EXECUTIVE SUMMARY

This Water Resource Plan (Plan) is intended to provide the City of Fernley (City) a document to guide future decisions related to the City’s water supply, transmission and distribution system, and its ability to meet customer water demands into the future. This executive summary provides a snapshot of the key findings from each chapter of the Plan. In total, the Plan is comprised of an Introduction and four topic-focused chapters.

INTRODUCTION

Since its incorporation in 2001, the City’s population has doubled to approximately 19,700 people and is continuing to grow into a significant economic center where residents live, work, and recreate. As a signatory party to the Truckee River Operating Agreement (TROA), the City is in a favorable position to manage its surface and groundwater rights in such a way that the water system operates in an efficient manner in both drought and non-drought years. In addition to other recently completed or forthcoming planning efforts, this Plan provides the City the framework for maintaining a high level of service for its water customers.

CHAPTER 1: WATER RIGHTS

Chapter 1 presents information on the City’s water rights which include both groundwater and surface water supplies. Currently, the City holds water rights for approximately 8,900 acre-feet annually (AFA) for groundwater in the Fernley Hydrographic Area and 2,100 AFA for groundwater in the Brady’s Hot Springs Hydrographic Area. In addition, the City has approximately 9,700 AFA of Truckee River under Claim No. 3 of the Orr Ditch Decree. The City’s current total volume of water rights for municipal purpose is approximately 20,700 AFA.

Currently, there are approximately 7,300 developed lots which are within the City’s water service area. It is important that the City’s water supply is protected and managed to provide adequate water resources in the future. Key recommendations of this chapter include a dedication rate analysis, development and adoption of specific water management policy, and a domestic well credit analysis.

CHAPTER 2: WATER SOURCE RELIABILITY

Chapter 2 discusses the water system’s current capacity, its water supplies and budget, the quality of surface water and groundwater sources, a water source risk analysis, and drought/climatic effects. The City currently operates an untreated groundwater well and transmission system, a water treatment plant, and potable transmission, distribution, and storage systems. Currently, the City relies upon groundwater from six wells to supply its customers. During recent years, an average of 3,943 AFA have been pumped from the supply wells, and during peak summer months, the raw water well pumps are operating at 41% of their capacity. Based on current well capacity and potable water storage within the system, it is estimated that the City could serve an additional 2,956 equivalent dwells units (EDU’s) without significant improvement or expansion.

Since its construction in 1905, the Truckee Canal, owned by the United States Bureau of Reclamation (USBR) and operated by the Truckee-Carson Irrigation District, has provided a substantial amount of groundwater recharge in the Fernley Hydrographic Area. Groundwater levels in the area can fluctuate based on the amount of water diverted to the Truckee Canal in a given year. The City has acquired approximately 9,700 AFA of Claim No. 3 water rights and is currently pursuing the construction of infrastructure to integrate surface water into its supply. In addition, the City has executed a contract with the United States Bureau of Reclamation that authorizes the City to storage water in upstream reservoirs in...
accordance with TROA. The surface water supply, in conjunction with the upstream storage, will provide a reliable additional source of water for the City’s customers.

For the City to provide a reliable water supply to its customers, it must actively manage potential changes which may affect its water sources and supply. It will be important to monitor the development of future legislative actions and new regulations which may be imposed by the Nevada State Engineer. Although the City currently uses only groundwater sources, surface water in the region plays a large role in the availability of all water. When the City begins to rely on its surface water source, low precipitation years and drought will play an even larger role in water availability.

CHAPTER 3: MANAGEMENT OF WATER RESOURCES

Chapter 3 describes the availability of water rights used by the City and how those resources can be conjunctively managed to provide a sufficient volume of water to meet its water service demands. When the surface water infrastructure is constructed, the City will need to transition to an integrated water management approach. Review of a study prepared by Precision Water Resources Engineering, indicates that the firm yield of the City’s surface water rights is estimated to be 6,500 AFA. However, to ensure this firm yield, the City will need to manage direct diversions under its Claim No. 3 water rights and when to store this water in reservoirs under an existing TROA agreement. The ability to store water will provide an important supply in dry years when the natural flow of the Truckee River cannot supply the City’s full surface water demand. In addition, use of the surface water supply will need to be comanaged with use of groundwater supplies. The City currently has 8,900 AFA of groundwater rights within the Fernley Hydrographic Area. The City also has 2,100 AFA of groundwater in the Brady’s Hot Springs Hydrographic Area which could be brought into the basin. Significant infrastructure needs to be developed so that this source can also be integrated into the water supply.

Based on these rights, the volume of water that the City can rely upon for dedication is 17,500 AFA (i.e., 6,500 AFA of surface water plus 8,900 AFA groundwater from the Fernley Hydrographic Area and 2,100 AFA from the Brady’s Hot Springs Hydrographic Area). The average amount of water dedicated per EDU is 0.638 AF. Based on this average dedication rate, the City could serve up to a total of 27,432 EDU’s considering its 17,500 AFA of available water supplies. The capacity of the City’s water production and transmission system is currently limited by the storage plus supply analysis as allowed for under Nevada Administrative Code 445A. This analysis determined that the existing groundwater pumping infrastructure and potable storage tank system can support an additional 2,956 EDU’s, or a total of 10,256 EDU’s, without system expansion or improvement. The transmission system has the capacity to convey all water produced by the existing water treatment plant.

CHAPTER 4: FUTURE WATER RESOURCES

Chapter 4 quantifies the potential for population growth in the Fernley area, the associated increased water demands, and recommendations to ensure long-term use of water sources. The Comprehensive Master Plan states the City’s population is likely to double its current residential population to approximately 40,000 people over the next 20 years. However, growth rates are variable and could fluctuate significantly. The projected water demand for a population of 40,000 would be 15.14 MGD, or approximately 8,100 AFA, which includes assumed commercial and industrial demands. The water treatment plant has a capacity of 20 MGD, so it will be able to support the 20-year growth projection. Responsible water resource planning considers time frames beyond the 20-year land use planning horizon. When these time frames are considered, the City expects that the full quantity of its existing water resources will be needed to serve customers of the water system.

The City holds groundwater rights in the Fernley Hydrographic Area and the Brady’s Hot Springs Hydrographic Area. To help protect the future groundwater resource(s), it is recommended that additional groundwater characterization studies, resource monitoring, and water rights management practices be
implemented on an annual or more frequent basis. These actions will support future water source development, maintenance, and management.

Development of the surface water and Brady’s Hot Springs water supplies will provide significant redundancy within the water system. The City may also be able to take advantage of treated effluent from the wastewater treatment plant as population and water demands increase. Potential regionalization of water supplies and emergency intertie infrastructure with neighboring utilities could be pursued to provide additional resiliency.
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INTRODUCTION

1.0 PURPOSE

The purpose of this Water Resource Plan (Plan) is to provide the City of Fernley (City) with a documented plan and policy related to the City’s ability to provide a sustainable water supply to its customers in periods of above and below average precipitation. The purpose of this Introduction is to provide information regarding the City and explain its need for the Plan.

2.0 BACKGROUND

On June 20, 2018, the City Council of Fernley, Nevada awarded a contract to Farr West Engineering to complete a Water Resource Plan (Plan). This Plan is separated into four chapters, with each addressing a specific component of this Plan as follows:

- Chapter 1 – Water Rights
- Chapter 2 – Water Source Reliability
- Chapter 3 – Management of Water Resources
- Chapter 4 – Future Water Resources

3.0 CITY OF FERNLEY

Although Fernley was established as a township in 1906, it only recently became incorporated as a city in 2001. As shown in Figure I-1, the City is located in Lyon County, Nevada. The City is currently transitioning from a rural agricultural and ranching community to a medium-sized suburban city. The City has a population of approximately 19,700 people and includes surrounding agricultural areas. The population has more than doubled since becoming incorporated in 2001. This is mainly due to economic development within City limits, to the west at Tahoe-Reno Industrial Center, and in the Reno-Sparks metropolitan area.

The City anticipates that it will continue to grow and is interested in transitioning from a bedroom community or commuter town to a place where the residents live, work, and recreate. As part of this transition, the City of Fernley Comprehensive Master Plan was updated in 2018. In order for the City to grow, it will need to properly manage its water resources to continue meeting its existing customer needs and expand to meet future water demands. In addition to the Comprehensive Master Plan, the City is preparing this Water Resource Plan and an update to its Water System Master Plan in an effort to maintain a high level of service for its water system in perpetuity.
Figure I-1
City of Fernley, NV

The data contained herein does not represent survey delineation and should not be construed as a replacement for the authoritative source. No liability is assumed by Farr West Engineering as to the sufficiency or accuracy of the data.

The data is in feet and is scaled at 1" = 4,000'.

City Boundary
Parcels
Major Roads
Railroad
TCID Canal
Truckee River
County Boundary

City of Fernley, NV

5510 Longley Lane
Reno, NV 89511
(775) 851-4788
www.farrwestengineering.com

Client: Fernley
Printed: 10/2/2019
4.0 NEED FOR A WATER RESOURCES PLAN

Currently, the City is relying entirely on its groundwater source to supply water to its customers. However, the City also has a significant volume of Truckee River surface water rights and is currently constructing infrastructure to utilize this source. With the recent implementation of the Truckee River Operating Agreement (TROA), the City will need to have a definitive guiding document to base water management decisions on. This Plan will detail recommended management practices of the surface water source in conjunction with groundwater sources to estimate the reliable supply available to the City on an annual basis.

This Plan is the City’s first Water Resource Plan. It is recommended that this Plan be updated every five to ten years to incorporate any changes in boundary conditions, including but not limited to: Nevada water law, economic growth, land use planning, water quality and water yields. Additionally, Senate Bill 150 (effective July 1, 2019) requires governing bodies to develop and maintain a water resource plan for a period of no more than 10 years without update. This Plan will help guide the City in decisions related to water resources including future investments in the water system and water sources.

Water resource planning is tied to the City’s Comprehensive Land Use Master Plan, and information from the Comprehensive Master Plan was used to develop this Plan. However, because of the length of time it takes to identify, permit, and construct infrastructure to bring new water resources on line, the planning horizon for this Water Resources Plan is significantly greater than that used for the Comprehensive Master Plan.

