.1 Concrete Parshall Flumes

Concrete Parshall flumes are inline, open-channel measuring structures in which the canal water flows over a broad, flat converging section, through a narrow downward sloping throat crest section, and then diverges on an upward sloping floor.[288] The water is measured as it passes through the throat crest. One measurement gives the rate of flow and can determine on the basis of time how much water passed through. Usually there is a measuring rod or point attached to or painted on the flume.

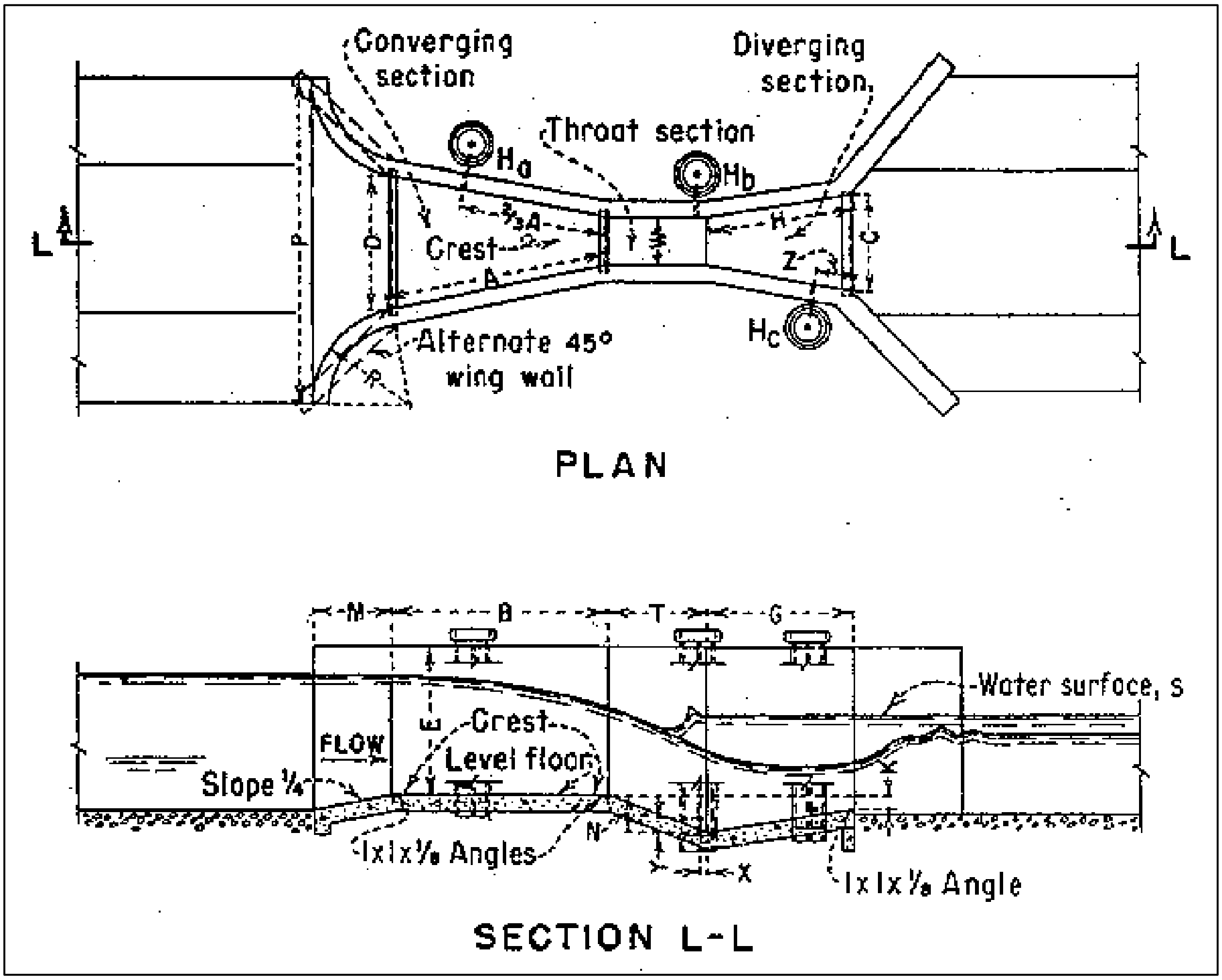

Figure 4.92 Schematic drawing of a Parshall flume.[289]

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[288] Aisenbrey et al., *Small Canal Structures*, 244.

[289] Bureau of Reclamation, *Water Measurement Manual*, revised reprinted 2001 (Washington, D.C.: U.S. Government Printing Office, 2001), 8-31. https://www.usbr.gov/tsc/techreferences/mands/wmm/WMM_3rd_2001.pdf [accessed January 2023].

Figure 4.93 Measuring water flow at a concrete Parshall flume (Colorado).[290]

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[290] Amy Zimmer, "Time Machine Tuesday: The Parshall Flume," https://www.coloradovirtuallibrary.org/resource-sharing/state-pubs-blog/time-machine-tuesday-the-parshall-flume [accessed December 2023].

4.5.1.2 Metal Parshall Flume

Beginning in the 1980s, prefabricated metal flumes began to replace older wooden and some concrete Parshall flumes, especially at farm turnouts. The Reclamation website advertises approved outsourcing companies who manufacture prefabricated metal and fiberglass Parshall flumes. Most of these flumes would not be considered historic.[291]

Figure 4.94 Though metal Parshall flumes have existed for decades, in recent years they have become popular and are often prefabricated to the specific need of the lateral.[292]

4.5.1.3 Concrete Modified Parshall Flumes

Modified Parshall flumes are usually altered to fit a specific canal profile. These are referred to as modified Parshall flumes or short-throated Parshall flumes. The modifications are made downstream of the throat and measuring area. In these, the downward sloping section of the floor can be extended into a more rectangular shoot to permit the water to flow easier into the canal or a stilling pool.[293] Figures 4.95 and 4.96 show a schematic of a modified Parshall flume and a photograph of a modified Parshall flume on an unknown Reclamation project.

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[291] Openchannelflow, Inc., "Custom Size Cutthroat Flumes," https://www.openchannelflow.com/blog/custom-size-cutthroat-flumes [accessed January 2023].

[292] Ibid.

[293] Aisenbrey et al., *Small Canal Structures*, 259; Bureau of Reclamation, *Water Measurement Manual*, 8-3.

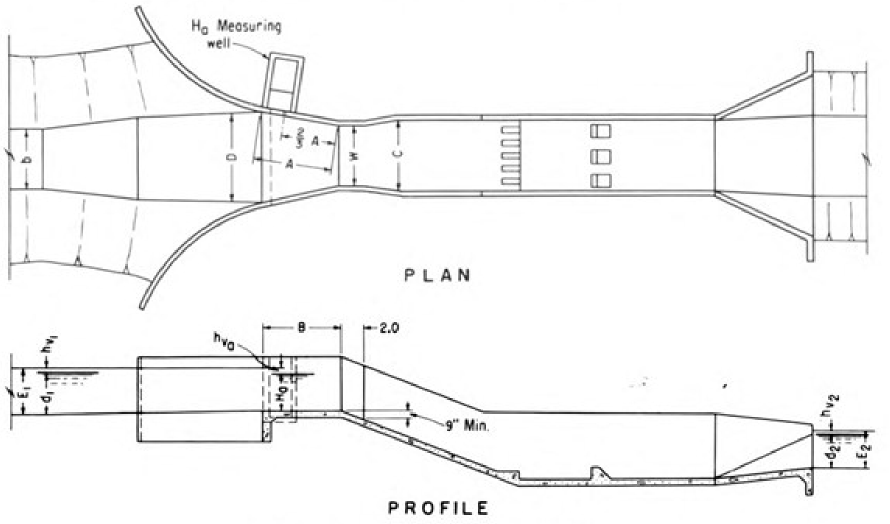

Figure 5-12. **Modified Parshall flume. 103-D-1233**

Figure 4.95 A schematic drawing of a concrete modified Parshall flume.[294]

Figure 4.96 A Parshall flume modified to the canal size, emptying water into a stilling basin on an unknown Reclamation project.[295]

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[294] Aisenbrey et al., *Small Canal Structures*, 259.

[295] Bureau of Reclamation, *Water Measurement Manual*, 8-3.

4.5.1.4 Metal Modified Parshall Flumes

More recently, Reclamation has been using galvanized steel and fiberglass modified Parshall flumes. These are more than likely not historic structures, as concrete was the material of choice for most projects over 50 years old (as of 2023). However, they are increasingly used on projects. Figure 4.97 shows a photograph of a smaller, metal cutthroat modified Parshall flume. Note the short downstream length.

Figure 4.97 A photograph of a modified Parshall flume.[296]

4.5.2 Stilling Wells (measurement)

4.5.2.1 Wooden Stilling Wells

Stilling wells are used in coordination with Parshall flumes and other head orifices to permit a more careful and accurate reading of the water flow. Their primary purpose is to provide a water surface free from fluctuations. These are attached to the flume or measuring structure via small pipes, in which are located the measuring instruments. The water level in the stilling well is the same as the pressure points in the flume. However, the water is quieter, and more accurate measurements can be obtained.[297] These wells should not be confused with stilling basins that are used on dams, canals, turnouts, flumes or, siphons, whose purpose is similar but not for measuring water flow.

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[296] Openchannelflow, Inc., "Custom Size Cutthroat Flumes."

[297] Aisenbrey et al., *Small Canal Structures*, 260.

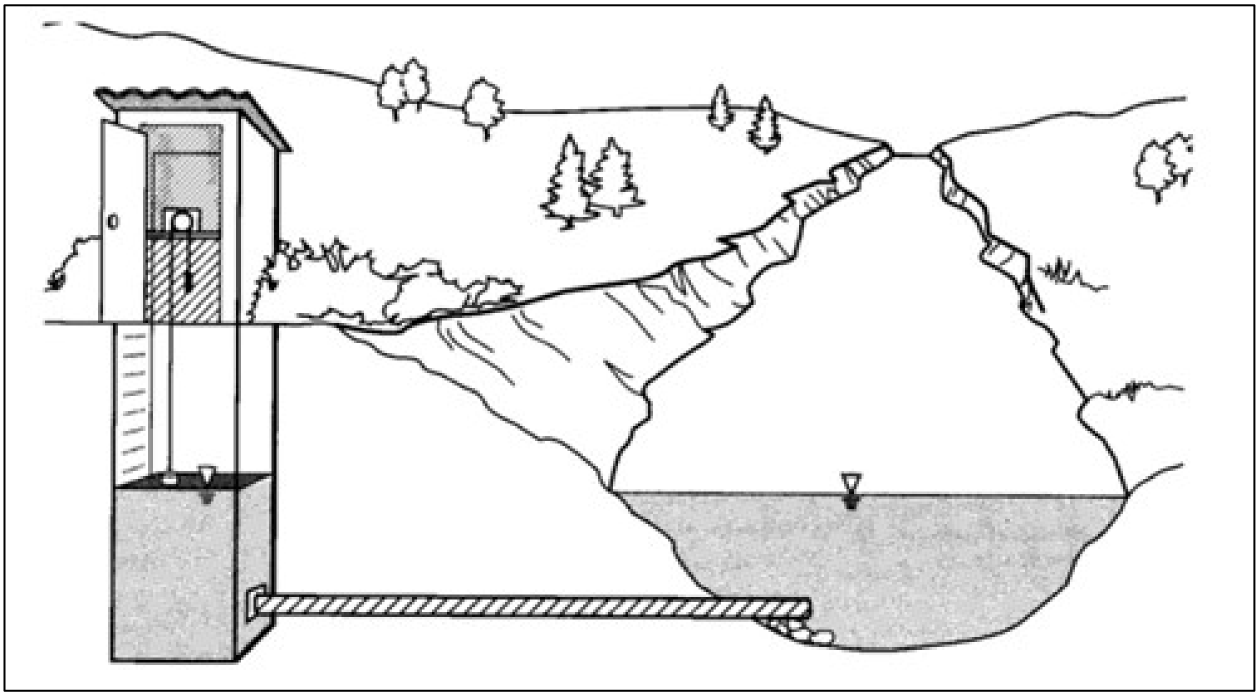

Figure 4.98 Schematic of one kind of stilling well measuring device. This would be attached to a Parshall flume to obtain a good measurement.[298]

Figure 4.99 Wooden top of a stilling well showing the instrument for measuring water height in a Parshall flume on an unknown Reclamation project.[299]

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[298] Intermountain Environmental, Inc. (IEI). “Stilling Wells.” https://www.inmtn.com/agriculture/canal-control/flume-weir-flow/stilling-wells/ [accessed January 2023].

[299] Bureau of Reclamation, *Water Measurement Manual*, 6-11.

4.5.2.2 Metal Stilling Wells

Metal stilling wells perform the same function as wooden stilling wells and are more numerous. Figure 4.100 shows a metal unit being installed next to a water measuring device on an unknown Reclamation project.

Figure 4.100 A metal stilling well placed into an irrigation system on an unknown Reclamation project (courtesy of Bureau of Reclamation).

4.5.2.3 Concrete Stilling Well

Like metal and wooden stilling wells, concrete well structures are more popular and is generally the material of choice, especially on larger Reclamation projects.

Figure 4.101 West façade of the stilling well in the Parshall flume of the Florence Casa Grande Canal in the San Carlos Irrigation Project (Arizona).[300]

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[300] Greta Rale and Helena Reuter, *Historic American Engineering Record Documentation of the China Wash Flume, Pinal County, Arizona* (Denver, Colorado: Bureau of Reclamation, 2016), 23.

Figure 4.102 This photograph shows the Parshall flume, stilling well, and the gauging well on the right at the Florence Casa Grande Canal in the San Carlos Irrigation Project (Arizona).[301]

4.5.3 Weirs (as measurement devices)

Measurement weirs are overflow structures built across an open channel to measure the rate of water flow. Measurement weirs, if built correctly and maintained properly, will measure lower rate flows from 1 to 100 cfs. They are identified by the shape of the opening. Most Reclamation weirs used in measuring water flow are either rectangular, Cipoletti, or V-notch weirs with fixed openings. Cipoletti weirs have trapezoidal-shaped notches rather than rectangular or V-shaped notches to permit water flow. Traditionally, Reclamation weirs are concrete, though early examples are wooden and may still be in use on some projects. Measurement weirs can be combined with other important structures within an irrigation system. Weirs can also have an adjustable opening to raise or lower water flow. Types of all three weirs are shown in the graphic below.

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[301] Rale and Reuter, *China Wash Flume*, 23.

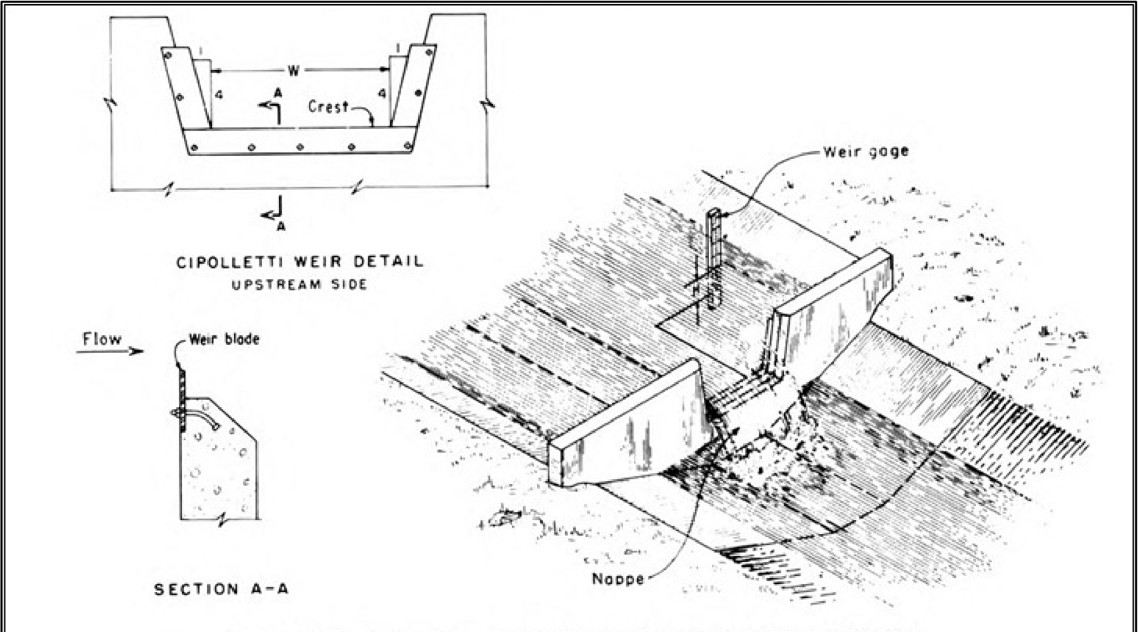

Figure 5-16. **Cipolletti weir in a permanent bulkhead–free-flow conditions. 103-D-1236**

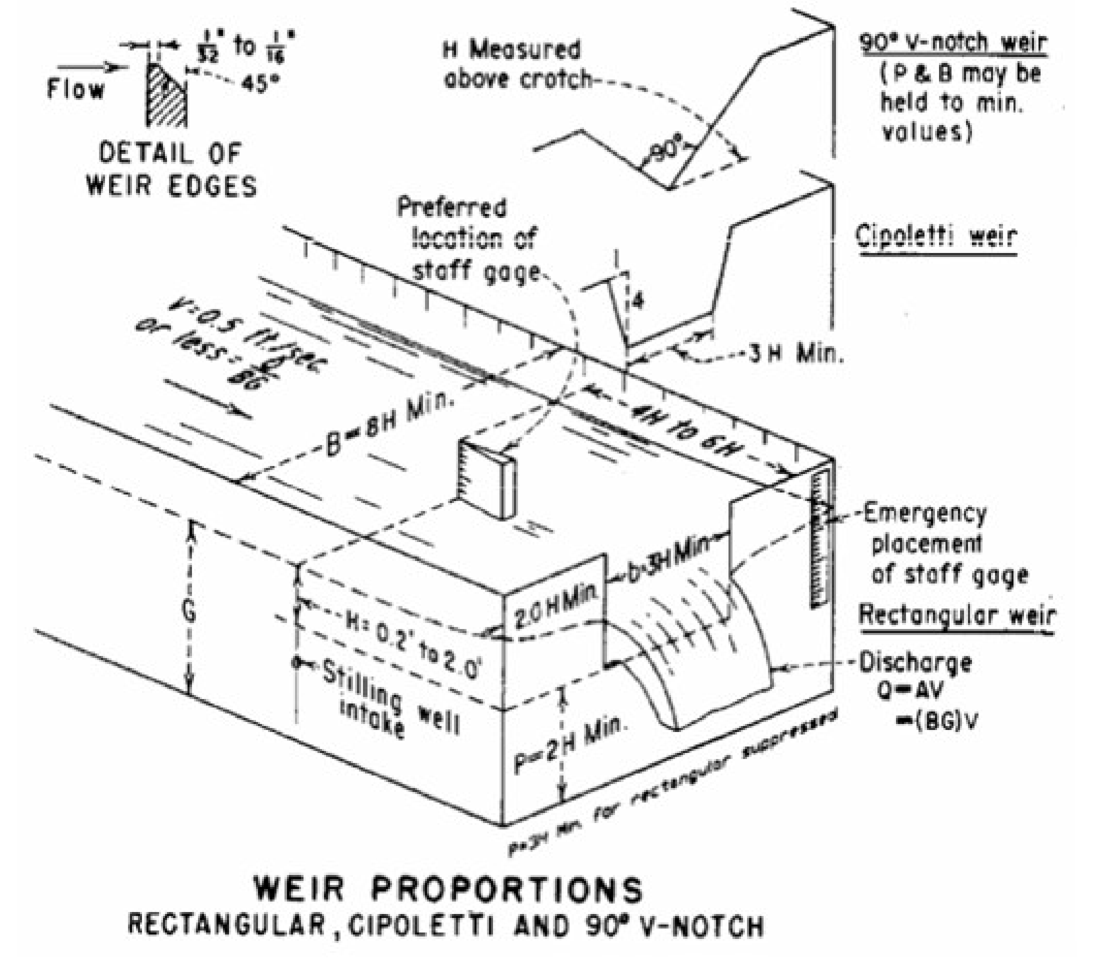

Figure 4.103 Schematic drawings of measuring weir. The only difference between the designed weirs is the notch through which the water flows.[302]

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[302] Aisenbrey et al., *Small Canal Structures*, 263.

4.5.3.1 Cipoletti Weir

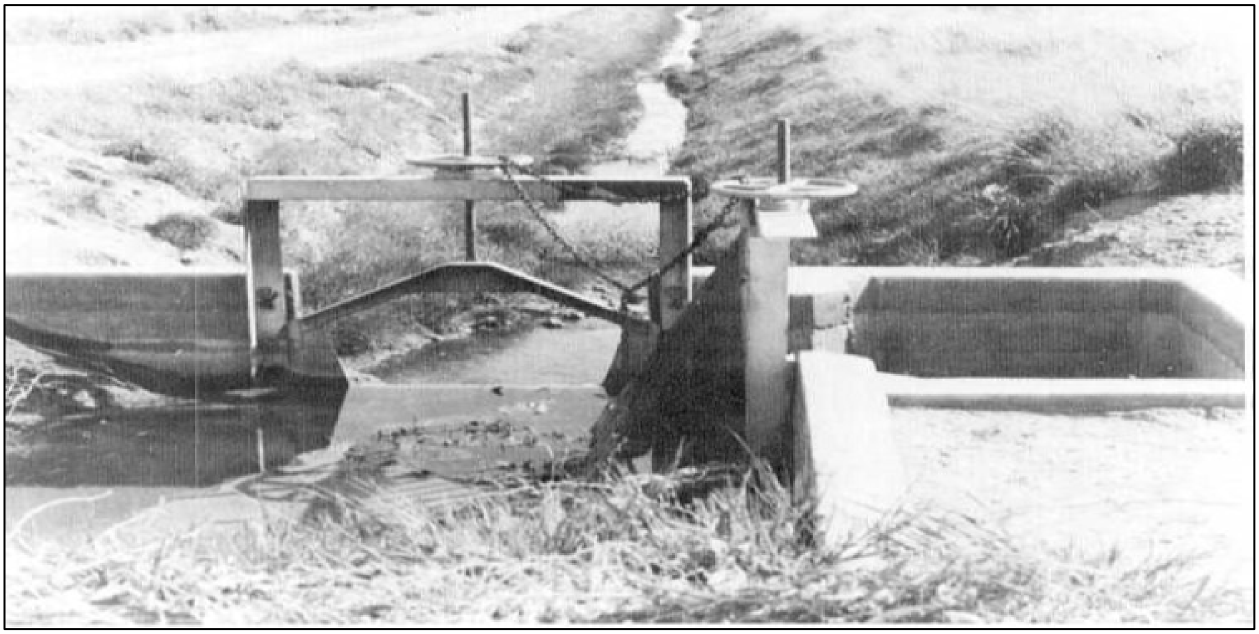

Figure 4.104 An example of a Cipoletti weir combined with a division turnout to measure and separate water from a canal on an unknown Reclamation project.[303]

Figure 4.105 A Cipoletti weir with a measuring rod (at right) on an unknown Reclamation project.[304]

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[303] Aisenbrey et al., *Small Canal Structures*, 162.

[304] Ibid., 263.

4.5.3.2 Weir Boxes

Weir boxes are used by Reclamation in combination with pipe turnouts to measure the water flow rate to lateral canals or to an individual farm. Reclamation uses three- and four-foot weir boxes. The water passes from a gated turnout into a pipe, then to system of baffles, and finally into the weir box. Thus, by the time the water hits the weir pool, it is smooth, free from turbulence, and easy to measure.[305] All historic weir boxes were concrete. However, since the 1980s, similarly designed metal weir boxes have appeared in Reclamation projects.

Figure 4.106 Ditch rider delivering water through a weir to a farm ditch. The scale in the photograph indicates 0.51 second feet of water going through the weir to a farm on the Yakima Project (Washington State) (courtesy of Bureau of Reclamation).

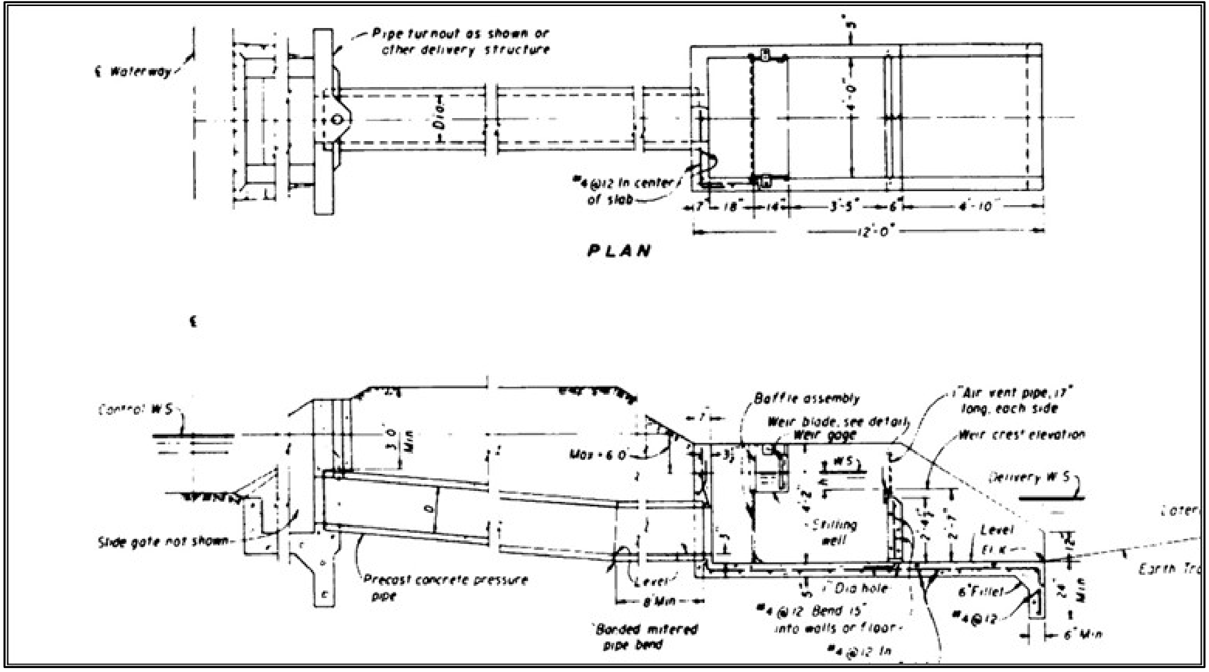

Figure 4.107 Schematic drawing of a typical weir box for measuring water flow to a lateral. The box is at the far right of the structure.[306]

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[305] Aisenbrey et al., *Small Canal Structures*, 292-293.

[306] Ibid., 292.

4.5.3.3 Open Flow Meters

Open flow meters are propeller-type meters installed at the end of a gravity pipe turnout to measure and record the rate of flow through the pipe into laterals or farm canals. The propeller is moved by the energy of the water passing through the pipe. The propeller activates a register and gives a direct volumetric reading in gallons. They are most effective at measuring when the conduit is fully flowing.

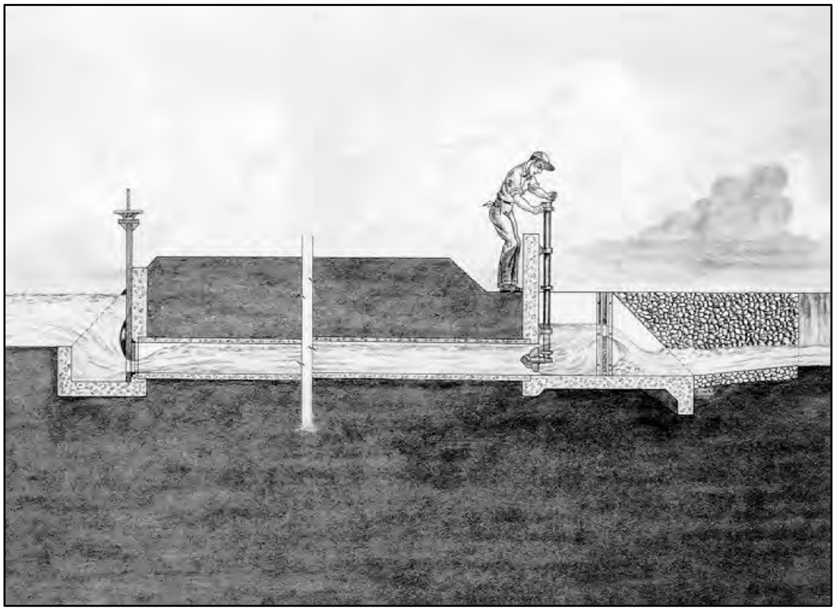

Figure 4.108 Typical propeller meter installation. Note the inspector reading the register at the top of the pipe.[307]

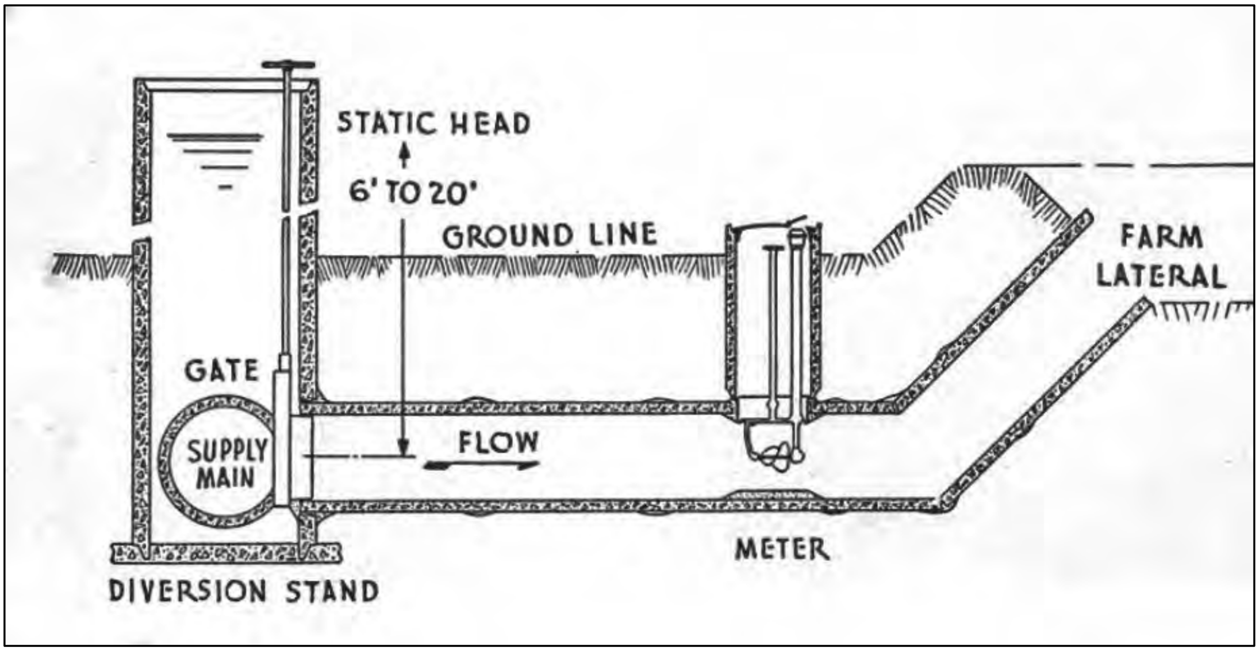

Figure 4.109 Schematic drawing of a turnout from a main canal with a flow meter to record the water flow.[308]

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[307] Bureau of Reclamation, *Water Measurement Manual*, 14-8.

[308] Knight, *Field Guide*, 141.

4.6 Cleansing Devices

4.6.1 Trash Gates or Racks

Debris or trash gates or racks are incorporated into several aspects of the irrigation process. Importantly, large trash gates can be incorporated into the main canal headgates to remove animal carcasses or trees or made smaller to strain out other items. Smaller trash gates can be incorporated into laterals, sublaterals, or ditches. They can also be used in syphons and culverts. Smaller trash gates are hinged to permit the removal of debris without the worker getting into the canal. Some can be removable, especially in small ditches and drains.[309]

4.6.1.1 Metal Trash Racks used in Canal

Metal trash racks include iron or steel bars or rods welded close enough together to permit water to flow freely but not debris. The trash must be removed periodically to prevent it from impeding water flow.

Figure 4.110 4.110 A trash rack in a lateral combined with a foot bridge in the Lower Rio Grande Project (Texas).[310]

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[309] Holleran, *Historic Context*, 68.

[310] Knight, *Field Guide*, 131.

4.6.1.2 Metal Trash Racks used in Culverts

These trash racks are commonly used to screen out debris from the culvert to keep water flow consistent.

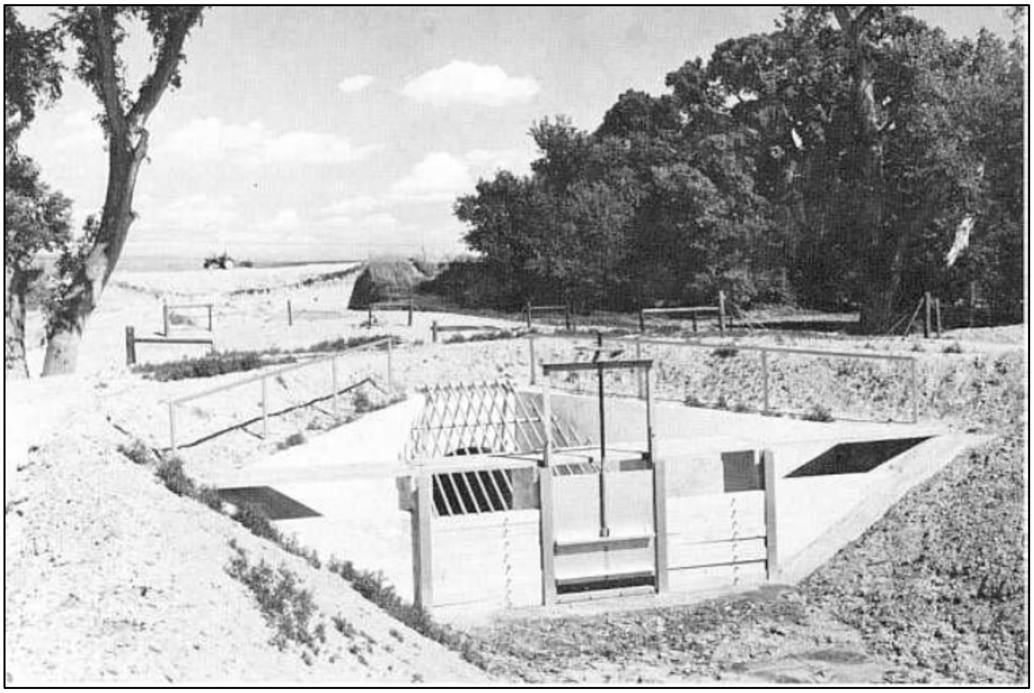

Figure 4.111 Trash gate over pipe mouth in a check inlet to a pipe (culvert) structure on an unknown Reclamation project.[311]

4.6.1.3 Metal Trash Racks Over Pumping Plant Dam Intake Structures

Metal trash racks are placed in front of a pumping plant's intake to keep out debris.

Figure 4.112 The style of trash rack used at the Senator Wash Pumping Plant, looking down on the rack from above, showing debris in the Colorado River Storage Project (Arizona).[312]

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[311] Aisenbrey et al., *Small Canal Structures.*

[312] Bureau of Reclamation, *Bureau of Reclamation's Arizona Centennial Legacy Project: Reclamation and Arizona, A Century of Cooperation, Lower Colorado Region*, 2012. https://www.usbr.gov/lc/phoenix/AZ100/index.html [accessed February 2023].

4.6.1.4 Self-cleaning Metal Trash Rack

Newer technology has allowed for improved self-cleaning trash racks.

Figure 4.113 A self-cleaning metal trash rack being installed over an older drainage ditch trash gate on the Tetsel Ditch Project (Arizona; non-Reclamation Project).[313]

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[313] Tom Gill, "Affordable Self-Cleaning Trash Rack, Irrigation Districts can now build their own self-cleaning, solar-powered trash rack," In *Bureau of Reclamation, Water Operation and Maintenance Bulletin # 236* (Denver, Colorado: Technical Service Center, 2014), 15-19.

4.6.2 Sand Traps

A sand trap is a larger version of the stilling basin used in measuring water flow. However, its use is different in the irrigation system. It permits the velocity of the water flow to slow and suspended particles of dirt and debris to settle out of the water. It is a cleaning device and is typically used with a headgate. Sand traps include a gate to permit flushing (or sanding out) the material caught in the trap. Sometimes waste gates are used for the same purpose of capturing debris. Sand traps have been used in more recent years to protect water quality when the sand being caught contains street runoff or mine tailings.

Figure 4.114 This image shows a number of features, including an iron headgate, a trash rack, a sand trap, and a flume as part of the main canal. The sand trap is the wide area behind the headgate where sand and debris can settle before the water enters the flume. The concrete feature on the right is the flushing gate where debris is flushed back into Sweetwater Creek (Idaho).[314]

4.7 Associated Structures/Components

All Reclamation projects have additional structures associated with the project. Warehouses, living quarters, powerplants, farmsteads, and agricultural fields can all be part of the Reclamation project and should not be ignored by researchers. However, the scope of work for this project covered only the water control (irrigation) features, beginning at diversion dams and continuing to non-Reclamation property. Only the Reclamation-built, -owned, or -managed structures are under consideration in this report.

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[314] Werner, *Lewiston Orchards*, 12.

However, field workers will encounter examples of these associated structures on various projects. A few examples of each type are described below.

4.7.1 Habitation Sites

All Reclamation projects contain various types of human occupational sites. Construction camps, warehouses, administration buildings, headquarters for irrigation districts, farms, residences, management houses, and twentieth-century subdivision encroachments all form a part of the landscape when evaluating Reclamation irrigation projects. Examples of habitation sites are shown in Figures 4.115 through 4.122.

4.7.1.1 Construction Camps (archaeology sites)

Figure 4.115 The site of the former CCC Camp BR-11 at the Moon Lake Project (Utah) is an archaeology site today.[315]

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[315] Bureau of Reclamation, *W.C. Austin Project*, A-73.

4.7.1.2 Warehouses and Other Non-residential Buildings

Figure 4.116 Corrugated metal warehouse WC-47 on the W.C. Altus Irrigation Project (Oklahoma) in 1991.[316]

Figure 4.117 Corrugated metal garage WC-48 on the W.C. Altus Irrigation Project (Oklahoma) in 1991.[317]

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[316] Pfaff and Wingate, *W.C. Austin Irrigation*.

[317] Ibid.