5.0 BOUNDARY CONDITIONS

Table I-1 provides boundary condition values which will be used throughout this Plan. An equivalent dwelling unit (EDU) is a common unit of measurement for water service. For this Plan, the number of EDU’s is assumed to be equal to the current number of water connections which is 7,300. A detailed EDU analysis was not completed; however, an average day demand of 480 gallons per day per EDU was calculated based on the recent average water production and the number of connections.
### Table I-1: Summary of the City’s Customers, Resources, and Usage

<table>
<thead>
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<th>Totals</th>
</tr>
</thead>
<tbody>
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<td><strong>A. Service Connections</strong></td>
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</tr>
<tr>
<td>1. Residential Single-Family</td>
<td>6,531</td>
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<tr>
<td>2. Residential Multi-Family</td>
<td>99</td>
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<tr>
<td>3. Commercial/Industrial</td>
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<td><strong>4. Total Connections/Meters</strong></td>
<td>6,935</td>
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<td><strong>5. Total Equivalent Dwelling Units (EDU’s)</strong></td>
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<td><strong>B. Water Rights Direct Volume (acre-feet)</strong></td>
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</tr>
<tr>
<td>1. Groundwater – Municipal</td>
<td>8,900</td>
</tr>
<tr>
<td>2. Surface Water – Truckee River</td>
<td>9,700</td>
</tr>
<tr>
<td>3. Surface Water – Brady’s Hot Springs Area</td>
<td>2,100</td>
</tr>
<tr>
<td><strong>4. Total Resources</strong></td>
<td>20,700</td>
</tr>
<tr>
<td><strong>C. 2017 Water Production (acre-feet)</strong></td>
<td></td>
</tr>
<tr>
<td>1. Groundwater</td>
<td>3,846</td>
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<tr>
<td>2. Surface Water Diversion</td>
<td>0</td>
</tr>
<tr>
<td>3. Surface Water Storage</td>
<td>0</td>
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<tr>
<td><strong>4. Total 2017 Sources</strong></td>
<td>3,846</td>
</tr>
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1 Source: Table A-14 (Hansford Economic Consulting, 2016).

ii The number of EDU’s (Stanka Consulting, LTD, 2018) is larger than the total number of meters because commercial and industrial uses consume water at different volumes than residential uses (i.e. EDU) and some meters supply water to more than one lot.

### 6.0 WATER FACILITIES

The City has one water treatment plant with a 20 million gallons per day (MGD) capacity with an ultimate buildout capacity of 30 MGD. The existing treatment plant is equipped to treat up to 15 MGD of surface water (CDM Smith, 2016). A raw surface water pipeline will need to be constructed prior to treatment of surface water at the plant and is currently in design and planning.
CHAPTER 1: WATER RIGHTS

1.0 PURPOSE
This chapter provides documentation of the City of Fernley’s (City) existing water rights as a basis for subsequent water resource management analyses and recommendations. This chapter also outlines recommendations that the City can pursue in the future.

2.0 SUMMARY
The City owns approximately 20,700 acre-feet (AF) of groundwater and surface water rights for municipal purposes within the water service area. Of this total approximately 8,900 AF is groundwater within the Fernley Hydrographic Area, 9,700 AF are associated with Truckee River Decree water rights, and 2,100 AF is groundwater within the Brady’s Hot Spring Hydrographic Area. An analysis of existing water right dedication rates shows that adequate water rights have been accepted for existing growth, however long-term development will require improvements to the water system by construction of a surface water intake.

Recommendations for future analysis, study, and long-term planning for water rights are discussed briefly here and include additional dedication rate analysis and a domestic well credit analysis.

3.0 WATER RIGHTS IN NEVADA
The Nevada Division of Water Resources (NDWR) is the regulatory authority for water rights in the State of Nevada. The Nevada State Engineer (NSE), as head of this division, approves or denies water right applications, establishes limitations to water usage, and manages dam safety operations within the State.

3.1 WATER RIGHT PRIORITY AND APPROPRIATION STATUTES AND REGULATION
The legal process to acquire water rights and transfer those rights to the subject property is defined by Nevada Revised Statutes (NRS) Chapters 533 and 534, Nevada Administrative Code (NAC), and internal office policy. All water, whether above or below the surface of the ground is owned by the public. Nevada water right law is based on the prior appropriation doctrine, otherwise known as “first in time, first in right.” By filing an application to appropriate through the office of the Nevada State Engineer (NSE), surface water resources have been appropriated since 1905 and groundwater resources in Nevada have been appropriated for use since 1939. The priority date establishes what water rights can be curtailed by the NSE when pumpage in a hydrographic basin annually is determined to be detrimental to the resource.

Another pillar of Nevada water law is the concept of beneficial use. Beneficial use is the basis, measure, and limit to the water right. This means that only the portion of the water right that can be used beneficially is established as the perfected, or certificated water right. To allow water right owners flexibility to place their rights to beneficial use, there is a process to change or move the permitted location of these water rights to meet project demands.

For general purposes, statutes for groundwater rights and surface water rights are in separate chapters in the NRS. While these rights have generally been administered separately, current legislative actions have established conjunctive use management requirements that the Nevada State Engineer must adhere to. For our purposes, we will consider groundwater rights and surface water rights separate, though long-term water right management should consider conjunctive use implications.

3.2 WATER RIGHT OWNERSHIP
Water right ownership processes are important to understand as those requirements have implications for water right banking agreements and dedications for water service. Based on our analysis, a component of City water rights were deeded to the City with a commitment for future service connection created by
agreement. This “beneficial interest” to the water right can be applied to future service connections or transferred for the benefit of other projects.

3.3 WATER RIGHT MAINTENANCE – PROOFS OF COMPLETION AND BENEFICIAL USE

A water right permit granted by the NSE includes a requirement that a Proof of Completion of the works of diversion be filed. This affidavit provides information on the well construction, metering and other information as requested by the State Engineer. A water right permit can be further perfected by Certification.

To Certificate a water right records of the amount of water used for a beneficial purpose must be reported to the NSE. This statement of use is referred to as Proof of Beneficial Use. A water permit issued by the State Engineer is limited to the amount that can be applied to beneficial use. Once the Proof of Beneficial Use has been filed and approved that volume becomes the limit of the specific water right. Additional water cannot be used unless additional water rights are acquired and moved to same point of diversion. These requirements must be met to keep water rights in good standing.

If the water right owner cannot file the applicable Proof of Completion or Proof of Beneficial Use, Extensions of Time can be filed with NDWR. Current NRS provides the ability for water right owners to extend due dates to maintain the good standing of their water rights if the permittee is applying a steady application of effort and is proceeding with reasonable diligence to complete the project.

The City will need to continue to devote staff effort and resources to maintain the good standing of their water rights, including meeting NDWR due dates for Proof of Completion, Proof of Beneficial use and water use reporting. Extensions of time will continue to be particularly important as the City is not responsible for building municipal and industrial projects; only maintaining the water service to these projects once completed.

3.4 WATER RIGHT MAINTENANCE - CITY OF FERNLEY PROOF OF BENEFICIAL USE

The City owns groundwater and surface water rights. The City’s groundwater rights are permitted for both irrigation and municipal purposes. The City’s irrigation water rights have been certificated for use at the golf course. While there are many certificated water rights owned by City there are many permits have not been perfected.

Water rights permitted by NDWR for municipal or quasi-municipal purposes may show beneficial use by submitting the number of units (i.e. houses or “rooftops”) multiplied by the dedication rate per unit. The calculation of water put to beneficial use for the purposes of obtaining a water right certificate is based on these total units. Additional information regarding water right dedication rates is provided in Section 7.0.

4.0 FERNLEY AREA HYDROGRAPHIC BASIN

The City owns groundwater rights in Fernley Area Hydrographic Basin Number 76 (Fernley Hydrographic Area). Portions of the Fernley Hydrographic Area are situated in Churchill, Storey, Lyon and Washoe Counties. Perennial yield is the estimated amount of groundwater that can be withdrawn and consumed annually. The Fernley Hydrographic Area is unique as compared to other basins in Nevada in that the primary contribution to the basin yield is recharge from the Truckee Canal which passes through the basin and local irrigation. These waters are the basis for the volume of groundwater rights approved by the NSE and have been estimated above the appropriative total in several studies dating back to 1973.

Groundwater inflows to and outflows from a basin are tabulated in a water budget. Chapter 2 compares the water budget for the current state of the Fernley Hydrographic Area to previous water budgets, while Chapter 3 provides an estimate of the water budget considering future conditions. The previous and current groundwater budgets indicate that the City can put to use its full allocation of groundwater rights if current sources of recharge are maintained.
On December 30, 1977, the NSE signed Order No. 699 designated the basin as coming under additional regulatory protections based on groundwater appropriations in the hydrographic basin. This allows the NSE (among other things) to manage the order new appropriations are processed and designate a preferred beneficial use to manage those appropriated water rights.

On November 21, 1989, the NSE signed Order No. 1101 which designated a portion of the Fernley Area Hydrographic Basin with a preferred use of municipal, quasi-municipal, and domestic purposes. Further restriction was placed on new appropriations in the hydrographic basin with no new appropriations granted after this date for irrigation purposes. This designation is generally referred to as “Preferred Use – Irrigation Denied” (PUID) on NDWR basin boundary mapping. The portion of the basin that came under this regulation was the Fernley Town Utilities water and wastewater service area circa 1977. The NSE signed subsequent Order No. 1081 on August 30, 1993 that expanded the PUID area to remain consistent with the utility service area circa 1993.

Finally, the NSE issued a domestic well credit program under Order No. 1184 that would provide a credit to the public water system for single family dwellings that cease diversion from their domestic well and connect to the water system. There are restrictions and requirements to participate in this order, notably the lot must have been approved by the local governing body for service by an individual domestic well prior to July 1, 1993. The domestic well program will be discussed in more detail in subsequent sections of this chapter.

4.1 WATER RIGHT APPROPRIATION AND GROUNDWATER PUMPAGE

Per NDWR records shown in Table 2-1, the comparison of the hydrographic basin budget to the total groundwater appropriation and the estimated annual pumpage volume provides a general basis for future regulatory oversight by the NSE. The current perennial yield represented by the NSE plus additional recharge referenced in USGS water budgets and NSE Rulings is used in the table below to establish an approximate hydrographic basin budget. Additionally, the City’s water supply must continue to be protected and managed to ensure the availability of adequate water resources in the future. Section 8.0 includes recommendations for future analysis and study to ensure adequate water rights are maintained to support the City into the future.