4.7.1.3 Farmsteads

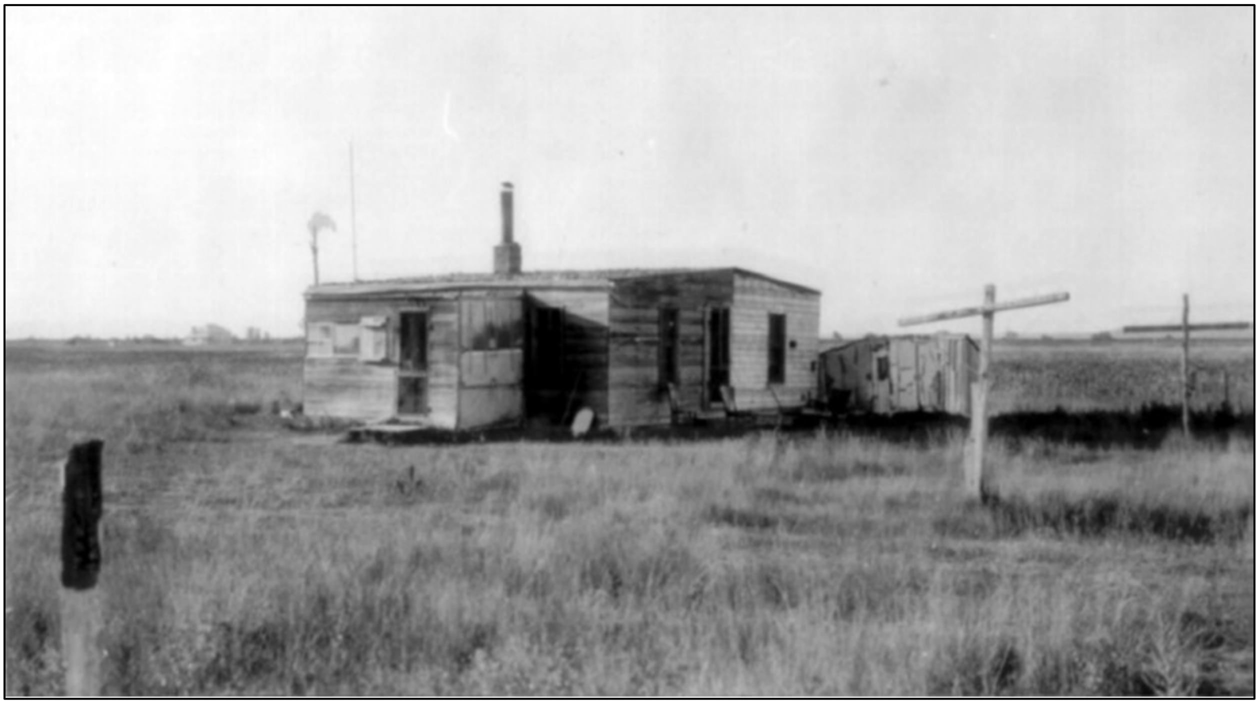

Figure 4.118 An abandoned farmstead on the North Platt Project (Nebraska), c1910.[318]

Figure 4.119 A successful farmstead on the Okanogan Project (Washington).[319]

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[318] Rowley, *Origins and Growth*, 123.

[319] Ibid., 122.

4.7.1.4 Ditch Rider and Powerplant Operator Homesteads

Figure 4.120 Housing projects for ditch riders within the Columbia River Basin Project (Washington).[320]

Figure 4.121 Water plant operator's residence at the Lewiston Orchards Project (Idaho).[321]

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[320] Bureau of Reclamation, *Columbia Basin Annual History* (1954).

[321] Bureau of Reclamation, *Lewiston Orchards Project, Idaho: Annual Project History – Calendar Years 1949 and 1950* (Denver, Colorado: Bureau of Reclamation, 1952).

4.7.1.5 Twentieth-Century Community Development

Figure 4.122 The Salt River Project canal surrounded by the City of Phoenix, Arizona, in 2021 is an example of the impact of irrigation on developments. The red arrow points to the Reclamation canal.[322]

4.7.2 Hydroelectric Features

4.7.2.1 Hydroelectric Powerplants and Substations

The Reclamation Service soon found that the generation of hydroelectric power at their projects could help to fund the project. Hydroelectric plants are common at most large dams and reservoirs within the Reclamation system. They can be represented by simple substations, like the Albion Substation on the Minidoka Project, or complex systems like the Estes Powerplant on the Colorado-Big Thompson Project. These are typically evaluated separately as they function independently of the conveyance and irrigation systems.

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[322] Bureau of Reclamation, *Lewiston Orchards Project* (1952), 81.

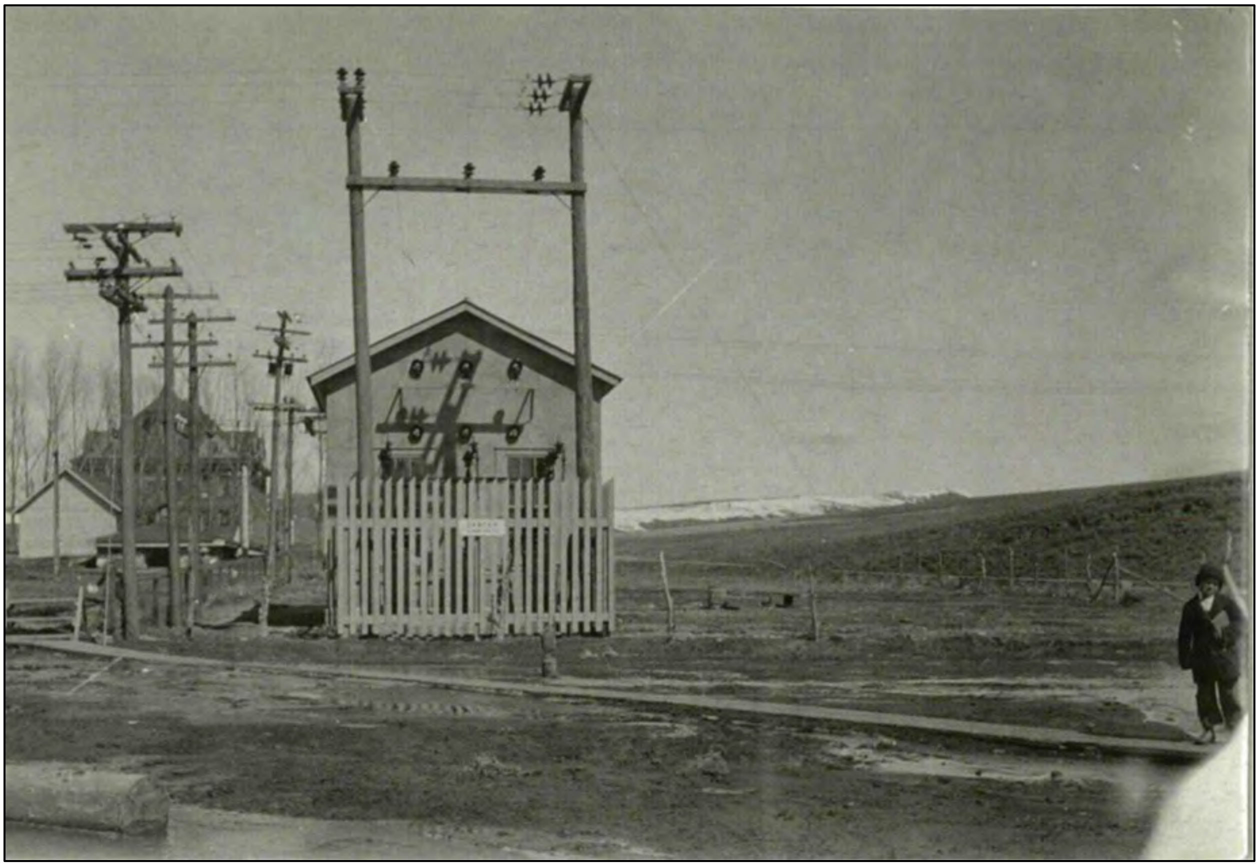

Figure 4.123 An example of a small substation on a Reclamation project, this photo shows the Albion power substation on the Minidoka Project (Idaho).[323]

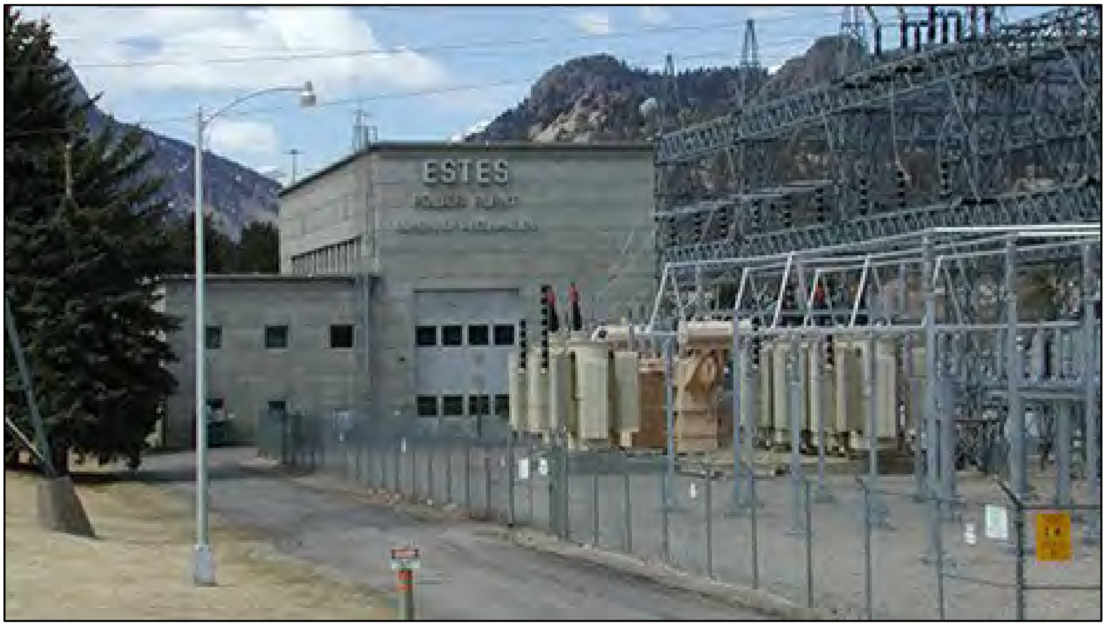

Figure 4.124 An example of a larger powerplant is the Estes Powerplant on the Colorado-Big Thompson Project (Colorado).[324]

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[323] Bureau of Reclamation, *Minidoka Project History*, 177.

[324] National Park Service, "Colorado: Estes Powerplant," https://www.nps.gov/articles/6-hydroelectric-power-and-the-bureau-of-reclamation.htm [accessed January 2023].

4.7.2.2 Transmission Power Lines

Transmission and distribution lines played a critical role bringing power from Reclamation projects to the public and businesses. Though they are considered separate from the water control features, powerplants are cultural features that should not be overlooked in surveys. However, like powerplants, these are often recorded separately, and some individual contexts already exist. The transmission corridors are built, operated, and managed by agencies other than Reclamation.

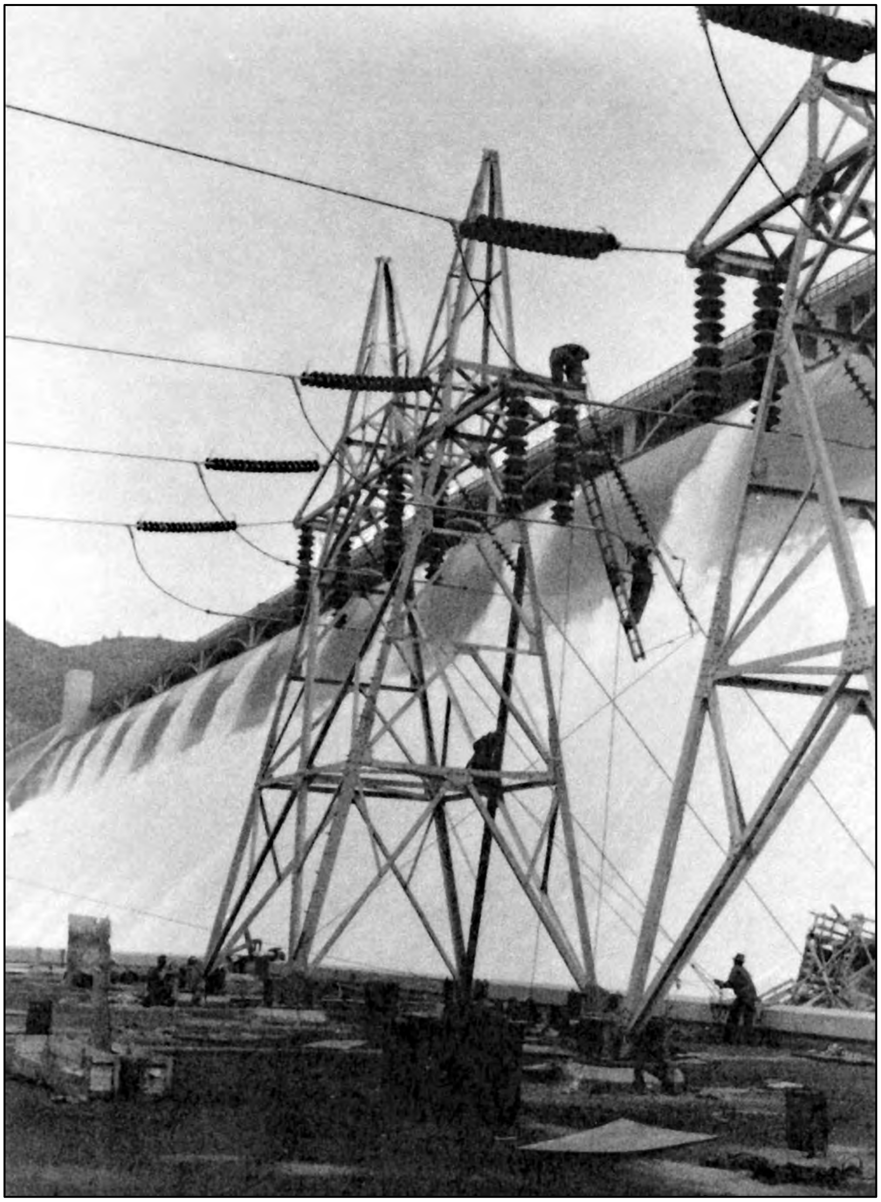

Figure 4.125 Transmission power lines from the hydroelectric plant at the Reclamation's Grand Coulee Dam Powerplant (Washington).[325]

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[325] Bureau of Reclamation, "Construction History Photo Gallery." https://www.usbr.gov/pn/grandcoulee/history/construction/gallery/36.html [accessed February 2023].

4.7.3 Bridges

4.7.3.1 Wooden Bridges

Wooden bridges are becoming rare in Reclamation projects, as the agency is upgrading them to concrete and steel. However, some older projects still contain wooden bridges; sometimes they are left in place as foot bridges.

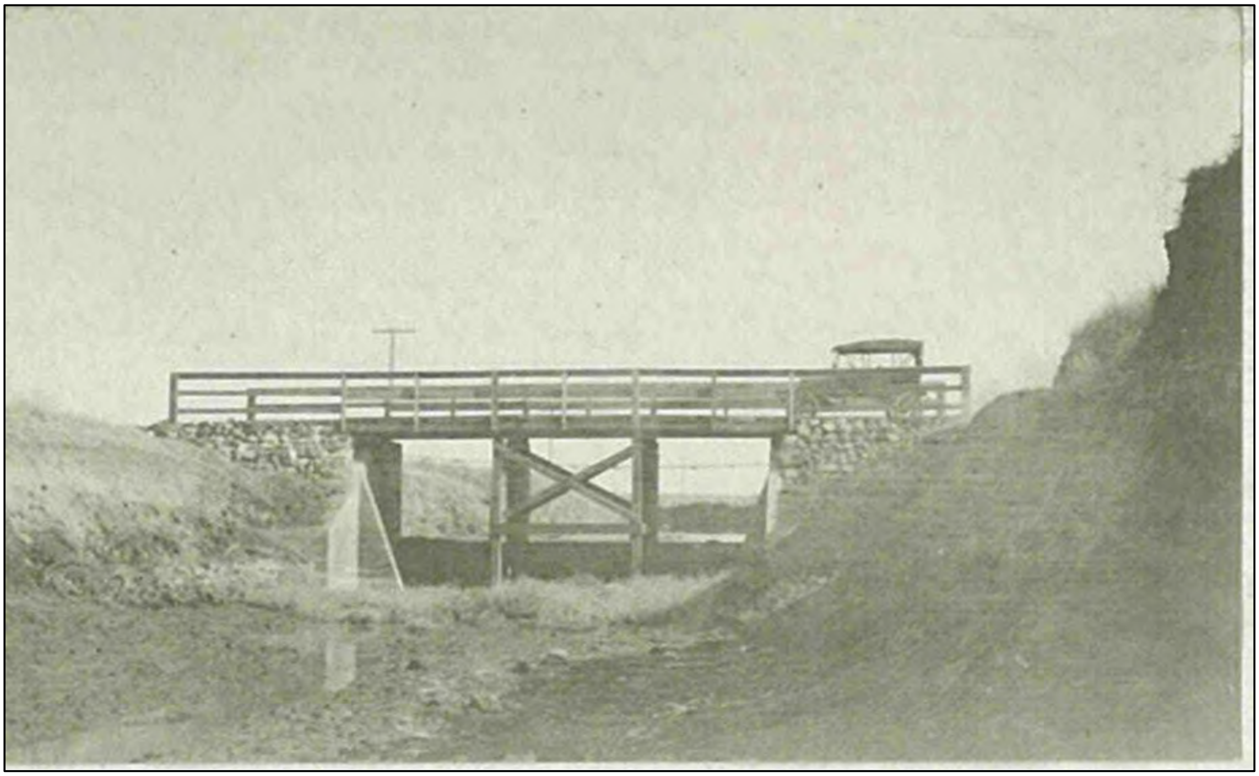

Figure 4.126 A timber bridge across a check on the Minidoka Project (Idaho).[326]

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[326] Bureau of Reclamation, *Minidoka Project History*, 43.

4.7.3.2 Concrete Road Bridge

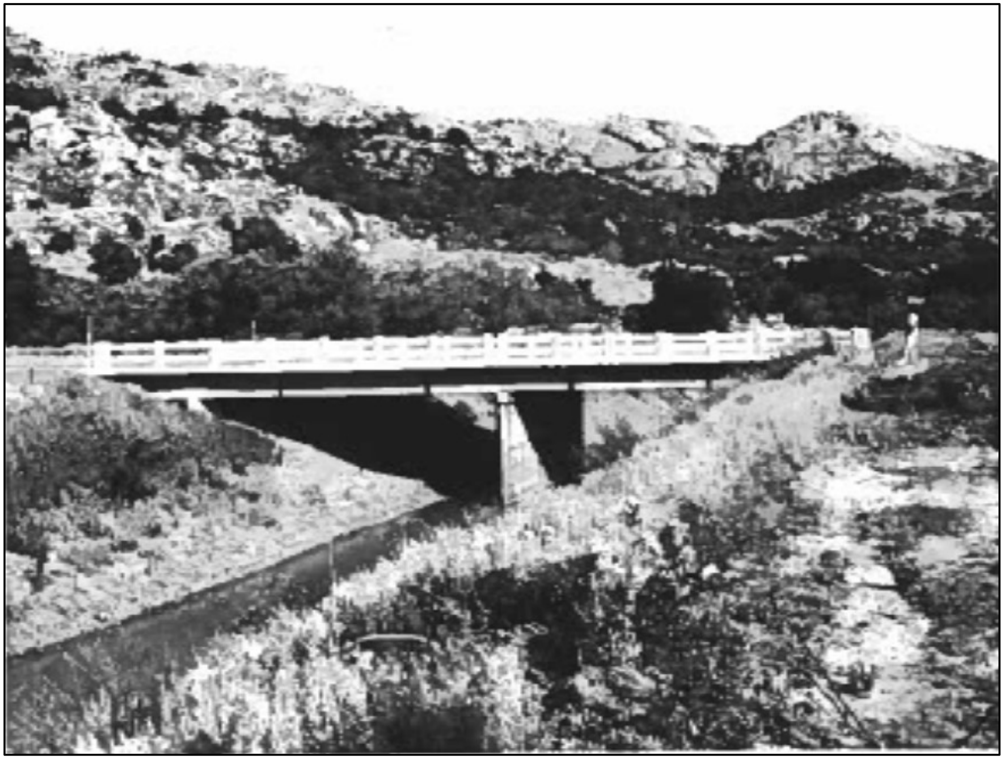

Figure 4.127 Highway Bridge #44 over the main canal on the W.C. Austin Project (Oklahoma) built in 1941. Common elements on nearly every Reclamation project are road or highway bridges.[327]

4.7.3.3 Steel Truss Bridge

Figure 4.128 Steel constructed bridge over the Altus Dam Diversion Channel (Oklahoma).[328]

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[327] Pfaff and Wingate, *W.C. Austin Irrigation.*

[328] Ibid.

4.7.4 Other Miscellaneous Structures

4.7.4.1 Water Treatment Plants

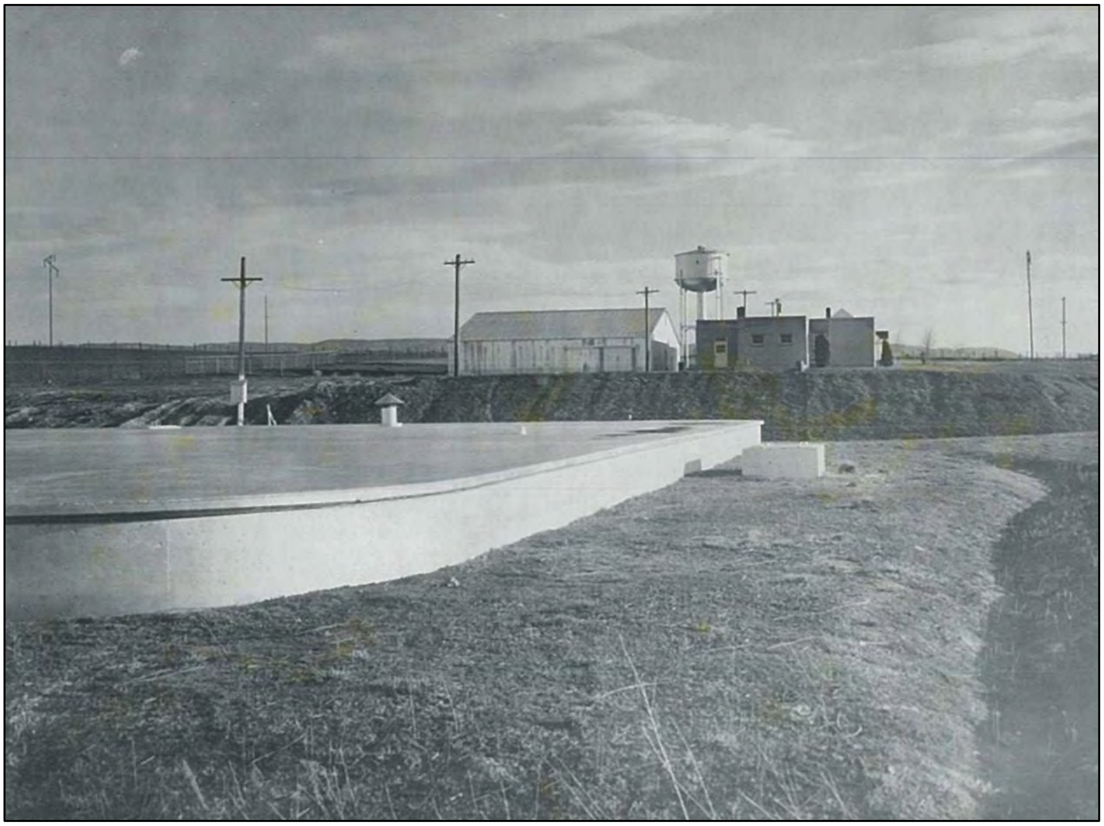

Figure 4.129 Lewiston Orchards Water Treatment Plant (Idaho).[329]

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[329] Bureau of Reclamation, *Lewiston Orchards Project, Idaho: Annual Project History – Calendar Years 1951-1961, Volume III* (Denver, Colorado: Bureau of Reclamation, 1961).

4.7.4.2 Administration Buildings

Figure 4.130 Former CCC buildings used by the Klamath Project (California) for administration purposes.[330]

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[330] Bureau of Reclamation, *W.C. Austin Project*, A-99.

4.7.2.3 Agricultural Fields

Figure 4.131 Sugar beets growing in an irrigated field on the Salt River Project (Arizona) in 1916.[331]

Figure 4.132 Irrigated fields in the Columbia River Basin Irrigation Project (Washington).[332]

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[331] Autobee, "Salt River Project."

[332] Bureau of Reclamation, "Irrigation Operations begin for Columbia River Basin," https://www.usbr.gov/newsroom/news-release/4103 [accessed February 2023].

4.7.2.4 Fish Passes

Figure 4.133 Pool and traverse style fish pass.[333]

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[333] Crawford and Gosden, “River and Canal Structures,” 11-19.

Figure 4.134 Fish bypass channel.[334]

Figure 4.135 Larinier style fish passage.[335]

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[334] Crawford and Gosden, “River and Canal Structures,” 11-19.

[335] Ibid., 11-19.

Figure 4.136 An early pool and traverse fish passage with baffles on the Feed Canal on the Orland Project.[336]

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[336] Davis, *Irrigation Works.*

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5.0 Sample Water Conveyance Projects and Their Associated Features

5.1 Previous Evaluative System Studies

This chapter reviews the critical supporting elements of Bureau of Reclamation projects. To help bring this substantial amount of information into better focus, four existing contexts of irrigation projects are summarized to synthesize the basic component parts that experts have agreed make a project. Secondly, 18 Reclamation projects have been selected for study in this context. They range from the largest, the CVP of California that irrigates up to 3 million acres, to one as small as the Lewiston Orchards Project in Idaho, which irrigates 4,000 acres. Other projects were selected to provide a variety of component types, regionality, and period of construction. Table 5.1 shows a summary of each project and their key components.

To compare overviews more carefully, we reviewed several existing state-wide contexts on linear features. California, Colorado, Texas, Wyoming, and Oregon have established historic contexts for irrigation works within their states.[340] A 1993 examination of the W.C. Austin Project in Oklahoma also established a good methodology for evaluating irrigation systems.[341] Using these documents, the authors compared them in such a way as to show various views about topics such as integrity issues, systems eligibility, irrigation projects as historic districts, eligibility of individual features, and the critical need for good archival research.

Though the Oregon context was most succinct in its discussion, each context agreed that irrigation projects, specifically large ones like those constructed by Reclamation, contain at least four specific elements. To qualify as a system, those include a source of water and diversion structure, a main canal, lateral canals, and sublateral canals or delivery ditches.[342] To these, since she deals with the Lower Rio Grande and the need for pumping plants, Knight (2009) adds those items as a critical component. Halloran, as his 2005 study deals more with all forms of canals and ditches, states that a control device, usually found in a turnout in a lateral in a Reclamation project, is included in the simplest components of an irrigation system. They also all agree that these systems include other components as varied as water treatment facilities, power generation plants, all forms of flumes, siphons, measuring devices, bridges, culverts, and a host of other features important for the successful distribution of water to farms in a diverse geographical environment.

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[340] For California see JRP and CALDOT, *Water Conveyance Systems*; for Colorado see Holleran, *Historic Context*; for Texas see Knight, *Field Guide*; for Oregon see Oregon State Historic Preservation Office, *Guidance for Recording and Evaluating Linear Cultural Features,* 2013, https://www.oregon.gov/oprd/OH/Documents/OR_Linear_Resources_Guidance.pdf [accessed August 2023]. As a final note, as the current context was nearing completion, the Wyoming SHPO completed its own document: Jonathan C. Horn and Michael J. Prouty, *Water in Wyoming: A History of Irrigation from 1868-1979* (Montrose, Colorado: Alpine Archaeological Consultants, Inc., 2023). Due to the timing of its completion, the Wyoming context is not synthesized here, but should be consulted for evaluation efforts, as appropriate.

[341] Pfaff and Wingate, *W. C. Austin Irrigation*.

[342] Oregon SHPO, *Guidance for Recording*, 13; Knight, *Field Guide*, 229; Holleran, *Historic Context*, 82-83; Pfaff and Wingate, *W.C. Austin Irrigation*, 6.

Table 5.1 Projects reviewed for this study, including location, water bodies, years of construction, acres of irrigation, important components, and other pertinent information.

Project	**Location (State)**	**Primary Water Bodies**	**Primary Construction Period**	**Irrigated Acres**	**Key Components/Notes (per Reclamation Project Histories)**	**NRHP Evaluation**
Salt River	Arizona	Salt and Verde Rivers, 250 groundwater wells	1903-1911	26,500	Six storage dams (2 constructed by Reclamation), 1,259 miles of canals, laterals, and ditches, 842 are lined and piped. Also includes ancillary hydro and steam plants.	Yes, listed as Multiple Property Listing (2016); components well documented through HAER collections; certain components covered under a PA
Minidoka	Idaho	Snake River	1904-1927	1,000,000	Five main dams, two diversion dams, canals, laterals, drains, and water supply wells; interred Japanese-Americans built and repaired portions of canal system In World War II	Main Dam Powerplant is NRHP listed; Portions determined eligible and documented through HAER; Gravity Division determined eligible
Milk River	Montana	Milk River	1906-1939	121,000	Seven diversion dams, pumping plant, 200 miles of canals; 219 miles of laterals; and 295 miles of drains	Evaluation (1991) found system eligible under A, B, C, and D as a system
Sun River	Montana	Sun River	1907-1929	100,000	Gibson Dam and Reservoir, Willow Creek Dam and Reservoir, Pishkun Dikes and Reservoir, Sun River Diversion Dam, Fort Shaw Diversion Dam; nine canal systems; 131 miles of canals, 562 miles of laterals, 265 miles of drainage ditches; Gibson dam noted as being prototype for trial-load method	Evaluation (1991) found system eligible under A, C, and D as a system
Kendrick	Wyoming	North Platte	1936-1946	24,000	Two dams and powerplants; Casper Canal system is 59 miles long, 190 miles of laterals and sublaterals, 41 miles of drains; includes headgates on Alcova Reservoir, 6 concrete lined tunnels, several siphons, highway and farm road bridges,	Irrigation system may qualify under Multiple Property Listing "Depression Era Projects in Wyoming, 1929-1943".

Project	Location (State)	Primary Water Bodies	Primary Construction Period	Irrigated Acres	Key Components/Notes (per Reclamation Project Histories)	NRHP Evaluation
Columbia Basin	Washington	Columbia River	1933-1952	671,000	Grand Coulee Dam, powerplant complex, pump plants, 7 additional dams, 5 main canals	Portions evaluated, determined eligible, and documented through HABS/HAER
Rapid Valley	South Dakota	Castle Creek	1942-1958	9,000	Pactola Dam, Deerfield Dam; no Reclamation completed or managed canals	Various ditches in the Lower Rapid Valley were recorded through HAER documentation in the early 1990s.
Frenchman-Cambridge Division	Nebraska	Frenchman and Republican River	1947-1961	16,400	Four dams and reservoirs; six main canal systems with 63mi of canals, 43 miles of laterals, 51 miles of drain lines; includes the notable 2,364-foot-long Oxford Siphon.	No information found on a determination of eligibility
Lewiston Orchards	Idaho	Clearwater and Snake Rivers	1947-1951	3,900	Four diversion structures, main canal, three reservoirs.	No information found on a determination of eligibility
Balmorhea	Texas	Underground reservoir	1946-	10,000	Flows from underground reservoir; began as pre-Reclamation project.	No information found on a determination of eligibility
Almena Unit	Kansas	Prairie Dog Creek	1961-1964	5,763	Two dams, two canals, and systems of laterals and drains	No information found on a determination of eligibility
Navajo Indian	New Mexico	San Juan River	1962-present	110,630 (planned)	Main canal open and unlined; siphons; 13mi of tunnels; 7 miles of siphons on main canal; only Reclamation project fully operated by Native Americans; project completion ongoing	Does not appear to have been evaluated; however, is a more recent system
Garrison Division	North Dakota	Missouri River	1944-1970s	260,000 (planned), 4,940 (actual)	Dam built by USACE; Reclamation completed irrigation works; 79-mile Main Canal	Reclamation components are less than 50 years of age; not yet evaluated
Middle Rio Grande	New Mexico	Rio Grande	1954-1975	90,000	Isleta, San Acacia, Angostura, and Cochiti Diversion Dams; canals, laterals, and drains, supports six Pueblo Indian communities	Does not appear to have been evaluated; however, is a more recent system

Project	Location (State)	Primary Water Bodies	Primary Construction Period	Irrigated Acres	Key Components/Notes (per Reclamation Project Histories)	NRHP Evaluation
Lower Rio Grande	Texas	Rio Grande	1958-1969	100,000	Reclamation assumed control of local districts in the 1950s, and performed rehab and upgrades of canals, laterals, pipelines, gates, and other features; reclamation retains maintenance responsibility of both divisions.	Project as a whole not evaluated; numerous individual districts documented and evaluated
Umatilla	Oregon	Umatilla River	1905-1927	30,000	Cold Springs Dam, Feed Canal Diversion Dam and Canals, Maxwell Diversion Dam and Canal; Three Mile Falls Diversion Dam, West Extension Main Canal, McKay Dam.	Portions of East Division evaluated and documented through HAER
Colorado-Big Thompson	Colorado	Colorado River	1938-1956	615,000	Particularly challenging engineering across Continental Divide; consists of 100 structures; including dams, canals, pump stations, siphons, tunnels, powerplants, conduits, feeder canals, includes Alva Adams Tunnel.	Context developed and property types identified; previous evaluation occurred when much of the project was less than 50 years of age.
Central Valley	California	Sacramento River, Trinity River, American River	1937-1944	3,000,000	Extends 400 miles, 20 dams and reservoirs, 11 powerplants, 500 miles of major canals, along with conduits, tunnels, and other facilities	Reclamation prepared a draft multiple property listing, but did not finalize; known eligible components include the Delta-Mendota, Friant-Kern Canal, Contra Costa Canal, Tracy Pumping Plant, Shasta Dam

As an early example of a statewide context, Pfaff and Wingate (1993) examined the W.C. Austin Project in southwest Oklahoma. They adapted their study of the project by what they called a “four systems framework.”[343] They divided the irrigation system components into four subsystems, including:

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[343] Pfaff and Wingate, *W.C. Austin Irrigation*, 50.

- Irrigation/technology subsystem.
- Construction subsystem.
- Support subsystem.
- Settlement subsystem.[344]

Pfaff and Wingate's 1993 context defined the irrigation/technology subsystem as the features directly involved in the storage, diversion, and channeling of water for irrigation or other uses.[345] The construction subsystem included the planning, constructing, and altering of the irrigation features. Support subsystems are defined as those related to post-construction ongoing operations and maintenance of the project. Settlement subsystems are features built by Reclamation that are identified with the development and settlement of the area such as community centers, demonstration farms, townsites, businesses, etc. Pfaff and Wingate (1993) determined that the W.C. Austin Project's Altus Dam was eligible for the NRHP on a national level because of its "unusual construction of masonry" in the New Deal era, when this style of construction was largely abandoned for poured concrete. They assessed the W.C. Austin Project's irrigation system as potentially eligible on a state-wide, but not national, level, as the first example in Oklahoma of Reclamation's efforts to introduce irrigation into a "semi-arid climate."[346]

Figure 5.1 W.C. Austin Main Canal near Station 39, 1945.[347]

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[344] Pfaff and Wingate, *W.C. Austin Irrigation*, 51.

[345] Ibid., 52.

[346] Ibid., 67.

[347] Oklahoma Historical Society, "Rock Lining Blanket Material, Photograph 5-AL-11. View looking south (downstream) along Main Canal near Station 39 showing rock lining blanket material." W.C. Austin Project, photo #R390-335.1, https://gateway.okhistory.org/ark:/67531/metadc2020365/ [accessed February 2023].

The significance of Pfaff and Wingate's (1993) study was that it attempted to assess NRHP eligibility of an entire Reclamation-built subsystem where many of the components have been altered or compromised yet contribute to the eligibility of the whole subsystem. Most importantly, their subsystem approach allows for a category, such as the settlement subsystem, to be an eligible resource, even if the other subsystems are not. However, this view is not consistently accepted by other investigators or SHPOs. An example of this type of assessment is explained in Knight (2009) regarding the Cameron County Irrigation District #2 in San Benito, Texas. In that case, the irrigation system is one contributing resource within a historic district. The individual buildings are the other contributing resources. The combination of the irrigation system and the historic buildings form the historic irrigation district.

Using Pfaff and Wingate's (1993) approach, the irrigation subsystem would be a single component and thus assessed as a single property. The buildings, on the other hand, are assessed as a settlement subsystem. The buildings, if found to be a historic district, would each be a contributing resource. That historic district may or may not include the irrigation subsystem as a single contributing resource. Pfaff and Wingate permit the divorce of the irrigation subsystem from the settlement subsystem. One is eligible as a historic district, and one is not eligible at all. If, however, the irrigation subsystem, though not eligible by itself, could be a contributing resource to the historic district, then it would be included as a single resource within the historic district. On this point, Knight (2009) and Pfaff and Wingate (1993) would likely agree.

In 2005, Holleran produced a study of irrigation ditches and canals in the State of Colorado. Though his study covered such notable Reclamation projects as the Grand Valley and Colorado-Big Thompson, what is important for this analysis was his discussion of key water distribution components such as diversion dams, headgates, main canals, laterals, siphons, flumes, recording devices, and spreaders. Holleran's most important contribution is providing an explanation and framework for the design and use of the individual features and components of an irrigation system. For example, he explains that headworks (headgates) permit water to flow safely and efficiently into a canal or ditch. In Reclamation projects, diversion dam headgates are a component of a diversion dam. These dams, he points out, are not to retain water but to regulate its flow from a natural body through the headgate into a main canal (hence diversion). Diversion dam headgates, he notes, frequently contain other features such as spillways, sand traps, measuring flumes, recording devices, and debris grates that are lost on the casual observer but form additional components critical to successful irrigation operations. Headgates may also be "simple single structures controlling water into a ditch" for a farmer's field.[348] These are often referred to as turnouts or lateral headgates. He goes on to explain that lateral and ditching headgates rarely contain other components. Holleran (2005) is particularly helpful in explaining the development, construction, and variations between canals and ditches, and explaining the difference between the two.

Main canals are elaborate or large ditches that carry water to further distribution lines from a central diversion point.[349] Holleran notes that main canals and large laterals are merely big ditches conveying water. Because of Colorado's mountainous terrain and mining tradition, nearly all projects there are gravity-fed; that is, they use gravity to move water around. This contrasts with areas such as the Lower or Middle Rio Grande projects in Texas and New Mexico, which utilize pumps to circulate water due to the flatness of the terrain. In Colorado, Holleran (2005) observes that ditches can be as simple as a farmer's earthen ditch moving water around in his field, to large rock tunnels through mountains. He discusses that over time, ditches and canals have been lined. Those lining materials can include wood, clay, textile, metal, tile, pre-

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[348] Holleran, *Historic Context*, 54.

[349] Ibid., 56-57.

formed concrete units, and poured concrete. To prevent water loss through evaporation, concrete piping of open ditching has become the most popular form of lining over the past 50 years.

Holleran (2005) identifies laterals as water conduit distribution lines moving water from a main canal to individual farmers' fields. They are usually larger than most ditches, and are sometimes as large as the main canal, but may be "small and refer to channels only inches wide or distribution pipes."[350] It is usually a term of function rather than size. Typically, Reclamation projects end at a lateral headgate that places water into a farmer's property; it may include the lateral canal, and it may not. Holleran (2005) noted that these can be miles long and represent a definitive feature on the landscape, but are frequently minimally documented, if documented at all. Reclamation-built irrigation districts tend to name or number canals or laterals within their projects.

Flumes and siphons are some of the more architecturally intriguing aspects of an irrigation system. They tend to draw attention and often cause investigators to overlook additional features. Flumes carry water across depressions or ravines. They begin and end with changes in water velocity, as fluids move faster in a flume than in most other canals or ditches. To avoid erosion at the point of entrance and exit, headgates and tailgates are usually present. Historically, flumes have been constructed of wood, iron, steel, and even fiberglass, but today are generally concrete and rest on concrete supports. Siphons move water through enclosed piping under pressure. They usually move the water short distances and are most frequently seen conveying water from a farmer's ditch into the furrows in their fields. However, they can appear as large piping on support frames, or simple rubber hoses.

One of the most difficult concepts to convey to the general public is how the water is evenly distributed across farmer's fields. Holleran explains that farmers have two methods of bringing the correct amount of water to their crops. The first method uses small field laterals that bring water down the farmer's furrows and raise the water until it reaches the desirable point on the planting beds. The second method uses spreaders that were turned with a plow and moved water across a pasture, spreading the flooding water evenly.[351] Holleran (2005) explains the various key components of an irrigation system, as well as many of the additional features demanded by the geography of the local terrain. Some of these additional features are easy to overlook due to their apparent commonality and the investigator's attention on the primary conveyance item.

Knight (2009) looks closely at integrity issues regarding irrigation systems and their component parts. More importantly, her study of the Lower Rio Grande region in Texas reveals how geography can demand a component feature that is not necessarily a part of other irrigation systems. Her narrative clarified, for purposes of assessing eligibility for the NRHP, the impact of recent improvements on the integrity of an irrigation system. She set clear boundaries about eligibility that made assessing an irrigation system more efficient. Perhaps more importantly, her study of Lower Rio Grande irrigation revealed the importance of the use of lifts or pumping stations in that region. This local differentiation from traditional gravity-fed systems that characterize most Reclamation projects requires the flexibility to see differences in geography as both diverting from traditional irrigation and yet, in the larger picture, fundamentally similar. Lift stations are not unusual; however, due to the terrain in the Lower Rio Grande, lift or pumping stations are a crucial component of irrigation. Large-scale irrigation simply could not function without pumping stations in the Lower Rio Grande Valley. She notes that in the Lower Rio Grande, geography demanded

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[350] Holleran, *Historic Context*, 66.

[351] Ibid., 66.

that lift stations or pumping plants be present at laterals, and even at the ditching on the third level of distribution.[352]

Figure 5.2 Recent piping of the GK Lateral of the Gunnison River Project (Colorado).[353]

Figure 5.3 Minidoka Pump Plant (Idaho), c1904 (NARA Photograph #294675).

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[352] ESCO Construction Company, "GK Lateral and Silt Pump Canal Pipelines", completed 2018, https://escoconstructioncompany.com/projects/gk-lateral-silt-pump-canal-pipelines/ [accessed January 2023].

[353] ESCO, "GK Lateral".

Knight (2009) observed that all irrigation projects contain several specific components. They must contain a source of water and a diversion feature (headworks), conveyance features (main canal), distribution features (laterals), and delivery and removal features (ditching). Knight (2009) tended to focus on the individual irrigation/technology subsystem. She spent a great deal of time explaining the details and importance as well as the role each component plays in the functioning of the irrigation system. Knight's (2009) study differed from the others in that Reclamation did not initiate most of the projects in the Lower Rio Grande. Rather, they assumed ownership of several irrigation districts to improve and manage. Thus, her study focuses on Reclamation and non-Reclamation projects, and takes into consideration privately held ditches that supersede the scope of most studies examining Reclamation-constructed projects.

Like the others, Knight defines diversion as the "movement of water from a river into the irrigation system."[354] She identifies other features associated with the diversion of water such as dams, headgates, inlet channels, and pumping plants. The main canal "carries the water from the primary source, the river, and distributes it throughout the irrigation system."[355] She notes that these were usually constructed above the surrounding grade, but pumps were again necessary where they were below grade. Laterals, she explains, were turnouts from the main canal distributing the water to the farmer's fields. She explained that to extend water to large areas, the Lower Rio Grande projects employed sublaterals. She goes on to say that these were often "shallower and narrower than laterals," but moved water further out to the fields.[356] Knight's study gives an excellent explanation about how water was moved from the main canal into the laterals, and from the laterals into the farmer's ditches, using check gates and turnouts. It explains the furrow irrigation used by the farmers and the extensive use of small siphons to pull water from a ditch into farmer's furrows. Like Pfaff and Wingate (1993), Knight (2009) provides detailed studies of additional components such as weirs, flumes, drains, linings, vents, diversion stands, and surge chambers, among others. The study contends that irrigation systems are single structures and component parts that cannot be eligible for the NRHP independent of the system of which they belong. Pfaff and Wingate (1993) would call this the "irrigation/technology subsystem."

Knight (2009) also studied individual components such as offices, ditch rider and settlement houses, bridges, and roads, etc. as individual features unrelated directly to the irrigation/technology subsystem, and thusly can be assessed architecturally as an individual resource. However, she insists that irrigation systems should be assessed as a single "structure" and not as a "district" or as individual components. She quotes the National Park Service (NPS) bulletin that states "a network of historic irrigation canals" should be considered as "one contributing structure."[357] She goes on to say that individual irrigation systems in Texas are structures and not districts.[358] She states that they are not districts because they are "composed of a number of features or components that are seamlessly integrated into a single system."[359] Her argument concludes:

> A main canal without laterals would not allow for the conveyance of water to its final destination, the farms. Nor can a check gate be considered separately from the canal. Removed from its context, the

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[354] Knight, *Field Guide*, 94.

[355] Ibid., 126.

[356] Ibid., 169.

[357] National Park Service, *How to Complete the National Register Registration Form* (1997), 17, in Knight, *Field Guide*, 224.

[358] Knight, *Field Guide*, 224.

[359] Ibid., 226.

> check gate is merely a non-functioning appurtenance. Nor can the canal function without the check gate, as the water would flow without regulation, leaving some farmers without water. While an irrigation system might appear to have a linkage of features, these are not individually unique structures. Rather than being characterized by an informal "linkage" or grouping, such as houses in an historic district, these components are inter-connected and dependent upon one another, like the windows, doors and structural members of a single house.[360]

Knight (2009) concludes that the NPS's determination that irrigation networks be assessed as a single structural system is correct. She goes on to say that the most feasible way to address these complex systems is that only when multiple irrigation structural systems are part of a nomination are they assessed as a district. She notes that when an irrigation system is combined with sites, buildings, homes, farmlands, or other objects united historically with the system but not part of the irrigation system itself (what Pfaff and Wingate [1993] would say is combining two or more subsystems), then the use of historic district is the proper designation. She emphatically states that individual components of an irrigation system are not eligible for listing in the NRHP because they "are not individually capable of representing the historic significance of the system."[361]

Knight and the other contextual studies agree that exceptions to this would be individual components that have such exceptional "engineering magnitude" that it might be considered a structure in its own right. An example might be a historic pumphouse with its original machinery still in existence.[362] The pumphouse with its 50+ year-old machinery may be eligible for the NRHP on its own, even though it is only a component of the larger irrigation system for which it provides lifting power. Another example might be the 12,820-foot Soap Lake Siphon in the Columbia Basin Project, making it one of the longest siphons in the world. However, in most cases, the individual components will lack distinction.

In assessing the systems, Knight makes several key points. She states that an absence of historic components diminishes the integrity of the system. Therefore, a full knowledge of the extent of the character-defining features of the entire system is critical. On this topic she demands good archival research to properly identify the character-defining features of the system under evaluation. She concludes that the component parts of an irrigation system must retain a sufficient level of integrity of design and location.[363] Generally speaking, Knight believes urban intrusions destroy integrity of location and feeling. She states that the underground placement of piping over once-open ditching "represents a loss of integrity of location."[364] This loss, she observes, can be offset if enough of the original ditching remains to reflect the location, feeling, design, and integrity of the overall system. In conclusion, she states that if more than 50 percent of the main canals and laterals have been converted to underground piping, or 50 percent of the character-defining elements of the system are absent or lack integrity, the system will not be eligible for NRHP. Knight's (2009) assessment and study of irrigation systems provide a basis for assessing irrigation systems, though there are some who disagree with her conclusions.

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[360] Knight, *Field Guide*, 226.

[361] Ibid., 231.

[362] Ibid., 231.

[363] Ibid., 240.

[364] Ibid., 263.

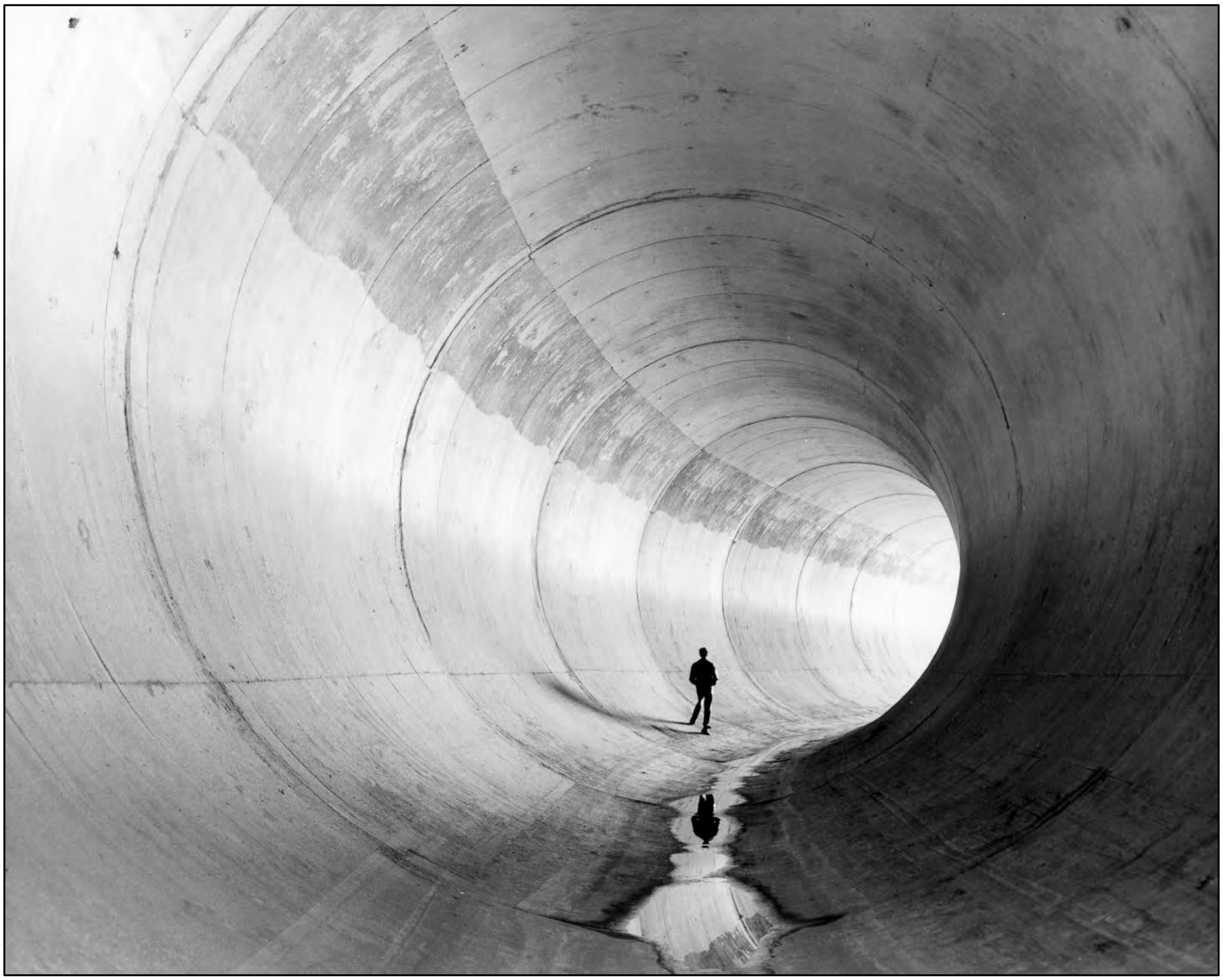

Figure 5.4 Soap Lake Siphon on the Columbia Basin Project (Washington), 1952.[365]

The Oregon SHPO (2013) published a work on linear resources with a strong focus on irrigation projects in their state.[366] They defined cultural features as "long, narrow, individual structures, or as linked to a district, and designed to convey something [usually water] long distances." [367] They point out that these irrigation districts were "dendritic in form and consisted of up to seven primary ingredients." They observed that all irrigation districts must have a source of water and diversion structure, main canal, lateral canals, sublateral canals, delivery ditches, and drains to qualify as a system.[368] They go on to state that these systems often have associated features as varied as water treatment facilities and power generation plants.

The Oregon SHPO (2013) study concentrated on recording features such as the width, depth, and profile of canals and ditches. They also focused on helping the reader recognize other associated features of

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[365] University of Washington Digital Collections, "Soap Lake siphon, Washington, approximately 1942." Photograph, 1942, https://digitalcollections.lib.washington.edu/digital/collection/grandcoulee/id/78/rec/1 [accessed August 2023].

[366] Oregon SHPO, *Guidance for Recording.*

[367] Ibid., 2.

[368] Ibid., 13. Though the Oregon SHPO added drains, we would remove that as a critical component. Clearly, not all Reclamation projects have drains and those are not critical for an eligible system.

a system such as culverts, berms, roads, diversions, walls, weirs, bridges, basins, and siphons, etc.[369] They noted that individual laterals and ditches built by the farmers to move water from a Reclamation-built lateral should be considered part of the irrigation system when evaluating the system. However, they also noted that "when the farm itself is being evaluated, the irrigation ditch built by the farmers would be included in the context of the property it irrigates, rather than the system of which it may be a part."[370] Knight would have likely disagreed with this assessment and kept the features neatly separated into Reclamation vs. local/farmer systems.

However, the Oregon SHPO (2013) context is most helpful in clarifying critical components of an irrigation system: that is, a source of water and diversion structure, a main canal, lateral canals, sublateral canals, delivery ditches, and drains and wasteways.[371] All other features may or may not be present for an NRHP-eligible irrigation system. The elements of an irrigation system are dependent on the geography of the region and the extent of the project. This is consistent with Knight's approach that archival research is crucial to determining critical components to an individual system. They would agree that geography helps determine which features are critical to individual systems. For example, whereas lift stations are a critical component of Lower Rio Grande irrigation systems, they may not be a critical component of an Oregon-based project, which is more reliant on gravity for functionality.

For purposes of the current study, a weakness of the Oregon SHPO (2013) context, like that of Knight's (2009), is that they were examining all linear features, including those beyond Reclamation's responsibility. This context limits the extent of Reclamation projects to the Reclamation-constructed, -owned, or -managed portions of those projects. This effectively eliminates most delivery ditches and many drains from consideration within a Reclamation nomination since they are not Reclamation-constructed, -managed, or -owned. Weipricht et al. (1981) state it emphatically when discussing the Newlands Project NRHP District, saying that the nomination considered:

> only those components of the Newlands Project that are either owned by Reclamation or for which Reclamation holds a right-of-way. It did not include components of the irrigation system, such as privately owned farms and associated structures (e.g., ditches and laterals) that fall outside Reclamation's legal authority."[372]

Thus, we could conclude from the Oregon SHPO's study that Reclamation critical components of an NRHP-eligible system would be the source of water, diversion structure, main canals, and lateral canals, and not privately owned canals, ditching, and features.

Synthesizing these studies, one observes that in Reclamation-sponsored projects, the NRHP evaluation should focus on the agency-built portion of the project. Nearly all the studies agree that the presence of a source of water, headgate, main canal, lateral canals, and sublateral canals are necessary for a system to be eligible for the NRHP. Where constructed by Reclamation, wasteways and drains and other components within the Reclamation-managed, -owned, or -built system must also be considered. However, generally,

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[369] Oregon SHPO, *Guidance for Recording,* 13

[370] Ibid., 13.

[371] Ibid., 13. Also note that while most projects do have wasteways or drains, not all do. The absence of drains would not disqualify an otherwise eligible irrigation system.

[372] Wilbur E. Weipricht, Wendell Bell, and Donald Abbe, *The Newlands Reclamation Project (Truckee-Carson Project).* National Register of Historic Places Nomination Form (Washington, D.C., 1981), 16.

Reclamation responsibility "stops where the individual privately held property begins," regardless of how elaborate the design or interesting the field system.

In 2000, JRP Historical Consulting Services (JRP) and the California Department of Transportation (CALDOT) jointly published a water conveyance systems historic context and evaluation procedures report for the CALDOT Environmental Program. The report was more of a history of water conveyance systems than a study of irrigation alone. However, they looked closely at the CVP, a primary Reclamation project. They also reviewed typical components of a conveyance system. They concluded that key components and features consisted of diversion structures, conduits, flow control and cleansing devices, and associated resources. These were generally consistent with other contexts. They concluded that, "all delivery systems consist of a diversion structure, conduit [main canal/ lateral canals], and functional association with one or more activities such as agriculture, mining, water supply, etc." The report went on to note that "some provision for disposing of excess wastewater, what others called drains or wasteways, will be present."[373]

The JRP and CALDOT (2000) study takes a broader view of water conveyance systems. The report differs in three areas. First, they group the distribution system into a single category, which they call the "conduit," and they look at water conveyance for other uses such as mining, similar to Halloren (2005).[374] They also make a separate category of the flow control, measuring, and cleansing devices, a category that Knight's (2009) study did not consider as a primary category, but rather discussed these structures at length as a distribution or delivery feature. Like the others, JRP and CALDOT stressed the importance of archival research and studying the whole system, not just a component part.[375] JRP and CALDOT's (2000) context differs from Knight (2009) and most of the others in that it allows, "defining particular systems as individual properties or historic districts."[376] However, JRP and CALDOT's context is much broader than just irrigation conveyance systems, and must allow more flexibility than an irrigation study alone, a weakness and a strength of the report.

The remainder of this chapter briefly examines 18 current Reclamation projects that represent the range of work completed by the agency over the past 120 years. Each section briefly describes the original project and geographical terrain, authorization, years of construction, river systems, key elements, acreage irrigated, status, and known alterations of the system.

5.2 Salt River Project

The Salt River Project is a large Reclamation project in central Arizona spanning Maricopa, Gila, and Pinal counties. The project covers 240,000 acres (13,000 square miles) in the Salt and Verde rivers of the Lower Colorado River Basin. It was one of the first projects authorized for Reclamation in 1903 and has directly contributed to the growth of the greater Phoenix, Arizona, area. The project is currently listed on the NRHP at a national level of significance because "the water and power it provided was integral to the transformation of a series of small desert wayside communities into one of America's most expansive, urbanized metropolitan areas in less than three-quarters of a century."[377] The Salt River Project helped

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[373] JRP and CALDOT, *Water Conveyance Systems*, 83.

[374] Ibid., 83.

[375] Ibid., 89-90.

[376] Ibid., 90.

[377] Lynn McDonald and Jim Bailey, *Salt River Project Multiple Property Submission*, National Register of Historic Places Multiple Property Documentation Form (Washington, D.C., 2017), 5.

Phoenix to become a primary leader in the Sun-Belt housing boom of the post-World War II period by "providing the necessary power for air-conditioning, a crucial factor in the development of this region of the United States."[378]

The Salt River Project's irrigation development is being studied as a benchmark for other Reclamation irrigation projects. Other factors such as power generation or recreational opportunities that Reclamation projects contain are not the focus of this study. Rather, attention is given to the nationally significant development of Reclamation irrigation systems and features potentially eligible for the NRHP. The Salt River Project offers an opportunity to observe the development of irrigation in the area and how the irrigation element of a project is affected by residential, recreational, and industrial changes. The Salt River Valley Water User's Association (SRWUA) was the formal irrigation district that eventually took over management of the Reclamation-built system in 1917.[379]

Major components of the Salt River Project include the Granite Reef Diversion Dam; the Grand Canal (the project's main canal); secondary main canals, including the Arizona Canal, the South Canal, and its subsidiaries (the Tempe, Eastern, and Consolidated canals), and the Western Canal; and the North and South Highline laterals. The project consists of 130 miles of main canals, 924 miles of laterals and ditches, and 250 miles of drains. Also, the project contains numerous headgates, chutes, drops, gauge stations, ditch rider houses, bridges, railroad crossings, and many other features. [380] Most of the canals and laterals were constructed between 1907 and 1915 in the early period of Reclamation work. The Consolidated Canal was lined and enlarged in the mid-1920s. The overall size of the project made it one of the largest projects constructed by Reclamation.

By 1916, the southwestern part of the project was experiencing problems with water logging. Drainage pumps had existed from pre-Reclamation work, but between 1918 and 1924, the SRWUA installed new pumps and drain lines to remove the water and return it to the system's canals, thus saving the water. The drains became a new component of the project both in removing excess water and permitting its reuse.

The system uses water from the Salt and Verde rivers that has been stored in the Reclamation-built Theodore Roosevelt Dam and Reservoir on the Salt River and the Bartlett Dam and Reservoir on the Verde River. To these, the SRWUA added three storage dams on Salt River and a privately built dam on the Verde River (the Horseshoe Dam). These dams and lakes, primarily located on the Salt River, form a chain of lakes 60 miles long that supply water to the Salt River Project.[381] About 22 miles east of Phoenix, the Granite Reef Diversion Dam, located four miles downstream from the convergence of the Verde and Salt rivers, funnels water into the main canal and begins the irrigation conveyance system.[382] McDonald and Bailey point out that the Granite Reef Diversion Dam retains its historic integrity, having not been substantially altered since 1920.[383]

McDonald and Bailey recommended that drainage lines and pumps were primary components of the Salt River Project. They discussed appurtenant features such as flumes, chutes, gauges regulating structures, bulkheads, and weirs, etc., as part of the conveyance system. They suggested that "representative examples" of these elements of a system contribute to the integrity of the district despite the fact that most of the

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[378] McDonald and Bailey, *Salt River Project Multiple Property Submission*, 5.

[379] Ibid., E-20 and E-23.

[380] Ibid., F-37.

[381] Autobee, "Salt River Project," 16.

[382] Ibid., 3.

[383] McDonald and Bailey, *Salt River Project Multiple Property Submission*, F-38.

features no longer have historic integrity.[384] They finally conclude that the change from the original agricultural setting to an urban setting alone does not result in a lack of integrity.[385] They go on to state that with respect to integrity of design, “it retains its design and configuration for at least a portion of its length” and “representative examples” of certain appurtenant features remain and are used as support for the district’s eligibility for the NRHP.

These findings conflict with Knight’s (2009) in south Texas, where she concluded that any feature or system with more than 50 percent of its laterals and ditching converted to piping had lost historic integrity and would not be eligible for the NRHP.[386] Knight (2009) also contradicts McDonald and Bailey’s (2017) findings as she states that the change from rural to urban destroys the integrity of setting. McDonald and Bailey (2017) assess the entire Salt River Project as a historic district with multiple components (i.e., Storage Regulation dams, Diversion-conveyance systems, Powerplants, Auxiliary Construction Works, Ongoing Support Features). They note that many sections and features of the diversion-conveyance system have no historic integrity. However, they say, there are enough “representative examples” with integrity of each of the primary components, that together they make the conveyance system a contributing resource of the larger historic district. However, they also say that the individual features of the diversion conveyance system are nominated as a single historic district. Knight’s findings directly contradict that effort.[387]

The early canals and laterals were “open earthen ditches with structures to control flow and distribution and few sections were lined.” [388] However, improvements and repairs conducted by the CCC during the 1930s included the process of lining the canals and replacing the original wooden structures with concrete versions. Between the end of World War II and the mid-1980s, many of the laterals and canals were converted to underground piping, and some components were moved. By the early 2010s residential, commercial, and industrial development in the Phoenix area had consumed thousands of acres of farmland, and most of the former laterals in the system were carrying water for urban use.[389] Despite these extensive alterations of construction and use, McDonald and Bailey (2017) found that out of 124 miles of laterals inventoried in their study, 27 miles were still open canals in their original locations and warranted preservation. They pointed that these are “representative examples” of original ditching with historic integrity that “would contribute to a historic district.”[390] The current PA covering the Salt River Project notes that, in addition to the NRHP-eligible canals (Arizona, South, Eastern, Grand, Tempe, Western, Highland, and San Francisco Lateral Canals), other features with unknown eligibility include the Glendale and Little Maricopa Ditch piped laterals. The PA further notes that the remaining piped laterals were not eligible for the NRHP.[391]

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[384] McDonald and Bailey, *Salt River Project Multiple Property Submission*, F 39-41.

[385] Ibid., F-41.

[386] Knight, *Field Guide*, 263.

[387] McDonald and Bailey, *Salt River Project Multiple Property Submission*, F-37-41.

[388] Ibid., F-37-41.

[389] Ibid., F-39-39.

[390] Ibid., F-39-39.

[391] Programmatic Agreement Among the Bureau of Reclamation, Phoenix Area Office, The Arizona State Historic Preservation Officer and Salt River Project Regarding Historic Preservation for the Salt River Project System of Historic Main Canals, Laterals, and Associated Features (2013).

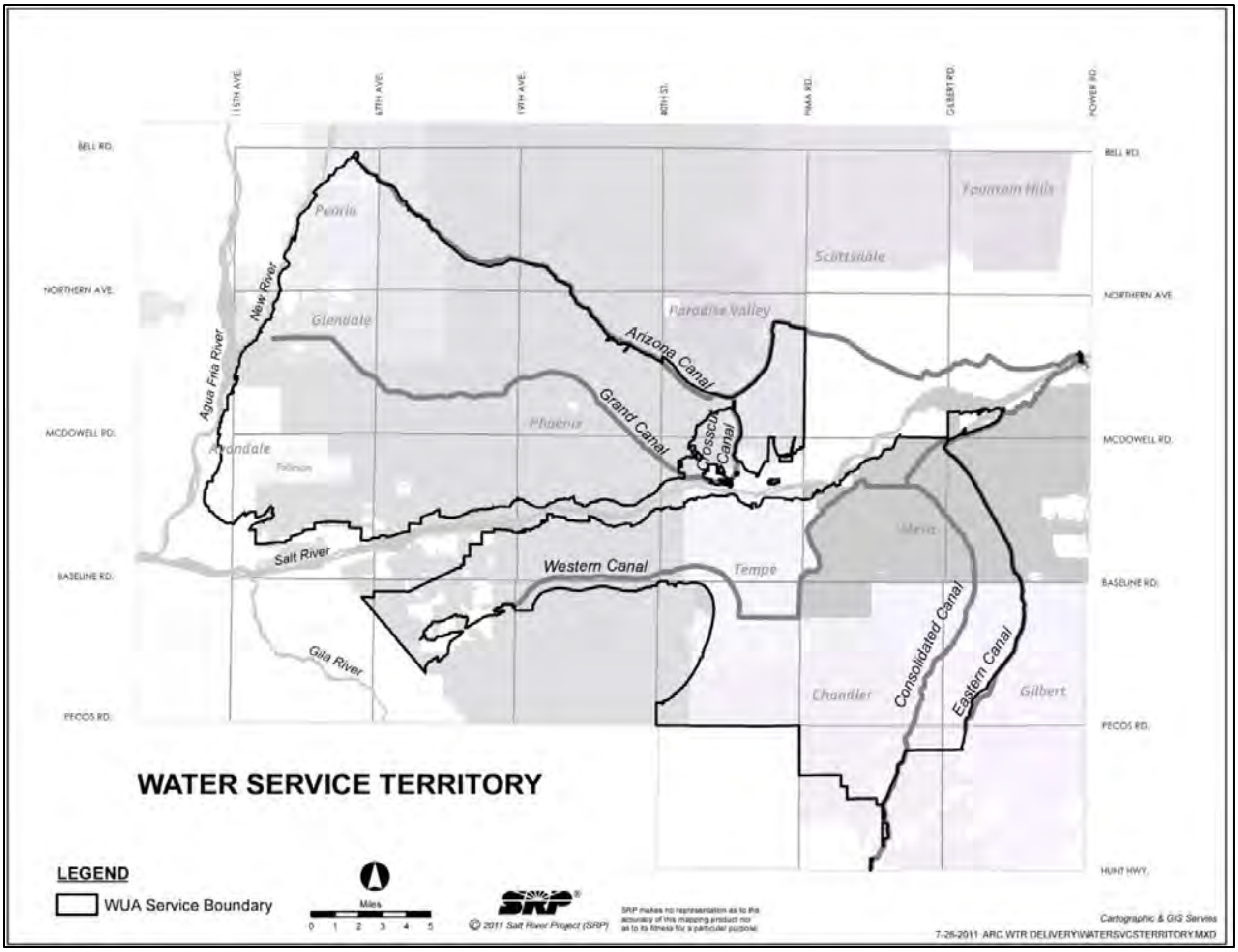

Figure 5.5 Salt River Project Map (courtesy of Bureau of Reclamation).

5.3 Minidoka Project

The Minidoka Project was one of the first undertaken by the new Reclamation Service in 1904 and was one of the first to incorporate hydroelectric power from the onset of the project.[392] It straddles two states, southeastern Idaho and northeastern Wyoming. The Snake River divides the southern and northern parts of the Minidoka Project. As of 2000, the project involved more than 19,000 farms and 1.1 million acres available for irrigation and stretches 300 miles along both sides of the river.[393] Today, along with irrigation, the project has power generation, recreational, and fish and wildlife preservation components. On April 23, 1904, the Secretary of the Interior approved the project and allocated the first $2.6 million for its construction. The Minidoka Dam and Lake Walcott Reservoir were completed in 1906 and the Minidoka

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[392] Though Minidoka was one of the first to incorporate hydroelectric power, the Salt River Project was the first to actually incorporate it in its planning. The generated power was not only used to supply the construction camp but also the cement plant. Afterwards, through power sales, it contributed substantially to paying for the project.

[393] Laura Woodworth-Ney, "Water, Culture, and Boosterism: Albin and Elizabeth DeMary and the Minidoka Reclamation Project, 1905-1920," In Bureau of Reclamation, *The Bureau of Reclamation: History Essays from the Centennial Symposium, Vol. 2*, (Denver: U.S. Department of the Interior, Bureau of Reclamation, 2010), 385-402.

Powerplant came online in 1909.[394] The dam and powerplant were located six miles south of the town of Minidoka, Idaho. The North Side Canal extended eight miles in a southwest direction from the dam. The South Side Canal extended from the pumping plant. The north side canals would be gravity fed, but the ones on the south side of the river would be dependent on pumping plants to move water to higher benchlands. The enlargement of Jackson Lake in Teton National Park began in 1906 but was not completed until 1916. Increasing the lake's capacity was necessary when engineers determined that the project needed more water.[395] In 1926, Reclamation contractors built American Falls Dam to further increase the project's storage capacity. In 1973, Congress authorized the American Falls Reservoir District to finance and construct a replacement dam. The new American Falls Dam was completed in 1978.

Other parts of the project were completed over the next 10 years. The Milner-Gooding Canal was completed in 1929, and the Milner Lake Diversion Dam was completed in 1931. Between 1937 and 1939, Reclamation added several canals and dams to the project, including Island Park Dam (1939), Grassy Lake Dam (1939), Cross Cut Diversion Dam (1938), Cascade Creek Diversion Dam (1937), Cascade Creek Feeder Canal (1937), and Cross Cut Feeder Canal (1938) [396]. These later features were originally part of the Upper Snake River Division, but in 1940 they were transferred to the Minidoka Project. At the same time, Reclamation transferred the Fremont-Madison Division to the Minidoka Project. World War II interrupted any additional work on the project. In 1954, the agency created a North Side Pumping Division for the Minidoka Project. Canals and laterals were created by 1956 in Unit A, and by 1963 in Unit B of the project's new division.

Early and sizable projects such as Minidoka challenged Reclamation engineers and managers. The South Side Canal and some pumping canals were enlarged early in 1912. By 1914, wasteways on the north side were also altered.[397] Jackson Lake Dam was strengthened in 1929. Alterations to the Milner-Gooding Canal were conducted in the 1930s to seal cracks. Finally, in the early 1930s, the South Side Main Canal was enlarged.[398]

Decades later, as the elements of the project aged, several major changes and replacements occurred. The American Falls Dam was replaced in 1978. Though it was not part of the Minidoka Project, a major failure in a Reclamation-built dam occurred in 1976, when further upstream the Teton Dam failed. The massive rush of water caused erosion and severely tested downstream Minidoka Project facilities, but none failed. In 1989, Reclamation completely replaced the foundation for Jackson Lake Dam. In the 1990s, Minidoka Powerplant's Units 6 and 7 were rebuilt and Units 8 and 9 were added.

Throughout the decades, drainage continued to be a problem for the project. Water seepage created ponds and then swamps in low-lying areas. The inundated lands turned "white" from alkaline water, and rising ground water ruined wells. Quicksand areas developed where water and sand mixed, sometimes trapping animals. Insufficient drainage created problems for the farmers.[399]

During World War II, nearly 10,000 Americans of Japanese ancestry were confined in the Hunt Internment Camp. Detainees worked on parts of the Minidoka Project, including maintenance on the

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[394] Eric Stene, *Minidoka Project History* (Denver: Bureau of Reclamation History Program, 1997), 7. Note that private concerns built the Milner Dam in 1905 (Stene, *Minidoka Project History*, 12).

[395] Stene, *Minidoka Project History*, 8-9.

[396] Ibid., 14.

[397] Ibid., 19-20.

[398] Ibid., 21-22.

[399] Ibid., 25.

Milner-Gooding Canal from 1942 to 1945. The site of the former camp is inside the Gooding Division of the project. Today, it is managed by the NPS as the Minidoka National Historic Site, honoring the former residents.[400] The project also served as a Prisoner of War camp for Germans and Russians pressed into German service from 1944 to 1946.

Portions of the project have been listed on the NRHP, documented through HAER, or determined eligible for the NRHP. The Gravity Division canal system was determined eligible for the NRHP under Criterion A in 2019 in the areas of agriculture, reclamation, and early settlement of southeastern Idaho. Reclamation determined that the system represented a standard construction and was not eligible under Criterion C, but they left open the possibility that unidentified individual elements may be eligible.[401]

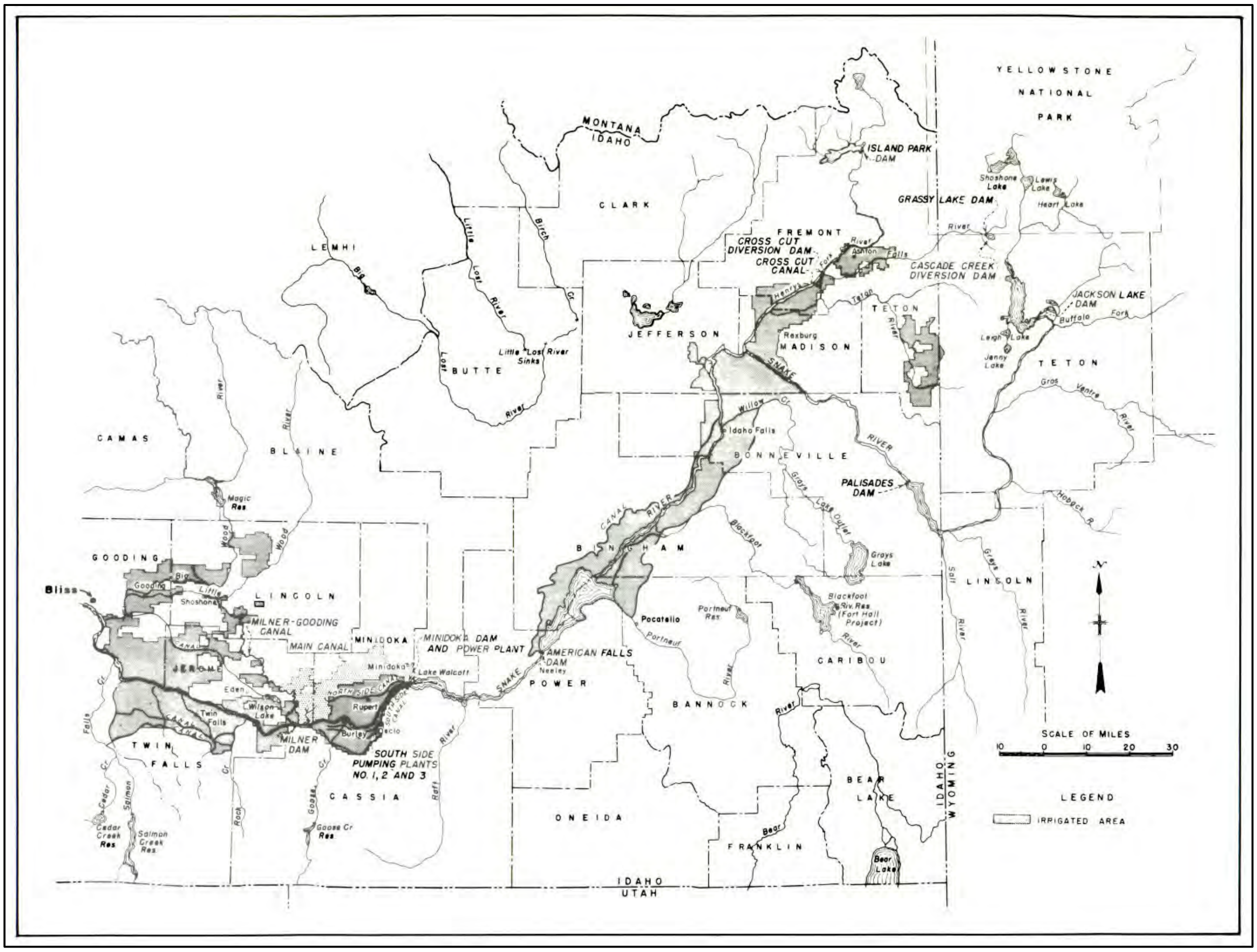

Figure 5.6 Map of the Minidoka Project.[402]

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[400] Stene, *Minidoka Project History*, 26-27; National Park Service, "Minidoka: An American Concentration Camp," www.nps.gov/miin [accessed August 2022].

[401] Bureau of Reclamation, *Minidoka Gravity Division Historic Context and Evaluation* (Denver, Colorado: Bureau of Reclamation, 2019), https://www.usbr.gov/pn/snakeriver/landuse/culturalresources/18usfocr06mgd.pdf [accessed August 2023].

[402] Bureau of Reclamation, *Minidoka project: Idaho and Wyoming, 16 counties* (Washington, D.C.: Bureau of Reclamation, 1983), 2.

5.4 Milk River Project

The Milk River Project is in north/central Montana and runs along a 165-mile stretch of the river in Blaine, Phillips, and Valley counties, with features in Hill and Glacier counties. It is one of the few projects that is multinational, in that part of the river runs through southern Canada, and coordination with the Canadian Government was necessary for its successful completion. The project irrigates some 120,000 acres in the Chinook, Malta, and Glasgow divisions of the project.[403] Runoff from the Glacier National Park through Swift Current Creek Diversion Dam is stored in Lake Sherburne for release into the St. Mary River via the St. Mary Canal. The water travels 200 miles through northern Montana, the Canadian Province of Alberta, then back to Montana before being stored in the Fresno Reservoir on the Milk River. It is then released downstream where several diversion dams transfer water to irrigation fields.

The project was one of the first five projects authorized by the Secretary of the Interior in March 1903 and initiated by Reclamation.[404] Construction began on the Dodson Diversion Dam in Montana in 1906. Further authorizations occurred in 1935, as part of the New Deal, and in 1944.[405] Despite initial work in Montana, complete work on the water storage system could not begin until the U.S. and Canada settled issues over water use, which they did in the Boundary Waters Treaty of 1909. Also at issue was the use by the Blackfoot Indian Nation, as their reservation straddled the project lands. By 1910, two water associations were formed: the Upper and Lower Milk River Water Users Association and the United Milk River Users Association.[406] However, agreements with the Federal Government were not completed until 1912.[407] Though construction began in 1906, the project was not completed until after World War II. Interestingly, early construction on the last 10 miles of the St. Mary Canal was carried out through the Blackfoot Indian lands, as that portion of the canal ran through their reservation.

The St. Mary Canal delivers water from the St. Mary River via the canal to the north branch of the Milk River. This was an ambitious and risky task and was the first of several trans-basin diversions completed by Reclamation. It also involved the Blackfoot Tribe in construction and in irrigating reservation lands. The plan was to have the water stored in a dam at the mouth of the St. Mary River and transferred 30 miles via the canal to the Milk River. The water flowed into Canada and traveled 200 miles back to the U.S., where it was stored behind the Fresno Dam and Reservoir. Embroiled in the Canadian-U.S. agreement for water sharing, it took eight years to build the canal and was completed in 1915.[408]

Meanwhile, the 8,000-foot-long Dodson Diversion Dam was completed in 1910. The dam diverts water from the Milk River for the Malta Unit of the project. The North Canal and South Canal, completed in 1915, begin at the dam but on opposite sides of the river. The Dodson South Canal is of particular interest, as it

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[403] Simonds, "Milk River Project," 2.

[404] The other initial projects include Salt River Project, Arizona; Uncompahgre Project, Colorado; North Platte Project, Wyoming/Nebraska; Truckee-Carson (Newlands) Project, Nevada.

[405] Simonds, "Milk River Project," 5.