Table 1-1: Fernley Hydrographic Basin

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Acre-Feet Annually (AFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin Budget (Approximate)</td>
<td>600 – 18,000¹</td>
</tr>
<tr>
<td>Appropriative Groundwater</td>
<td>11,641</td>
</tr>
<tr>
<td>2015 Estimate Pumpage</td>
<td>5,907</td>
</tr>
</tbody>
</table>

¹ This range is based on information from multiple sources. Chapter 2 provides additional detail regarding the Fernley Hydrographic Area water budget.

ii NDWR estimated pumpage for Fernley Hydrographic Area.

4.2 WATER RIGHT PRIORITY

Water right priority dates are established on the date an application to appropriate is filed with NDWR. These dates are used if the NSE curtails groundwater use in a hydrographic basin. Table 1-2 summarizes the volume and priority of the City’s groundwater rights relative to the approximate groundwater appropriation in the Fernley Area Hydrographic Basin.
Table 1-2: Fernley Hydrographic Area (FHA) Water Right Priority Summary

<table>
<thead>
<tr>
<th>City of Fernley Priority Date</th>
<th>City of Fernley Duty (AFA)</th>
<th>FHA Permitted Rights (AFA)</th>
<th>FHA Certificated Rights (AFA)</th>
<th>FHA Total Rights (AFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/12/1958</td>
<td>107</td>
<td>12</td>
<td>107</td>
<td>120</td>
</tr>
<tr>
<td>8/25/1964</td>
<td>389</td>
<td>294</td>
<td>1,316</td>
<td>1,610</td>
</tr>
<tr>
<td>4/30/1973</td>
<td>1,056</td>
<td>888</td>
<td>1,389</td>
<td>2,277</td>
</tr>
<tr>
<td>10/22/1975</td>
<td>1,171</td>
<td>1,004</td>
<td>3,018</td>
<td>4,022</td>
</tr>
<tr>
<td>6/10/1976</td>
<td>3,778</td>
<td>3,610</td>
<td>3,018</td>
<td>6,628</td>
</tr>
<tr>
<td>6/14/1976</td>
<td>6,506</td>
<td>6,506</td>
<td>3,018</td>
<td>9,524</td>
</tr>
<tr>
<td>12/23/1977</td>
<td>8,900</td>
<td>8,733</td>
<td>3,020</td>
<td>11,754</td>
</tr>
<tr>
<td>9/11/1978</td>
<td>8,900</td>
<td>8,733</td>
<td>3,020</td>
<td>11,754</td>
</tr>
</tbody>
</table>

5.0 WATER RIGHT INVENTORY

The City’s water right inventory includes groundwater, surface water, storage, and effluent water rights appropriated through NDWR. Water rights are permitted and certificated for use under municipal, wildlife, storage, and irrigation beneficial purposes. The City’s groundwater and surface water resources are considered separate sources of water which provide approximately 20,000 AF of source water annually. The following is a description of the City’s water rights at the time of this Plan, which provides background on the current and future water use by the City. These water rights are also summarized in Table 1-3.

5.1 AGGREGATED WATER RIGHT VOLUMES

Water right total combined duty (TCD) is a method for tracking the overall volume allowed under a series of permits, certificates, or proofs. Water right applications can be approved for diversion rate only to facilitate water system and project needs. These water rights do not add volume to the overall total, and they can be commingled with other water rights in a TCD permit term. The following is a short summary of each TCD limitation relative to the City of Fernley water rights. The total volumes from each source are not commingled or supplemental under water right permit terms. The total aggregated water right volume is based on groundwater and Truckee River TCDs. Storage water rights are based on these two volumes respectively.

5.1.1 Total Combined Duty – Groundwater Rights

The TCD of City of Fernley groundwater rights is 8,900.36 AFA. This water is currently permitted and certificated for municipal purposes. Approximately 1,739 AFA is currently certificated of this total volume. This volume will be used to evaluate total potential service connections by the City. Based on our analysis additional water rights may be able to be certificated. For the purpose of this Water Resource Plan a volume of 8,900 AFA will be used to evaluate potential service connections to the City.

5.1.2 Total Combined Duty – Groundwater Irrigation Rights

The TCD of City of Fernley groundwater rights issued for irrigation purposes is 1,469.04 AFA for the irrigation of 406.2 acres. These permits support irrigation at the golf course and are limited to a duty of 4.0 AF per acre from all sources. For the purpose of this Water Resource Plan a volume of 1,500 AFA will be used to evaluate potential utilization of this water right.
5.1.3 Total Combined Duty – Truckee River Surface Water Rights
The TCD of City of Fernley Truckee River rights issued for municipal and storage purposes is approximately 9,653.798 AFA. For the purpose of this Water Resources Plan a volume of 9,700 AFA will be used to evaluate total potential service connections by the City.

5.1.4 Total Combined Duty – TROA Storage Water Rights
The TCD of City of Fernley Truckee River Operating Agreement Storage rights issued for municipal and wildlife (storage) purposes is approximately 4,709.205 AFA. This volume is included in the TCD for all City of Fernley Truckee River water rights.

5.1.5 Total Combined Duty – Storage and Effluent Water Rights
The TCD of City of Fernley storage water rights is 3,413.40 AFA (or 3.05 MGD) at the wastewater treatment facility. This represents treatment facility capacity under water right permit terms. Delivery of effluent is contingent upon treatment facility capacity and total municipal connections. There is currently one certificated diversion of treated effluent; the Fernley Wildlife Management Area managed by the Nevada Department of Wildlife (NDOW) which takes diversion of up to 1,360 AFA. Depending on treatment facility outflow additional effluent water right and service can be pursued.

5.2 TOTAL COMBINED DUTY TABLE
The TCD of water rights permitted or certificated for municipal purposes is approximately 20,700 AFA. This is the volume subject to our water right audit. These volumes have been approximated for planning purposes. Table 1-3 summarizes the approximate TCD groups for the City of Fernley:

Table 1-3: Total Combined Duty

<table>
<thead>
<tr>
<th>Source of Water</th>
<th>Total (AFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Volume for Municipal Uses</strong></td>
<td></td>
</tr>
<tr>
<td>Groundwater – Municipal</td>
<td>8,900</td>
</tr>
<tr>
<td>Surface Water – Truckee River</td>
<td>9,700</td>
</tr>
<tr>
<td>Groundwater – Brady’s Hot Springs HA</td>
<td>2,100(^i)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20,700</td>
</tr>
<tr>
<td><strong>Additional Sources</strong></td>
<td></td>
</tr>
<tr>
<td>Groundwater – Irrigation</td>
<td>1,500</td>
</tr>
<tr>
<td>Surface Water - TROA Storage</td>
<td>4,709</td>
</tr>
<tr>
<td>Treated Effluent – Storage</td>
<td>3,413(^ii)</td>
</tr>
</tbody>
</table>

\(^i\) This is a future water source; infrastructure is needed before use within City service area.

\(^ii\) The City holds a permit for use of 1,360 AFA of this volume at the Fernley Wildlife Management Area.

6.0 CITY OF FERNLEY WATER RIGHT REVIEW
A preliminary water right review was performed on the City of Fernley dedication records to:

1. confirm the amount of water rights allocated to municipal connections, and
2. estimate available water rights for future development within the service area.

This audit can be used to assist with determinations on future dedication rates and policies related to future development within the service area.

6.1 WATER RIGHT ALLOCATIONS
The water right audit performed for this chapter included an analysis of City of Fernley water right allocation database and supporting water right transfer deeds. Additional work is needed to refine some
water right allocations, such as commercial and industrial connections, and to evaluate assignment of beneficial interest (or equivalent process) of water rights banked with the City of Fernley. For the purpose of this chapter, planning level estimates are used to estimate available groundwater and Truckee River water available for dedication.

### 6.1.1 Water Right Allocations and Water Usage Records

Splitting water right usage, or consumption, from water right dedication is important for long term water resource management. Additionally, total water usage should generally be less than total water right allocations to protect the standing of the utility with the NSE and to ensure sustainability of the water utility into the future. This difference can be attributed to minor factors in addition to the consumptive use which make up the dedication total.

### 7.0 DEDICATION RATE ANALYSIS

Water rights permitted by NDWR for municipal or quasi-municipal purposes may show beneficial use by submitting the number of units (i.e. houses or “rooftops”) multiplied by the dedication rate per unit. The calculation of water put to beneficial use for the purposes of obtaining a water right certificate is based on these total units. This is because the components of a dedication rate typically include:

- Consumptive use per unit
- System loss
- Unanticipated public uses (i.e. greenbelts, parks)
- Drought protection (including safe yield factors)
- Environmental considerations
- Protection of downstream uses

The specific rates for each component vary from system to system based on studies, planning documents, and legal agreements. In this case, dedication rates are reviewed, and recommendations are approved and adopted by the Fernley City Council. Water rights that are dedicated for municipal development are still required to maintain Proof of Completion of Work and Proof of Beneficial Use due dates or those rights are subject to cancellation. For a water purveyor or municipality to prove beneficial use, the general requirements include water use measurements and evidence of completed residential, commercial, or industrial units. The certificated water right is based on the dedication rate across the number of applicable units. In effect, full consumption of the water right is not necessary to achieve full beneficial use in a municipal water right situation. In other words, full beneficial use includes system loss, drought protection, and safety factors which may or may not be quantified in water production volumes.

### 7.1 EQUIVALENT RESIDENTIAL CAPACITY

The Equivalent Residential Capacity (ERC) process through NDWR established a total of approximately 7,300 lots created by various land maps. This process performed a review and analysis of NDWR subdivision records, or tract maps, recorded with Lyon County to update total lots with water rights dedicated to the City. The total lots created were then compared to the original water right dedication rate to evaluate a conversion to a lesser dedication rate. This is generally referred to as a “consumptive use analysis” and is typically used to established adequate dedication rates in a water utility.

### 7.2 SURFACE WATER YIELD AND DEDICATION RATE

Currently, the City does not rely on its volume of surface water rights to meet customer demands. The City has yet to establish a separate dedication rate for its surface water rights. Chapter 3 of this Water Resources Plan will analyze management of water resources and consider long-term water right strategies, including evaluation of surface water reliability and firm yield and a dedication rate analysis.
8.0 RECOMMENDATIONS
Recommendations for future analysis, study and long-term planning for water rights are discussed briefly here and include additional dedication rate analysis, and a domestic well credit analysis.

8.1 WATER RIGHT POLICY DEVELOPMENT
The City of Fernley should continue to designate a responsible party to manage and maintain their water rights and will serve/dedication records. This is currently undertaken by the City Engineer’s office. New policies related to items such as Proof of Beneficial Use filing and dedicated water assignments will help the City manage new development opportunities and future regulatory changes.

8.2 DETAILED WATER RIGHT AUDIT ANALYSIS
Effort is needed to evaluate current water right allocations to existing parcels and subdivisions. Research performed as of February 2018 evaluated water right deed transfers and NDWR water allocations. This effort will provide a basis of the total connections originally established using Truckee River surface water and what development was committed against groundwater.

8.3 DEDICATION RATE ANALYSIS
Dedication rate analysis is needed to support new growth for the City of Fernley. A functional dedication rate that accounts for firm yield from the Truckee River and consumptive use is needed to support future growth within the City service area.

8.4 DOMESTIC WELL CREDIT ANALYSIS
The domestic well credit program was designed to allow for lots created prior to 1993 under a domestic well to connect to a water utility without needing to obtain an additional groundwater right. Per NSE Ruling 1184 there are a number of lots that can be connected to the system with this credit. Analysis of these lots should be completed to determine total lots that can be connected under this program.

8.5 EFFLUENT WATER RIGHT DEVELOPMENT
Excess water right under primary storage permits can be used to start development of an effluent water delivery system by filing secondary applications on those rights. This volume can support certain outside irrigation, landscaping, industrial cooling, or other non-potable uses that offset treated water demands. Additional primary storage and secondary use applications can be filed based on the capacity of the treatment facility. Approximately 2,000 AFA would potentially be available for reuse under current condition estimates.
CHAPTER 2: SOURCE WATER RELIABILITY

1.0 PURPOSE

The purpose of this chapter is to identify existing water resources available to the City of Fernley (City) and to assess the availability, capacity, quality, and risk associated with each source.

2.0 EXISTING WATER SYSTEM DESCRIPTION & CAPACITY ANALYSIS

The City of Fernley operates a municipal water system that provides potable water to approximately 7,300 connections. Currently, the City treats groundwater from six wells before delivering water to customers. In order to provide water service, the City operates non-potable groundwater well and transmission systems; water treatment plant; and potable transmission, distribution, and storage systems. Figure 2-1 is a map of the City’s water systems. Details of these systems will be provided in the following sections.

2.1 RAW WATER RESOURCES

The City currently holds permits for both surface and groundwater sources. Currently, only groundwater wells are utilized for municipal water services. All wells are within the Fernley Area Hydrographic Basin Number 076 (Fernley Hydrographic Area) and the produced groundwater requires treatment at the water treatment plant. Table 2-1 provides a summary of the pumping capacity for each production well. The pumping capacity is based on the pump currently installed at each groundwater production well and not the well’s maximum capacity. All wells, except Wells 9 and 9A, operate off of the “Raw Water” tank level (HGL = 4,342). Wells 9 and 9A operate off of the “Blend” raw water tank level (HGL = 4,176). See Section 2.3 for additional details.

Table 2-1: Groundwater Well Summary

<table>
<thead>
<tr>
<th>Well</th>
<th>Pumping Capacity (gpm)</th>
<th>Pumping Capacity (AFA)</th>
<th>Potential Well Capacity (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well 4</td>
<td>1,600</td>
<td>2,580</td>
<td>1,800</td>
</tr>
<tr>
<td>Well 9</td>
<td>1,400</td>
<td>2,260</td>
<td>1,600</td>
</tr>
<tr>
<td>Well 9A</td>
<td>1,100</td>
<td>1,780</td>
<td>1,200</td>
</tr>
<tr>
<td>Well 11</td>
<td>2,550</td>
<td>4,120</td>
<td>4,200</td>
</tr>
<tr>
<td>Well 13</td>
<td>900</td>
<td>1,450</td>
<td>2,200</td>
</tr>
<tr>
<td>Well 14</td>
<td>2,050</td>
<td>3,310</td>
<td>3,500</td>
</tr>
<tr>
<td>Well 8</td>
<td>500</td>
<td>810</td>
<td>500</td>
</tr>
<tr>
<td>Total Pumping Capacity</td>
<td>8,560</td>
<td>13,810</td>
<td>15,000</td>
</tr>
<tr>
<td>Firm Pumping Capacity</td>
<td>6,010</td>
<td>9,690</td>
<td>--</td>
</tr>
</tbody>
</table>

Sources: i City of Fernley Engineer 12/2018

ii Well Completion Reports

iii Well 9 and Well 9A are near each other, the combined production capacity of these wells is limited to 1,460 gpm (2,350 AFA) when both are in operation due to proximity and system configuration. The pumping capacity of each is show, but the Total Pumping Capacity (TPC) and Firm Pumping Capacity (FPC) values are based on the combined 1,460 gpm for these two wells.

iv The City holds a water right permit for Well 8, which supplies construction water and is not connected to the City’s water system, and the City does not have any plans to connect it. Therefore, Well 8 is not included in the Total Pumping Capacity (TPC) or Firm Pumping Capacity (FPC) values.
Figure 2-1: Water System Overview

The data contained herein does not represent survey delineation and should not be construed as a replacement for the authoritative source. No liability is assumed by Farr West Engineering as to the sufficiency or accuracy of the data.

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Reno, NV 89511
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www.farrwestengineering.com

This data is generated through a variety of methods including ground surveys, aerial photography and digital mapping services. For more information on the methodology and sources of data, please contact the project manager or the data provider.
Figure 2-2 shows the utilization of the raw water wells in the system for total pumping capacity (TPC) and firm pumping capacity (FPC) scenarios including monthly and yearly averages. During peak summer months the raw water well pumps are operating 46% of the time (approximately 11.0 hours per day) assuming all pumps are in service and theoretically 66% of the time (approximately 15.8 hours per day) if the largest well pump was out of service (i.e., firm pumping capacity). Well utilization is an important key performance indicator that should be regularly tracked and assessed. It provides a quick reference to remaining system capacity, changes in seasonal demand, and can provide insight into system performance/operational issues when considered in conjunction with other operational parameters (such as pump run time).

![Figure 2-2: Average Groundwater Pumping Capacity Utilization (July 2013 to June 2018)](image)

**Figure 2-2: Average Groundwater Pumping Capacity Utilization (July 2013 to June 2018)**

### 2.2 TRANSMISSION AND DISTRIBUTION SYSTEM

As briefly discussed in Section 1.0, the City operates a non-potable transmission system and a potable transmission and distribution system. Table 2-2, Table 2-3, and Table 2-4 provide a summary of pipe lengths based on pipe size, pipe material, and installation year, respectively.

In general, depreciation schedules for pipe materials range from 60 to 100 years. The oldest pipe in the system is approximately 55-years old. As this pipe continues to age, the City should ensure that leaks, breaks, and repairs are recorded and mapped to help develop capital improvement projects. Doing this will help ensure the most effective use of water system funds as pipes age and approach the end of their usable lives.
### Table 2-2: Potable and Non-Potable Pipe Diameter Summary

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Potable Pipe Length (ft)</th>
<th>Potable Length (mi)</th>
<th>Non-Potable Pipe Length (ft)</th>
<th>Non-Potable Length (mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>89,700</td>
<td>17.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>349,800</td>
<td>66.3</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>10</td>
<td>34,200</td>
<td>6.5</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>12</td>
<td>81,100</td>
<td>15.4</td>
<td>3,800</td>
<td>0.7</td>
</tr>
<tr>
<td>14</td>
<td>39,500</td>
<td>7.5</td>
<td>9,300</td>
<td>1.8</td>
</tr>
<tr>
<td>16</td>
<td>150</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>18</td>
<td>65,800</td>
<td>12.5</td>
<td>25,100</td>
<td>4.8</td>
</tr>
<tr>
<td>20</td>
<td>1,600</td>
<td>0.3</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>24</td>
<td>25</td>
<td>0.0</td>
<td>15,000</td>
<td>2.9</td>
</tr>
<tr>
<td>30</td>
<td>5,200</td>
<td>1.0</td>
<td>3,300</td>
<td>0.6</td>
</tr>
<tr>
<td>36</td>
<td>8,700</td>
<td>1.6</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>42</td>
<td>3,300</td>
<td>0.6</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total Length</strong></td>
<td><strong>679,075</strong></td>
<td><strong>128.6</strong></td>
<td><strong>56,600</strong></td>
<td><strong>10.7</strong></td>
</tr>
</tbody>
</table>

### Table 2-3: Potable and Non-Potable Pipe Material Summary

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Potable Pipe Length (ft)</th>
<th>Potable Length (mi)</th>
<th>Non-Potable Pipe Length (ft)</th>
<th>Non-Potable Length (mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos Concrete</td>
<td>131,500</td>
<td>24.9</td>
<td>3,500</td>
<td>0.7</td>
</tr>
<tr>
<td>PVC</td>
<td>547,600</td>
<td>103.7</td>
<td>53,100</td>
<td>10.1</td>
</tr>
<tr>
<td><strong>Total Length</strong></td>
<td><strong>679,100</strong></td>
<td><strong>128.6</strong></td>
<td><strong>56,600</strong></td>
<td><strong>10.7</strong></td>
</tr>
</tbody>
</table>

### Table 2-4: Potable and Non-Potable Pipe Installation Year Summary

<table>
<thead>
<tr>
<th>Installation Decade</th>
<th>Potable Pipe Length (ft)</th>
<th>Potable Length (mi)</th>
<th>Non-Potable Pipe Length (ft)</th>
<th>Non-Potable Length (mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960’s</td>
<td>16,400</td>
<td>3.1</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>1970’s</td>
<td>111,200</td>
<td>21.1</td>
<td>1,300</td>
<td>0.2</td>
</tr>
<tr>
<td>1980’s</td>
<td>95,700</td>
<td>18.1</td>
<td>2,200</td>
<td>0.4</td>
</tr>
<tr>
<td>1990’s</td>
<td>187,700</td>
<td>35.6</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>2000’s</td>
<td>264,500</td>
<td>50.1</td>
<td>53,100</td>
<td>10.1</td>
</tr>
<tr>
<td>2010’s</td>
<td>3,600</td>
<td>0.7</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total Length</strong></td>
<td><strong>679,100</strong></td>
<td><strong>128.6</strong></td>
<td><strong>56,600</strong></td>
<td><strong>10.7</strong></td>
</tr>
</tbody>
</table>

1 In most cases pipe length has been rounded to the nearest 100-feet. As a result of rounding error, the total length of pipe reported may be slightly different between Table 2-2, Table 2-3, and Table 2-4.