[406] There is a difference between a water users' association and an irrigation district. An irrigation district is a local agency that builds and operates an irrigation system and has the authority to levy taxes for that purpose. A water users' association is an organization established by a group of farmers to manage water resources along a particular water course, and membership is voluntary. During this period, Reclamation encouraged the creation of these associations primarily for accounting reasons. It was much easier to contract for water deliveries with one entity than with each individual farmer, which did occur on some projects (courtesy of Andrew H. Gahan, August 2022).

[407] Simonds, "Milk River Project," 2.

[408] Ibid., 11-12; see also Bureau of Reclamation, "St. Mary Unit Projects," https://www.usbr.gov/gp/mtao/stmary/index.html [accessed August 2023].

is 43 miles long. At about the 21-mile point, the Bowdoin Canal (lateral) forks to the south and carries water to irrigation sublaterals for dispersion into the lands in the southern part of the Malta Unit of the Project. The South Canal continues eastward, distributing water through laterals on its south side, until it ends at the Nelson Reservoir, which is used for storage for the Malta Unit.

Work on other features took longer. Construction on the Lake Sherburne Dam and Reservoir began in 1914, with infilling beginning in 1918. However, the component fixtures and spillway were not completed until 1921.[409] The Nelson Reservoir was not completed until 1915 with the embanking of the Nelson Dikes, and the Nelson North and South Canals were finished in 1918. The Dodson, Bowdoin, and Nelson canals and their related dams and reservoirs all serve the Malta Unit of the project. The Nelson South Canal ends back at the Milk River after releasing water through its laterals into lands on its south side. The remaining water continues downstream to the Vandalia Diversion Dam.

The Vandalia Diversion Dam lies southeast of the Nelson Dam, approximately 44 miles downstream. The dam and its adjoining Vandalia South [Main] Canal were completed in 1917.[410] They supply water to the irrigation fields through their laterals on the north side of the canal as well as those areas on the south side of Milk River between the communities of Vandalia and Nashua. These features form the Glasgow Unit of the Milk River Project.

Meanwhile in the 1930s during the Depression, New Deal funding provided for an additional water storage unit upstream of the Dodson Diversion Dam. The Fresno Dam and Reservoir were completed in 1939 and provided additional water for the project. In 1946, the Dodson Pumping Unit was constructed on the Dodson North Canal about 2.5 miles north of the Town of Dodson. The pump lifted water over 20 feet into the Dodson Pump Canal, a lateral of the North Canal that irrigates 1,000 acres on the north side of the river.

Between the Fresno Dam and the Dodson Diversion Dam was a stretch of the river under private irrigation. Five Native American-owned irrigation districts control waters into the area, called the Fort Belknap Reservation (today the Chinook Unit of the Milk River Project). When floods destroyed the primary diversion dam (Paradise Division Dam), Reclamation negotiated with the districts for the construction of a new dam, which was completed in 1966.[411] The Chinook District, though located along the Milk River between two sections of the Milk River Project, remained in Nakoda and Aaniiih Tribal hands.

In the 1920s, the Nelson Reservoir was enlarged and many of the original wooden turnouts and control structures were replaced. In the 1960s and 1980s, the Lake Sherburne Dam underwent substantial renovations. Other maintenance and repairs have been consistently conducted over the years; however, the canals and most laterals follow their original design. All the main canals are still open, as are many laterals. Control features are also still observable, though no doubt upgraded over time.

A 1991 cultural resources study provided a detailed analysis of the project The study included 139 historic features and discussed the project's property types, including dams, siphons, flumes, drops, wasteways, and others. The study recommended that the Milk River Project was eligible as a system under

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[409] Simonds, "Milk River Project," 17.

[410] Bureau of Reclamation, "St. Mary Unit Projects."

[411] Simonds, "Milk River Project," 22.

NRHP Criteria A, B, C, and D. The report does not call out any particular features as being individually unique, but does itemize major canals, siphons, flumes, and crossings.[412]

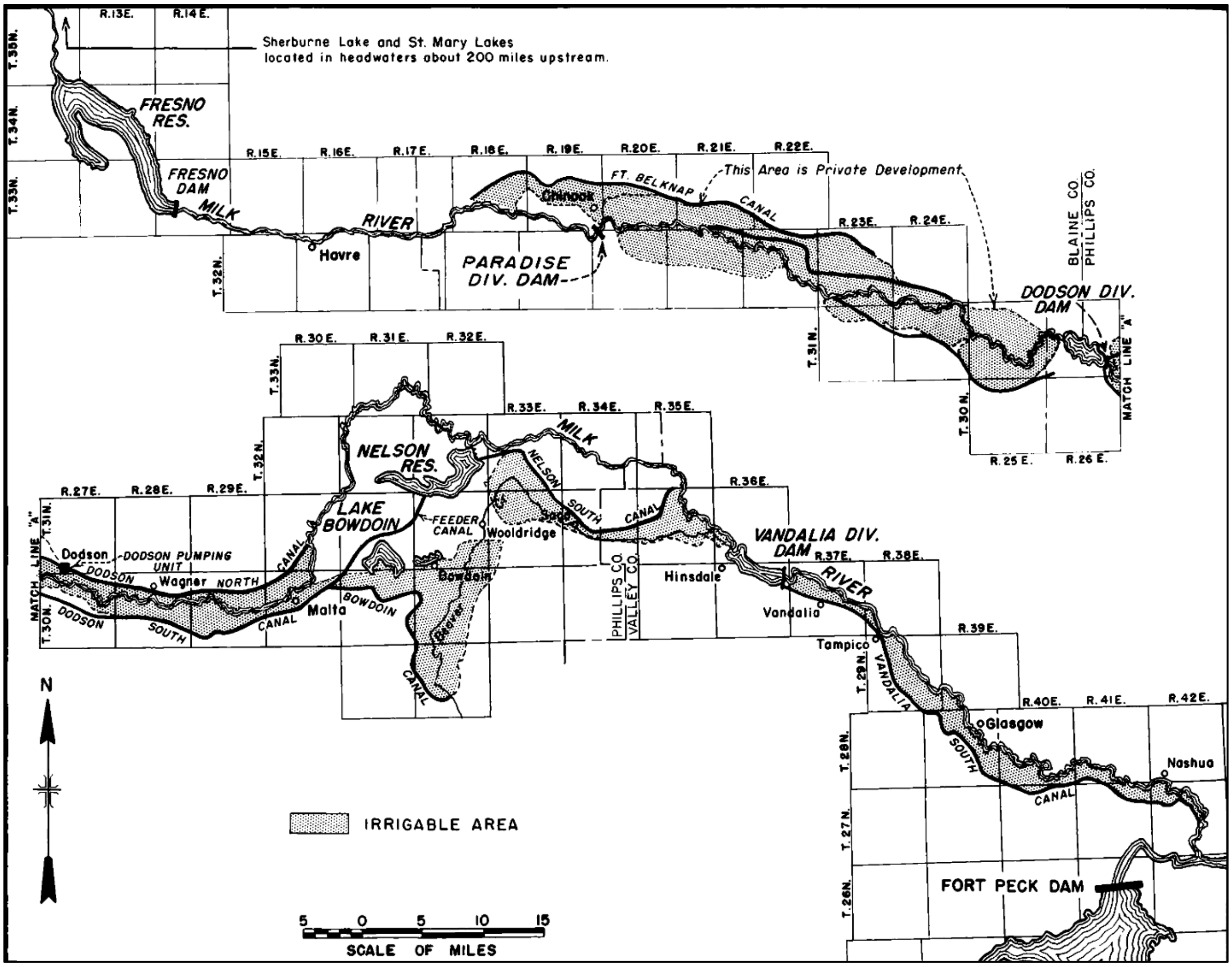

Figure 5.7 Map of the Milk River Project.[413]

5.5 Sun River Project

The Sun River Project was authorized on February 26, 1906, when the Secretary of the Interior provided $500,000 from the Reclamation Fund to irrigate 100,000 acres along the Sun River in central Montana. The Sun River Project comprises 91,000 acres, including 81,000 acres in the Greenfields Division north of the river, and 10,000 acres in the Fort Shaw Division south of the river.

The project draws its water from the Sun River and its two main tributaries, the North and South Forks. Gibson Reservoir, located above Gibson Dam at the mouth of the Sun River watershed, is the primary storage facility for the project. Located three miles downstream from Gibson Dam is the Sun River

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[412] Rolla L. Queen, Roy Wingate, and Brit Allan Storey, *Historic Cultural Resources of the Milk River Project* (Denver, Colorado: Bureau of Reclamation, 1991).

[413] Bureau of Reclamation, *Milk River project: Montana, Blaine, Glacier, Phillips, and Valley Counties* (Washington, D.C.: Bureau of Reclamation, 1983), 2.

Diversion Dam, which moves water into the Pishkun Supply Canal. That canal carries the water to the Pishkun Reservoir, an off-stream reservoir 15 miles northeast of Gibson Dam. To the southeast is Willow Creek Dam and Reservoir on Willow Creek, which is supplied with supplemental water from the Sun River through the Willow Creek Feeder Canal that stems from the Pishkun Supply Canal. Water released from Pishkun Reservoir flows through the Sun River Slope Canal that branches into several main canals for distribution to the Greenfields Division. Water for the Fort Shaw Division diverts directly from the river through the Fort Shaw Diversion Dam into the Fort Shaw Canal. Nine canal systems cross the project, totaling 131 miles, with 562 miles of laterals and 265 miles of drainage ditches.[414]

The first canal to be constructed was the Fort Shaw Diversion Dam and Canal. The dam is a rock-filled structure with concrete headworks that spans 400 feet across the Sun River. The canal stretches 12 miles eastward from the diversion dam and includes a 1,565-foot-long siphon across Simms Creek. The main canal was completed in 1908.[415] This was the first attempt by a Reclamation project manager to use electric drag lines in the construction, in contrast to mule-drawn scrapers. The C-lateral off the main canal has an interesting 65-foot drop constructed as a stepped waterfall, and the C-1 Wasteway drain has a 29-foot drop. Both features veered from normal Reclamation-constructed drops in that they used the natural terrain instead of concrete basins to still the water once it had fallen from the heights. The Pishkun Supply Canal is a 12-mile-long canal complete with two tunnels and a 700-foot-long pipe to bring water from the Sun River Diversion Dam to the Pishkun Reservoir, where it is stored for use. The canal was completed in 1920 and expanded in 1938. The Pishkun Reservoir is formed by eight earth-filled dikes ranging in height from 10 to 50 feet with an overall length of 9,050 feet. The Pishkun Reservoir was completed for service in 1931, but like much of the project, it was enlarged by 1941.[416] Construction of the Sun River Diversion Dam began in 1911 and was completed four years later.[417]

Other features soon followed. The Willow Creek Dam and Reservoir was completed in 1911 and the reservoir was filled by 1916, though the dam was increased in 1917 and again in 1941. Between 1917 and 1919, Reclamation constructed the Sun River Slope Canal and the Spring Valley Canal to furnish water for the Greenfields Division. They extend 32 miles from the Pishkun Reservoir to a drop at Fairfield, Montana.[418] The Greenfield Main Canal heads at the termination of the Spring Valley Canal and extends 24.5 miles further to the northeast, distributing water through laterals. It also supplies water to the Greenfields South (Lateral) Canal, two miles below its initiation at the end of the Spring Valley Canal. The Greenfields South (Lateral) Canal runs 16.7 miles over benchland, and it also supplies water for the 10.7-mile-long Mill Coulee Canal. The two Greenfield canals and their extensions were completed after World War I in 1920.

The increased water requirements in the 1920s led to the construction of the Gibson Dam as part of the Sun River Project. At the Gibson Dam, Reclamation engineers first experimented with innovative mathematics, called the Trial-Load Method, to build the half-moon, concrete, arched dam between 1926 and 1929. The completion of the dam brought the initial construction on the Sun River Project to an end. The project was expanded in the 1930s through the New Deal initiatives, but no new major features were added. To offset flood damage in the early 1970s, new gates were installed at the Gibson Dam, and further modifications were completed at the dam in the early 1980s. Modifications have continued at the Fort Shaw

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[414] Autobee, "Sun River Project," 4.

[415] Ibid., 10.

[416] Ibid., 17.

[417] Ibid., 15.

[418] Ibid., 17.

Canal and Willow Creek Dam as well as other parts of the project since the 1980s. Since the early 2000s, the Fort Shaw Irrigation District has attempted to "modernize its infrastructure by converting open canals to buried pipe."[419] The level of these modern improvements may have a negative effect on the Sun River Project's eligibility for the NRHP.

A 1990 cultural resources study provided a detailed analysis of the project, including 160 historic features and a discussion of property types, including the project's dams, siphons, flumes, drops, wasteways, and other types. The study recommended that the Sun River Project as a system was eligible for the NRHP under Criteria A, C, and D. The report further identified notable individual features, including the Fort Shaw Canal and Headworks, Drop C, Simms Creek Siphon, Arnold Coulee Drop and Stilling Basin, and the Sun River Slope Canal, among others.[420]

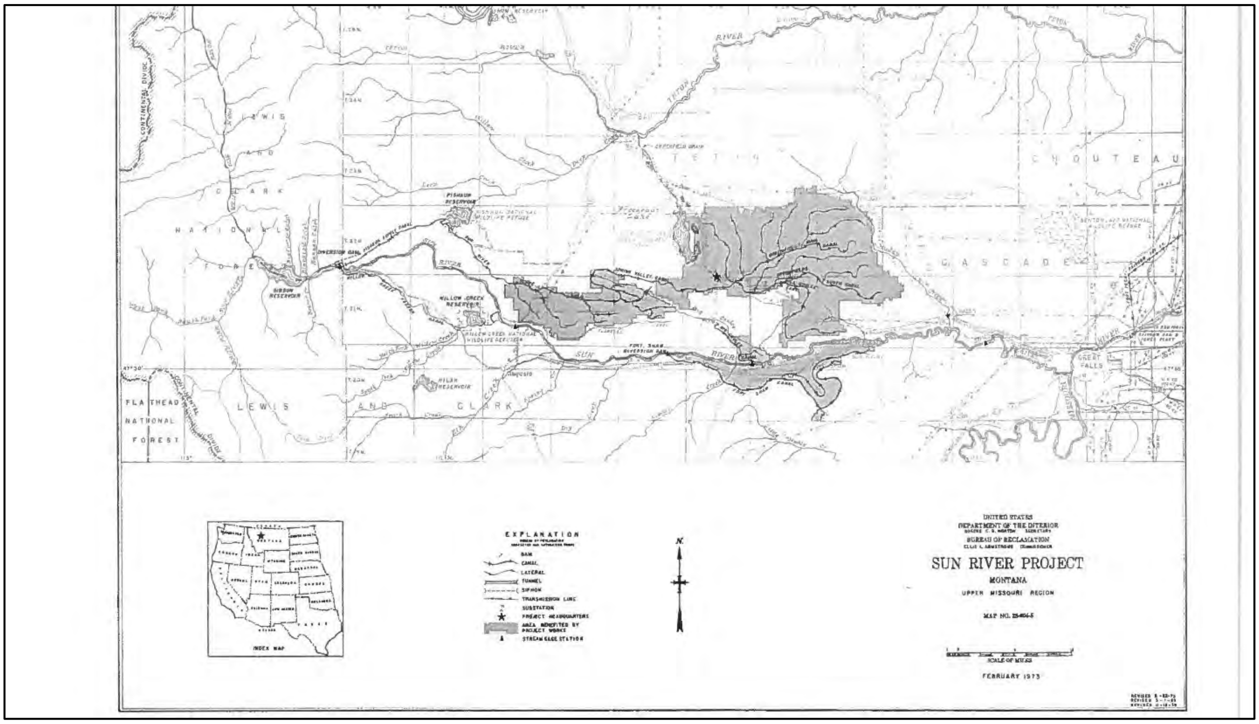

Figure 5.8 Sun River Project Map (courtesy of Bureau of Reclamation).

5.6 Kendrick Project (Casper Alcova Project)

The Kendrick Project is a typical Reclamation Project located in central Wyoming. Originally authorized by President Franklin Roosevelt in August 1935 as the Casper Alcova Project, a New Deal initiative, it serves the agricultural needs of Carbon and Natrona counties, and specifically the water needs of Casper, Wyoming. In anticipation of congressional approval of the project, in 1933 local landowners created the Casper Alcova Irrigation District to oversee the operations and management once it was completed. In 1937, the project was redesignated the Kendrick Project after a prominent Wyoming Senator who helped

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[419] Fort Shaw Irrigation District Webpage: http://www.mtfsid.com/history.html [accessed August 2022].

[420] Rolla L. Queen, Louise Watson, Roy Wingate, and Brit Allan Storey, *Historic Cultural Resources of the Sun River Project* (Denver, Colorado: Bureau of Reclamation, 1990).

expose the Teapot-Dome Scandal.[421] Research could not locate an official NRHP evaluation of the Kendrick Project, but a multiple property listing, *Depression Era Federal Projects in Wyoming, 1929-1943*, notes dams, reservoirs, and irrigation projects "like the Kendrick Project" as a property subtype likely to be eligible.[422]

The project involves two storage dams and reservoirs. The Alcova Dam and Reservoir was built on the North Platte River near the town of Alcova, about 30 miles south of Casper. A second dam, the Seminoe Dam and Reservoir, was constructed for water storage and power generation 37 miles further upstream. The two dams and reservoirs service 66,000 acres of irrigatable land in the vicinity of Casper. The Alcova Dam was completed in 1938, and a powerplant was added in 1955. The Seminoe Dam and Reservoir was completed in 1939. Nearly as soon as the Alcova and Seminoe dams were created, recreational facilities were added by the CCC, and recreation became an important part of the project.

The water flow system incorporates two other dams and reservoirs. Water from the Seminoe Reservoir flows north down the North Platte River to the Kortes Dam and Reservoir and the Pathfinder Dam and Reservoir, then into the Alcova Reservoir where it is held for use. The Kortes Dam and Reservoir is a small power generation unit built by Reclamation between 1946 and 1951.[423] It has no irrigation authorization except that it is on the Platt River between the Seminoe and Alcova Dams. The Pathfinder Dam and Reservoir are key features of the North Platte Project and one of the first constructed by Reclamation (built between 1905-1909). It impounds water from the Sweetwater River. However, water coming down the Platte River enters the Pathfinder Reservoir. Excess water impounded at Pathfinder is released down the Platte River for irrigation as needed into the Alcova Reservoir.

The Alcova Dam serves as a headgate for the Casper Canal, a 59-mile main canal that includes six concrete-lined tunnels. Water from the Alcova Dam passes through a spillway and tunnel on the northwest side of the reservoir into the Casper Canal. The canal flows north and northeast before turning southeast though the City of Casper and ending at a drainage of the North Platte River. The project contains 190 miles of laterals and sublaterals and 41 miles of drains.[424] Today, about 24,000 acres are irrigated within the project.[425]

Most of the improvements to the system have focused on the dams and reservoirs, with only incidental improvements to the distribution system. The large main canal remains open, as are many of the laterals, some sublaterals, and drains. The project represents an excellent example of the kind of work done in the middle period of Reclamation construction, with its open canals and laterals, as well as drains, siphons, tunnels, and other measuring devices. The project is often referred to as a multi-purpose project; that is, along with irrigation, its Congressional authorization also included power generation, fish and wildlife protection, flood control, recreation, and providing public water to the City of Casper. These multi-purpose projects aided the irrigation component by helping to provide revenue and keeping the cost of the irrigation repayment lower.

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[421] Klajic, "The Kendrick Project," 9-10.

[422] Michael Cassity, *Depression Era Federal Projects in Wyoming, 1929-1943*. National Park Service Multiple Property Documentation Form, NRIS # 64501171, 2013.

[423] The Kortes Dam was built under authorization of the Flood Control Act of 1944 as part of Reclamation's Pick-Sloan Missouri River Basin Program.

[424] Bureau of Reclamation, "Kendrick Project," https://www.usbr.gov/projects/index.php?id=3400 [accessed August 2022].

[425] Ibid.

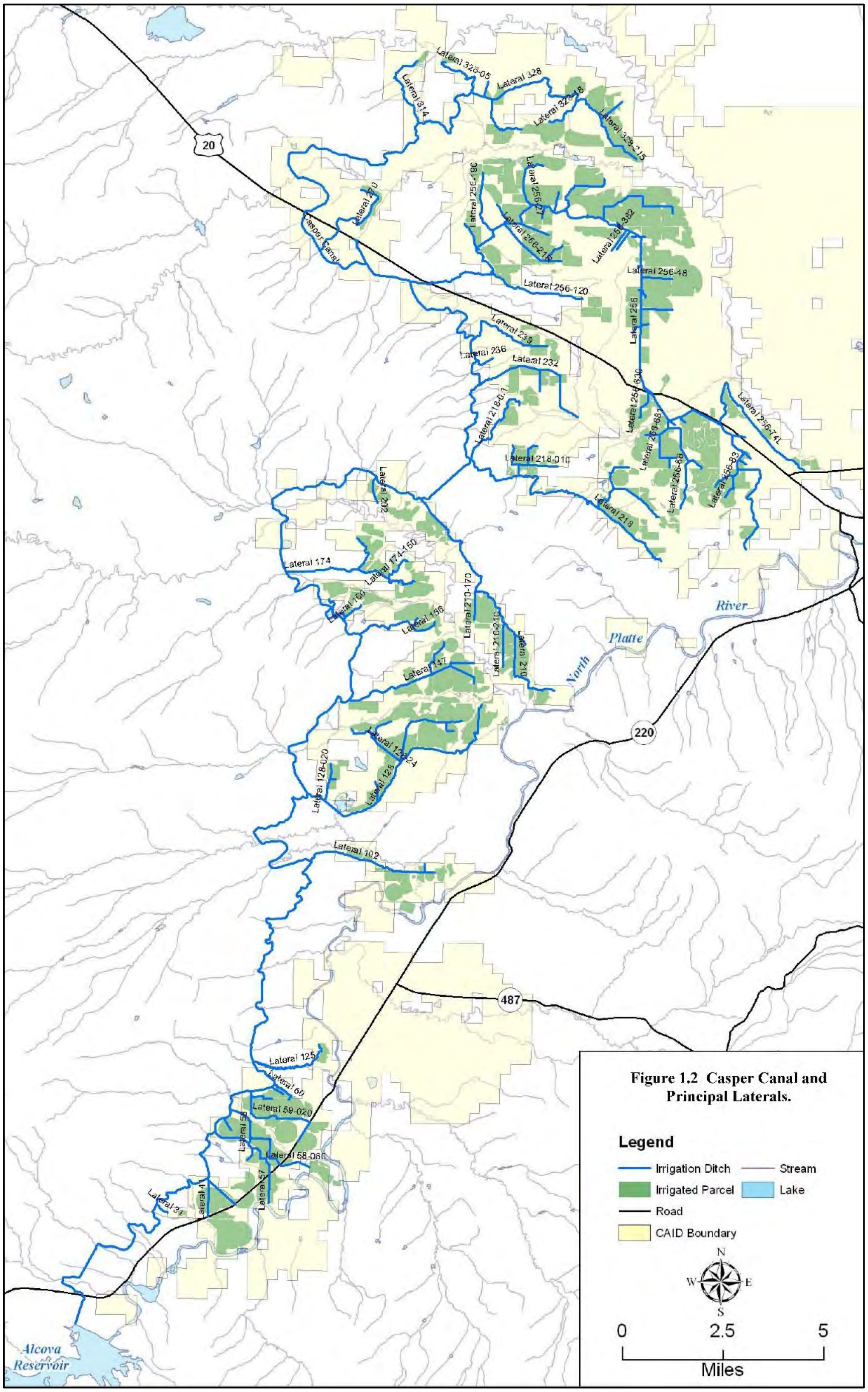

Figure 5.9 View of the Kendrick Project with the Casper Canal and key laterals.[426]

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[426] Anderson Consulting Engineers, *Casper Alcova Irrigation District GIS Project, Level II* Study, A report prepared for the Wyoming Water Development Commission (Ft. Collins, Colorado: 2008), 1.4.

5.7 Columbia Basin Project

The Columbia Basin Project was another large project taken on by Reclamation. The Grand Coulee Dam was built as one of the largest New Deal projects that created Franklin D. Roosevelt Lake and served as the primary, but by no means the only, reservoir for the project. The dam was built as much for flood control and electric power generation as irrigation but was projected to irrigate up to 1,100,000 acres in the basin of the Columbia River. The dam was completed prior to World War II, but not all the generators were brought online until 1949. While none of its dams or irrigation related features have been placed on the NRHP, components have been determined eligible and documented through the HABS/HAER program, including the Grand Coulee Dam, a pump plant, Banks Lake Dry Falls Dam and Main Canal Headworks, a Siphon-Breaker Building, and the Banks Lake Feeder Canal.

The irrigation portion of the project was authorized March 10, 1943, in congressional action called the Columbia Basin Project Act of 1943.[427] The Quincy, East and South Irrigation District compose the project. The system stretches more than 110 miles from the Grand Coulee Dam to the meeting of the Columbia and Snake rivers. Key components of the irrigation system included the Dry Falls Dam, Banks Lake, the Feeder Canal, the Main Canal, the West, East High, and East Low Canals, the 200-foot-high Potholes Dam (now O'Sullivan Dam), Potholes Reservoir, Potholes East Canal, and the Equalizing Reservoir. Additionally, the Royal Branch Canal, Wahluke Branch Canal, and Eltopia Branch Canal all served as large lateral canals for the system. The Columbia Basin Project included two other reservoirs, Soap Lake, and Scooteney Reservoir along with dikes and headworks for each of these. Other features of the system include the Scooteney, Royal Branch, Winchester, Finegold, Lind Coulee, and Frenchman Hills wasteways or drains. The system draws on four large tunnels and siphons, the Bacon Siphon Tunnel, the Crab Creek Siphon, the Broken Rock Siphon, and 12,820-foot Soap Lake Siphon. This latter siphon was the longest in the world at the time of construction in 1955.[428] The size of the project and the location of main canals below grade in many locations required the use of more than 200 pumping plants or lift stations.[429]

Finally, the system contains some of the largest features built by Reclamation. Along with the 671,000 irrigated acres, the giant, Grand Coulee Dam impounds Franklin D. Roosevelt Lake that stretches 151 miles, almost to the Canadian border. In addition to the 27,800-acre O'Sullivan Reservoir and seven hydroelectric powerplants, this massive system contains the 41-mile long Wahluke Branch Siphon and Canal, 87-mile-long East Low Canal, 1,900 miles of laterals, and 3,500 miles of drains or wasteways, not to mention numerous other features including chutes, spillways, conduits, flumes, turnouts, and measuring devices.[430]

Though the main features were largely completed by the mid-1950s, construction of laterals and ditches continued well into the 1960s. There have been some substantial changes to the system. The Outlet Conduit at the O'Sullivan Dam was sealed. The Feeder Canal was altered in the early 1980s when its cut and cover conduit was replaced by an open flume and the canal itself was enlarged. In 1980, the Bacon Siphon and Tunnel were doubled in size and two tunnels now exist. Many of the water pumps were replaced with combination, generator/pumps.[431]

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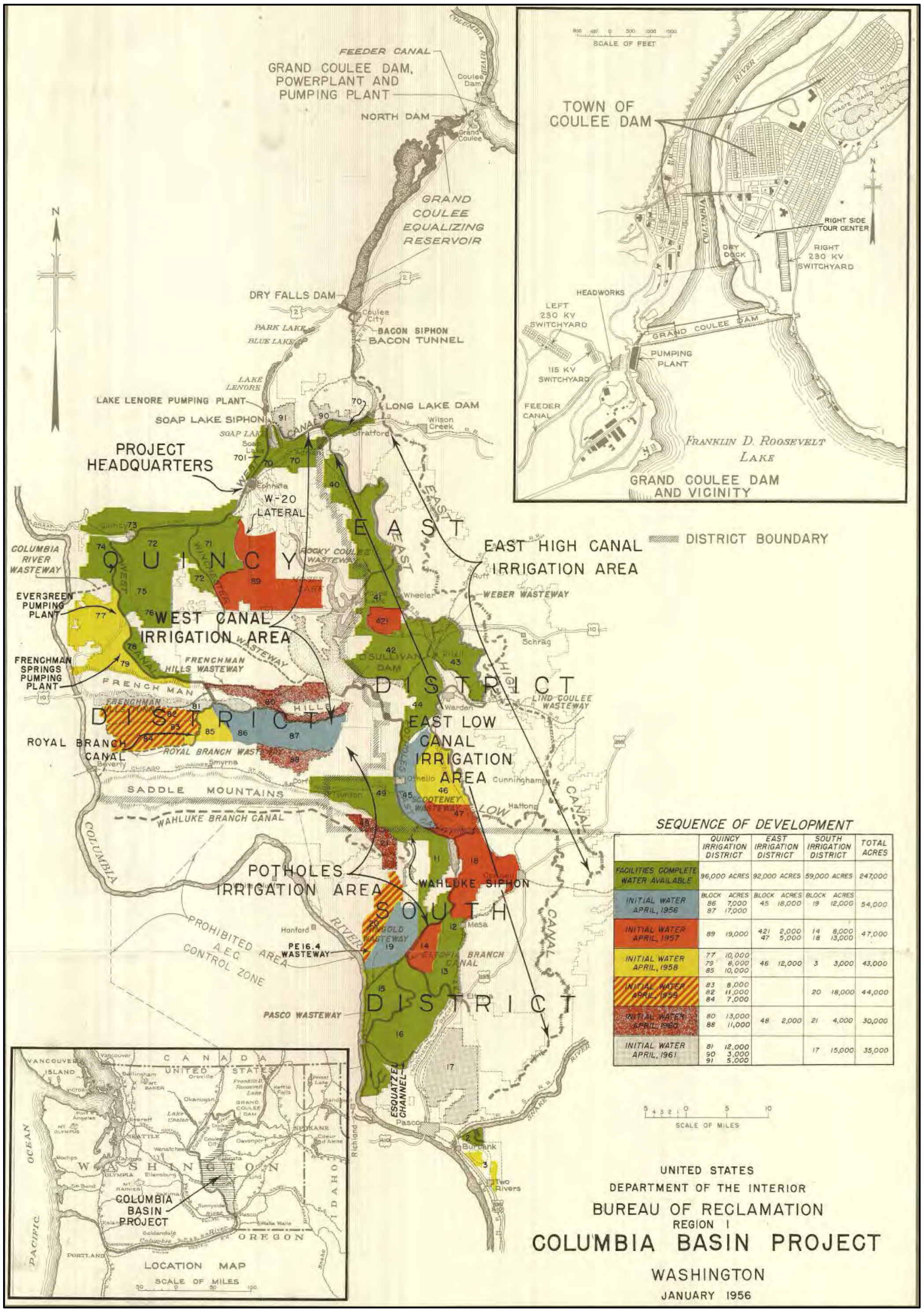
[427] Simonds, "Columbia Basin Project," 12.

[428] Ibid., 41.

[429] Ibid., 48.

[430] Ibid., 48.

[431] Ibid., 63-65.



SEQUENCE OF DEVELOPMENT

	QUINCY IRRIGATION DISTRICT		EAST IRRIGATION DISTRICT		SOUTH IRRIGATION DISTRICT		TOTAL ACRES
FACILITIES COMPLETE WATER AVAILABLE	96,000 ACRES		92,000 ACRES		59,000 ACRES		247,000
	BLOCK	ACRES	BLOCK	ACRES	BLOCK	ACRES	
INITIAL WATER APRIL, 1956	86 87	7,000 17,000	45	18,000	19	12,000	54,000
INITIAL WATER APRIL, 1957	89	19,000	421 47	2,000 5,000	14 18	8,000 13,000	47,000
INITIAL WATER APRIL, 1958	77 79 85	10,000 8,000 10,000	46	12,000	3	3,000	43,000
INITIAL WATER APRIL, 1959	83 82 84	8,000 11,000 7,000			20	18,000	44,000
INITIAL WATER APRIL, 1960	80 88	13,000 11,000	48	2,000	21	4,000	30,000
INITIAL WATER APRIL, 1961	81 90 91	12,000 3,000 5,000			17	15,000	35,000

Figure 5.10 Map of the main features of the Columbia Basin Project.[432]

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[432] Bureau of Reclamation, *Columbia Basin Annual History, Vol. XXIII, Part 1* (Washington State, 1955).

5.8 Rapid Valley Project

The Rapid Valley Project is located along Castle Creek, a tributary of the larger Rapid Creek located in the Black Hills in Pennington County, South Dakota.[433] Along with the irrigation of nearly 9,000 acres, the project provides water to Rapid City and its nearby neighbor, Ellsworth Air Force Base (AFB). Primary features of the project include the Pactola Dam and Reservoir, and the Deerfield Dam and Reservoir, located 25 miles west of Rapid City. President Franklin D. Roosevelt approved the project in early 1942, though work on the Deerfield Dam had begun the previous year. The Rapid Valley Water Conservancy District was formed in 1942 to manage the project once it was completed by Reclamation. Work continued on the project during World War II as Civilian Service Program (CSP) workers took up where CCC workers left off in June 1942. CSP workers were mostly conscientious objectors who agreed to work in other capacities than serve in the military. Work on the dam and reservoir was completed in 1946.[434] Between 1952 and 1958, Reclamation completed the Pactola Dam and Reservoir to provide additional water for the project. Since the completion of the Pactola Dam in the late 1950s, the only improvement in the system was the enlargement of the Deerfield Dam in the early 1980s.

Project water primarily moves from the Deerfield Reservoir and Pactola Reservoir through Castle Creek and Rapid Creek to supply water to the Rapid City/Ellsworth AFB area and to the irrigation districts along the valley. However, Reclamation did not complete any work on the canal system or the distribution system of the Rapid Valley Water Conservancy District. Rather, the agency sells water directly to the irrigation districts in the Rapid Valley and releases the water as requested but has no further involvement with the distribution system.

Research found no information on the NRHP status of the main Reclamation-owned components, including the two dams. However, various ditches, none of which are owned by Reclamation, were recorded through HABS/HAER documentation in the early 1990s.

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[433] Christopher J. McCune, "Rapid Valley Unit, Pick Sloan Missouri Basin Program" (Denver: Bureau of Reclamation History Program, 2001), 2.

[434] Ibid., 15.

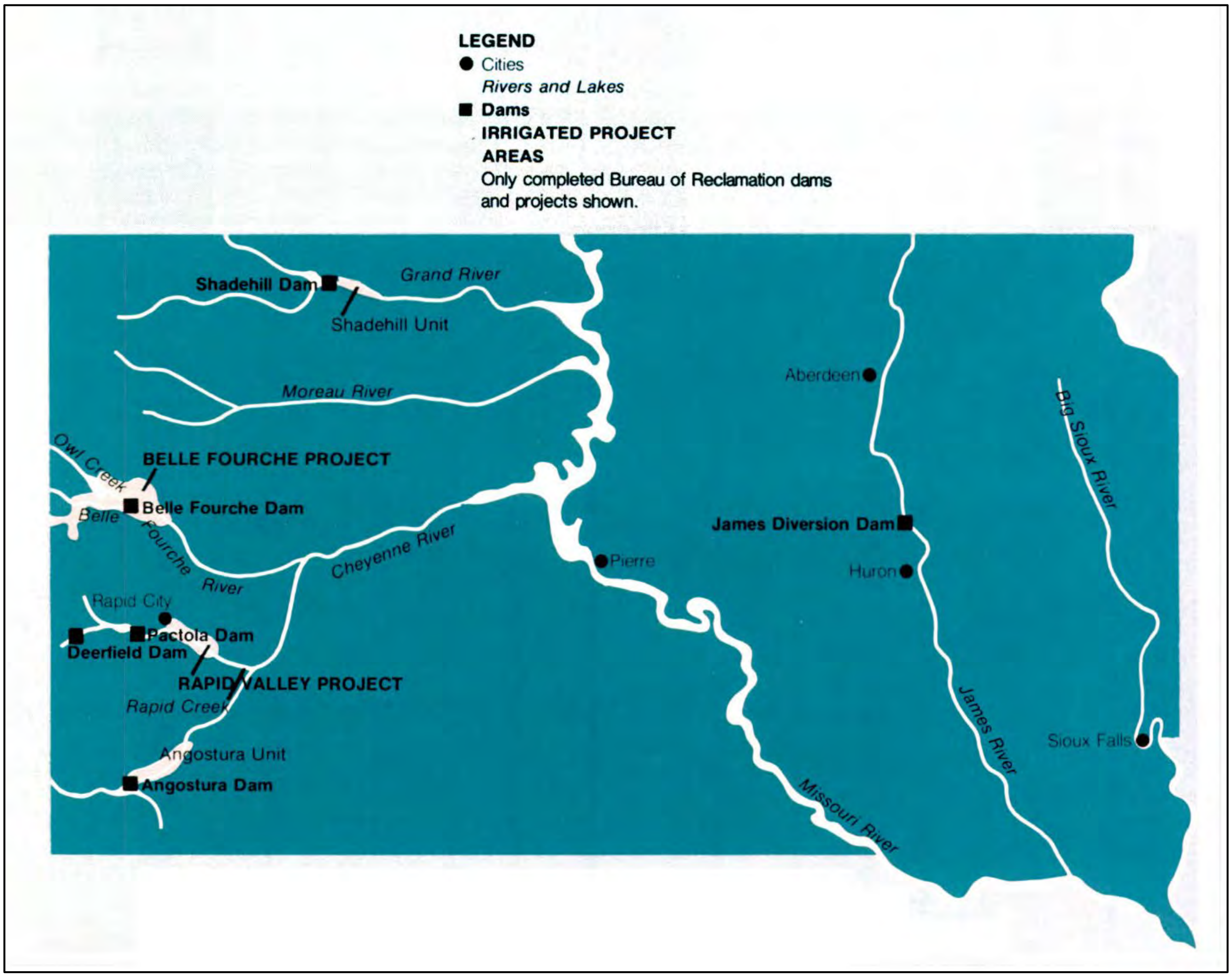

Figure 5.11 Map of the Rapid Valley Project in southwest South Dakota with the location of the Deerfield and Pactola Dams and Reservoirs.[435]

5.9 Frenchman-Cambridge Division, Pick Sloan Missouri Project

The Frenchman-Cambridge Division Project is a portion of the Pick-Sloan Missouri Basin Program in southwest Nebraska. It covers an area of 66,000 acres, but only 16,400 acres is irrigated lands along the Republican and Frenchman rivers and Medicine and Red Willow creeks. The project is three miles wide and stretches 110 miles east to west from Trenton to Palisade near the Kansas/Nebraska border. It encompasses parts of seven counties.[436] The project has four storage reservoirs: the Harry Strunk, Swanson, Hugh Butler Lake, and Enders reservoirs. It contains 63 miles of main canal, 43 miles of laterals, and 51 miles of drain lines.[437] It was authorized as part of the Pick Sloan Missouri Basin Project under the Flood Control Act of 1944. The project consists of five separate units that work together: the Frenchman, Meeker,

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[435] Bureau of Reclamation, *South Dakota: Bureau of Reclamation projects* (Washington, D.C.: Bureau of Reclamation, 1983), 18.

[436] Tina Marie Bell, "Frenchman-Cambridge Division: Pick-Sloan Missouri Basin Project" (Denver: Bureau of Reclamation, 1997), 1.

[437] Ibid., 12.

Red Willow, Cambridge, and Oxford units. The project was authorized as a joint irrigation and flood control project.

Along with the four reservoirs, the main components consist of the Culbertson Diversion Dam and canal system, the Meeker Canal System, the Red Willow Creek Diversion Dam and canal systems, the Bartley Diversion Dam and canal systems, and the Cambridge Diversion Dam and canal systems. Other notable features include the 2,364-foot Oxford Siphon, and the combination of Upper Meeker, Meeker Extension, and Driftwood canals that form a single 27-mile-long canal. Parts of the project predate Reclamation efforts at irrigation. Most of the project was built in the 1950s and was completed by 1964.[438]

Several changes to the project began in the late 1960s, when Reclamation converted 50 miles of open laterals into closed piped conduits. By the mid-1980s, some 109 laterals and sublaterals were enlarged and piped.[439] However, a search of the system on Google Maps seems to reveal that, though the laterals are largely closed, the piped main canals are still open, with some portions lined, and a few laterals still open. Research did not identify any information regarding an evaluation of this system or its components.

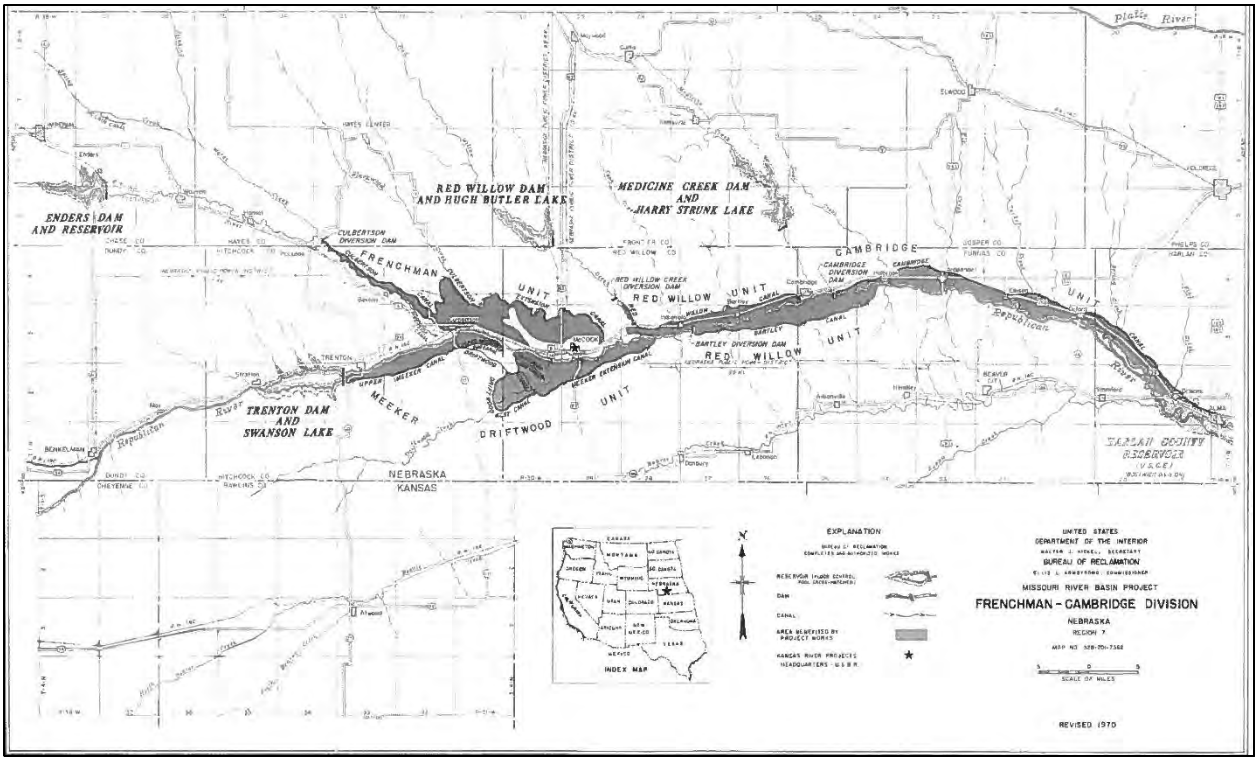

Figure 5.12 Drawing of the Frenchman-Cambridge Division Project, Nebraska (courtesy of Bureau of Reclamation).

5.10 Lewiston Orchards Project

Located near the confluence of the Clearwater and Snake rivers in Idaho, the Lewiston Orchards Project was a private irrigation project initiated in 1906. In 1946, Congress authorized Reclamation to rehabilitate and rebuild the Lewiston Orchards Irrigation District project. The project facilities included four diversion structures (Webb Creek, Sweetwater, West Fork, and Captain John), the Sweetwater main canal, three small

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[438] Bell, "Frenchman-Cambridge Division", 21.

[439] Ibid., 25.

storage reservoirs (Soldiers Meadow, Reservoir `A`, and Lake Waha), and the system for the distribution of irrigation and domestic water. The project irrigated 3,900 acres when completed. The Lewiston Orchards Project includes a water purification unit, as residential water was one of the authorizations for the project. Construction began on the project in 1947 and was completed in 1951.[440] Today, nearly all the irrigation lands have been converted into residential and commercial subdivisions. The primary function of the Lewiston Orchards Project is providing clean water for more than 14,000 residents of Lewiston.

Water for the project begins at the Webb Creek Diversion Dam, southeast of Lewiston, Idaho. A gravity-fed system, it moves north down Webb Creek though the Webb Creek Canal and siphon into a small branch of the East Fork of Sweetwater Creek. Water then moves north down the creek through the Sweetwater Diversion Dam and then to the Sweetwater Canal. From the canal, it flows north/northwest to the "A" Reservoir. Water is also diverted from Lake Waha, through the West Fork Diversion Canal into the West Fork of Sweetwater Creek, then through the Sweetwater Diversion Dam and into the Sweetwater Canal. Finally, further south, water flows from Captain John's Creek into the Soldier's Meadow Reservoir, south of the Nez Perce Reservation, via the Captain John's Diversion Canal. From the reservoir, water is released into Webb Creek and flows north to the Webb Creek Diversion Dam and Canal. It is a complicated system for such a small acreage. Water is stored in Reservoir A and released westward to the Lewiston Orchards irrigation acreage through the project's main canal. Research did not identify any information regarding an evaluation of this system or its components.

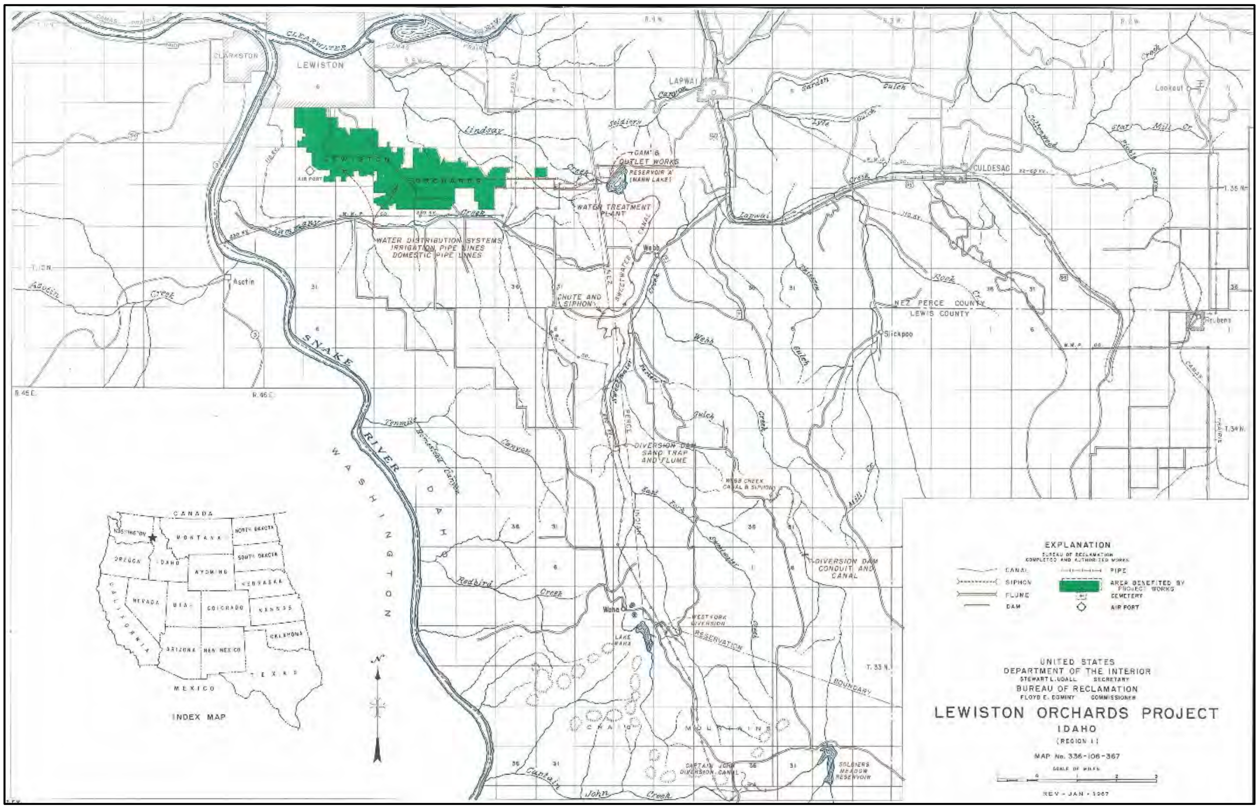

Figure 5.13 Lewiston Orchards Project, Idaho with the main features of the water distribution system (courtesy of Bureau of Reclamation).

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[440] Bureau of Reclamation, "Lewiston Orchards Project, General," https://www.usbr.gov/projects/index.php?id=475 [accessed August 2022].

5.11 Balmorhea Project

The Balmorhea Project is located in the Trans-Pecos River region of West Texas. This project provides supplemental irrigation to 10,600 acres along Toyah Creek in the Madera Valley of West Texas.[441] The irrigated area stretches 15 miles along Toyah Creek, from 4 miles above to 11 miles below Balmorhea, Texas, from which the project derives its name. Unlike other Reclamation projects where the supply stems from surface flows, water for this project originates in an underground reservoir surfacing at San Solomon, Griffin, and other local springs. San Solomon Springs acts as the above-ground reservoir for the project. As a New Deal project in the mid-1930s, the CCC built a large rock and mortar retaining pool at San Solomon Springs that serves as a recreation area and source of water for the project.

Early irrigation efforts began in the area in the 1880s to feed cattle, and in 1909 the Toyah Valley Irrigation Company was organized. After reorganization, the Toyah Valley Irrigation Company changed its name to the Reeves County Water Improvement District in 1917. However, by the 1930s, additional fields available in the district could not be used due to a shortage of water from Madura Creek. Additionally, the Lower Parks Reservoir, which served as backup for San Solomon Springs, was shrinking due to increased silting by Toyah Creek. Reclamation took over the project from private interests after World War II in 1946 and completed the work in 1947. They rebuilt or constructed the Phantom Lake Canal, the Inlet Feeder Canal, and the Madera Diversion Dam as large primary features of the system.[442]

Reclamation engineers observed the need for more water for the project and located it in Phantom Lake on the western edge of the project. They also planned to increase the size of the Lower Parks Reservoir originally established before Reclamation assumed ownership of the project. To accomplish these objectives, they planned a canal from Phantom Lake to the Main Canal, and a second canal from the Main Canal to the Reservoir, which would increase water flows into the reservoir, especially during the spring. They constructed a concrete-lined canal from Phantom Lake Spring that extended 2.33 miles east to join water from the Madera Diversion Dam in Madura Creek. Then, the waters from the Madura Creek and Phantom Lake Spring moved eastward an additional 1.8 miles through the Madera Diversion Canal to link up with the Main Canal at San Solomon Springs (today part of Balmorhea State Park) in Toyah Vale.

Meanwhile, Reclamation built a new Main Canal that begins at San Solomon Springs and extended north and east, carrying the consolidated waters at San Solomon Springs toward the irrigatable lands. One mile east of San Solomon Springs, the Inlet Feeder Canal forks off and moves 2.8 miles further southeast to the Lower Parks Reservoir (today Lake Balmorhea). Reclamation used the canal to collect excess spring waters coming through the Main Canal in the reservoir. On the east side of the reservoir, Reclamation built the Outlet Canal that extends about 3.1 miles north to link with the Main Canal.[443]

These efforts gave the Main Canal additional water from the reservoir during dry months. Reclamation also dug a new Main Canal that began at San Solomon Springs and moved east through the project area. The two new canals, Phantom Lake Canal and Feeder Canal, were concrete-lined. Contractors for Reclamation also restructured the Madera Diversion Dam in Madera Creek to include new headworks, abutment strengthening, and two dikes, but essentially left the original diversion dam, a 13-foot-high, 950-foot-long dam across the creek, intact. At the Madera Dam, the waters from the creek and Phantom Lake Spring join and form the Madera Diversion Canal, bringing water to San Solomon Springs. At San Solomon Springs, the waters from the three sources combine to move through the project's Main Canal

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[441] Wm. Joe Simonds, "Balmorhea Project" (Denver, Colorado: Bureau of Reclamation History Program, 1996), 2.

[442] Ibid., 4-6.

[443] Ibid., 9.

northeastward to the project's irrigation lands. When Reclamation completed work, they built a linkage to an additional source of water, constructed a second drain for capturing excess spring waters, and increased the size of the Lower Parks Reservoir as a back source for water during long, hot summers. The additional water also permitted the irrigation district to expand from 7,500 acres to over 10,000 acres of irrigatable farmlands.[444]

After completing the renovations for the existing project, from 1951 to 1953, Reclamation rebuilt and concrete-lined 3 miles of laterals, including additional lining of the Inlet Feeder Canal and other laterals in the system. Reclamation also installed a Parshall flume in the Main Canal. Additionally, in the mid-1950s, they added cattle guards, Cipoletti weirs, and metal gates, and rebuilt four bridges at the west end of the project. In 1957, the Madura Canal was enlarged, and in the late 1950s additional lining of the entire system was added. By 1964, Reclamation contractors had lined 45 miles, or nearly 90 percent of the system. The concrete-lined laterals had 2-foot bottoms and 3.5-foot depths. Throughout the 1960s and 1970s, Reclamation continued to repair and replace damaged and worn sections with new concrete portions. By 1974, all but 4 miles of the once all-earthen canals and laterals were concrete-lined. Repairs had also been made to the dikes around the Lower Parks Reservoir and the Inlet Feeder Canal. Most of these repairs were completed in the mid-1970s. [445] As a direct result of Reclamation's intervention into the project, crop values soared from $48.59 per irrigated acre in 1946 to $227.47 by 1957.[446]

Research did not identify any information regarding an evaluation of this system or its components. However, according to Knight (2009), the lining of the canals in themselves do not necessarily remove the system from consideration for NRHP eligibility. The system improvements were part of Reclamation's plan from the beginning and were a primary reason for taking on the project. Most of the alterations in the project were completed nearly 50 years ago and fit the age for eligibility. Further archival work regarding alterations made since the 1970s is necessary to determine if other elements such as location, overall design, or integrity have been compromised by the later improvements.

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[444] Simonds, "Balmorhea Project," 9.

[445] Ibid., 11-2.

[446] Ibid., 15.

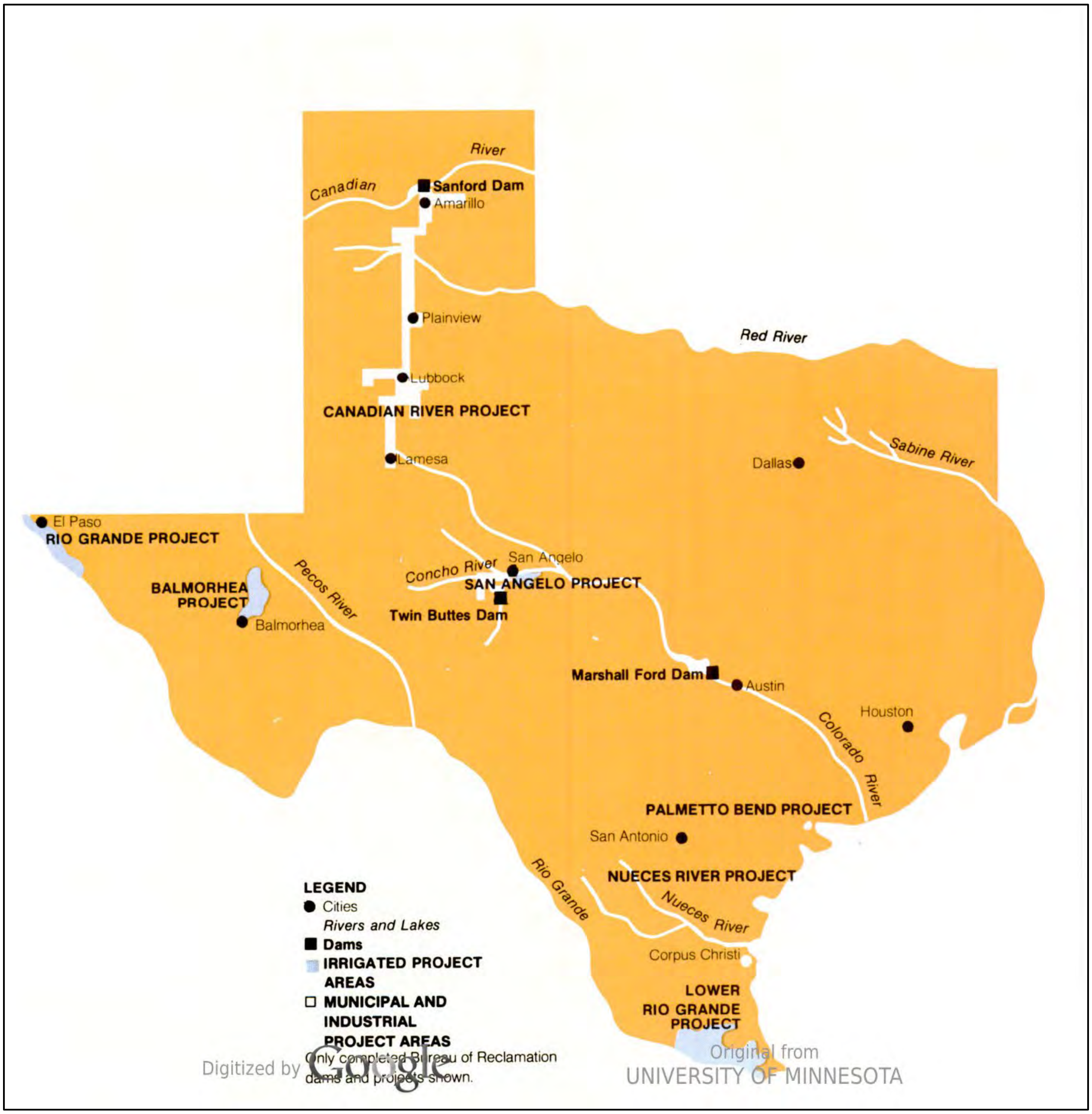

Figure 5.14 Location of the Balmorhea Project in west Texas.[447]

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[447] Bureau of Reclamation, *Texas, Bureau of Reclamation projects* (Washington, D.C.: Bureau of Reclamation, 1983) 20.

5.12 Almena Unit of the Pick Sloan Missouri River Program

The Almena Unit of the Pick Sloan Missouri Basin Program is in north-central Kansas along the valley of Prairie Dog Creek in Norton and Phillips counties. The project consists of the Norton Dam, Keith Sibelius Reservoir, Almena Diversion Dam, Almena Main and South Canals, and an extensive system of laterals and drains that serve 5,700 acres of irrigatable lands in the valley. The project was authorized for Reclamation in 1946 but construction did not begin until December 1961. The project was completed in May 1967.[448] The irrigation project has been expanded for municipal water, fish and wildlife restoration, and recreation, as well as flood control. The irrigation portion of the project stretches along Prairie Dogs Creek from 2 miles southwest of Almena to 3 miles east of Long Island, Kansas, a distance of 20 miles.

The Almena Main Canal begins at the diversion dam east of Norton, Kansas, and stretches 20.1 miles east to west of Woodruff, Kansas. One-half mile south of the Town of Almena, the South Canal forks off to the southeast and irrigates lands on the south side of Prairie Dogs Creek. It stretches over 8 miles and ends southeast of the intersection of West Granite Road and West 1488 Road.

A series of archaeological investigations near the Main Canal, South Canal, and several laterals has revealed alterations in the form of piping and lining for substantial sections of the canals and laterals. In 2005 and 2009, several lateral sections on the south side of Prairie Dogs Creek around Long Island were converted to inground piping.[449] Other sections west of Long Island, near the county line, and near the fork where the Almena South Canal branches off the Main Canal have also been piped. In 2019, 2.35 miles of the northeastern section of the Main Canal was piped, and it appears that the old canal was abandoned, with the new piping installed adjacent to it. In 2022, Reclamation abandoned 7.25 miles of the South Canal and buried new plastic piping adjacent to the old canal. Research did not identify any information regarding an evaluation of this system or its components. Materials obtained from the Kansas SHPO regarding the Almena system were all related to archaeology.

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[448] Bureau of Reclamation, "Almena Unit: Construction," 1. https://www.usbr.gov/projects/index.php?id=339 [accessed August 2023].

[449] Bill R. Chada, "Letter of Findings Report, Almena Irrigation District Survey" (Bureau of Reclamation, Great Plains Region Office: Grand Island, Nebraska, 2005), 4; Bill R. Chada, "Letter of Findings Report, Almena Irrigation District Survey" (Bureau of Reclamation, Great Plains Regional Office: Grand Island, Nebraska, 2009), 4.

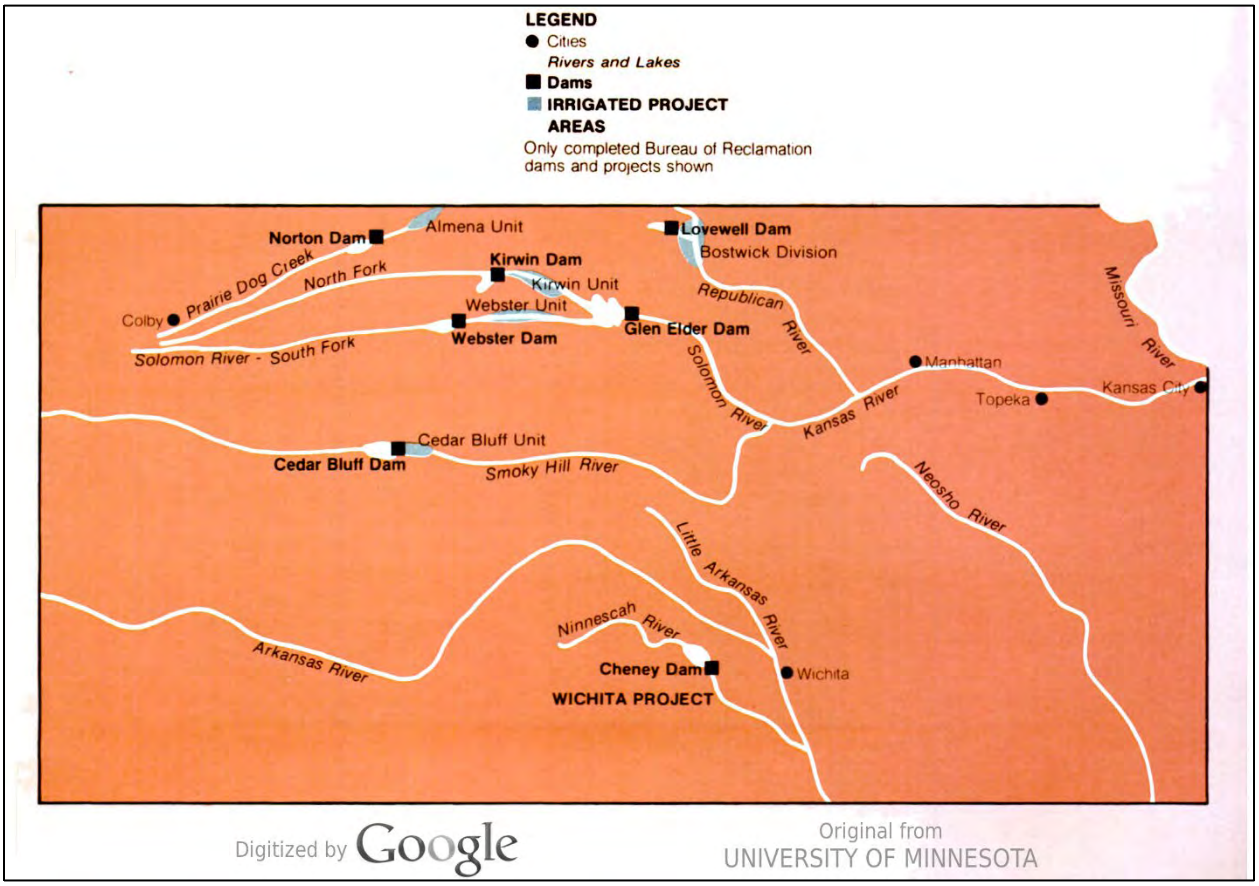

Figure 5.15 Location of the Almena Unit (northern Kansas) of the Pick Sloan Missouri River Project, Kansas.[450]

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[450] Bureau of Reclamation, *Kansas: Bureau of Reclamation projects* (Washington, D.C.: Bureau of Reclamation, 1979) 16.

5.13 Navajo Indian Irrigation Project

The Navajo Indian Irrigation Project was decades in development; to date, it has not been completed. It was the combination of two previously considered projects: the South San Juan River Project and the Shiprock Project. The irrigation system was to provide water for 110,630 acres of land along the south side of the San Juan River in New Mexico, nearly all of it within the Navajo Indian Reservation located in southwest New Mexico. After many delays, the Navajo Indian Irrigation Project was authorized on June 13, 1962.[451] The Navajo Indian Irrigation Project was often overlooked by Reclamation and not given priority. However, as one author pointed out, construction delays were caused by the late authorization and disagreements with the BIA and the Navajo Tribe.[452]

The project included an earthen dam across the San Juan River to create an extensive reservoir for water runoff storage. Construction began immediately and Reclamation completed the dam in 1963 and infilling of the 1.7-million acre-feet of water was completed by 1967. The water distribution portion of the project included a 46.3-mile-long Main Canal and two sublaterals (Gravity and Amarilla) along with the Burnham and Coury laterals. The project also included 15 concrete siphons, seven tunnels stretching 12.8 miles, more than 100 miles of additional sublaterals and ditching, an underground piping system, and a small powerplant.[453]

After ongoing changes and alterations, the Reclamation plan ultimately led to a Main Canal that would bring water to 11 blocks of 10,000 acres within the reservation. By 1970, with construction of the Main Canal not complete, the Tribe formed the Navajo Agricultural Products Industries (NAPI) to manage the project and converted the project into a tribal corporation, rather than the original plan of individual ownership. However, both individual and collective farming techniques were to be used in operating the farms. A 13-member management board would run the project.[454]

The Main Canal was left open and unlined, but the tunnels that covered 7 of the 46 miles were lined, and the siphons were concrete. The Main Canal was opened in 1976 and the Gravity and Amarilla canals were added in the late 1970s. By 1982, water was available to about 50,000 acres, but development stagnated in the 1980s. In 1986, NAPI took formal control of the operations. By the late 1990s, Navajo Tribal members had taken over all operations. In the early 2000s, Reclamation had completed the Burnham lateral and Gallegos pumping station. By 2022, under Navajo management, water had been provided to 81,000 acres within the project. The project is distinctive in that it is the only fully Native American-operated, Reclamation-developed project. It is also unique in that it contains 13 miles of tunnels and 7 miles of siphons along the Main Canal. [455]Research did not identify any information regarding an evaluation of this system or its components. However, this is a newer system where construction is ongoing.

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[451] Glasser, “Navajo Indian Irrigation,” 14.

[452] Ibid., 17.

[453] Ibid., 18.

[454] Ibid., 22.

[455] For information about the NAPI, see the Navajo Agricultural Products Industries webpage: https://napi.navajopride.com/history/.

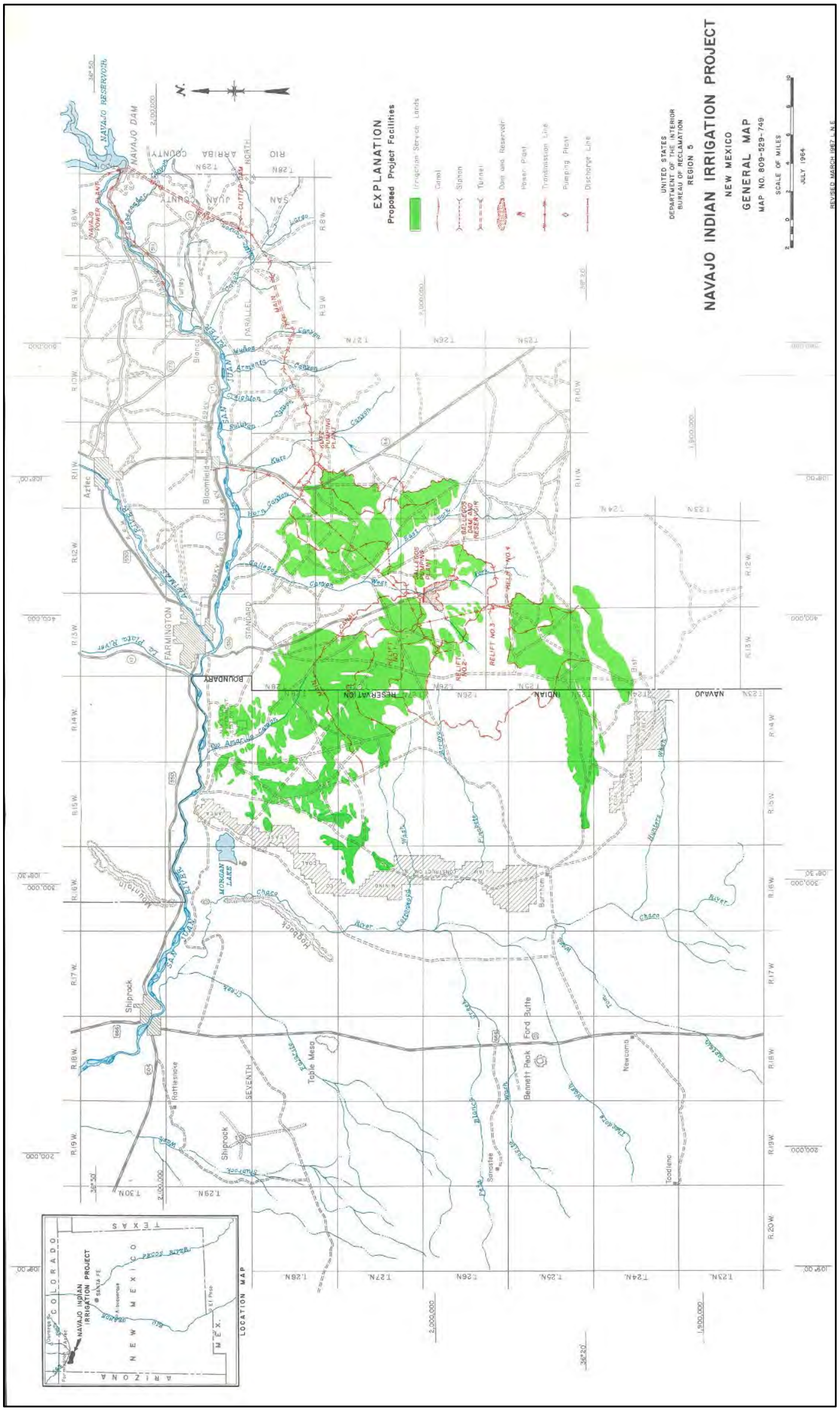

Figure 5.16 Map of the Navaho Indian Irrigation Project with the lands authorized by Congress to be irrigated and the key components.[456]

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[456] Bert Levine, “Navajo Indian Project” (unpublished manuscript in the records of the Bureau of Reclamation, n.d.), 53.

5.14 Garrison Diversion Unit Project

The Garrison Diversion Unit is an irrigation project formed by the Garrison Dam on the Missouri River in North Dakota. The dam forms Lake Sakakawea and Lake Audubon. Though the Garrison Project was a Reclamation project, the Garrison Dam was built by USACE in the 1950s and given to Reclamation to complete the irrigation works. It includes a single lake divided by Lake Audubon Causeway (U.S. Highway 83). Though the Garrison Dam was completed in 1956, the Garrison Unit was authorized in 1965 for the irrigation of up to 250,000 acres in eastern and central North Dakota. It was also planned for flood control, a municipal water source, recreation, and fish and wildlife preservation. The plan included the Garrison Dam, Lake Sakakawea, Lake Audubon, the Snake Creek Pumping Plant, the 79-mile-long McCluskey Main Canal, the Lone Tree Reservoir on the Sheyenne River, and the New Rockford Canal. The Garrison Diversion Unit was another unit of the Pick-Sloan Missouri River Basin Program.

The irrigation project is managed and run by the Garrison Diversion Conservancy District. Unfortunately, the authorized 250,000 acres of irrigated lands did not fully materialize. However, parts of the project were completed, most notably the Snake Creek Pumping Plant and the McCluskey Main Canal. The Snake Creek Pumping Plant was constructed to add additional water to Lake Audubon. Water was then released through the McCluskey Canal on the east side of Lake Audubon and traveled eastward to the Lone Tree Reservoir. From there, it was released to irrigation fields via the New Rockford Main Canal.

The project became immersed in the environmental movement of the 1970s and large portions of the planned irrigation project have not materialized. [457] Specifically, the project was on President Jimmy Carter's "hit list" of water projects that he considered unnecessary. This contributed to the failure to complete the planned work. The Lone Tree Dam and Reservoir were not built and were decommissioned from the project in 2000.[458] Though the New Rockford Canal was constructed, it was not used as part of the irrigation project, and is now separately operated and maintained by Reclamation, independent from the Garrison Unit.

Along with environmental and Presidential concerns, the project became mired in the cost of land acquisition, the economics of irrigation, and an international problem where the Canadian Government became concerned that water would flow from the Missouri River Basin into the Hudson Bay Basin.[459] Congress debated and discussed the project from the mid-1960s until the mid-1980s. After being finally reapproved on a smaller basis in 1986, it again ran into Congressional financing troubles and was not finalized until 2000. However, development has been very slow. As of 2016, only 4,940 acres of the more than 260,000 originally approved acres have received water from the Garrison Unit Project. Owners of another 6,310 acres have permits to irrigate but had not as of the 2016 report.[460] Most of the 260,000 acres have been used for fish and wildlife protection and recreational sites.

The McCluskey Canal was completed in the late 1970s. It is a concrete-lined, open canal that has been unchanged since its construction. The canal extends generally west to east beginning in McLean County, then moves southeast, then northwest, ending in central Sheridan County. Funding from Congress for the

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[457] Garrison Diversion, "History and Federal Legislation," http://www.garrisondiversion.org/about/HistoryFederalLegislation/ [accessed August 2022]. The project became immersed in President Jimmy Carter's "hit list" of projects he considered unnecessary.

[458] Ibid.

[459] Ibid.

[460] Advanced Engineering and Environmental Services (AE2S), *McClusky Canal Irrigation Master Plan Report* (2016), 4.

project has been inconsistent. The irrigation fields are located between Mile Marker 1.7 and 10, with the fields located on the north side of the extensive canal.[461] No part of the water distribution system is yet 50 years old except for the Garrison Dam and the two lakes that were built in the 1950s. Because of the general lack of age, research did not identify any previous evaluations of the system or its components.

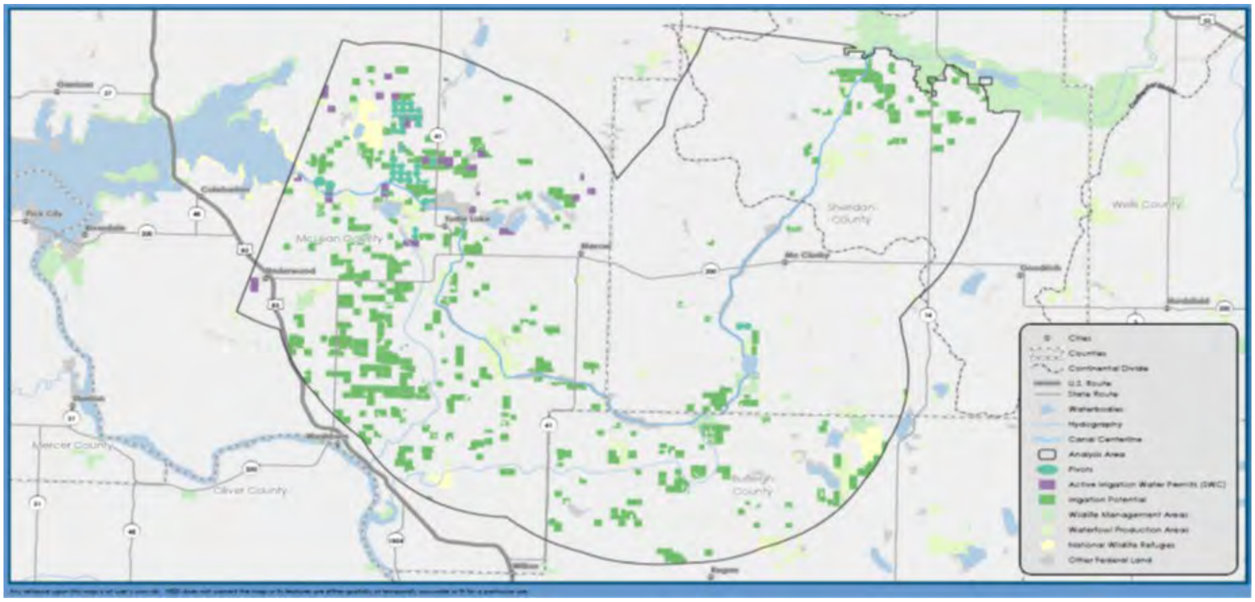

Figure 5.17 Map of the projected Garrison Unit Project, the McCluskey Canal, and the current irrigated fields.[462]

5.15 Middle Rio Grande Project

The Middle Rio Grande Project in New Mexico was authorized for Reclamation, with the USACE as a contributing agency, by Congress on June 30, 1948. As part of the Flood Control Act of 1948, the project was set to "improve and stabilize the economy of the Middle Rio Grande Valley" by rehabilitating the facilities originally built and operated by the Middle Rio Grant Conservancy District (MRGCD).[463] The original district project was completed in the 1930s. In the early 1950s, Reclamation began work on the extensive four-county project, rehabilitating many of the dams and irrigation and drainage works. The project area covers 89,652 acres of irrigatable lands on both sides of the Middle Rio Grande, including 30,000 acres for six southern Pueblo Indian communities.[464] There are four subdivisions of the project: the Cochiti, Albuquerque, Belen, and Socorro divisions. Each division has its own diversion dam and conveyance system. At more than 200 miles long, the project is one of Reclamation's largest projects in terms of length.

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[461] AE2S, *McClusky Canal Master Plan*, 6

[462] AE2S, "Irrigation Master Plan, McCluskey Canal, North Dakota," Figure 2.6, https://www.ae2s.com/irrigation-master-plan [accessed January 2023].

[463] Bureau of Reclamation, "Middle Rio Grande Project: History," https://www.usbr.gov/projects/index.php?id=508 [accessed August 2022].

[464] Ibid.

The irrigation portion begins near the town of Velarde, New Mexico, and follows the river valley 225 miles south, ending at the headwaters of the Elephant Butte Reservoir. The project also covers 55 miles of river channel maintenance from the Elephant Butte Reservoir to the Caballo Reservoir, but this section has no irrigation features. Construction features improved or rehabilitated by Reclamation include the El Vado Dam on the Rio Chama about 160 miles north of Albuquerque, New Mexico. Work also included the Angostura, Isleta, Cochiti, and San Acacia diversion dams along with their corresponding irrigation canals, laterals, sublaterals, and drainage ditches.

The Cochiti Dam serves the Cochiti Division in the far north of the project and supplies water through the Cochiti Main Canal. Angostura Diversion Dam serves the Albuquerque Division south of the Cochiti Division and supplies water through the Albuquerque Main Canal to the irrigation fields. South of Angostura Diversion Dam, the Isleta Diversion Dam serves the Belen Division through the Belen Main Canal. Finally, in the far south, the San Acacia Diversion Dam serves the Socorro Division through the Socorro Main Canal, but the dam can divert excess water to the Low Flow Conveyance Channel.