Table 2-5 summarizes the booster stations in the water system. The NE Booster station is operated by the water level in the Raw Water tank and pumps water from the Blend tank into the Raw Water tank pressure zone prior to being conveyed to the water treatment plant for treatment. In other words, the NE Booster station is required to pump water from Wells 9 and 9A into the Raw Water tank for use at the water treatment plant. The Sage Ranch booster station is operated by the water level in the Sage Ranch tank for eventual...
distribution of potable water to the Sage Ranch pressure zone(s). It should be noted that the Sage Ranch pressure zone(s) have a relatively small number of connections compared to the main pressure zone.

Table 2-5: Booster Station Summary

<table>
<thead>
<tr>
<th>Station</th>
<th>Raw/Potable</th>
<th>Capacity (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE Booster</td>
<td>Raw</td>
<td>715 (580)³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,300 (1,125)³</td>
</tr>
<tr>
<td>Sage Ranch</td>
<td>Potable</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td></td>
<td>285</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
</tr>
</tbody>
</table>

¹ The flow from the N.E. Booster station decreases to the rate shown in (parentheses) when Well 14 is running.

### 2.3 STORAGE

The City of Fernley utilizes non-potable and potable water tanks to operate the water system. Table 2-6 provides information about each of the tanks in the City’s system. Two raw water tanks are filled by system wells (see Table 2-1) and provide a stable flow of raw water to the water treatment plant. Prior to distribution, water is held in a WTP Contact tank until 4-log disinfection is achieved. Although this tank provides additional storage of treated water, it is not located at a high enough elevation to supply water if there were a system malfunction. Treated water is pumped (up to 14,000 gpm) to the distribution system by way of a high-pressure transmission main, pressure reducing valves and three primary water storage tanks. In general, the distribution system operates as an “open” system that floats on the Ricci, Northeast, and Sage tanks. The Sage Ranch booster station supplies water to the Sage Ranch tank which is 200-feet higher than the main pressure zone.

All City potable water tanks are designed to provide operational, emergency and fire storage (see NAC 445A.6674 through 6675). The amount of water designated for operational storage can vary between and even within systems based on system demands and hydraulics. The emergency storage volume can also vary, but a volume of 75% of operational storage is generally considered adequate. Fire storage volume is dictated by the local fire authority and is commonly based on the International Fire Code Table B105.1(2). System administrators, manager, and operators should monitor tank operational parameters to ensure that adequate storage volume is identified to meet each of these required parameters.
Table 2-6: System Storage Summary

<table>
<thead>
<tr>
<th>Tank</th>
<th>Raw/Potable</th>
<th>Overflow Capacity (gal)</th>
<th>Operational Capacity (gal)</th>
<th>Diameter (ft)</th>
<th>Overflow Depth (ft)</th>
<th>HGL Overflow Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Water</td>
<td>Raw</td>
<td>2,461,000</td>
<td>2,397,000</td>
<td>105</td>
<td>38</td>
<td>4342</td>
</tr>
<tr>
<td>Blend</td>
<td>Raw</td>
<td>94,000</td>
<td>90,000</td>
<td>27</td>
<td>22</td>
<td>4176</td>
</tr>
<tr>
<td>WTP Contact</td>
<td>Raw(^{ii})</td>
<td>1,616,000</td>
<td>1,599,000</td>
<td>110</td>
<td>23</td>
<td>4214</td>
</tr>
<tr>
<td>Sage Ranch</td>
<td>Potable</td>
<td>533,000</td>
<td>515,000</td>
<td>55</td>
<td>30</td>
<td>4542</td>
</tr>
<tr>
<td>Ricci</td>
<td>Potable</td>
<td>1,501,000</td>
<td>1,462,000</td>
<td>82</td>
<td>38</td>
<td>4342</td>
</tr>
<tr>
<td>Northeast</td>
<td>Potable</td>
<td>2,559,000</td>
<td>2,488,000</td>
<td>110</td>
<td>36</td>
<td>4342</td>
</tr>
<tr>
<td>Sage</td>
<td>Potable</td>
<td>2,461,000</td>
<td>2,397,000</td>
<td>105</td>
<td>38</td>
<td>4342</td>
</tr>
<tr>
<td><strong>Raw Storage Total</strong></td>
<td></td>
<td><strong>4,172,000</strong></td>
<td><strong>4,086,000</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Potable Storage Total</strong></td>
<td></td>
<td><strong>7,054,000</strong></td>
<td><strong>6,862,000</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{i}\) Operational storage assumes that the “High Tank” setpoint to shutdown water supply to the specific tank zone is one foot below the overflow depth. This level can vary from tank to tank depending on system hydraulics, SCADA system responsiveness, tank diameter, etc.

\(^{ii}\) Although water in the WTP Contact tank has been treated, it is not at an elevation to supply water in the event of a system malfunction; therefore, the operational capacity of the WTP Contact tank is not included as potable water storage in this chapter.

### 2.4 WATER TREATMENT

The City of Fernley operates a 20 MGD water treatment plant to treat raw groundwater from the City’s groundwater wells. The primary contaminant that the City provides treatment for is arsenic. Historical raw water and current potable water arsenic concentrations are shown in Table 2-7. The maximum contaminant level for arsenic is 10 µg/L.

Table 2-7: Raw Groundwater (2005 to 2009) and Potable Water Arsenic and TDS (2017) Concentrations \(^{i}\)

<table>
<thead>
<tr>
<th>Well</th>
<th>Arsenic Maximum Conc (µg/L)</th>
<th>Arsenic Minimum Conc (µg/L)</th>
<th>TDS Maximum Conc (µg/L)</th>
<th>TDS Minimum Conc (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well 4</td>
<td>43</td>
<td>33</td>
<td>577</td>
<td>430</td>
</tr>
<tr>
<td>Well 9</td>
<td>52</td>
<td>43</td>
<td>924</td>
<td>800</td>
</tr>
<tr>
<td>Well 9A</td>
<td>62</td>
<td>38</td>
<td>880</td>
<td>750</td>
</tr>
<tr>
<td>Well 11</td>
<td>60</td>
<td>43</td>
<td>560</td>
<td>225</td>
</tr>
<tr>
<td>Well 13</td>
<td>63</td>
<td>45</td>
<td>450</td>
<td>360</td>
</tr>
<tr>
<td>Well 14</td>
<td>71</td>
<td>45</td>
<td>720</td>
<td>590</td>
</tr>
<tr>
<td>Treated Water(^{ii})</td>
<td>4</td>
<td>4</td>
<td>550</td>
<td>470</td>
</tr>
</tbody>
</table>

\(^{i}\) (Nevada Division of Environmental Protection, n.d.; City of Fernley, 2017)

\(^{ii}\) (Consumer Confidence Report, 2017)
The City’s 2017 Consumer Confidence Report (CCR) and the EPA’s Safe Drinking Water Information System (SDWIS) were reviewed. Potable water meets drinking water standards and the City has not been subject to any health based or monitoring violations in recent years.

### 2.5 SYSTEM DEMAND

Within the City’s service area, water flows are metered at numerous locations. Water metering locations include raw water wells, water treatment plant influent, water treatment plant effluent, booster pump stations, select pressure release valve (PRV) stations (i.e., Mesa Drive PRV), and at all customer service connections. For the purpose of this plan, water meter data at the raw water wells (source) and customer service connections (end user) were reviewed and analyzed. Figure 2-3 shows the monthly average groundwater pumping along with the cumulative pumping capacity of the City’s groundwater wells. The groundwater pump capacities are not shown in any particular order and are included to provide a comparison of monthly pumpage to combined pump capacity. The monthly average groundwater pumping also provides the seasonal demand curve. This seasonal demand curve is typical, showing increased system demand during warmer months when irrigation occurs and reduced demand during cooler non-irrigation months. Maximum summer pumpage is 3.1 times higher than minimum wintertime pumpage.

![Figure 2-3: Monthly Average Groundwater Pumpage and Cumulative Capacity](image-url)

Table 2-8 shows the average annual pumping rate and total pumpage for each well in the system. The average yearly pumpage (or the “groundwater demand”) from July 2013 to June 2018 is 3,944 AF. Current groundwater demand from Fernley’s municipal wells is approximately 44 percent of the 8,900 AFA municipal groundwater rights owned by the City.
Table 2-8: Average Annual Groundwater Pumpage by Well (July 2013 to June 2018)

<table>
<thead>
<tr>
<th>Well</th>
<th>Average Annual Pumping Rate (gpm)</th>
<th>Pumpage (AFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well 4</td>
<td>1,003</td>
<td>807</td>
</tr>
<tr>
<td>Well 8</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Well 9A</td>
<td>488</td>
<td>393</td>
</tr>
<tr>
<td>Well 11</td>
<td>1,549</td>
<td>1,246</td>
</tr>
<tr>
<td>Well 13</td>
<td>567</td>
<td>456</td>
</tr>
<tr>
<td>Well 14</td>
<td>1,284</td>
<td>1,033</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>–</strong></td>
<td><strong>3,944</strong></td>
</tr>
</tbody>
</table>

Figure 2-4 shows the percentage of revenue water (customer meter volume divided by well pumpage). The remaining percentage, what is not sold to customers, is commonly referred to as non-revenue water. From 2015 through 2018, revenue water in the City fluctuated between 78.7% and 88.5% on an annual basis, with a non-weighted average of 85.2%. There are numerous factors that can contribute to non-revenue water, including, system leaks, process losses at the water treatment plant, water meter inaccuracies, system flushing, unbilled authorized consumption, unmetered connections, and unauthorized or illegal consumption.