Major rehabilitation was completed on the El Vado Dam by 1955 and on the four diversion dams between 1955 and 1958. Considerable rehabilitation of the project canals, laterals, and drains were completed by 1961. Reclamation added a low conveyance channel between the Acacia Diversion Dam and the Narrows of the Elephant Butte Reservoir in 1959. In 1975, USACE completed the conversion of the Cochiti Diversion Dam into the Cochiti Dam for flood control, but incorporated diversion headworks into the dam.[465] Other substantial changes include new headworks for the San Acacia Diversion Dam in 1961.[466] That dam conveys water into the Socorro Main Canal for the Socorro Division. In 1975, Reclamation also tied the canal into Drain Unit #7 to reuse water removed through the drainage system. An overview of the alterations made in the 1950s indicates that canals remain open, as do many laterals. Except for Albuquerque, the spread of suburbanization has not affected the project.

The project contains numerous Native American archaeological sites, and was the object of a lawsuit regarding the environmental degradation of fish habitats caused by the Cochiti Dam. Over the decades, clearing of the floodway resulted in the establishment of dense vegetation and large trees within the formerly open floodplains. Humans have introduced a litany of non-native, invasive species; that and the lack of native tree regeneration has been an environmental concern.[467]

Research did not identify any information regarding an evaluation of this system or its components. However, this is a newer system where construction is ongoing. Peripherally, the Elephant Butte Dam and Elephant Butte Irrigation District have both been listed on the NRHP, but these are within the confines of the main Rio Grande Reclamation Project.

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[465] Middle Rio Grande Conservancy District Webpage: https://www.mrgcd.com/work-schedules/ [accessed August 2022].

[466] Bureau of Reclamation, "Middle Rio Grande."

[467] Ibid.,

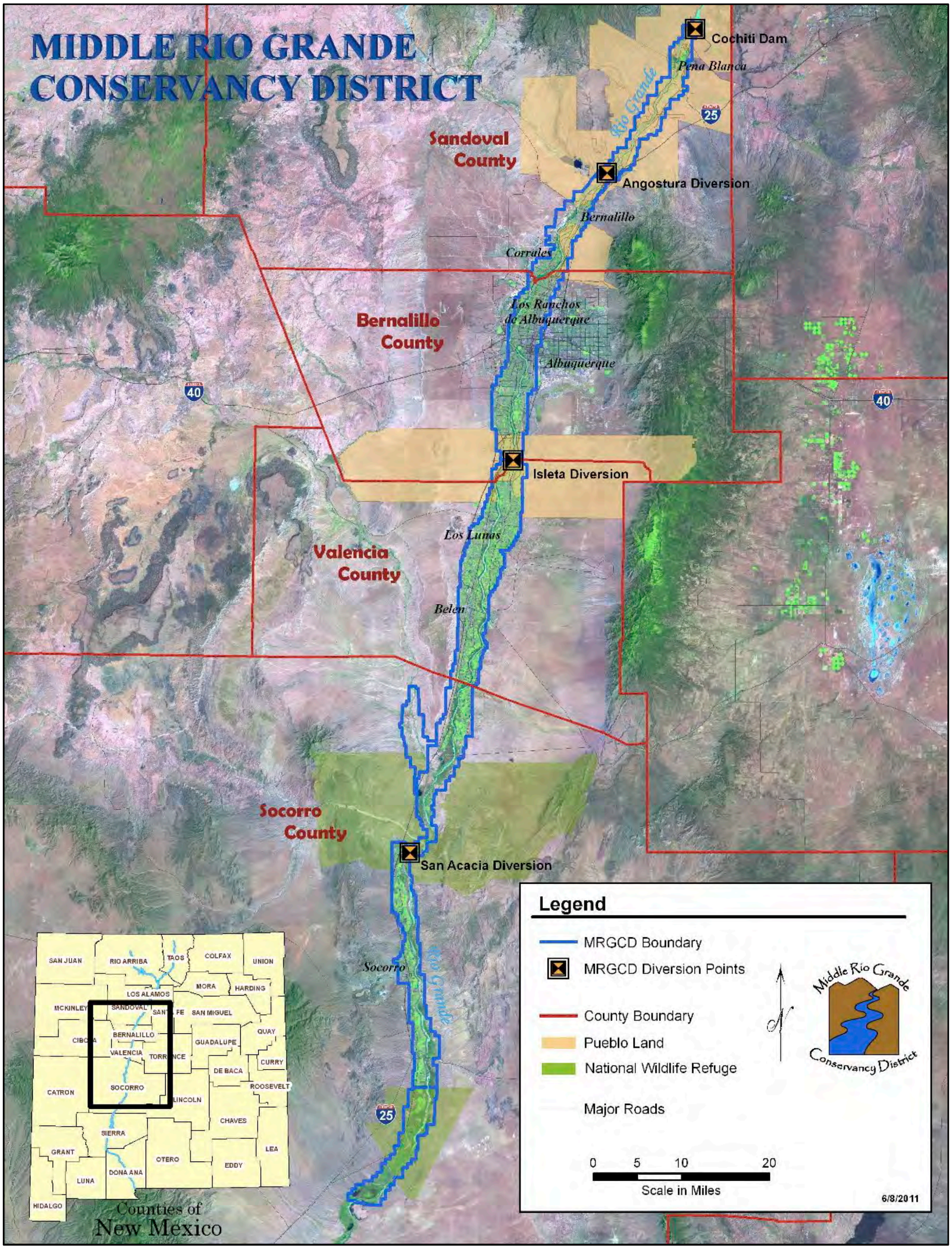

Figure 5.18 Map of the Middle Rio Grande Project with the diversion dams and the individual divisions served by the project.[468]

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[468] Sam Markwell, "Water Users Suing Middle Rio Grande Conservancy District: The Devil is in the Details" (*La Jicarita*, October 18, 2012), https://lajicarita.wordpress.com/2012/10/18/ [accessed August 2022].

5.16 Lower Rio Grande Project

The Lower Rio Grande Project was primarily a rehabilitation project for two former divisions or irrigation districts in the Lower Rio Grande Valley in Texas. In the early 1950s, board members of the two divisions, recognizing the aging of their respective systems and the difficulty in obtaining enough water for the irrigation of nearly 100,000 acres along the Lower Rio Grande, appealed to Reclamation for help.[469] The project was approved in 1958 and 1959, and plans were completed for both divisions by 1960.[470]

The La Feria Division contains 35,000 acres of irrigatable land. Reclamation completed a rehabilitation on the entire irrigation network by lining 21 miles of canals and laterals, repairing 35.1 miles of formerly unlined canals and laterals, and replacing 54.5 miles of open canals with closed pipelines. This latter improvement included 9.6 miles of formerly lined laterals. They also repaired or replaced numerous structures and pumping installations, enlarged the storage basin, cleaned and improved the drainage system, and built maintenance roads along 153 miles of drain line.[471]

The Mercedes Division contains 181.5 miles of earthen canals and laterals, 94 miles of lined canals, and 40 miles of pipeline and contains 72,000 acres of irrigatable lands. The irrigation district had made little improvements to their system.[472] Reclamation rehabilitated and lined 136 miles of canals and laterals. Part of this included rebuilding 94 miles of lined canals and placing 21 miles of pipeline in formerly open lines. They repaired or replaced check gates and turn-out gates as well as other structures, including pumping installations.[473] They also extended the storage and desilting basin. They cleaned and rebuilt drain lines and ditches and, as with the La Feria Division, added 250 miles of access roads along the drainage system.[474] Currently, the Mercedes Division of the Lower Rio Grande Project contains several pumping plants, 13.5 miles of canals, 6.5 miles of unlined laterals, 58.3 miles of concrete-lined laterals, and 248.9 miles of concrete pipelines.[475]

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[469] These divisions include the La Feria Division, also known as the La Feria Water Control and Improvement (Irrigation) District, Cameron County #3, and the Mercedes Division also known as the Hidalgo and Cameron Counties Water Control and Improvement [Irrigation] District # 9. See United States Department of the Interior, Assistant Secretary of the Interior, *Mercedes Division, Lower Rio Grande Rehabilitation Project, Texas. A report on the Mercedes Division on the Lower Rio Grande Rehabilitation Project in Texas, pursuant to Section 9 (a) of the Reclamation Project Act of 1939* (Washington, DC: U.S. Government Printing Office, 1957), iii-iv; United States Department of the Interior, Assistant Secretary of the Interior, *La Feria Division, Lower Rio Grande Rehabilitation Project, Texas. A supplemental report on the La Feria Division on the Lower Rio Grande Rehabilitation Project in Texas, pursuant to Section 9 (a) of the Reclamation Project Act of 1959* (Washington, DC: US Government Printing Office, 1959), iii-iv.

[470] Bureau of Reclamation, "Lower Rio Grande Rehabilitation Project," https://www.usbr.gov/projects/index.php?id=344 [accessed January 2023].

[471] Ibid.,

[472] Lila Knight et al., *Hidalgo and Cameron Counties Irrigation District # 9, Intensive Survey and Final Recommendations,* prepared for the Texas Department of Transportation (Kyle, Texas: Knight and Associates, 2010), 18.

[473] Ibid., 18.

[474] Ibid., 18.

[475] Ibid., 18.

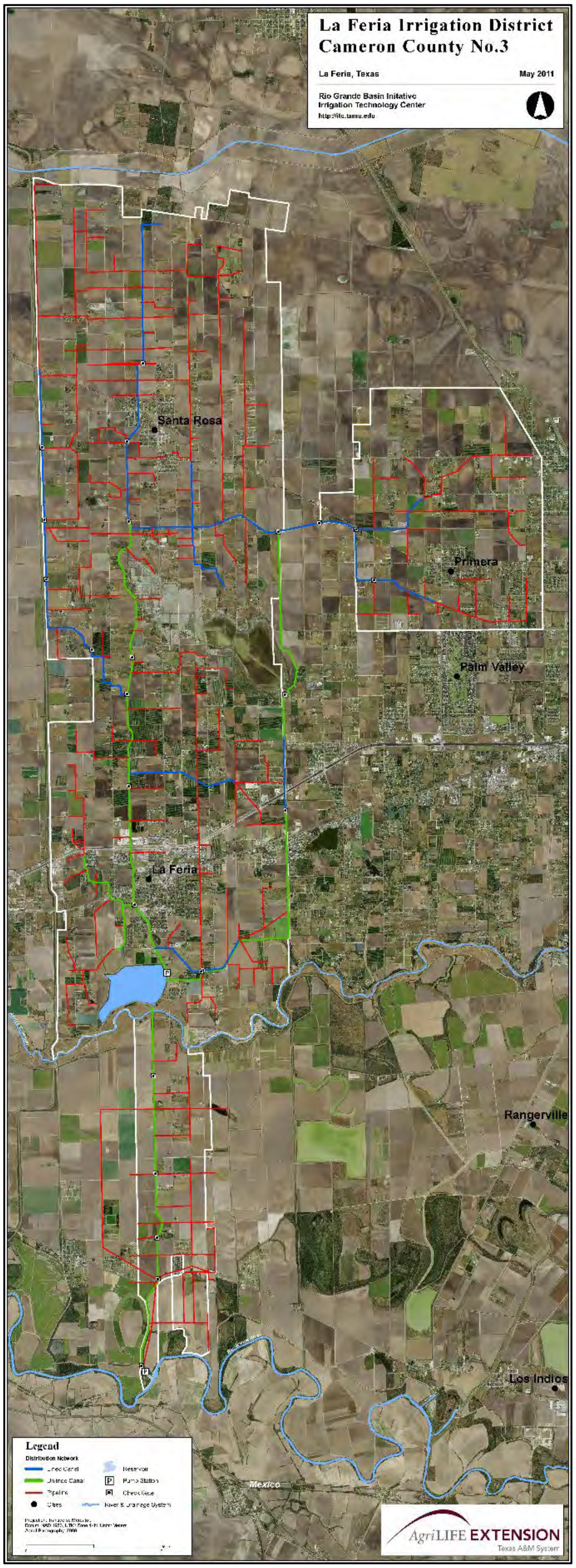

Figure 5.19 Map of the current La Feira Division irrigation network.[476]

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[476] Courtesy of AgriLife Extension, Texas A&M University, College Station, TX. Online at: https://idea.tamu.edu/files/2018/07/La-Feria [accessed August 2022].

Work was completed in 1969. In 1980, the district changed its name to the Hidalgo and Cameron Counties Irrigation District No. 9. Reclamation retains the maintenance responsibilities for both divisions of the project. Urban development, especially around the towns of Weslaco and Mercedes, has reduced the acreage irrigated by the Mercedes Division in 2010 to 55,000 acres. However, water supply to the communities is a secondary authorization for the district. A map of the current division with its irrigation network is shown in Figure 5.20.

While the Lower Rio Grande Project as a whole does not appear to have been evaluated for the NRHP, from 2008 to 2010, the Texas Department of Transportation contracted with Knight and Associates to document and evaluate 36 irrigation districts in the Lower Rio Grande area. In 2010, Knight et al. assessed the Mercedes Division as not eligible for the NRHP; its various numbered irrigation districts were individually assessed. They assessed one office building associated with the Division, the American Rio Grande & Irrigation Company (later the Hidalgo and Cameron Counties Irrigation District No. 9), as eligible for the NRHP.[477] No assessment has been conducted on the La Feira Division.

Knight et al. (2010) also noted that the Anacuitas Flume located on Main Canal A within the Mercedes Division was distinctive and was the only historic flume on the project. However, they noted that the feature alone "cannot convey [the] historic significance of the irrigation system," and that it "has suffered from a lack of historic integrity due to minor changes in design," specifically the loss of integrity of setting and feeling.[478] Chapter 7 provides a listing of the districts and systems surveyed. The Lower Rio Grande Project is a good example of a locally managed system where Reclamation later assumed management.

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[477] Knight et al., *Irrigation District #9*, 43-44.

[478] Ibid., 44.

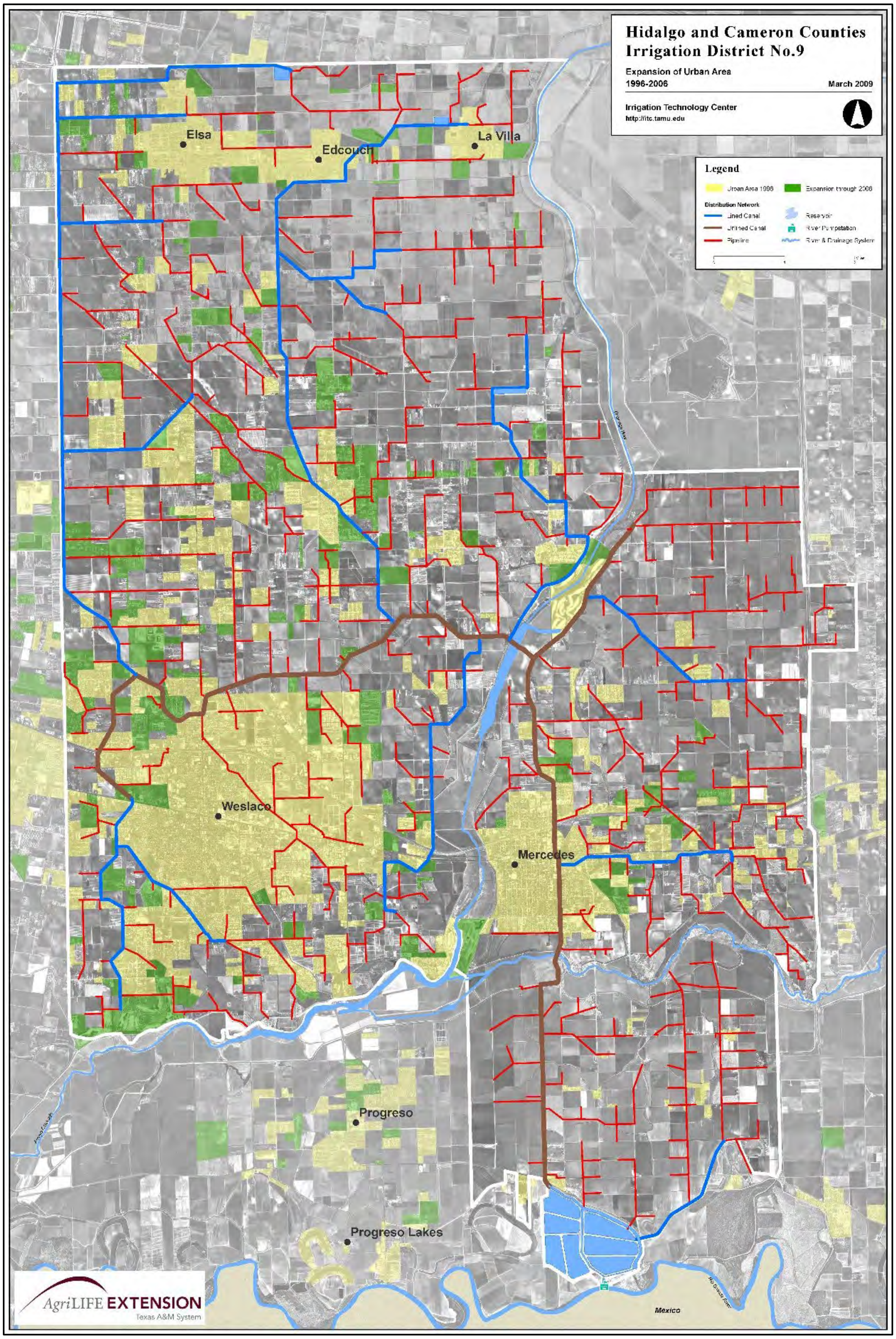

Figure 5.20 Map of the current (2022) Mercedes Division irrigation network.[479]

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[479] Courtesy of AgriLife Extension, Texas A&M University, College Station, TX. Online at: https://idea.tamu.edu/files/2018/07/HCCID9-2009_Urban96-06 [accessed August 2022].

5.17 Umatilla Project

The Umatilla Project is located in north/central Oregon, on the south side of the Columbia River in Morrow and Umatilla counties. Water is obtained from the Umatilla River and McKay and Butter creeks to irrigate 17,000 acres and to supplement 13,000 additional non-project lands. The Umatilla Project was an early Reclamation project, having been authorized as one project with two divisions on December 4, 1905. The Reclamation Service purchased the assets of the Maxwell Land and Irrigation Company and established the Umatilla Water Users Association (later the Hermiston Irrigation District) and the West Extension Irrigation District.[480] Today, three diversion dams serve three irrigation districts. The Hermiston Irrigation District, the Stanfield Irrigation District, and the Westland Irrigation District are within the East Division. The West Division consists of the West Extension Irrigation District. A South Division within the project includes only the McKay Dam and Reservoir on McKay Creek. It releases supplemental water into the Umatilla River that is diverted further downstream. Through this supply, the project supplements 13,000 more irrigatable lands that are not part of the Reclamation project.

Reclamation completed the Cold Springs Dam in 1908. It releases water into the Stanfield Irrigation District lands of the project. The Feed Canal Diversion Dam diverts water upstream from the Umatilla River for infilling the reservoir. Water from the diversion dam travels via the 25-mile-long Feed Canal to the reservoir. Water is then released as needed from the Cold Springs Reservoir into the A-Line Canal for the Stanfield Irrigation lands. Additionally, the Stanfield Irrigation lands receive water from the Furnish Diversion Dam on the Umatilla River. Water from this diversion dam travels via the Furnish Ditch into the Stanfield Irrigation lands. However, the Furnish Dam and Furnish Ditch are not owned, operated, or built by Reclamation and are not part of this project discussion.

The Maxwell Diversion Dam removes water from the Umatilla River about 1.0 mile west of Hinkle, Oregon, and feeds it via the Maxwell Canal into the Westland Irrigation District. The Maxwell Diversion Dam was completed in 1915. All three diversion dams (Cold Springs, Feed Canal, and Maxwell) are in the East Division, which irrigates nearly 11,000 acres.[481] The A-Line Canal is the primary irrigation delivery canal. The East Division became fully operational in 1926 and Reclamation turned over operation to the Hermiston Irrigation District at that time.

Feed Canal carries water from the Umatilla River to the Cold Springs Reservoir, and is an unlined, gravity flow, earthen canal for much of its 25-mile length. The A-Canal is a gravity flow, concrete-lined, main canal that carries water for 12 miles southwest of the Cold Springs Dam, irrigating the Stanfield Irrigation District lands. As it nears the Umatilla River near Cottonwood Bend, it empties unused water into the Maxwell Canal to be carried back to the reservoir and further irrigate the Westland Irrigation District.

The West Division obtains water from the Umatilla River via the Three Mile Falls Diversion Dam, 3 miles south of the Town of Umatilla. It diverts the water down the 27-mile-long West Extension Main Canal that feeds the irrigated lands on the northwest side of the project. The West Division contains about 6,500 acres of irrigated land.[482] The West Division was completed by 1926 and was turned over to the West Extension Irrigation District for operations and maintenance at that time. The McKay Dam and Reservoir was constructed primarily to store water as a supplementary source for the other two divisions and other

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[480] Eric Stene, “Umatilla Project” (Denver: Bureau of Reclamation History Program, 1993), 4.

[481] Kelsey J. Doncaster et al., *Historic American Engineering Record, Umatilla Project, East Division Irrigation System*, HAER # OR-66 (2012), 3.

[482] Doncaster et al., *HAER Umatilla Project*, 3.

non-Reclamation lands. It was initiated in 1923 and completed in 1927. The McKay Dam and Reservoir are the only features in the South Division.[483] Within a few years of construction, Reclamation saw the need for improved drainage and developed a wasteway system to remove excess water and return it to the water flow.

The irrigation districts have piped much of their sublaterals and ditches. In 2012, substantial rehabilitation and replacement of features in the project occurred; however, the main canals and primary laterals remained mostly open, with only some having been concrete-lined.

While the entirety of the Umatilla Project does not appear to have been evaluated as a whole, portions of the East Division have been determined eligible and key components have been documented through HABS/HAER. These include the irrigation system, Cold Springs Dam, Outlet Works Gate Tower Bridge, Feed Canal and Headworks, and other feed canals. The Oregon SHPO database notes that the features may contribute to a historic district. A listing of the HABS/HAER documentation can be found in Chapter 7.

5.18 Colorado-Big Thompson Project

Few Reclamation projects were authorized with as much rancor, regionalized debate, and by such a level of "pitched, public, and national debate," as that of the Colorado-Big Thompson Project.[484] Located in Colorado, and notable for crossing the Continental Divide, one author claimed that "notoriety has been the companion of the Colorado-Big Thompson Project at every step."[485] It was the only Reclamation project that stirred any environmental-related backlash between the early twentieth-century Progressivism and the environmental activism of the late 1960s. Simply put, the project plan was to store water in created reservoirs on the west side of the Continental Divide in Colorado. This intra-basin transfer caused division between the water users on either side of the mountain range. The water would be carried via a transmountain diversion tunnel under the Rocky Mountain National Park. The water that emerged on the east side of the divide would be conveyed down the mountains via a series of drops, permitting hydro-electric power generation. Then, the water would be collected into the Big Thompson River and distributed for irrigation to 720,000 acres on the east side of the divide.

Omitting discussion of the authorization struggle, Reclamation's project includes four dams and reservoirs west of the Continental Divide, the 13.1-mile Alva B. Adams Tunnel in the center, and east of the divide more than 100 major features including nine additional dams, 60 reservoirs and dozens of canals. It extends 250 miles west to east, irrigating 720,000 acres and suppling water for nearly half a million people.[486] The Northern Colorado Water Conservancy District (NCWCD), founded in 1935, covers 1.5 million acres in seven Colorado counties and manages the project. The project was authorized by Congress on June 24, 1937, with an estimated price of $44 million. Ultimately, the NCWCD was tasked with providing $28 million of the funds, with the Federal Government providing the balance through Reclamation.

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[483] Bureau of Reclamation, "Umatilla Basin Project," https://www.usbr.gov/projects/index.php?id=410 [accessed August 2023].

[484] Autobee, "Colorado Big Thompson," 8.

[485] Ibid., 2.

[486] Ibid., 2-3.

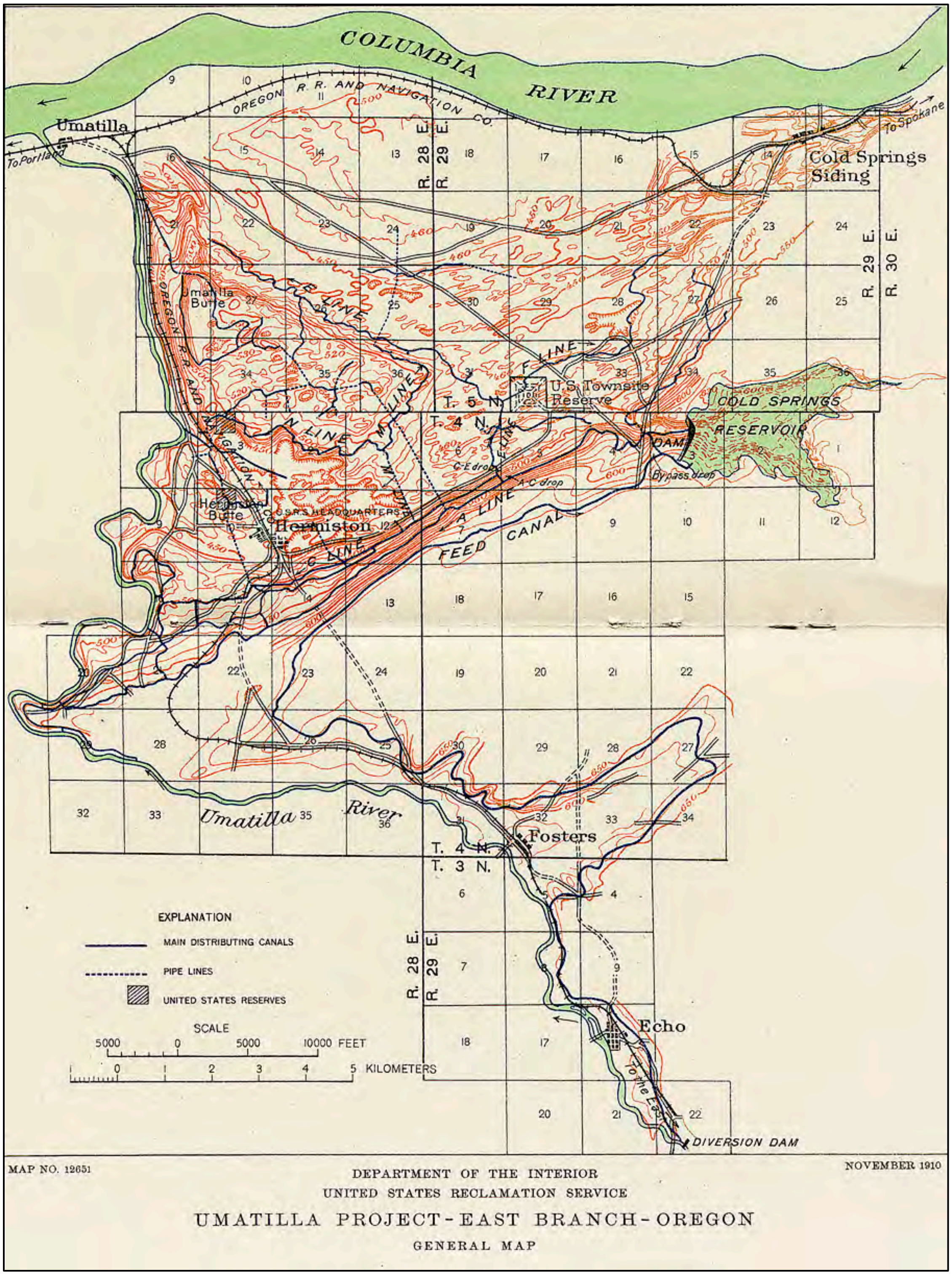

Figure 5.21 Map of the Umatilla Project near the Columbia River in north/central Oregon.[487]

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[487] United States Reclamation Service, "Umatilla Project Map, 1910," online at the Oregon History Project website https://www.oregonhistoryproject.org/articles/historical-records/umatilla-project-map-1908/#.ZDcHB87MK3C [accessed March 2023].

Three important elements of the project differentiate it from previous projects. First, it provided supplemental water to existing farmlands rather than creating new irrigated lands. Second, Congress exempted the water user's 160-acre land rule that was then in effect for Reclamation projects. Finally, in a growing trend in large Reclamation water projects, nearly 50 percent of the cost would be repaid through revenues derived by hydroelectric power generation. To satisfy environmental demands for the protection of Rocky Mountains National Park, Reclamation agreed to construct what would become the Alva B. Adams diversion tunnel underneath the national park.

Work was begun on the Green Mountain Dam and Reservoir and powerplant on the Blue River in 1938 and on the Alva B. Adams Tunnel in 1940. Work also began on the Granby Dam diversion canal, and Lake Granby and its accompanying dikes on Willow Creek, a subsidiary of the Colorado River. From early 1942 until late 1943, construction stopped on most aspects of the project due to World War II.[488] The tunnel was completed and opened in June 1944. Other work resumed in 1946, and by 1951 work on the western slope was completed. Construction on the eastern slope continued until August 11, 1956, when the project was declared completed. The Colorado-Big Thompson Project includes a total of 13 dams and 10 reservoirs, with more than 117 miles of shoreline and nearly 1 million acre-feet of water storage.[489] It contains 11 powerplants and 18 primary pumping plants along with flumes, canals, surge tanks, siphons, and hundreds of other features built over 18 years. It was the second largest project undertaken by Reclamation, surpassed only by the CVP in California. After completion, the NCWCD took over management of the eastern slope irrigation and water supply network, but the western slope dams and reservoirs remain under Reclamation management.

No part of the Colorado-Big Thompson Project has been listed on the NRHP, nor have any features been documented through HABS/HAER. A historic context and property type narrative, along with evaluation criteria, were prepared in 1999, but due to the relative age of the project at the time (many features were less than 50 years of age), a determination of eligibility was not officially made.[490]

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[488] Autobee, "Colorado Big Thompson," 20.

[489] Ibid., 28. Of note, the purpose of the Green Mountain Dam was to address "West Slope" interests, as it provided replacement storage for water diverted by the project to the eastern slope.

[490] Christine Pfaff, *The Colorado-Big Thompson Project: Historic Context and Description of Property Types* (Denver, Colorado: Bureau of Reclamation, 1999).

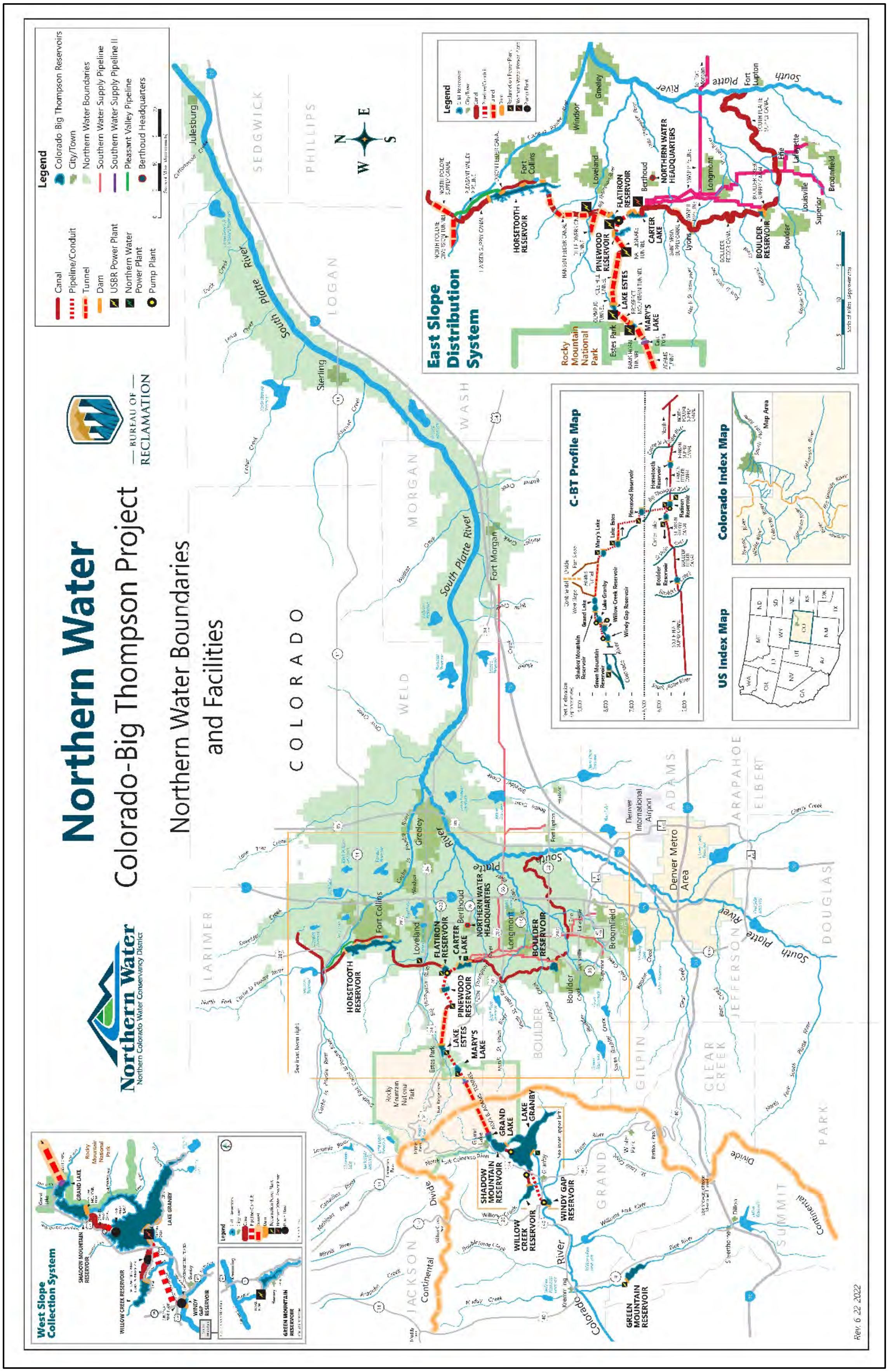

Figure 5.22 Colorado-Big Thompson Map (courtesy of Bureau of Reclamation).

5.19 Central Valley Project

The CVP, located in California, was the most ambitious effort attempted by the Bureau of Reclamation. California had been studying the Sacramento and San Joaquin watersheds for decades beginning in the 1870s. By 1911, the State of California created its own State Reclamation Board and provided the board $33 million to control flooding in the Central Valley of the state. However, little beyond planning occurred until 1921, when the State Engineer developed a plan for the entire state, including the two watersheds. More plans followed and by 1933, in the middle of the Great Depression, the state authorized a $170 million bond to finance the "Central Valley Project." The Depression, however, made it impossible for the state to sell the bonds, so California turned to the Federal Government for assistance.[491]

California was unable to obtain financing from the Federal National Recovery Act, so it applied to the Federal PWA for grants and loans to construct the project. The state legislature created the Water Project Authority to manage the project for California. President Franklin Roosevelt issued an executive allocation for funds under the Emergency Relief Appropriation Act of 1935 to begin the project. By the end of that year, Roosevelt had approved the project's Kennett (later Shasta) and Friant dams, along with the Contra Costa and Delta divisions.[492] The Rivers and Harbors Act of 1937 appropriated $12 million for the work to begin. However, the Act authorized only navigation, flood control, and regulation on the river systems. Reclamation's role for irrigation and public water use was a secondary priority, followed by power generation.

In the late 1930s, project work began on the Kennett Dam, later renamed the Shasta Dam and Reservoir, and was completed during World War II. It was one of the few projects allowed to continue during the war due to the power it would supply to industries in California. Ironically, power generation, the least important priority in the project, proved vital to its completion. Despite difficulties overcoming the Reclamation's 160-acre land rule, construction continued on the various aspects of the project through the 1940s and into the 1950s. New divisions were added to the growing project as, along with Reclamation, the USACE and several state government entities became involved with the massive project.

The USACE completed the Folsom Dam in 1956 and turned it over to Reclamation. The USACE built several dams for the CVP and the California State Water Plan. Reclamation found itself acquiring water from the USACE dams for irrigation since the agency did not have authorization to use its water for irrigation. The California State Water Plan contained an extensive $1.7 billion water control project for northern California. This became a sister project with the CVP and shares many of its facilities. This project features 22 dams and three primary aqueducts, and funnels about 30 percent of its water to the CVP San Joaquin Valley District; the other 70 percent is used for residential, industrial, and municipal water supplies, mostly in southern California.[493]

The CVP is a "complex operation of interrelated divisions" consisting of the Shasta Division with its Shasta Dam and Reservoir, flood control, hydroelectric power, and irrigation project on the Sacramento River.[494] The Trinity River Division supplements the Sacramento River with water from the Trinity River in the Klamath River Basin. The Sacramento River Division, downstream from the Shasta Dam, diverts water into several California counties for irrigation. In addition, releases from the Shasta Dam provide water to the Delta Division that helps control salinity in the San Francisco Bay area. Several other divisions provide

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[491] Stene, "CVP Overview," 6.

[492] Ibid., 7.

[493] Ibid., 10-11.

[494] Ibid., 12-13.

irrigation and flood control, including the large Friant Dam. This dam releases water both north into the Madera Canal and south into the southern California area around Bakersfield through the Friant-Kern Canal.

Despite all these divisions, the Delta Division is the key to the project. It transports water from the Sacramento River into the San Joaquin Valley and farmlands within the division. This is necessary, as the Friant Dam diverts nearly all the waters of the San Joaquin River south for irrigation into the Southern San Joaquin Valley. Thus, the Delta Division replenishes water in the Sacramento/San Joaquin River Delta, keeping salinity low.

The project involves many other plants, facilities, dams, canals, aqueducts, and pumping stations. It encompasses 35 California counties and includes an area 500 miles long and 60 to 100 miles wide. It irrigates nearly 3,000,000 acres, which is 75 percent of all California irrigation lands and one-sixth of all irrigated lands in the United States.[495] Several parts of the project were caught in the environmental movement of the 1970s and sections of the project have never been built. Congress passed the Reclamation Reform Act of 1982, which recognized the large landholdings in the CVP and increased the land limitation to receive project water to 960 acres, ending the 160-acre requirement on Reclamation projects. The 1992 Central Valley Improvement Act (CVPIA) called for Reclamation to dedicate over one million acre-feet of project water for fish and wildlife enhancement and wetlands restoration.[496] The project remains extremely controversial in California; however, the project benefits a multibillion dollar agriculture industry, and the benefits from the $3 billion invested by Congress in the project annually add about $430 million (1992 dollars) to the California economy and is estimated to have saved in least $5 billion dollars in flood control damage between 1951 and 1992.[497]

The Bureau of Reclamation prepared a draft multiple property listing for the CVP in 2006, which was updated in 2009. While it was never formally submitted to the NPS, Reclamation considers the CVP as eligible for the NRHP, with major contributing features including the Delta-Mendota Canal, the Friant-Kern Canal, Contra Costa Canal, the Tracy Pumping Plant, and Shasta Dam. These features are also noted as significant in the CALDOT context for water conveyance structures in California.[498]

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[495] Stene, "CVP Overview," 14.

[496] Ibid., 12.

[497] Ibid., 15.

[498] Bureau of Reclamation (Mid-Pacific Region), *Environmental Impact Statement for the North Valley Regional Recycled Water Program*, 2015, https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=25643 [accessed August 2023].

Figure 5.23 Illustration of the comprehensive plan for the CVP in California with most of the main dams, reservoirs, canals, and drainages.[499]

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[499] JRP and CALDOT, *Water Conveyance Systems*, 75.

5.20 Conclusion

The first section of this chapter reviewed how SHPOs consider water conveyance systems, particularly the states of Texas, Oregon, Colorado, and Oklahoma. The contexts reviewed agree on many points about the elements of an NRHP irrigation system evaluation. Nearly all agree that they must contain key elements—specifically, a source of water and diversion headwork, a main canal, and lateral canals. From here the discussions vary somewhat. In a number of systems, particularly in Texas, the systems necessarily contain pumping plants. Several of the contexts carefully define other elements that might be included in an evaluation such as settlement areas, construction sites, or ongoing maintenance structures. However, Knight (2009) was the only study to clearly discuss the eligibility of systems that have been intensely altered from their original construction. This fits most logically into the question of whether underground piping destroys the integrity of a system's canals or ditches. Finally, there is the discussion of whether the entire system, including both Reclamation-built and non-Reclamation-built structures, must be considered before an eligibility recommendation is made. Using Knight's (2009) analysis, the system must include the sublaterals and ditches built by the farmers to obtain water for their fields. This requires the assessor to go beyond Reclamation-constructed features, a point with which historians such was Weipricht et al. (1981) disagree.