Figure 2-4: Annual Percentage of Revenue Water

Well pumpage data were evaluated to determine potable system demand. Table 2-9 provides a summary of the system demand and the equivalent demand per EDU for the average day demand (ADD) and estimates for the maximum day demand (MDD) and peak hour demand (PHD) based on both data sets. Multipliers of 2.1 and 2.0 were used for MDD to ADD and PHD to MDD, respectively. It should be noted that the City uses an Equivalent Residential Capacity (ERC) convention of 1,000 gpd for planning purposes.
Table 2-9: Water System Demand

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Well Pumpage Records (January 2015 to December 2017)</th>
<th>Rate per EDU^1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>System Rate (gpm)</td>
<td>Rate per EDU (gpd/EDU)</td>
</tr>
<tr>
<td>ADD</td>
<td>2,433</td>
<td>480</td>
</tr>
<tr>
<td>MDD (estimated)</td>
<td>5,108</td>
<td>1,008</td>
</tr>
<tr>
<td>PHD (estimated)</td>
<td>10,217</td>
<td>2,015</td>
</tr>
</tbody>
</table>

^1 EDU count of 7,300 used.

2.6 SYSTEM CAPACITY ANALYSIS

Minimum water system capacity requirements are established in NAC 445A sections 6672 through 66755. Although interrelated, water system capacity is often broken down into two components, water supply and water delivery. The focus of this memorandum is to focus on source water; therefore, the focus of this section will be on water supply capacity. NAC 445A.6672(3) requires that the water system has capacity to meet the following scenarios:

(a) Maximum day demand + fire demand with all water sources functioning
(b) Average day demand + fire demand with the most productive well out of service

NAC 445A allows for a combination of water supply wells and storage to satisfy the requirements. Table 2-10 provides a summary of the available system capacity, storage requirements, and excess storage capacity for the groundwater wells and potable storage tanks in the Fernley water systems for each scenario presented above. The analysis is based on a 24-hour period and assumes that there are 7,300 EDU’s in the water system. The capacity analysis did not consider treatment plant capacity since rated treatment plant capacity significantly exceeds well pumping capacity. Additional description of this analysis includes the following:

- “Potable Tank Storage” – It is assumed that each potable water tank is filled to its operational capacity (see Table 2-6) at the beginning of the 24-hour analysis period.
- “Well Supply in Excess of Demand” – This is the volume of water pumped in excess of the MDD or ADD, depending on the scenario (see Table 2-9). Under the “ADD + Fire without Largest Source”^1 scenario, the largest well is assumed to be out of service. This assumes 100% utilization of each well for a 24-hour period (see Table 2-) and that the aquifer has adequate capacity to sustainably operate at 100% pumping capacity.
- “Available System Capacity” – This is the total system capacity (tanks and wells over a 24-hour period) in excess of the system demand.
- “Fire Storage” – Fire demand is assumed to be 2,000 gpm for 2-hours. Typical residential dwellings (under 3,600 ft^2) have a fire demand of 1,000 gpm for 1-hour. However, a higher fire demand was assumed to compensate for larger dwellings, commercial properties, and industrial properties. Ultimately, fire demand should be determined by the Fire Department.
- “Operating Storage” – Operating storage was assumed to be equivalent to the ADD for 24-hours.
- “Emergency Storage” – Emergency storage was calculated to be 75% of the operating storage.
Table 2-10: Existing Customer Base System Capacity Analysis (7,300 EDU’s)

<table>
<thead>
<tr>
<th>Storage Type</th>
<th>MDD + Fire with All Sources</th>
<th>ADD + Fire without Largest Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capacity Requirement (kgal)</td>
<td>Capacity Balance (kgal)</td>
</tr>
<tr>
<td>Potable Tank Storage</td>
<td>6,862</td>
<td>6,862</td>
</tr>
<tr>
<td>Well Supply in Excess of Demand</td>
<td>4,970</td>
<td>5,152</td>
</tr>
<tr>
<td><strong>Available System Capacity</strong></td>
<td><strong>11,832</strong></td>
<td><strong>12,014</strong></td>
</tr>
<tr>
<td>Fire Storage</td>
<td>240</td>
<td>11,592</td>
</tr>
<tr>
<td>Operating Storage</td>
<td>3,503</td>
<td>8,089</td>
</tr>
<tr>
<td>Emergency Storage</td>
<td>2,627</td>
<td>5,462</td>
</tr>
</tbody>
</table>

Based on this analysis, the system has the source and storage capacity to meet the requirements of NAC 445A.6672. The “MDD + Fire with All Sources” is the limiting scenario and the analysis shows that there is a remaining system capacity of 5,462 kgal. Under the “MDD + Fire with All Sources” the existing well pumping infrastructure and potable storage tank system could theoretically support an additional 2,956 EDU’s¹, or 10,256 total EDU’s, without system expansion. Table 2-11 provides the two capacity analysis scenarios considering 10,256 EDU’s based on the excess capacity shown in Table 2-10.

Table 2-11: Existing System Maximum Capacity Analysis (10,256 EDU’s)

<table>
<thead>
<tr>
<th>Storage Type</th>
<th>MDD + Fire with All Sources</th>
<th>ADD + Fire without Largest Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capacity Requirement (kgal)</td>
<td>Capacity Balance (kgal)</td>
</tr>
<tr>
<td>Potable Tank Storage</td>
<td>6,862</td>
<td>6,862</td>
</tr>
<tr>
<td>Well Supply in Excess of Demand</td>
<td>1,991</td>
<td>3,733</td>
</tr>
<tr>
<td><strong>Total System Capacity</strong></td>
<td><strong>8,853</strong></td>
<td><strong>10,595</strong></td>
</tr>
<tr>
<td>Fire Storage</td>
<td>240</td>
<td>8,613</td>
</tr>
<tr>
<td>Operating Storage</td>
<td>4,921</td>
<td>3,691</td>
</tr>
<tr>
<td>Emergency Storage</td>
<td>3,691</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Capacity Requirement (kgal)</th>
<th>Capacity Balance (kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Storage</td>
<td>240</td>
<td>10,355</td>
</tr>
<tr>
<td>Operating Storage</td>
<td>4,921</td>
<td>5,434</td>
</tr>
<tr>
<td>Emergency Storage</td>
<td>3,691</td>
<td>1,743</td>
</tr>
</tbody>
</table>

3.0 SOURCES OF WATER

As stated in Section 2.1, the City of Fernley currently holds rights to both groundwater and surface water resources in and adjacent to the Fernley Hydrographic Area and is currently using groundwater sources to supply all water system demands. The City is pursuing water system improvements which would allow for the conveyance and treatment of surface water for distribution as well.

3.1 GROUND WATER CHARACTERIZATION

Ongoing characterization of the groundwater in the Fernley Hydrographic Area and adjacent areas is critical for the City of Fernley to sustainably meet existing demand and will serve obligations. Many efforts have

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¹ The number of additional EDU’s includes 900 will serves.
been completed to characterize the groundwater within and adjacent to the Fernley Hydrographic Area and include works by Epstein, et al (2007), Pohll, et al (2001; 2004), and Katzer, et al (1998). These efforts have provided a limited characterization of groundwater resources nor have they provided a definitive policy for future groundwater management.

3.1.1 Water Budget

Previous studies have contributed data and developed groundwater budgets for the Fernley Hydrographic Area as presented in Table 2-12. A water budget through 1973 was developed for Reconnaissance Report 57. In a subsequent study, documented by United States Geological Survey Open File Report 84-712, refined the budget for the Fernley Hydrographic Area based on data through the year of 1979. More recent water budgets were developed by the Desert Research Institute and included in Appendix H of Evaluation of groundwater and solute transport in the Fernley - Wadsworth area (Pohll, et al., 2001). These water budgets are presented in Table 2-12 for reference.

The 2018 water budget relies on information and relationships presented in previous studies. Additional studies have been reviewed to develop an estimate of the groundwater budget through 2019, presented in Table 2-12. This water budget was developed utilizing an estimate for basin groundwater pumpage from 2015 from the Nevada Division of Water Resources, an updated precipitation recharge estimate from a Desert Research Institute modeling study, and reductions of certain quantities as noted in Table 2-12 adjacent to the estimate. For example, it was assumed that the volume of surface water outflow to the Brady’s Hot Springs Hydrographic Area is related to irrigation deliveries and tailwater within the Fernley area. Similarly, the DRI water budgets estimate that approximately 40% of the irrigation diversions are used by the crops for evapotranspiration. This percentage was applied to the 2018 future water. For the purpose of this plan, the validity of values in previous studies were not evaluated and additional studies were not performed to provide an analysis of perennial and/or system yield.
### Table 2-12: Fernley Hydrographic Area Water Budget

<table>
<thead>
<tr>
<th>Components</th>
<th>Estimate of Basin Water Budget, AFA</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1973 (^i)</td>
<td>1979 (^ii)</td>
</tr>
<tr>
<td>Natural Recharge</td>
<td>608</td>
<td>608</td>
</tr>
<tr>
<td>Groundwater</td>
<td></td>
<td>Denburgh and Others, 1985 and 1973</td>
</tr>
<tr>
<td>Inflow</td>
<td></td>
<td>Future Groundwater Supply</td>
</tr>
<tr>
<td>Importation (Brady's HSA 75)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Treated Effluent</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Surface Water (Truckee River Diversion)</td>
<td></td>
<td>Denburgh and Others, 1985 and 1973</td>
</tr>
<tr>
<td>Truckee Canal Seepage</td>
<td>55,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Irrigation Diversions in Basin</td>
<td>26,000</td>
<td>13,350</td>
</tr>
<tr>
<td>City of Fernley Diversions</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**In Basin Subtotal:** 55,608 44,608 27,425 17,923  

| Groundwater Discharge               |                                      | Denburgh and Others, 1985 and 1973                                         |
| Truckee River Basin                 | 4,200 | 9,000 | 9,000 | 4,200 | Original estimate of 2,100 AF to both Tracey and Dodge Flat HSAs |
| Brady Hot Springs Basin             | 1,000 | 1,000 | 1,000 | 1,000 | No change in estimates                                                   |
| Carson Desert                       | 800 | 400 | 400 | 800 | Original estimate of 800 AF to Carson Desert                             |
| Surface Water Outflow               |                                      | Reduced irrigation eliminates tailwater flows                               |
| Brady Hot Springs Basin             | 4,000 | 4,000 | 4,000 | 0    | Reduced irrigation eliminates tailwater flows                             |

**Outflow**

| Evapotranspiration                  |                                      | Denburgh and Others, 1985 and 1973                                         |
| Reservoir/Lake Evaporation          | 6,120 | 6,100 | 1,500 | 1,796 | Lowering of groundwater levels reduces ET Closure term.                  |
| Phreatophytes and Playa             | 7,600 | 4,200 | 2,900 |          | Lowering of groundwater levels reduces ET                                  |
| Cropland                            | 39,000 | 15,000 | 5,400 | 1,360 | 40% of Fernley Irrigation Diversions                                     |
| Basin Groundwater Use               |                                      | 2015 Groundwater Estimate (includes domestic) \(^iv\)                        |
| Surface Water                       | - | - | 2,356 | 5,867 | Pending Fernley Surface Water Treatment                                  |
| Importation (Brady's HSA 75)        | - | - | - | - | Pending Development                                                       |

**Municipal Water Use**

| Subtotal                            | 55,120 | 43,700 | 27,856 | 17,923 |                          |

**Imbalance (Inflow minus Outflow):** 488 908 -431 0  

\(^i\) (Van Denburgh, Lamke, & Hughes, 1973)  
\(^ii\) (Van Denburgh & Arteaga, 1985)  
\(^iii\) Includes 1,898 AFA from the South Virginia Range, 285 AFA from the Virginia Range, and 292 AFA from the Truckee Range  
\(^iv\) (Nevada Division of Water Resources, 2017)
A few key inflow and outflow components which were not included in all previous study include return flows due to treated wastewater effluent and impacts as a result of geothermal activities. While these components are not anticipated to provide a significant volume of inflow or outflow; each component has a potential to impact the water budget in the Fernley Hydrographic Area. A water budget for the future condition will be provided as part of Chapter 3.

3.1.2 Hydrogeology

Although groundwater models have been completed, the stratigraphy of the alluvial basin is poorly documented. The depth to bedrock was evaluated in the report titled *A Gravity and Magnetic Fields Derived Bedrock Elevation Model for the Fernley/Wadsworth Basin, Washoe and Lyon Counties, Nevada* (Widmer, 2001) and Table 2-13 shows the generalized production potential based on a limited review of resistivity geophysical logs.

A break in the alluvial sequence has been also observed in the Carson Desert Hydrographic Area at a depth of 770 ft where locally the occurrence of a mudstone unit separates granite derived sediment from volcanic sourced sediment. This significant change in depositional environments may be coincident with the aquitards encountered from 750 to 850 ft in the Fernley Hydrographic Area.

<table>
<thead>
<tr>
<th>Depth Below Ground Surface (Feet, Below Ground Surface)</th>
<th>Production Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 250</td>
<td>Moderate capacity aquifers</td>
</tr>
<tr>
<td>250 to 380</td>
<td>High capacity aquifers</td>
</tr>
<tr>
<td>380 to 470</td>
<td>Intervals containing moderate aquitards</td>
</tr>
<tr>
<td>470 to 750</td>
<td>Significant aquifers</td>
</tr>
<tr>
<td>750 to 880</td>
<td>Significant aquitards</td>
</tr>
<tr>
<td>880 to 1,010</td>
<td>Locally Significant aquifers</td>
</tr>
</tbody>
</table>

3.1.3 Groundwater Level Data

Studying historical water level trends is a fundamental process for understanding impacts to aquifers and estimating groundwater budgets. For example, a declining water level may indicate that the basin budget is in a deficit, prompting subsequent investigation into the cause of the decline which may be from decreased recharge or increased pumping in the basin or by activities outside of the basin. The Nevada Division of Water Resources and United States Geologic Survey do not collect water level data in the Fernley Hydrographic Area.

The Truckee Canal is documented to provide a significant amount of recharge to the Fernley Hydrographic Area. A drought which extended from the mid-1980s through the mid-1990s resulted in decreased diversions to the Truckee Canal for delivery to TCID for several years. Depth to groundwater during this time increased from reduced groundwater recharge from seepage of surface water from the Truckee Canal. Since approximately 2005, groundwater levels in the wells have remained fairly steady and, in some cases, have increased.
3.1.4 Water Quality

Water quality within the Fernley Hydrographic Area varies significantly and includes water derived from recent recharge as well as bicarbonate water with low total dissolved solids (TDS). Recharge from irrigation water diversions mixes with typically high TDS sulfate-chloride water which occurs at depth and outside the areas of canal seepage and irrigation.

The Safe Drinking Water Information System (SDWIS) provides a database for each of the City of Fernley wells from 1990 through 2008 and for the combined outflow from 2008 to present for the water treatment plant. Arsenic is currently the only constituent that exceeds the Nevada maximum contaminant level (MCL) for raw water. The City exceeds the EPA recommended secondary maximum contaminant level (SMCL) for TDS but remains below enforceable State MCLs. Concentrations in the northeast part of the basin are 3 times the Nevada SMCL of 1,000 mg/L which is twice the EPA SMCL of 500 mg/L. Total dissolved solids and sulfate concentrations appear to have been increasing by approximately 3.5 percent per year which could be a result of sampling methods, blending percentages or degrading water quality. However, the degradation of water quality is typically non-linear and a significant change to the hydrogeologic setting (e.g., lining the Truckee Canal) may result in an increased rate of degradation in water quality.

Aquifer storage and recovery may require treatment prior to storage and again after recovery from the aquifer. Minimizing treatment by improved characterization of water quality variations may be able to decrease treatment costs significantly. Numerous water quality investigations have been completed and should be reviewed before developing a sampling plan. Since only limited deep-water quality data are available for the aquifer downhole sampling should be completed for the deeper wells. Sampling of the deeper aquifers is most economical during pump or well maintenance. The sampling plan should be part of a groundwater management plan and viewed as a preventative measure to avoid increased treatment costs in the future. Additionally, any future project which utilizes groundwater or the aquifer as a water source or storage facility (e.g., ASR) should also include an assessment of groundwater quality as a cornerstone of the feasibility of the project.

3.2 SURFACE WATER

In order to realize the full benefit of all available water resources, utilization of surface water presents significant benefits to the City. Surface water could be utilized in many ways, including:

- Direct diversion with treatment and distribution,
- Direct diversion with treatment and storage in the aquifer for extraction at later date, and/or
- Treatment and distribution with a combination of upstream storage, aquifer storage and extraction.

There are benefits and drawbacks to each alternative and it is recommended that the City pursue a more detailed study into the conjunctive use of its water resources prior to selecting a preferred management strategy.

The City currently has the rights to approximately 10,000 AFA under Claim No. 3 of the Orr Ditch Decree and upstream storage in multiple Truckee River storage reservoirs. The City’s Claim No. 3 water rights hold a relatively senior priority in comparison to other water rights in the Orr Ditch Decree. However, the capability to store water in upstream reservoirs is key to provide a reliable water source in average precipitation years and through periods of drought. Storage of water in the reservoirs must be consistent with the provisions of the Truckee River Operating Agreement (TROA). Per TROA, storage in upstream reservoirs is based on a priority system which changes depending on reservoir storage capacity, drought conditions, and management actions. TROA allows the City to store approximately 10,000 AF of credit water during normal hydrologic conditions. In 2017, Fernley executed a contract with the United States Bureau of Reclamation (USBR) that authorizes Fernley to store its water in Bureau managed reservoirs in accordance with TROA. The City has the fifth lowest storage priority which means its credit water in
storage may be subject to being reduced in heavy precipitation years. Section 7.F of TROA (Fernley Municipal Credit Water), and the contract with the USBR, establishes the City’s rights to upstream storage and when the water can be used.

In subsequent chapter’s, this plan will consider the impacts of TROA and analyze the firm yield of the City’s Claim No. 3 water rights in conjunction with the reservoir storage authorized under TROA.

4.0 WATER SOURCE ALTERNATIVES

The purpose of this section is to review alternatives to provide additional groundwater and/or surface water supply to the City of Fernley. This section will specifically review aquifer storage, recharge, and recovery (ASR) alternatives and water importation. This memorandum is not intended to provide any new analysis of these options nor recommendations for implementation; but rather to provide a general discussion of ASR options, a summary of previous work and a discussion of the benefits of each of the alternatives. Previous studies have been completed which include information highlighting the importance of finding, developing and utilizing alternative water supplies. Reports reviewed include:

- Acquiring and Operating an Aquifer Storage, Recharge, and Recovery Program in Nevada (Stanka Consulting, Ltd., 2011)
- Evaluation of Soil Deposits for an Aquifer Storage, Recharge, and Recovery Program in the Fernley Hydrographic Basin (Stanka Consulting, LTD., 2012)
- City of Fernley Water Supply Supplemental Storage Analysis (Stanka Consulting, Ltd., 2013)

4.1 AQUIFER STORAGE AND RECOVERY PROGRAM

In the early 2010’s the City of Fernley completed several investigations considering the feasibility of an Aquifer Storage and Recovery (ASR) program. An ASR program recharges an alternative water source (e.g., surface water) into the groundwater aquifer for storage until the water is extracted for use at a later time. Water is introduced to the aquifer either through infiltration basins or groundwater recharge wells to increase the quantity of water recharging the aquifer. This artificially recharge water can be pumped out of the aquifer and treated for potable uses. There are numerous factors that can impact the cost and success of an ASR program, including:

- the recoverability characteristics of the aquifer;
- permitting requirements and costs;
- construction, operation, and maintenance costs;
- water quality sampling and monitoring costs;
- increased risk of contaminating the aquifer;
- and added operational complexity.

The City filed an application for an ASR project with NDWR. However, the application was protested by the US Bureau of Reclamation (USBR) and later withdrawn by the City. The development of an ASR project remains a viable policy option for future consideration.