The remainder of the chapter summarizes 18 Reclamation projects that were selected to provide a variety of geography, size, components, and need. Reclamation maintains 180 separate projects, ranging from vast works such as the Central Valley Project to small works such as the Lewiston Orchard Project, with only a few thousand acres. The summaries are often short on irrigation-specific information. These were summarized as general background for the reader to understand something of the conditions, timing, and context for different projects built by Reclamation. Notably, historians have tended to focus on the grand elements of a project, such as the dam, reservoir, hydroelectric powerplants, and pumping plants, some of which have little to do with irrigation but fit into the multipurpose authorizations of Reclamation projects since the 1930s.

Regarding eligibility on the national level, many of the early systems are either listed on the NRHP or have been determined eligible. These projects played an important role in the development of the western United States throughout the twentieth century and represent the first substantial Progressive-Era investment by a non-military agency. In this sense, Reclamation's early projects are a precursor to the New Deal spending and subsequent federal investments in natural resources development. These projects also tend to be well-documented due to their age. In addition to some projects being listed on the NRHP, others have been documented through HABS/HAER. Later Reclamation projects included additional federal investment, particularly with the New Deal funding and funding as a result of World War II. Some of these projects are also recognized as eligible for the NRHP and their components have been documented through HABS/HAER.

Other key systems such as the CVP, the Colorado-Big Thompson Project, and the Columbia River Basin Project have either been treated as eligible or are likely eligible for the NRHP. As national-level projects, they used innovative techniques and overcame huge challenges to bring water to arid regions. Their size and scope were so massive, they changed Reclamation and contributed to the development of key regions of the United States. These projects may represent good opportunities for multiple property listings (or in the case of CVP, finalizing the document) or HABS/HAER documentation. Smaller projects from the mid-twentieth century have been vastly under studied and may represent good options for selective Section 110 historic resource studies.

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6.0 National Register of Historic Places Criteria and Evaluation

6.1 Overview and Applicability

The Bureau of Reclamation manages thousands of miles of irrigation networks, which contain countless individual structural components that are critical to the systems' functionality. The agency routinely conducts maintenance, repair, and upgrades and, as a federal entity, it must comply with applicable cultural resource laws and regulations. The NHPA is the primary federal legislation protecting cultural resources. In the NHPA, Congress states that the Federal Government will "provide leadership in the preservation of the prehistoric and historic resources of the United States," including resources that are federally owned, administered, or controlled. The NHPA requires agencies, such as Reclamation, to identify its significant resources, evaluate them for NRHP eligibility, and plan for the protection of listed or eligible historic properties. The current context focuses on the extent of these systems, along with individual features or feature types, that were constructed, owned, or managed by the Bureau of Reclamation. This chapter provides evaluation guidance for the federal agency-built portions of projects and focuses on national areas of significance.

The NHPA established the NRHP, which is a list of buildings, structures, objects, sites, and districts that have demonstrated significance to U.S. history, architecture, archaeology, engineering, and/or culture. The NRHP is maintained by the Secretary of the Interior and is managed by the NPS Keeper of the Register. The criteria for listing a property on the NRHP were developed by the Department of the Interior and are found in 36 Code of Federal Regulations (CFR) Part 60.

Section 110 of the NHPA requires that federal agencies identify and inventory historically significant properties that are eligible for listing on the NRHP. **Section 106** of the NHPA requires the Federal Government to take into account the effects of its actions on historic properties prior to implementation of the action. For the Bureau of Reclamation, Section 106 applies to all proposed actions on federal lands and any proposed activities that are federally supported or funded. Consultation with the SHPOs and/or the ACHP is a critical step in this process. Section 106 compliance can also be accomplished using agreed-upon streamlined methods and agreement documents such as PAs. The agreements, which are developed among federal agencies, the ACHP, and SHPOs, provide efficient section compliance guidance for specified historic properties and/or undertakings.

This context is designed to support Reclamation's Section 106 compliance activities relevant to its water distribution infrastructure. Section 5.1 provided a synthesis of existing state-based contexts, which in most cases also address features and elements beyond Reclamation's (i.e., federal) management. Regardless, those contexts provide established and reasonable methods of examining irrigation systems and their varied components.

Under NRHP guidance, and as presented in established contexts, Reclamation conveyance systems are classified as structures.[500] Collectively, a system's individual components were engineered to convey water

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[500] It is important to note that districts, comprised of the conveyance systems and other associated resources, may also be present. Knight (*Field Guide*) and other authors provide evaluation guidance for broader districts. This context, however, focuses on structural systems.

from a source to an end user. In general, all existing studies for *conveyance systems* tend to agree that the following items **must be present and retain integrity** for system to be eligible for the NRHP:

- a source of water,
- a diversion headgate,
- a main canal, and
- lateral canals.

Further, each system must also be evaluated for other components that *may be necessary* for a system to be eligible for the NRHP. For example, in the Lower Rio Grande, pumping stations play a crucial role in the circulation of water through the irrigation system due to the relatively flat geography. For Lower Rio Grande, these stations must be present for a system to be eligible. Therefore, it is important for investigators to determine which components are critical to a particular system's functionality, the historical presence and distribution of features, and thereafter, the collective integrity. A breakdown of the types of features often observed in a Reclamation irrigation system is outlined below. Note that not all systems will have every feature.

- **Diversion Structures** include diversion dams, weirs, pumping stations or pump houses;
- **Conduit Structures** include main canals and laterals, wasteways or drains, flumes, siphons, or piping systems;
- **Flow Control Devices** include headgates, checks, turnouts, distribution boxes, drops, and chutes;
- **Measuring Devices** include Parshall flumes, modified Parshall flumes, stilling wells, measurement weirs, weir boxes, flow meters or gauges;
- **Cleansing Devices** include trash racks and sand traps;
- **Associated Features** include habitation sites; hydroelectric plants, substations, and lines; administration and operations buildings; bridges; treatment plants; and fish passages, etc.

The above categories are based on shared physical characteristics and design qualities. Because a survey of systems and individual features was not included in the scope of this project, there is no complete inventory of how many systems or features fall into these property types and subtypes. However, this context provides guidance for identifying features and evaluating systems. Resources within that do not fall under any of the defined property type categories should be evaluated individually. Importantly, it is also critical when evaluating systems for investigators to understand where the federal systems end and where other user systems begin. For example, early Reclamation projects included a large range of components, from main canals to cleaning devices. Later systems may have only included a dam and main canal, beyond which other entities sponsored, constructed, and managed their own conveyance and distribution systems.

6.1.1 Consideration of Individual Components

Because these components are functionally linked, the individual parts are unlikely to possess individual distinction, except in rare cases. In a review of existing studies, the most prevalent individually eligible irrigation-related components are the primary dams. These represent substantial construction projects by themselves and sometimes include associated hydroelectric components and feeder canals. However, as noted, main dams are not included as part of this context.[501] Within the conveyance systems, individually eligible components may include a significant feature, such as a siphon or tunnel, that responded to a particular engineering challenge, or a rare remnant example of a particular type of construction that more broadly has been replaced with modern materials (e.g., wooden flumes, wooden headgates, iron turnouts).

6.2 Applying the National Register Criteria for Evaluation

The Secretary of the Interior has developed the National Register Criteria for Evaluation (36 CFR Part 60.4) to assist in the evaluation of properties eligible for inclusion in the NRHP. The NPS has published guidance for applying the criteria in *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation*. To qualify for the NRHP, a property **must have significance and retain historic integrity**. To be listed on the NRHP, or be considered eligible for listing on the NRHP, a property must meet at least one of the four criteria:

A. Associated with events that have made a significant contribution to the broad patterns of our history.
B. Associated with the lives of persons significant in our past.
C. Embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction.
D. Have yielded, or may be likely to yield, information important in prehistory or history.

Properties may be listed under **Criterion A (Events)** for associations with one or more important events that are defined in a historic context. Moreover, the property cannot merely possess an association with an event, it must have an *important* association with the event or historical trends. Reclamation's conveyance systems had a critical impact on the ultimate settlement and agricultural development of the western United States. Indeed, all federal irrigation projects would have an important association with that broad trend, but a historic context helps identify certain key Areas of Significance. As illustrated in this context, and as guided by *National Register Bulletin 15*, these Areas of Significance may include Agriculture, Conservation, Community Planning and Development, Industry, Landscape Architecture, Politics/Government, and Social History. Section 6.4 provides additional discussion of each of these areas.

Properties may be listed in the NRHP under **Criterion B (People)** for their association with the lives of significant individuals. The individual in question must have made significant contributions directly associated with the property type. From a national level, this Criterion is unlikely to apply to conveyance systems unless, for example, the system is the *single resource most closely associated with an individual* who was instrumental in its promotion or construction. Further, simply naming a system or part of a system (such as the Olmstead Tunnel in the Provo River Project [Utah] or the Alva B. Adams Tunnel in the Colorado-Big Thompson Project [Colorado]) for an individual does not make it eligible for the NRHP. The individual's association must be demonstrated as significant and direct.

To be eligible for listing on the NRHP under **Criterion C (Engineering)**, properties must meet at least one of four requirements: (1) embody distinctive characteristics of a type, period, or method of

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[501] As noted, main dams are afforded their own context and evaluation criteria in Billington, Jackson, and Melosi, *Large Federal Dams.*

construction; (2) represent the work of a master; (3) possess high artistic value; or (4) represent a significant and distinguishable entity whose components may lack individual distinction (e.g., districts). *National Register Bulletin 15* defines distinctive characteristics (e.g., character-defining features) as "the physical features or traits that commonly recur" in properties; type, period, or method of construction is defined as "the certain way properties are related to one another by cultural tradition or function, by dates of construction or style, or by choice or availability of materials and technology." Criterion C will frequently be applied to Reclamation's conveyance systems, which may be eligible as a work of an important engineer or reflect an innovative type or even scale of engineering. As implied in *NRHP Bulletin 15*, comparing systems will be critical in understanding how one system may reflect, or stand apart from, a broad engineering trend. For resources to be eligible under Criterion C, they must retain a high degree of integrity of location, design, materials, and workmanship. In other words, a property must retain a sufficient degree of overall physical integrity to convey a sense of its historical engineering and functionality.

Under **Criterion D (Information Potential)**, properties may be listed on the NRHP if they have yielded, or may be likely to yield, information important in prehistory or history. Two requirements must be met for a property to meet Criterion D: (1) the property must have, or have had, information that contributes to the understanding of history or prehistory, and (2) the information must be considered important. This criterion generally applies to archaeological sites. In a few cases, it can apply to buildings, structures, and objects if the property itself is the principal source of information and the information is important. For example, a building or feature that displays a unique structural system or unusual use of materials, and where the building or feature itself is the main source of information (i.e., there are no construction drawings or other historic records), might be considered under Criterion D. In addition, as noted in Chapter 5, certain areas, such as habitation sites, may need to be considered under a separate context and would require consideration under Criterion D.

6.3 Level of Significance

NRHP-eligible resources can be significant at the national, state, or local level. It is important to note that this context considered only a national level significance because the conveyance systems were foremost federally planned, funded, and constructed properties that occurred in a linear fashion over thousands of miles and more broadly within the geography of 17 western states. It is possible that one of the systems may meet one of the NRHP Criteria in areas of significance at state and local levels, but that would require more detailed research into each system's origins, its history, and the individual features that remain reflecting those associations.

For example, the North Platte Project, one of Reclamation's earliest projects, may be eligible at the national level for the NRHP. The project served as a "testing lab of Reclamation's earliest attempts at design" and at the "engineers and administrators' efforts to overcome weather, workforce and local construction demands." The project involved a dam, reservoir, main canal, lateral canals, and sublaterals, along with a powerplant. While this system may be eligible at the national level of significance, it may also possess local and state significance given the early impetus and attempts to benefit regional agriculture and development.[502]

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[502] Autobee, "North Platte Project," 1.

6.4 Areas of Significance

When evaluating historic significance, irrigation systems should be assessed for NRHP eligibility as a whole, and should focus on the original federal systems at their fullest extent and with associated functional support features. In assessments for NRHP eligibility, systems should first be evaluated under Criterion A, for their association with important historic events, and under Criterion C, for their physical representation of historically important developments and trends in design and construction. Reclamation systems are less likely to be considered under Criteria B or D. To qualify, a system must retain sufficient integrity specific to the individual theme(s) and the period of significance defined for that theme.

Agriculture

Reclamation was first and foremost a means of conveying water for agricultural development in the West. Simply put, without the Federal Reclamation systems, agricultural development would have stagnated or developed at a smaller regional level. The Belle Fourche Project in South Dakota stands as an early example of the success in deriving agricultural benefits from Reclamation efforts. The area around Belle Fourche, South Dakota, was a livestock center and shipping point, but the low rainfall levels in this region of the western part of the state restricted large-scale agriculture. Reclamation efforts from 1904 to 1914 resulted in more than 50,000 acres of grazing lands being converted over to agricultural products.

Conservation

Reclamation systems were a primary means of managing a natural resource, but conservation was not an authorized mission until 1938. Significance in the area of conservation will likely be established in a project's Congressional authorization or as a later significant byproduct agreed to by the agency and using parties. For example, a system may be significant in this area if it has original design elements intended to facilitate species or resource conservation. In addition, it could qualify if it represents a concerted effort during a period of environmental stewardship to retrofit diversion dams or other structures to rehabilitate aquatic species through such features as fish passages.

The Columbia River Basin Project serves as an early example. Political compromises over conservation were necessary when the New Deal project threatened to destroy the important salmon and steelhead fish harvesting industry along the Columbia River in Washington. Congressional debates led to fish passes being added to the project to mitigate the damage via the Mitchell Act of 1938. While these early conservation efforts focused on the fish harvesting business, interest in protecting the natural world helped lead to the establishment of the U.S. Fish and Wildlife Service in 1940.

Engineering

Reclamation systems will all likely be evaluated for engineering significance. A system may have significance in this area if it represents a good example of a type of construction or innovative engineering design. For example, the feat of designing and constructing the large Friant-Kern Canal for the CVP was a significant engineering achievement for Reclamation. The Friant-Kern Canal serves as the project's main canal and traverses 152 miles through numerous geographical features. The canal includes 228 bridges and 245 utility line crossings and uses large siphons and culverts to move water through the rich agricultural region. The canal begins at the Friant Dam in central California and extends to the Kern River near Bakersfield in southern California. It represents Reclamation's longest main canal. Reclamation projects may also have been critical to the innovation and proliferation of certain types of construction materials. For example, Reclamation was an early and major proponent of the use of reinforced concrete in construction applications. Prior to the twentieth century, wood, brick, and natural rock were the primary construction materials, even in the West. Reclamation seized on the practical use of concrete to minimize maintenance and extend longevity in their structures such as dams, bridges, canal linings, piping, and all types of conveyance features.

Industry

This is the technology and process of managing materials, labor, and equipment to produce goods and services. In some cases, significance in industry may be tied to a system's facilitation of growing and marketing a particular agricultural crop in a region, or the growth of an industrial product. Most industrial significance for Reclamation projects is likely to be derived from the hydropower component of a project, separate from the conveyance system itself. For example, Hoover Dam generated power critical to the aluminum industry during World War II, which in turn supported the manufacture of aircraft and ships on the West Coast.

Politics/Government

Early Reclamation systems were selected by the Reclamation Service Director and approved by the Secretary of the Interior. Since 1924, all Reclamation systems have been authorized by Congress, but that does not automatically qualify them for the NRHP. Under this area of significance, a system should be representative of a project constructed under a specific piece of legislation, or perhaps represent the type of limited construction prevalent during a period of austerity. A system may also be representative of a collective effort between federal, state, local, or Tribal governments. Due to the political nature of federal projects, all Reclamation projects are examples of political persuasion and negotiations. However, some projects are particularly associated with extensive political maneuvering. One such project was the Colorado-Big Thompson in Colorado. This project pitted National Park proponents and conservationists against Reclamation irrigation supporters in Congress. The maneuvering led to an uneasy compromise that permitted Reclamation to build the Alva B. Adams Tunnel under the Rocky Mountains National Park. The issue was complicated as it involved two entities within the same federal agency (NPS and Reclamation). It was further complicated by the interstate battle between "West Slope" and "Front Range" water interests.

Community Planning and Development

Reclamation conveyance systems had a tremendous effect on the development of towns and communities in the western U.S. Indeed, a community may not have begun if it were not for the availability of irrigated agricultural lands in the vicinity. However, this is a broad area of significance, and a Reclamation system may have only been one driving factor of a community's development. Mining or railroad construction may have also played a role. Therefore, for an irrigation system to qualify under this area, a context must prove a direct and significant link to a community's development and the system must possess the physical qualities to express that particular time.

A prime example is the Salt River Project in Arizona where Reclamation provided the critical component, water, for the development of Phoenix, Arizona. The Salt River Project brought farmers to the region during the early 1900s, and its hydroelectric component brought industrial expansion after World War II. Reclamation provided for the growth of a series of small hamlets into today's metroplex.

Social History

During the Great Depression, the Federal Government looked to its agencies to build and implement large construction projects to supply employment for and improve the lives of American citizens. The vast social experiment of the New Deal left a distinct footprint on federal infrastructure and many Reclamation projects were begun, expanded, or completed during this period. Some notable examples included the All-American Canal, a component of the Boulder Canyon Project; the Riverton Project in Wyoming; the Moon Lake Project in Utah; and the Uncompahgre Project in Colorado.

Ethnic Heritage

Properties can be significant in the area of Ethnic Heritage if they represent the history of individuals with a common identity. For example, Native Americans provided labor for several Reclamation projects. In the early 1960s, agreements were reached with the Navajo in New Mexico. The Navajo Indian Irrigation Project included Native Americans for labor as well as ownership. Work on the dam and reservoir began in 1963 and today it irrigates about 81,000 acres of Tribal lands. The project is managed by the Navajo Agricultural Products Industry, which has been instrumental in its continued development and expansion. Of note, the project also contains 13 miles of tunnels and 7 miles of siphons. Similarly, during World War II, detained Japanese Americans worked on parts of the Minidoka Project, including maintenance on the Milner-Gooding Canal. Projects involving other distinct ethnic groups appear to be minimal, but such associations (such as preponderance of a labor force) would need to be determined through archival research.

Landscape Architecture

While all systems are inherently vast, man-made structures across the landscape, to qualify in the area of landscape architecture, a system or part of a system should be considered if it possesses specific design features that “further our enjoyment or appreciation of the land.” [503] Some researchers [504] suggest that qualifying systems may have had features such as wooden flumes to blend in with the surrounding landscape. A good example of the impact Reclamation has had on the West is the irrigation landscape created at the Bitter Root Project in Montana by Flumes #13 and #15. The two wooden flumes, constructed in the 1930s, continue to carry water for the project’s canals and have become a local attraction. The flumes span two ravines at 800 and 200 feet, respectively, and stand on their original wooden bases. They represent an aesthetically pleasing view of Reclamation’s efforts to irrigate the Bitter Root Valley, and an era when horses and block and tackle hoisted the wooden frameworks into place. These wooden features, which are a local landmark, have been considered “Art on the Landscape” by various observers.[505]

Military

While conveyance systems were not designed for the purpose of national defense, some systems contributed substantially to the World War II effort or were accelerated during the war years. Specifically, the Shasta Dam project, the Adams Tunnel portion of the Colorado-Big Thompson Project, and the Grand Coulee Dam and Powerplant were permitted to continue through the war years so they could contribute to the war effort. The War Department recognized the necessity of electricity to power industries for national defense, and irrigation to produce crops to support the war effort. Other Reclamation projects such as the Boulder

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[503] Horn and Prouty, *Water in Wyoming*.

[504] Ibid.

[505] Maki, “Wooden Flumes.”

Dam Powerplant, the Elephant Butte Powerplant of the Rio Grande Project, and the Seminoe Dam and Powerplant in the Kendrick Project, all completed in the 1930s, provided electricity critical to support industries related to national defense during World War II. The W.C. Austin Project in Oklahoma encountered multiple war-related delays, but portions of the project were allowed to move forward to support the local water supply for the City of Altus, which had received an influx of military personnel due to a nearby Army Air Field.

6.5 Period of Significance

The Period of Significance is the length of time when a property associated with important events, activities, or persons, attained the characteristics which qualify it for NRHP listing. It typically begins with the period of construction. It may consist of a single year or of a broad span of time that contains multiple significant events or trends. Identifying a period of significance is important because it helps define what changes or alterations affect the aspects of integrity and, for purposes of long-term stewardship, helps property managers identify adverse effects. The period of significance need not always extend to the 50-year cutoff. Alternatively, a system's period of significance may extend on either side of the 50-year mark if it played a significant role during the environmental movement of the 1960s and 1970s.

One example is the role the Milk River Project in Montana played in the development of an agreement with Canada, at the time a Dominion of Great Britain. The river ran 107 miles through Canada. Unless an agreement could be reached and coordination established between the two countries, U.S. irrigation efforts were limited along the river. A reasonable period of significance for the Milk River Project may extend from 1906 to 1921, which would include the initial construction, the role of Reclamation in the successful negotiations for the Boundary Waters Treaty of 1909, the construction of the St. Mary Canal in 1915, and the completion of the project in 1921. The project was also unique in that it was the first to involve the use of Native American reservation lands, in this case, the Blackfoot Reservation.

6.6 Determining Integrity

A historic property determined to be significant under one of the four NRHP criteria must possess integrity. Integrity is the ability of a property to convey its significance through retention of the property's essential physical characteristics (i.e., character-defining features) from its period of significance. The NRHP identifies seven aspects of integrity, and an eligible property must possess several of these aspects. The assessments of a property's integrity are rooted in its significance. The reason why a property is important should be established first (Area of Significance), then the qualities necessary to convey that significance can be identified.

Reclamation conveyance systems consist of many different component parts and, in many cases, have operated for over one hundred years. These are large, functional systems that operate daily, and mechanical features wear down from ongoing use and require repair and replacement. They may be replaced in-kind with a similar feature, modified with more technologically advanced equipment, or even automated for remote operation. Water conservation in the West continues to be an ongoing concern, particularly in consideration of climate change, and upgrades to prevent evaporation may result in piping or other significant changes to open canals. Therefore, investigators must conduct research and interview Reclamation personnel to gain an understanding of what character-defining features remain within a system.

Location is defined as the place where a cultural resource was constructed or the place where the historic event occurred. For conveyance systems, the key consideration for location is a system's alignment. Generally, irrigation systems will retain integrity of location as it is not feasible to relocate large sections of canals, and individual component parts are typically co-located with the canal alignments. However, in some cases, portions of a system's features may have been abandoned, piped underground, or realigned. In such instances, investigators must determine whether the route or system pattern is visually cohesive enough to convey its functionality and whether key elements remain. Open canals that have been piped are generally considered to have lost integrity of location. Knight[506] notes that relocation or removal of smaller parts may not necessarily result in a loss of integrity. For example, relocating a small equipment shed, given the scale, would not impact integrity to the extent of relocating a primary pump station. It is also important to consider, for all aspects of integrity, if the changes occurred more than 50 years ago. Historic changes, even substantial ones, may not result in a loss of integrity.

Design is the combination of elements that create the form, plan, space, structure, and style of a cultural resource. Design can consist of both natural and physical elements and, as noted by Knight[507], is a "critical element" of an engineering system. For conveyance systems, design is dependent on the inter-relationship of all the component parts to convey water from its source to an end user. More succinctly, without design, a system cannot efficiently function. Determining integrity of design must consider both the collective system as well as the individual parts. For example, if a segment is relocated, not only does it lose integrity of location, but it may also lose integrity of design because the overall hydraulic practices have been altered. Similarly, if a segment of the system is modified with the replacement of multiple weirs, drops, etc., this may also affect integrity of design. The removal or replacement of minor features may not impact integrity, but the accumulated loss of features could. [508] Therefore, investigators must understand a system's engineering to determine if alterations have impacted its functionality and, ultimately, integrity of design.

Materials are the physical elements that, when combined during a particular period of time and in a particular pattern, form a cultural resource. For conveyance systems, this includes the construction materials of features, including the dams, canals, and various distribution features. Original materials may consist of concrete, wood, steel, or other metals. Because these hydraulic systems function constantly over time, materials have and will continue to be routinely replaced or altered. Therefore, it is important to consider whether the materials represent "like kind" replacements. For instance, a dam may be refaced with newer concrete, or windows and doors on a pumping station may be changed with similar and comparable units. However, it would not be uncommon to find incompatible uses of materials. Previously unlined canals may be freshly lined with concrete or fully enclosed with metal piping. Older wooden or metal gates may be replaced with concrete for longevity, or they may be automated for efficiency. For investigators in the field, it is important to consider the collective and cumulative effect of material changes in determining integrity and consider if the effects are found on major components (e.g., dams and main canals) versus minor parts (e.g., smaller gates and drops).

Workmanship is the physical evidence of the crafts of a particular culture or people during any given period in history or prehistory. For Reclamation conveyance systems, workmanship is effectively the presentation of a system's construction and functionality. This may consist of the presence of earthen or lined canals, their depth and width, and the architecture or visible engineering of various component parts.

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[506] Knight, *Field Guide*.

[507] Ibid.

[508] Ibid.

Integrity of workmanship and materials are generally linked, and it is likely that a loss of one would result in the loss of both. For example, changing the lining of a canal from earthen to riprap would affect its workmanship, as would replacing concrete gates with steel gates.

A resource's **setting** includes its surrounding physical environment. Irrigation networks were primarily constructed by the Federal Government to provide water for agricultural fields at a time when the West remained largely unsettled. Therefore in most cases, for integrity of setting, irrigation systems must generally retain their visual relationship to the rural and agricultural landscape. According to Knight[509], this "conveys the character of the irrigation system and its significance in providing water" to a particular region. Where communities developed and ultimately sprawled around canals and laterals, integrity of setting may be lost due to intrusive residential, commercial, or industrial development. Surrounding development may also introduce other non-historic features such as bridges, fencing, and landscape embellishments such as parks and greenways. Alternatively, if Reclamation irrigation systems were authorized for municipal water supply, surrounding development may not necessarily result in a loss of integrity. If canals were purposefully designed to flow through cities, an urban setting may reflect its purpose.

Association is the direct link between a property and an important historic event or person. For conveyance systems, association requires it to possess its historical use or functionality. In general, active systems will likely retain integrity of association if they are still used for their intended purpose. As Knight[510] detailed, integrity of association is retained "when a sufficient number of an irrigation system's canals, lift stations, and other features remain to convey a strong sense of connectedness between the irrigation property and a contemporary observer's ability to discern the historical activity which occurred at the location." More simply, association depends on the overall system remaining historically intact and visible. Impacts to integrity of association may result from the application of new technologies and new construction, or alternatively the abandonment of certain portions of the system or its features.

Integrity of **feeling** includes a property's ability to express its historic aesthetic at a particular period of time. Feeling is an intangible feature and subjective analysis. In general, feeling is the "cumulative effect" of combining the other aspects of integrity.[511] For example, a system that has multiple alterations impacting different aspects of integrity may be found to lack integrity of feeling, because it can no longer convey its overall historic aesthetic. The abandonment of multiple segments or features, while still technically intact, may result in a loss of feeling because they lack function and connectivity with the rest of the system.

National Register Bulletin 15 describes the following steps in assessing historical integrity:

1. Determine the essential physical features (component parts) that must be present for a property to represent its significance.
2. Determine whether the essential physical features are sufficiently visible to convey significance.
3. Compare the property with similar properties if the physical features necessary to convey significance are not well-defined.
4. Determine, based on the property's significance, which aspects of integrity are particularly important to the property in question and if they are intact.

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[509] Knight, *Field Guide*.

[510] Ibid., 257.

[511] Ibid.

For example, properties significant for their association with a particular event must retain key physical features associated with that event or period. Properties significant for their design and construction must retain the physical features that are the essential elements of the aspects of the construction that the property represents. Typically, a property should be recognizable to the period in which it attained its significance.

6.7 Establishing Boundaries

For Reclamation conveyance systems determined eligible for the NRHP, investigators should develop reasonable and concise boundaries that contain all NRHP-qualifying features. The boundary may encompass larger tracts near more substantial features such as dams or pump houses or may extend in a narrow linear fashion along canals and laterals. To the extent feasible, and as justified by the presence or absence of qualifying features, boundaries should conform and be limited to federal property ownership and legal rights-of-way. While the broader setting (such as agricultural fields or other landscape elements) may contribute to a system's integrity, it should not be included within the boundary unless owned or managed by the Bureau of Reclamation. Because the conveyance systems should be evaluated as structures or structural systems, boundaries should not be fragmented in the manner of a discontiguous district. An eligible structural system may, however, have contributing and non-contributing parts. These should be specified in any evaluation and mapped accordingly.

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7.0 A Landscape of Disparate Data

One of Reclamation's projected goals for this project was to try and quantify what systems and features have been documented. This data was anticipated to facilitate a baseline for conversations with the ACHP and SHPOs in the development of a Program Comment or streamlining the documentation process, given the vast landscape of Reclamation assets that routinely undergo Section 106 and 110 evaluations. However, researchers quickly discovered the morass of recordation techniques and variability in quality of data across the various states. Inquiries with the SHPOs of state archaeological site and historic resource files gave a mix of results. Some SHPOs were able to provide technical reports, contexts, and documentation, while other SHPOs directed researchers to state databases for historic resources. In the responses received, the authors found there to be no simple way of researching and collating an accurate listing of Reclamation-owned or -managed assets. In attempting to compile data, the authors also reviewed existing NRHP listings (NARA, online), HABS/HAER documentation (Library of Congress, online), and contacted various SHPOs. Despite the variability of data, we were able to develop a sampling of resources and resource types that have been recorded.

7.1 NRHP Listings

There are approximately 68 Reclamation Projects or features listed in the NRHP (Table 7.1). While many of the listings focus on individual primary components such as dams or main canals, there are a few representative listings that include multiple features. For example, The Salt River Diversion and Conveyance System Historic District (Arizona, listed in 2017) includes a period of significance from 1906 to 1938 and includes 10 contributing structures, two buildings, and over 1,000 acres. The contributing canals are further defined as "systems" within which the document generally discusses (but does not itemize) numerous features such as checks, turnouts, bridges, laterals, checks, drops, and siphons. The Carlsbad Irrigation Historic District (New Mexico, listed in 1996) includes a landscape of over 5,400 acres and 30 contributing features including the dam, embankments, railroad dikes, spillways, bridges, wasteways, flumes, siphons, supply ditches, and bifurcation works. In Nevada, the Truckee-Carson Irrigation District (Newlands Project, listed in 1981) was listed with six dams, 69 miles of main canals, 312 miles of laterals, and 345 miles of open drains. In Oregon, the Central Oregon Canal Historic District was listed in 2019 under the *Carey and Reclamation Acts Irrigation Projects Multiple Property Documentation Form*. The district, with a period of significance from 1905 to 1937, includes a total of 41 acres, one site, and 28 structures including main canals, bridges, chutes, flumes, and numerous headgates and drops. There are relatively few Multiple Property Documentation Forms; those that exist include *Carey and Reclamation Acts Irrigation Projects in Oregon, 1901-1978*, the *Newlands Project (Truckee-Carson Irrigation District)*, and the *Salt River Project*.

Table 7.1 Reclamation Project or Feature NRHP listings.

State	Project/Listing	NRIS Reference #, Year
Arizona	Coolidge Dam [San Carlos Irrigation Project]	81000135, 1981
	Hohokam-Pima Irrigation Sites	66000184, 1966
	Lower Salt River Multiple Resource Area	79003806, 1979
	Park of the Canals	75000350, 1975
	Salt River Project [Multiple Property Listing]	100001454, 2016
	Salt River Project Diversion and Conveyance System Historic District	100001454, 2017
	Burgess Lateral	09000221, 2009
California	Crawford Ditch	91001522, 1991
	Big Gap Flume	01000719, 2003
	Anaheim Union Water Co. Canal and Pomegranate Road	98001604, 1998
	Irrigation System (165 and 166) [Whiskeytown]	74002359, 1974
	San Buenaventura Mission Aqueduct	75000497, 1975
Colorado	Gunnison Tunnel	79000616, 1979
	Smith's Irrigation Ditch [the City Ditch]	76000555, 1976
	Waterwheel	77000372, 1977
	Havenmeyer-Wilcox Canal Pumphouse and Forebay	80000900, 1980
	Grand River Ditch [Grand Ditch & Speciman Ditch]	76000218, 1976
	Grand Valley Diversion Dam [Grand Valley Project]	91001485, 1991
	Hanging Flume	80000917, 1980
Idaho	Minidoka Dam and Powerplant	74000746, 1974
Montana	Big Horn Ditch Headgate,	76000174, 1976
	Crow Creek Water Ditch	00001492, 2000
	Crow Creek Water Ditch	01000323, 2001
Nebraska	Maginnis Irrigation Aqueduct	94001231, 1994
Nevada	Marlette Lake Water System	92001162, 1992
	Carson River Diversion Dam [Newlands Project]	81000380, 1981
	Derby Diversion Dam [Newlands Project]	78001727, 1978
	Lehman Orchard and Aqueduct	75000181, 1975
	Newlands Project MPDF (Truckee-Carson Irrigation District)	64000529, 1981
	Lake Tahoe Dam (as part of the Newlands MPDF)	81000713, n.d.
New Mexico	Carlsbad Irrigation District	66000476, 1966
	Elephant Butte Irrigation District	97000822, 1997
	El Barranco Community Ditch	86002296, 1986
	El Porvenir Community Ditch	86002300, 1986
	Encenada Community Ditch	86002303, 1986
	La Puente Community Ditch	86002294, 1986
	Parkview Community Ditch	86002305, 1986
	Plaza Blanca Community Ditch	86002298, 1986
	Tierra Amarilla Community Ditch	86002307, 1986
	Lower Animas Ditch	87001116, 1987
	Acequia Madre	8700118, 1987
	Acequia System of El Rancho de las Golondrinas	80002572, 1980
	Los Acequias	08000697, 2008
	Percha Diversion Dam [Rio Grande Project]	79001555, 1979
Oklahoma	Old Settlers Irrigation Ditch	83002070, 1983
	Fullerton Dam	76001562, 1976
Oregon	MPDF: Carey and Reclamation Acts Irrigation Projects in Oregon, 1901-1978	10000302, 2017
	Central Oregon Canal Historic District	100003461, 2019
	Pilot Butte Canal: Downtown Redmond Segment	100001303, 2017
	Vale Project: Lateral 278 Segment Historic District	Listed under MPA, 2017
	Central Oregon Canal: Brasada Ranch Segment	MP10000346, 2019
	Middle Ditch	01001150, 2001
	Osgood Ditch	01001151, 2001
	Wimer Ditch	0100152, 2001
	Birch Creek Ranch Historic Rural Landscape	97000882, 1997

State	Project/Listing	NRIS Reference #, Year
South Dakota	Belle Fourche Dam [Belle Fourche Project]	77001239, 1977
Texas	Espada Aqueduct	66000809, 1966
	El Paso Water Improvement District No. 1 [Rio Grande Project]	97000885, 1997
	Franklin Canal	92000696, 1992
	Mission Canal Company Second Lift Pumphouse	02000910, 2002
	Medina Dam	76002050, 1976
	Mission Creek Dam and Acequia Site	80004157, 1980
Utah	Newton Reservoir [Newton Project]	73001860, 1973
	Oak Creek Dam	99001091, 1999
	Tropic Ditch	95000432, 1995
	Crawford Irrigation Canal	86003732, 1987
	Flanigan Ditch	97001630, 1998
	Hurricane Canal	77001324, 1977
	Oak Creek Irrigation Canal	86003738, 1987
	Pine Creek Irrigation Canal	86003734, 1987
Washington	Okanogan Project, Conconully Reservoir Dam	74001969, 1974
Wyoming	Pathfinder Dam [North Platte Project]	71000888, 1971
	Buffalo Bill Dam [Shoshone Project]	71000890, 1971

NRIS = National Register Information System

7.2 HABS/HAER Documentation

Approximately 180 Reclamation projects or project components have been documented through the HABS/HAER program. Most are available through the Library of Congress online collection (https://www.loc.gov/pictures/collection/hh/). Some of the HABS/HAER projects date to the early 1970s, while others have been more recently completed. In most cases, documentation has included single features, primarily dams, canals, and ditches. However, in other cases, the documentation included a variety of features. For example, the Salt River Project (Arizona) underwent substantial documentation in the 1990s. Recorded features included major canal components (lined and unlined), laterals, dams, the spillway bypass, powerplants, wasteways, trash racks, and siphons. Similarly, the Merced Irrigation District (California) had several related structures recorded, including weirs and turnouts. The Carlsbad Irrigation District, Main Canal documentation (New Mexico) included siphons, check gates, turnouts, wasteways, laterals, and flumes.

Table 7.2 Projects and Features documented in HABS/HAER.

State	Project or Feature	Ref. No	Author
Arizona	Roosevelt Power Canal and Diversion Dam	AZ-4	David M. Introcaso
	Theodore Roosevelt Dam	AZ-6	Donald C. Jackson, 1992
	Coolidge Dam	AZ-7	David M. Introcaso
	San Francisco Canal	AZ-8	Jay C. Ziemann, 1986
	Waddell Dam	AZ-11	David M. Inrocaso, 1988
	Mormon Flat Dam	AZ-14	David M. Introcaso, 1989
	Horse Mesa Dam	AZ-15	David M. Introcaso, 1989
	Tempe Canal	AZ-16	Fred Anderson
	Grand Canal and Crosscut Hydro Plant	AZ-17	Fred Anderson and Carol Noland, 1990
	Arizona Canal	AZ-19	Shelly Dudley
	Crosscut Steam Plant	AZ-20	Barbara Behan, 1991
	Old Crosscut Canal	AZ-21	Fred Anderson
	Western Canal	AZ-22	Fred Anderson,
	Highline Canal and Pumping Plant	AZ-23	Fred Anderson, 1990

State	Project or Feature	Ref. No	Author
Arizona (continued)	Horseshoe Dam	AZ-24	Donald C. Jackson and Clayton B. Fraser, 1991
	Bartlett Dam	AZ-24	David Introcaso, 1990
	San Carlos Irrigation Project	AZ-50	Christine Pfaff, 1996
	San Carlos Irrigation Project, Marin Canal	AZ-50-E	N/A
	San Carlos Irrigation Project, China Wash Flume	AZ-50-F	Greta Rayle and Helana Ruter, 2016
	San Carlos Irrigation Project, Picacho Reservoir	AZ-50-G	
	San Carlos Irrigation Project, Pima Lateral	AZ-50-H	N/A
	San Carlos Irrigation Project, North Side Canal	AZ-50-I	N/A
	San Carlos Irrigation Project, San Tan Flood Water Canal	AZ-50-J	N/A
	San Carlos Irrigation Project, San Tan Indian Canal	AZ-50-K	N/A
	San Carlos Irrigation Project, Casa Blanca Canal	AZ-50-L	N/A
	San Carlos Irrigation Project, Southside Canal	AZ-50-M	N/A
	Agency Canal	AZ-50-N	N/A
	San Carlos Irrigation Project, Sacaton Flats Lateral	AZ-50-O	N/A
	San Carlos Irrigation Project, Blackwater Lateral	AZ-50-P	N/A
	San Carlos Irrigation Project, Florence Canal	AZ-50-Q	N/A
	Granite Reef Diversion Dam	AZ-51	Tonia Horton, 1998
	South Canal	AZ-52	Shelly C. Dudley, 1998
	Eastern Canal	AZ-56	Marc Campbell, 2000
	Crosscut Canal	AZ-60	Dan Killoran, James LaBar, and Sarah Stringer-Bowsher
	Wellton-Mohawk Irrigation System	AZ-68	Scott Thompson, Statistical Research Inc., 2006
	Wellton-Mohawk Irrigation System, Pumping Plant, Attachments G-BB are houses and other buildings	AZ-68-A	Scott Thompson, Statistical Research Inc., 2006
	Wellton-Mohawk Irrigation System, Pumping Plant No. 2	AZ-68-B	Scott Thompson, Statistical Research Inc., 2006
	Laguna Diversion Dam	AZ-87	T. Lindsey Baker and Steve Rae, 1971
California	Gage Irrigation Canal,	CA-120	Kevin B. Halleran, Christopher Foord, and Christine L Madrid, 1993
	Salinas River Project, Cuesta Tunnel	CA-153-A	Stephen D. Mikesell, 1994
	Reclamation District 1000	CA-187	Melinda A. Peak, 1997
	Reclamation District 1000, Pump Plant 1	CA-187-A	Melinda A. Peak, 1997
	Reclamation District 1000, Pump Plant 2	CA-187-B	Melinda A. Peak, 1997
	Reclamation District 1000, Pump Plant 3	CA-187-C	Melinda A. Peak, 1997
	Merced Irrigation District, Edendale Creek Turnout and Weir	CA-192-A	Cindy L. Baker, 1998
	Lassen Volcanic National Park, Lost Creek Flume (non-Reclamation)	CA-2114-A	N/A
	Tule River Hydroelectric Project, Water Conveyance Systems	CA-216	Thomas T. Taylor, 1998
	Colorado River Aqueduct	CA-226	J. Philip Gruen, 1998
	Iron Mountain Pump Plant, South of Danby Lake	CA-244	N/A
	Los Angeles Aqueduct, From Lee Vining Intake (Mammoth Lakes) to Van Norman Reservoir (San Fernando Valley)	CA-298	N/A
	Los Angeles Aqueduct, Lee Vining Structure	CA-298-A	N/A
	Los Angeles Aqueduct, Walker Creek Intake Structure	CA-298-B	N/A
	Los Angeles Aqueduct, Parker Creek Intake	CA-298-C	N/A
	Los Angeles Aqueduct, Mono Craters	CA-298-E	N/A
	Los Angeles Aqueduct, Hot Creek	CA-298-F	N/A
	Los Angeles Aqueduct, Owens River Gorge	CA-298-H	N/A
	Los Angeles Aqueduct, Aqueduct North of Bishop	CA-298-L	N/A
	Little Rock Dam	CA-8	Donald C. Jackson, 1981

State	Project or Feature	Ref. No	Author
Colorado	Baca Ditch	CO-100	Steve Rae and T. Lindsey Baker, 1971
	Grand Ditch	CO-3	C&K McWilliams and John Jenkins
	Montezuma Valley Irrigation Company System (pre-Reclamation)	CO-4	Gerhold, 1981
	Havenmeyer-Wilcox Canal System	CO-43	N/A, 1994
	High Line Canal	CO-43-A	John J. Roberts
	Twin Lakes Dam and Outlet Works	CO-63	Christine Pfaff, 1995
	Howard Ditch	CO-64	Steven F. Mehls, 1989
	Snake River Ditch (Oro Grande Canal No. 1)	CO-82	Jonathon C. Horn, 1994
	Hondius Water Line	CO-85	Michael J. Smith, 1997
	Grand Valley Diversion Dam	CO-90	Ann Emmons, 2004
	Uncompahgre Project, Gunnison Tunnel	CO-95	Steve Rae and T. Lindsey Baker, 1971
	San Luis Peoples' Ditch	CO-96	Steve Rae and T. Lindsey Baker, 1971
	Burlington Ditch	CO-45	James E. Sherow, R. Laurie Simmons, and Christine Whitacre, 1988
	O'Brian Canal	CO-46	James E. Sherow, R. Laurie Simmons, and Christine Whitacre, 1988
	Banter Ditch	CO-47	R. Laurie Simmons, Christine Whitacre, and James E. Sherow, 1988
	Twin Rocks Irrigation Ditch	CO-68	Sandra L. Rayl, 1991
	Trinidad Water Works	CO-97	Steve Rae and T. Lindsey Baker, 1971
Idaho	Snake River Irrigation Company	ID-10	Jean P. Yearly, 1986
	Leesburg Townsite, Ditches, Napais Creek, Salmon, Lemhi County, ID	ID-106X	Barry Gill
	Milner Dam and Main Canal of the Twin Falls Canal Company	ID-15	John A. Rosholt, and Allan R. Ansell, 1989
	Minidoka Project, Powerplant, and Southside Pump Division	ID-16	2002
	Boise Project	ID-17	Fredric Quivik, n.d.
	Boise Project, Boise Diversion Dam & Powerplant Addendum to Boise Project, Boise River Diversion Dam	ID-17A	Denis Gardner, Abigail Christman, Elizabeth Gales, n.d.
	Boise Project, Dear Flat Embankment	ID-17-B	Frederic L. Quivik and Amy Slaton
	Swan Falls Dam	ID-20	Susan M. Stacy, 1991
	Bonanza Hydraulic Mining Site	ID-23	Mitzi Rossillon, 1992
	Bonanza Hydraulic Mining Site, Ditch, Swamp Gulch, Salmon, Lemhi County, ID	ID-23-B	Lon Johnson and Barry Lee Gill
	Arrowrock Dam	ID-27	Kelsey Doncaster, 2013
	Cove Hydroelectric Development, Concrete-Lined Canal	ID-43-E	Sheri Murray Ellis, and James W. Steely, 2006
	Shoshone Falls Hydroelectric Project	ID-45	Sheri Murray Ellis and James W. Steely
	Woodville Canal Company	ID-9	Jean P. Yearly, 1987
Montana	St. Mary River Bridge and Siphon [Milk River Project]	MT-22	Kevin Murphy, 1984
	Bitter Root Irrigation District	MT-89	Christine Pfaff, 1999
	Glen Lake Irrigation District, Grave Creek Dam	MT-110-A	N/A
	Flint Creek Hydroelectric Project, Wood Stave Pipeline	MT-132-A	N/A
	Lower Yellowstone Project	MT-141	Jason Marmor and Kathleen Corbett, 2011

State	Project or Feature	Ref. No	Author
Montana (continued)	Lower Yellowstone Project, Diversion Dam	MT-141-A	Jason Marmor and Kathleen Corbett, 2011
	Lower Yellowstone Project, Headworks	MT-141-B	Jason Marmor and Kathleen Corbett, 2011
New Mexico	Carlsbad Irrigation District	NM-4	Mark Hufstetler and Lon Johnson, 1991
	Carlsbad Irrigation District, McMillan Dam	NM-4-A	N/A
	Carlsbad Irrigation District, Avalon Dam	NM-4-B	Mark Hufstetler and Lon Johnson, 1991
	Carlsbad Irrigation District, Main Canal	NM-4-C	Mark Hufstetler and Lon Johnson, 1991
	Carlsbad Irrigation District, East Side Canal	NM-4-D	Mark Hufstetler and Lon Johnson, 1991
	Carlsbad Irrigation District, Pecos River Flume	NM-4-E	Mark Hufstetler and Lon Johnson, 1991
	Dark Canyon Siphon	NM-4-F	Mark Hufstetler and Lon Johnson, 1991
	Carlsbad Irrigation District, Black River Canal	NM-4-G	Mark Hufstetler and Lon Johnson, 1991
	Carlsbad Irrigation District, Brantley Dam	NM-4-I	N/A
	Fruitland Irrigation Project, Yellowman Siphon	NM-6-A	Miles Gilbert, 1995
	Elephant Butte Reservoir	NM-20	Steve Rae and T. Lindsey Baker
Nevada	Hoover Dam	NV-27	Kurt Schweigert, 2002
	Truckee-Carson Irrigation District, Lower Diagonal No. 1 Drain	NV-6-K	C. Cliff Creger, 1997
Oregon	Rock Creek Mining District, Upper, Lower and Waterman Ditches	OR-9	Judy Ann Knokey and Suzanne Crowley Thomas, 1986
	McKay Dam	OR-18	Jeffrey A. Hess, 1991
	Pilot Butte Canal	OR-62	N/A
	Deschutes Irrigation and Power Company Canal	OR-63	N/A
	Umatilla Project, East Division Irrigation System	OR-66	Stephen Emerson, 2007; Kelsey J. Doncaster, 2012
	Umatilla Project, East Division Irrigation System, Cold Springs Dam	OR-66-A	Stephen Emerson, 2007; Kelsey J. Doncaster, 2012
	Umatilla Project, East Division Irrigation System, Outlet Works Gate Tower Bridge	OR-66-B	Stephen Emerson, 2007; Kelsey J. Doncaster, 2012
	Umatilla Project, East Division Irrigation System, Feed Canals and Headworks	OR-66-C	Stephen Emerson, 2007; Kelsey J. Doncaster, 2012
	Umatilla Project, East Division Irrigation System, Feed Canals, Between the Umatilla River and Cold Springs Reservoir	OR-66-D	Stephen Emerson, 2007; Kelsey J. Doncaster, 2012
	Umatilla Project, East Division Irrigation System, A-Line Canal	OR-66-E	Stephen Emerson, 2007; Kelsey J. Doncaster, 2012
	The Klamath Basin Project, "A" Canal Headworks House	OR-90-A	Patrick Welch, 1997
	Tumalo Irrigation District (Failed Carey Act Project)	OR-151	Charles T. Luttrell, Christine Pfaff, 2006
	City of Bend Water Intake	OR-162	Ward Tonsfeldt
South Dakota	St. Germain Ditch, Lower Rapid Valley Irrigation Ditches	SD-10	Lon Johnson, 1994
	Lone Tree Ditch, Lower Rapid Valley Irrigation Ditches	SD-11	Lon Johnson, 1994
	Iowa Ditch, Lower Rapid Valley Irrigation Ditches	SD-12	Lon Johnson, 1994
	Little Grant Ditch, Lower Rapid Valley Irrigation Ditches	SD-13	Lon Johnson, 1994
	Lower Rapid Valley Irrigation Ditches	SD-5	Lon Johnson, 1994
	Hawthorne Ditch, Lower Rapid Valley Irrigation Ditches	SD-6	Lon Johnson, 1994
	Cyclone Ditch, Lower Rapid Valley Irrigation Ditches	SD-7	Lon Johnson, 1994
	Lower Rapid Ditch (South Side Ditch), Lower Rapid Valley Irrigation Ditches	SD-8	Lon Johnson, 1994
	Rapid Valley Ditch (Murphy Ditch), Lower Rapid Valley Irrigation Ditches	SD-9	Lon Johnson, 1994
Texas	Franklin Canal	TX-125	Steve Rae and T. Lindsey Baker

State	Project or Feature	Ref. No	Author
	The Acequias of San Antonio	TX-1	T. Lindsay Baker, James D. Carson, and Joseph Minor, 1974
	Franklin Canal	TX-125	Steve Rae and T. Lindsey Baker, 1972
	Balmorhea Project	TX-129	Steve Rae, 1971
	Medina Dam	TX-130	Steve Rae and T. Lindsey Baker, 1972
	San Benito Irrigation System	TX-132	Carolyn Wright, Melissa Weidenfield, and Kathryn Plimpton, 2011
	Espada Acequia, Piedras Creek Aqueduct	TX-1-A	T. Lindsay Baker, James D. Carson, and Joseph Minor, 1974
	Espada Acequia, Diversion Dam, San Antonio River	TX-1-B	T. Lindsay Baker, James D. Carson, and Joseph Minor, 1974
	Alamo Madre Acequia	TX-1-C	T. Lindsay Baker, James D. Carson, and Joseph Minor, 1974
	Canon Ranch Eclipse Windmill	TX-7	James E. White, 1981
Utah	Hurricane Irrigation Canal, 1893-1902	UT-17	T. Allan Camp, 1972
	Irrigation Water Wheel, Hasting Ranch	UT-18	N/A
	Strawberry Valley Project	UT-26	N/A
	Irrigation Canals in the Uinta Basin	UT-30	George D. Kendrick
	Irrigation Canals in the Uinta Basin, White Rocks Canal	UT-30 A	James Jurale, David Stalheim, and Craig Fuller
	Irrigation Canals in the Uinta Basin, Ouray Park Canal	UT-30 B	James Jurale, David Stalheim, and Craig Fuller
	Irrigation Canals in the Uinta Basin, Highline Canal	UT-30 F	James Jurale, David Stalheim, and Craig Fuller
	Irrigation Canals in the Uinta Basin, White Rocks and Ouray Valley Canal	UT-30 H	James Jurale, David Stalheim, and Craig Fuller
	Irrigation Canals in the Uinta Basin, Knight Ditch	UT-30 I	James Jurale, David Stalheim, and Craig Fuller
	Irrigation Canals in the Uinta Basin, Rhodes Canal	UT-30 J	James Jurale, David Stalheim, and Craig Fuller
	Irrigation Canals in the Uinta Basin, Rock Point Canal	UT-30 K	James Jurale, David Stalheim, and Craig Fuller
	Jordan Narrows Irrigation and Hydroelectric System	UT-15	Steve Rae and T. Lindsey Baker, 1971
	Irrigation Canals in the Uinta Basin, Wissiup Homestead	UT-30-E	N/A
	Irrigation Canals in the Uinta Basin, Jepp Thomas Canal	UT-30-G	James Jurale, David Stalheim, and Craig Fuller, 1983
	Ogden Canyon Conduit	UT-51	Douglas s. Beckstead and Don Southworth, 1989
	Irrigation Diversion Canal, Bear River	UT-9	N/A
	Deer Creek Dam	UT-93	Gianfranco Archimede, 2003
	Deer Creek Dam, Salt Lake Aqueduct Intake Control Gate	UT-93-E	Gianfranco Archimede, 2003
	Mount Nebo Dam and Reservoir	UT-95	Steve Rae and T. Lindsey Baker, 1971
	Shem Dam	UT-96	Scott O'Mack, 2015
Washington	Outlook Irrigation District: Pumping Plant and Woodstove Pipe	WA-10	Alexy Simmons, 1984
	Tieton Dam	WA-20	David W. Harvey, 1988
	Salmon Creek Division Dam, Okanogan Irrigation Project	WA-68	Stephen Emerson, 2001
	Salmon Creek Division Dam, Main Canal Headworks	WA-68-A	Stephen Emerson, 2001
	Kachess Dam	WA-79	Cynthia de Miranda, Charlene K. Roise, and Marjorie Pearson
	Columbia Basin Project	WA-139	2016

State	Project or Feature	Ref. No	Author
Washington (continued)	Columbia Basin Project, Grand Coulee Dam and Franklin D. Roosevelt Lake	WA-139-A	Ann Hubber, 1997
	Columbia Basin Project, Grand Coulee Pump Generating Plant	WA-139-C	2016
	Columbia Basin Project, Grand Coulee Siphon-Breaker Building	WA-139-D	2013
	Columbia Basin Project, Banks Lake Feeder Canal and Headgates	WA-139-E	2016
	Columbia Basin Project, Banks Lake Dry Falls Dam and Main Canal Headworks	WA-139-F	2016
	Columbia Basin Project, Grand Coulee North Dam	WA-139-K	2016
Wyoming	Buffalo Bill Dam	WY-2	Daniel Clement, 1983
	Wind River Irrigation Project	WY-95	Blain Fandrich, 2008
	Wind River Irrigation Project, Coolidge Canal Trout Creek Crossing Structure	WY-95-A	Joseph Randolph, 2008
	Wind River Irrigation Project, Johnstown Diversion Structure	WY-95-B	Joan L. Brownell, 2009
	Wind River Irrigation Project, Lefthand Main Diversion and Left Hand Wasteway-Check Structures	WY-95-C	Joan L. Brownell, 2009
	Wind River Irrigation Project, Ray Canal Mill Creek Diversion Check Structure	WY-95-D	Joan L. Brownell, 2009
	Wind River Irrigation Project, Ray Lake Dam Outlet Works	WY-95-E	Joan L. Brownell, 2009

7.3 Reclamation Project Histories

The Bureau of Reclamation has a robust history program, including a collection of historic photographs, oral histories, story maps, and individual project histories.[512] Reclamation historians have compiled 203 histories of projects and their individual units or divisions. These histories generally provide information on regional background, project authorization, need, and funding, construction history and its physical components, impacts to local populations and industries, and information pertaining to other potential project-specific themes (environment, social history, ethnic history, etc.). Only two units or divisions remain to be written (Table 7.3).

Table 7.3 List of Reclamation Project histories.

Project (Link)	Project History (Y/N)
Ainsworth Unit, P-SMBP, Nebraska	Yes
All-American Canal, Boulder Canyon Project, California	Yes
Almena Unit, P-SMPB, Kansas	Yes
Angostura Unit, P-SMPB, South Dakota	Yes
Animas-La Plata Project, See also Colorado River Basin Project	Yes
Arbuckle Project	Yes
Armel Unit, P-SMBP, Colorado	Yes
Arnold Project	Yes
Avondale Project	Yes
Baker Project	Yes
Balmorhea Project	Yes
Belle Fourche Project	Yes
Bitter Root Project	Yes
Blackfeet Indian Irrigation Project, Montana	Yes
Boise Project, Idaho	Yes

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[512] An overview of Reclamation's history program is available at https://www.usbr.gov/history/. Specific project histories can be accessed at https://www.usbr.gov/history/projhist.html.

Project (Link)	**Project History (Y/N)**
Bonneville Unit, Central Utah Project, Utah	Yes
Bostwick Division, P-SMBP, Kansas and Nebraska	Yes
Bostwick Park Project, CRSP, Colorado	Yes
Boysen Unit, P-SMBP, Wyoming	Yes
Buffalo Rapids Project	Yes
Buford-Trenton Project	Yes
Burnt River Project, Oregon	Yes
Cachuma Project, California	Yes
Canadian River Project, Texas	Yes
Canyon Ferry Unit, P-SMBP, Montana	Yes
Carlsbad Project, New Mexico	Yes
Cedar Bluff Unit, P-SMPB, Kansas	Yes
Central Arizona Project	Yes
Central Utah Project, Unbuilt Units, Utah	Yes
Central Utah Project, Vernal Unit, Utah	Yes
Central Valley Project Overview, California	Yes
Central Valley Project, Auburn-Folsom Unit South, California	Yes
Central Valley Project, Folsom and Sly Park Unit, California	Yes
Central Valley Project, New Melones Unit, California	**No**
Central Valley Project, Sacramento River Division, Sacramento Canals Unit, California	Yes
Central Valley Project, U.S. Army Corps of Engineers Integrated Units	Yes
Chief Joseph Dam Project, Washington	Yes
Collbran Project, Colorado	Yes
Colorado River Basin Salinity Control Project, Multiple States	Yes
Colorado River Front Work and Levee System, Arizona, California, Nevada	Yes
Colorado River Project, Texas	Yes
Colorado River Storage Project, Flaming Gorge Unit, Utah and Wyoming	Yes
Colorado-Big Thompson Project, Colorado	Yes
Columbia Basin Project, Washington	Yes
Crescent Lake Dam Project, Oregon	Yes
Crooked River Project, Oregon	Yes
Crow Creek Pump Unit, P-SMBP, Montana	Yes
Crow Indian Irrigation Project, Montana	Yes
Dallas Creek Project, Colorado, Colorado River Basin Project	Yes
Dalton Gardens Project, Washington	Yes
Delta Division, CVP, California	Yes
Deschutes Project, Oregon	Yes
Dickinson Unit, P-SMBP, North Dakota	Yes
Dolores Project, CRBPA	Yes
East Bench Unit, P-SMBP, Montana	Yes
Eden Project, Wyoming	Yes
Emery County Project, Wyoming	Yes
Farwell Unit, P-SMBP, Nebraska	Yes
Flaming Gorge Unit, CRSP	Yes
Flathead Indian Irrigation Project, Montana	Yes
Florida Project, CRSP, Colorado	Yes
Fort Clark Unit, P-SMBP, North Dakota	Yes
Fort Peck Indian Irrigation Project, Montana	Yes
Fort Sumner Project, New Mexico	Yes
Frenchman-Cambridge Division, P-SMBP, Nebraska	Yes
Frenchtown Project, Montana	Yes
Friant Division, CVP, California	Yes
Fruitgrowers Project, Colorado	Yes
Fryingpan-Arkansas Project, Colorado	Yes
Garden City Project, Kansas	Yes
Garrison Diversion Unit, P-SMBP, North Dakota – See Jamestown Dam and Reservoir	Yes
Gila Project, Arizona	Yes
Glen Canyon Unit, CRSP, Arizona and Utah	Yes

Project (Link)	Project History (Y/N)
Glen Elder Unit, P-SMBP, Kansas	Yes
Glendo Unit, P-SMBP, Wyoming and Nebraska	Yes
Grand Valley Project, Colorado	Yes
Grants Pass Project, Oregon	Yes
Hammond Project, New Mexico	Yes
Hanover Bluff Unit, P-SMBP, Wyoming	Yes
Heart Butte Unit, P-SMBP, North Dakota	Yes
Helena Valley Unit, P-SMBP, Montana	Yes
High Plains States Groundwater Recharge Demonstration Program, Multiple States	Yes
Hondo Project, New Mexico	Yes
Hoover Dam, Boulder Canyon Project, Arizona and Nevada	Yes
Humboldt Project, Nevada	Yes
Hungry Horse Project, Montana	Yes
Huntley Project, Montana	Yes
Hyrum Project, Utah	Yes
Indian Irrigation Project, Blackfeet Project, Montana	Yes
Indian Irrigation Project, Crow Project, Montana	Yes
Indian Irrigation Project, Flathead Project, Montana	Yes
Indian Irrigation Project, Fort Peck, Montana	Yes
Indian Irrigation Projects Overview	Yes
Intake Project, Montana	Yes
James Diversion Dam P-SMBP, North Dakota	Yes
Jamestown Dam and Reservoir Project, P-SMBP, Noth Dakota	Yes
Jensen Unit, Central Utah Project, Utah	Yes
Kendrick Project, Wyoming	Yes
Keyhole Unit, P-SMBP, Wyoming and Nebraska	Yes
King Hill Project, Idaho	Yes
Kirwin Unit, P-SMBP, Kansas	Yes
Klamath Project, Oregon, California	Yes
Kortes Unit P-SMBP, Wyoming	Yes
Lewiston Orchards Project, Idaho	Yes
Little Wood River Project, Idaho	Yes
Lower Marias Unit, P-SMBP, Montana	Yes
Lower Rio Grande Rehabilitation Project, New Mexico	Yes
Lower Yellowstone Project, Montana and North Dakota	Yes
Lyman Project, Wyoming	Yes
Mancos Project, Colorado	Yes
Mann Creek Project, Idaho	Yes
Marshall Ford Dam –See Colorado River Project	Yes
McGee Creek Project, Texas	Yes
McMillan Delta Project, New Mexico – See Carlsbad Project	Yes
Michaud Flats Project, Idaho	Yes
Middle Rio Grande Project, New Mexico	Yes
Milk River Project, Montana	Yes
Minidoka Project, Idaho, Wyoming	Yes
Minot Extension, P-SMBP, North Dakota (Pending Website Upload)	Yes
Mirage Flats Project, Nebraska	Yes
Missoula Valley Project, Montana	Yes
Moon Lake Project, Utah	Yes
Mountain Park Project, Oklahoma	Yes
Narrow Dam	Yes
Navajo Indian Irrigation Project, New Mexico	Yes
Navajo Unit, CRSP, New Mexico and Colorado	Yes
Newlands Project, California and Nevada	Yes
Newton Project, Utah	Yes
Norman Project, Oklahoma	Yes
North Loup Division, P-SMBP, Nebraska	Yes
North Platte Project, Wyoming and Nebraska	Yes

Project (Link)	**Project History (Y/N)**
Nueces River Project, Texas	Yes
Oahe Unit, P-SMBP, South Dakota	Yes
Ogden River Project, Utah	Yes
Okanogan Project, Washington	Yes
Orland Project, California	Yes
Owl Creek Unit, P-SMBP, Wyoming	Yes
Owyhee Project, Oregon	Yes
Pacific Northwest-Pacific Southwest Intertie Project	Yes
Palisades Project, Idaho	Yes
Palmetto Bend Project, Texas	Yes
Palo Verde Diversion Project, California and Arizona	Yes
Paonia Project, Colorado	Yes
Parker-Davis Project, Arizona and California	Yes
Pecos River Water Salvage Project, New Mexico and Texas	Yes
Pick-Sloan Missouri Basin Program Overview	Yes
Pine River Project, Colorado	Yes
Preston Bench Project, Idaho	Yes
Project Skywater	Yes
Provo River Project, Utah	Yes
R. B. Griffith Water Project, Nevada	Yes
Rapid Valley Project, South Dakota	Yes
Rapid Valley Unit, P-SMBP, South Dakota	Yes
Rathdrum Prairie Project, Idaho	Yes
Rio Grande Project, New Mexico and Texas	Yes
Ririe Project, Idaho	Yes
Riverton Unit, P-SMBP, Wyoming	Yes
Rogue River Basin Project, Oregon	Yes
Rural Water Supply Projects	**No**
Salt River Project, Arizona	Yes
San Angelo Project, Texas	Yes
San Diego Project, California	Yes
San Felipe Project, CVP, California	Yes
San Juan-Chama Project, CRSP New Mexico	Yes
San Luis Unit, CVP, California	Yes
San Luis Valley Project, Colorado	Yes
Sanpete Project, Utah	Yes
Santa Maria Project, California	Yes
Sargent Unit, P-SMBP, Nebraska	Yes
Savage Unit, P-SMBP, Montana	Yes
Scofield Project, Utah	Yes
Seedskadee Project, Colorado River Storage Project, Utah	Yes
Shadehill Unit, P-SMBP, South Dakota	Yes
Shasta Division, CVP, California	Yes
Shoshone Project, Wyoming	Yes
Silt Project, Colorado	Yes
Smith Fork Project, CRSP, Colorado	Yes
Solano Project, California	Yes
Strawberry Valley Project, Utah	Yes
Sun River Project, Montana	Yes
Trinity Division, CVP, California	Yes
Truckee Storage Project, California and Nevada	Yes
Tualatin Project, Oregon	Yes
Tucumcari Project, New Mexico	Yes
Umatilla Basin Project, Oregon	Yes
Uncompahgre Project, Colorado	Yes
Vale Project, Oregon	Yes
Ventura River Project, California	Yes
Vermejo Project, New Mexico	Yes

Project (Link)	Project History (Y/N)
Vernal Unit, Central Utah Project, Utah	Yes
W. C. Austin Project, Oklahoma	Yes
Wapinitia Project, Oregon	Yes
Washita Basin Project, Oklahoma	Yes
Washoe Project, California and Nevada	Yes
Wayne Aspinall Unit, CRSP, Colorado	Yes
Weber Basin Project	Yes
Weber River Project, Utah	Yes
Webster Unit, P-SMBP, Kansas	Yes
Wichita Project, Kansas	Yes
Williston Project, North Dakota	Yes
Wind Electric Power Project	Yes
Yakima Project, Washington	Yes
Yellowtail Unit, P-SMBP, Montana	Yes
Yuma Auxiliary Project, Arizona and California – See Yuma Project	Yes
Yuma Project, Arizona and California	Yes

7.4 State Contexts, Relevant Project Studies, and the Data Deluge

One of the challenges in developing a comprehensive overview of Reclamation-related resources is the multitude of ways in which systems and their components are documented. In some states, researchers were provided broad historic resource information; other states directed the authors to use their online query systems. In Oklahoma, contact with the SHPO yielded survey information about the W.C. Austin Project, including the survey report and individual Bureau of Reclamation inventory sheets that were developed in the early 1990s. These sheets, provided by county, documented canals, laterals, turnouts, dikes, flumes, headgates, wasteways, weirs, dams, construction sites, bridges, various buildings, railroads, and demonstration buildings. However, none of these individual forms populate through the state's database.

In Texas, contact with the SHPO produced reports, summaries, and evaluations primarily of individual irrigation districts within the Lower Rio Grande Valley, which contained 26 historic-age districts and 3,500 miles of main canals and laterals. Most of the individual districts were evaluated in Knight's (2009) report[513] and in cooperation with the Texas Department of Transportation's Environmental Affairs Division. These reports are especially useful in documenting the number of irrigation property types and illustrating the various property types, including lift plants, conveyance structures, gates, siphons, and flumes, etc. Of the districts, one (Hidalgo County Irrigation District No. 2) was listed on the NRHP. Most of the districts were determined eligible.

In other cases, researchers were given state-sponsored contexts, historic resource reports specific to a project, or other irrigation-related documents. While this does not represent a comprehensive listing of studies, this robust list helps illustrate the extent to which projects, including individual features, have been studied across the West.

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[513] Knight, *Field Guide*.

Table 7.4 Other relevant studies.

State	Title/Project	Synopsis	Reference
Arizona	Lifeline to the Desert: Water Utilization and Technology in Arizona's Historic Era, 1540-1960	Context	SWCA n.d.
	History of Gates 7-13.4-41 and 7-13.4-42 and Associated Lateral	Mitigation	Dudley 2004
	Roosevelt Water Conservation District Canal	HABS-equivalent documentation	Solliday and Dudley 2000
	Archaeological Survey and Evaluation of Structural Components of the Roosevelt Power Canal.	Included review of flumes, tunnels, sluice gates, culverts, bridges, weirs, and siphons.	Ayers 1983
	Cultural Resources Survey of the Salt River Project Canals, Maricopa County, Arizona	Survey of Features	Aguila, et al. 1998
	The Historic Yuma Project: History, Resources Overview and Assessment	History and description of 125 features, identified significant features	Pfaff, et al. 1999
California	Water Conveyance Systems in California: Historic Context Development and Evaluation Procedures	Context	JRP and CALDOT 2000
Colorado	Historic Context for Irrigation and Water Supply Ditches and Canals in Colorado	Context	Holleran 2005
	Colorado-Big Thompson Project	Context and property type discussion, recordation of 163 features	Pfaff 1999
	Level II Historic Documentation Various Canals, including Highline, Stewart Ditch, North Delta, Ratliff and Root ditch, Aspen, Gould, Crawford Clifford Ditch, Grand Valley Diversion Dam. Available at https://www.usbr.gov/uc/DocLibrary/reports.html.	Photographic and Historic mitigation eligible system components	Various
Idaho	From Raindrop to Field: Irrigation History in Idaho, 1870-1970	Context	Draft, 2022
	Minidoka Gravity Division Historic Context and Evaluation	Evaluation of division	Bureau of Reclamation 2019
Montana	Historic Cultural Resources of the Milk River Project	Identified 139 historic features related to the project	Queen et al. 1991
	Historic Cultural Resources of the Sun River Project	Identified 160 historic features related to the project	Queen et al. 1990
Oregon	Guidance for Recording and Evaluating Linear Cultural Features	context	Oregon SHPO 2013
South Dakota	Homesteading and Agricultural Development Context	Context	Brooks and Jacon 1994
	History of Agriculture in South Dakota: Components for a Fully Developed Historic Context	Context	Witt et al. 2013
Oklahoma	The W.C. Austin Irrigation System Historic Inventory Project	Evaluation of the system and features	Pfaff 1993
Texas	A Field Guide to Irrigation in the Lower Rio Grande Valley	Context	Knight 2009
	Intensive Survey Results and Final Recommendations for NRHP Eligibility of the Irrigation Systems (one report per system): Cameron County Irrigation District # 6 Hidalgo County Irrigation District #1 Hidalgo County Irrigation District #19 Hidalgo County Irrigation District #15 Delta Lake Irrigation District #1 Delta Lake Irrigation District Character	Evaluation of system features	Knight var.

State	Title/Project	Synopsis	Reference
Texas (continued)	United Irrigation District Hidalgo and Cameron Co. Irrigation District #9		
	Inventory of Structural Components of Bexar-Medina-Atacosa Counties Water Control and Improvement District No. 1	Evaluation of USDA-NCRS Canals and laterals	U.S. Department of Agriculture 2000
	Cultural Resources Investigations of the Donna-to Brownsville Protective Levee System Rehabilitation Project [Lower Rio Grande Project]	Recorded 69 irrigation or drainage related resources	Geo-Marine, Inc., 2009
Wyoming	Water in Wyoming: A History of Irrigation from 1868-1979	Context	Horn and Prouty 2023

In using the state databases, the most notable challenge was accurately querying features, sites, and systems. For example, in Oregon, running a query for "canal" or "irrigation" populates 105 resources, but some of these overlap. Information about ownership (e.g., Reclamation), if available, may be collected by pulling the individual forms, but that information was not always recorded. Conducting a query for "Reclamation" generated only three resources, including a road, a building, and a Multiple Property Documentation Form (MPDF) for the Carey and Reclamation Acts Irrigation Projects. Similarly, Washington's database produced a number of hits, but the results need to be further refined as many of the populated records are duplicated. Again, determining whether the features were Reclamation-related proved time-consuming and sometimes inaccurate. The Kansas and Texas systems yielded a very small number of features.

Table 7.5 Sample of general database queries.

Feature	California[514]	Oregon	Washington	Kansas	Texas
Canal	281	53	930	4	3
Lateral	75	10	264	0	0
Ditch	143	211	183	4	1
Irrigation	66	38	281	1	1
Weir	12	9	46	0	0
Diversion Dam	24	14	597	0	0
Pump Station	14	11	2262	4	3
Siphon	9	3	35	0	0
Drain	35	9	54	0	0
Wasteway	4	0	101	0	0
Flume	6	8	24	0	0
Spillway	8	6	22	4	0
Turnout	5	1	10	0	0

Correspondence with Reclamation district offices yielded additional data estimates. For Wyoming, there have been an estimated 430 individual ditches and canals recorded, totaling 2,305 miles. Within the data, 320 were determined eligible, 316 not eligible, and 34 were unevaluated. For Utah, a total of 701 individual ditches and canals were recorded, totaling 1,274 miles. Of those, 243 are noted as eligible, 454 as not eligible, and four as unevaluated. For Colorado, a total of 8,504 ditches and canals have been recorded in the state (although some are likely duplicates), totaling 2,068 miles. For New Mexico, there are a total of 1,262 linear resources recorded (totaling 1,344 miles) and 170 structural or other related features.[515] While

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[514] Only includes 35 counties in which the CVP has a presence. A review of other counties may yield more hits.

[515] The numbers for Wyoming and Utah presented do not include duplicate entries. Raw data (including duplicates) for Utah has 1,401 ditches and canals and 2,108 miles of features, 726 eligible, 669 not eligible, and five unevaluated.

an accurate and detailed number of recorded features is difficult to discern due to entry methods and consistency, data clearly shows that a significant number of features, particularly canals, have been recorded.

7.5 Summary and PA Recommendations

Reclamation faces the daunting task of managing its physical assets for cultural resources compliance. Many projects are already 50 years of age and others are quickly reaching that milestone. Resources are not evaluated in a systematic manner and the documentation is not stored in a consistent and searchable system. While previous investigators have promoted a systematic approach to evaluation, field surveyors may be limited to small segments based on their projects' scopes of work, and therefore, the systems are documented in a piecemeal fashion.

Reclamation was seeking to develop a Program Comment to facilitate cultural resources compliance while addressing the operational and maintenance needs of its aging infrastructure. This was in part due to the redundant nature of the resources, as well as the abundant numbers of the resources that have been recorded, documented or otherwise studied. During the 1990s, the Department of Defense faced a similar challenge with its vast inventory of World War II and Cold War infrastructure, which was quickly reaching 50 years of age. As a result, the agency developed a series of Program Comments at the national level in consultation with the ACHP. These Program Comments broadly addressed and mitigated certain standardized resource types, such as Capehart-Wherry Housing, World War II temporary structures, ammunition storage magazines, and unaccompanied personnel housing. These were resource types found commonly at military installations across the United States. Stipulated mitigation included detailed historic contexts or photographic and historical documentation of representative resource types. Today, those resource types are generally excluded from Section 106 compliance.[516] To date, the ACHP has rejected Reclamation's request for a Program Comment. It may yet be possible for Reclamation to look at adopting an alternative streamlining effort, such as a Nationwide PA or continuing work on statewide PAs. Either agreement type could adopt a similar approach to that used by Army for Program Comments. PA stipulations could include: 1) identifying representative Projects/systems for HABS/HAER documentation, 2) identifying individual features worthy of recordation, 3) developing a story map of key histories and features, 4) developing a systematic method for Reclamation-sponsored evaluations, and 5) contributing to a Reclamation "Irrigation Wiki." These are discussed in more detail below.

7.5.1 Identify Representative Projects/Systems for HABS/HAER Documentation

Much of the existing HABS/HAER documentation focuses on key features such as dams, canals, and laterals, with less emphasis on the smaller components, effectively segregating the "systems approach" of significance and eligibility. Officially nominating Reclamation assets to the NRHP has taken a similar approach. In developing a PA, Reclamation should consider selecting representative *projects* for

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For Wyoming, raw data includes 1,049 ditches and canals, 3,059 miles, 381 eligible, 362 not eligible, 292 unevaluated. Wyoming and Utah data was provided via email from Zachary Nelson to Joseph Giliberti on July 17, 2023. Colorado data was provided via email from Zachary Nelson to Joseph Giliberti on July 12, 2023. Colorado data was supplied via email from Zachary Nelson to Joseph Giliberti on July 28, 2023.

[516] A sample of Program Comments can be found at https://www.achp.gov/program_alternatives/program_comments. Other agencies, such as the General Services Administration, have also begun using Program Comments as a compliance alternative.

HABS/HAER recordation based on significant engineering components, general integrity, or significant themes. The HABS/HAER recordation could record Reclamation-managed features from the main dams and canals down to a representative collection of smaller features, such as siphons and weirs, within that system. Chapter 5 identifies certain projects that have been determined NRHP-eligible and may be good options for full or supplementary HABS/HAER documentation. These include the Milk and Sun River projects in Montana, the Colorado-Big Thompson Project in Colorado, the Umatilla Project in Oregon, and the CVP in California.

7.5.2 Identify Individual Features Worthy of Recordation

A PA could itemize certain resource types that may be unique, rarely constructed, a remaining or early feature example, or a notably designed feature in an otherwise generic Reclamation system.

7.5.3 Develop a Story Map of Key Histories and Features

Reclamation has largely completed histories for its projects that provide key historical and construction detail. Information from these histories could be merged with historic photographs from the Reclamation collection in a series of story maps. Reclamation already has an existing online ArcGIS system, and in one case has developed a story map for fish habitat mitigation at Grand Coulee Dam. Story maps could present the engineering and academic historical information in a more public-friendly manner.

7.5.4 Develop a Systematic Method for Reclamation-Sponsored Evaluations

Some of the most notable projects, such as the Salt River Project, Minidoka Project, and Columbia River System, have been more systematically documented. Others have been more sporadically evaluated via individual components. In documenting the W.C. Austin Project, investigators developed a standardized form. These forms provided consistent documentation that could be adapted by Reclamation. These would not necessarily supplant SHPO forms but would be method for Reclamation to track its own historic assets. A *simple* form or database could be developed with fields for feature type (siphon, canal, lateral, flume, etc.), year built, district/unit, state, Project, brief description, evaluation year, NRHP determination, and a place to attach a pdf of a report or SHPO form. This could be incorporated into Reclamation's GIS system to begin building a historic resources database. Importantly, the form could also be required where other entities may be the sponsor agency for a Section 106 project, but where Reclamation serves as the lead federal agency.

7.5.5 Contributions to a Reclamation "Irrigation Wiki"

Reclamation has developed PAs with the Wyoming and Colorado SHPOs. One mitigation option of those agreements includes contributions to an "Irrigation Wiki" that is designed to gradually build a web-based synthesis of irrigation practices and history. The Wiki, which is intended for a general audience, may be expanded through data sources such as historic research, photos, videos, oral interviews, and design information. For purposes of the current context, a Wiki could broadly discuss the history of and the need for irrigation in the West, but could also focus on design, construction methods, materials, engineering, and specific water control feature types (see Chapter 4).

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