4.2 WATER IMPORTATION

Another potential source of water is importing groundwater from adjacent hydrographic basins. Table 2-14 lists hydrographic basins adjacent to the Fernley Hydrographic Area. Among other things, this table includes the perennial yield as determined by the Nevada Division of Water Resources and the current permitted volume of use. Of the basins listed in Table 2-14, the only basins that have remaining viable capacity for the City are the Brady’s Hot Springs and Fernley Hydrographic Areas (State of Nevada Division of Water Resources, 2018). The City of Fernley already holds water right permit 80184 which allows for up to 6.0 CFS or 2,100 AFA to be pumped from the Brady’s Hot Springs Basin. No project has been completed to construct the required wells and transmission system to convey this water to Fernley for
beneficial use. A proof of completion is required to be filed by December 1, 2020. Accordingly, efforts to characterize and develop the groundwater resource should start immediately.

### Table 2-14: Summary of Adjacent Hydrographic Basins

<table>
<thead>
<tr>
<th>Hydrographic Basin Name</th>
<th>Hydrographic Basin Number</th>
<th>Perennial Yield (AFY)</th>
<th>Underground Use – Municipal (AFY)</th>
<th>Underground Use – Other (AFY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernley</td>
<td>076</td>
<td>600</td>
<td>8,900</td>
<td>2,741</td>
</tr>
<tr>
<td>Brady’s Hot Springs</td>
<td>075</td>
<td>2,500</td>
<td>2,100</td>
<td>42</td>
</tr>
<tr>
<td>Pyramid Lake Valleyi</td>
<td>081</td>
<td>7,000</td>
<td>0.00</td>
<td>55</td>
</tr>
<tr>
<td>Dodge Flat</td>
<td>082</td>
<td>2,100</td>
<td>0.00</td>
<td>2,217</td>
</tr>
<tr>
<td>Tracy Segment</td>
<td>083</td>
<td>11,600</td>
<td>7,810</td>
<td>3,750</td>
</tr>
<tr>
<td>Carson Desert</td>
<td>101</td>
<td>2,500</td>
<td>5,908</td>
<td>14,618</td>
</tr>
<tr>
<td>Churchill Valley</td>
<td>102</td>
<td>1,600</td>
<td>0.00</td>
<td>9,354</td>
</tr>
</tbody>
</table>

i The City of Fernley holds water right permit 80184 for this water.

ii The City unsuccessfully attempted to appropriate waters in this basin in the late 1990’s. Securing additional rights in this basin is deemed unfeasible.

### 5.0 WATER CONSERVATION PLANNING

The City has a long history of complying with water conservation planning requirements with at least four previous studies being completed. While the most recent plan was completed in 2016, the NDWR currently provides the 2008 City of Fernley Water Conservation Plan (Stanka, 2008) as the document of record on their web site. Additionally, routine water conservation planning is a requirement of the USBR to utilize the Claim 3 municipal water. Farr West has reviewed the 2008 and 2016 water conservation plans and did not find any recommended actions which would be in conflict of any recommendations of this plan.

### 6.0 THREATS TO EXISTING AND FUTURE WATER RESOURCES

For the City to provide a reliable water supply to its customers, it must consider potential changes which may affect its water sources and supply. These threats are typically out of a water supplier’s control, however, with proper management and planning their impacts can be mitigated. This section identifies potential threats to the City’s existing and future water sources. Recommendations as to how the City can prepare for these threats is further discussed in Chapter 3.

### 6.1 REGULATORY ACTION

As discussed throughout this chapter, the City’s water sources are governed by State and Federal regulatory guidelines, water rights, the Orr Ditch Decree, TROA, and other contracts. The water available to the City from the Fernley Hydrographic Area and the Truckee River is also utilized by other entities and individuals according to their appropriation and priority.

The Nevada State Engineer (NSE) has the ability to regulate groundwater usage within a hydrographic basin by limiting water rights based on the priority dates of appropriations. If, in the NSE’s judgement, the hydrographic basin is over-appropriated and being overdrawn, the NSE can issue a curtailment Order. A curtailment Order establishes which water rights can be exercised, and which cannot, to protect the long-term health of the aquifer. This potential for a curtailment order represents a risk to the City if the NSE chooses to curtail based on the perennial yield. However, as discussed in Chapters 1 and 2, the perennial yield does not account for all recharge to the aquifer.
In addition, the City should monitor the development of new regulations. Conjunctive use regulations are currently being developed in the Humboldt Regional Hydrographic Basin. While previous legislative sessions have resulted in conjunctive use management statements, there are no specific regulations to guide how groundwater and surface water interaction or conflict will work through the existing permitting process. If new conjunctive use management regulations are developed, it may impact the City’s ability to change and exercise permitted and certificated groundwater rights.

Other potential regulatory actions that the City should consider include:

- Modification to activities and uses which impact basin inflows and outflows.
- Future reduction in water quality MCLs.

### 6.2 DROUGHT AND CLIMATE CHANGE

The City experiences a climate typical of the high desert or arid west and receives an average of five inches of rain per year. Although the City currently uses only groundwater sources, surface water in the region plays a large role in the availability of all water. As discussed in Chapter 1, the operation of the Truckee Canal for deliveries to TCID, which began in 1905, is well understood to provide a significant amount of groundwater recharge. The amount of water available for diversion by TCID is dependent on snowpack in the upper Truckee Basin and the resulting flow in the Truckee River. Figure 2-5 shows water year (October through September) flow at the Truckee River at Farad.

**Figure 2-5: Annual Flow for Truckee River at Farad (California Nevada River Forecast Center)**
As shown in Figure 2-5, an extended period of below average flow in the Truckee River occurred from the mid-1980s through the mid-1990s. This resulted in decreased diversions to the Truckee Canal for delivery to TCID. Groundwater levels during this time also declined which is assumed to be a result of the reduced surface water in the Truckee Canal to recharge the groundwater basin through seepage. When the City begins to rely on its surface water source, low precipitation years and drought will play an even larger role in water availability. The City requested Precision Water Resources Engineering to perform an analysis to estimate the amount of municipal demand which could be reliably served by its surface water rights. The results documented in *City of Fernley Municipal Surface Water Demand – Firm Yield Study* (Gacek, 2016) indicate that, through the use of storage capacity in the Truckee Basin Reservoirs, a significant amount of surface water will be available even through prolonged droughts. The 50-year model period used for the *Firm Yield Study* relied on hydrology from 1966 through 2015, which includes the prolonged drought during the mid-1980s through the mid-1990s. Chapter 3 and Chapter 4 will detail system management strategies which will provide the City the ability to fully utilize their full appropriation of water, ground and surface, year over year.

In addition to droughts, which are temporary, climate change is expected to have lasting effects on the availability of future water supplies. Climate is used in reference to weather conditions prevailing in an area over a long period of time. No climate study or evaluation was undertaken for the purpose of this Plan, but TMWA’s Water Resources Plan was reviewed and referenced regarding climate change and climate predications. Climate simulations do not provide strong consensus regarding precipitation trends as a result of climate change (Truckee Meadows Water Authority, 2016). Additionally, the California Department of Water Resources (CDWR) released a report *California Climate Science and Data for Water Resources Management* (California Climate Science and Data for Water Resources Management, 2015). This report included the Truckee River Basin as part of the North Lahontan hydrologic region. CDWR summarized the key climate vulnerabilities for the North Lahontan region as:

- Increased air and water temperatures would place additional stress on sensitive ecosystems and species;
- Loss of snowpack storage may reduce reliability of surface water supplies and result in greater demand on groundwater resources;
- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk; and
- Higher temperatures and longer dry seasons would increase wildfire risk.

CDWR provides a list of Resource Management Strategies that water supplies can consider as tools to adapt to climate change. The following are CDWR recommended Resource Management Strategies for the climate vulnerabilities identified:

- **Urban Water Use Efficiency:** Practices that maximize use of available water supplies by reducing waste and increasing efficiency.
- **System Reoperation:** Changing existing operation and management procedures for a water resources system consisting of supply and conveyance facilities and end user demands with the goal of increasing desired benefits from the system.
- **Conjunctive Management and Groundwater Storage:** Coordinated and planned use and management of surface water and groundwater resources to maximize the availability and reliability of water supplies.
- **Surface Storage – Regional/Local:** Human-made, above-ground reservoirs to collect water for later release when needed. Surface storage has played a key role where the quantity, timing, and location of water demand frequently does not match the natural water supply availability.
Although the timing and magnitude of warming and other climate change factors are unknown, resource management strategies such as those listed above will be useful considerations for climate change adaptation. Through the City's addition of a surface water supply in the near future, it will be critical to enact the strategies listed above and be able to continue use of these Resource Management Strategies through many different water supply conditions.

6.3 CONTAMINATION

The City is dedicated to providing quality service by consistently ensuring that an ample supply of safe drinking water is provided. Section 2.4 and Section 3.1.4 discuss water treatment and water quality of the potable water supply. This section focuses on protection of source water quality and ensuring water quality is maintained after leaving the treatment plant.

6.3.1 Groundwater

Changes to the water quality of the City’s groundwater sources can occur in one of two ways:

1. The concentrations of naturally occurring constituents could change over time, or
2. Groundwater sources could become contaminated as a result of human activities.

Currently, the naturally occurring constituent which poses the most immediate threat to groundwater sources is TDS. The City should routinely monitor TDS concentrations throughout the basin and develop future water sources based on their interrelation with high TDS concentrations. In order to reduce contamination threats, it is recommended that the City continue its Community Source Water Protection Plan (CSWPP) and monitor industrial and commercial uses in the basin for conformance with the CSWPP.

6.3.2 Surface Water

Although the City is not currently using surface water as a supply source, the City will need to develop a surface water quality monitoring program. The Truckee River is expected to provide a high-quality water source. The Truckee River is supplied by snowpack runoff and seepage or streamflow; however, diversions from the Truckee River for use by the City will occur downstream from the Cities of Reno and Sparks. In addition, the City’s treatment facilities will need to be capable of treating Truckee River water during possible events of high turbidity or chemical or biological contamination. Types of contamination events include:

- Turbidity events – normally low frequency events that are flushed by river flows within hours.
- Non-persistent toxic spills – spills of substances that would be flushed by river flows within an 8-hour period.
- Persistent toxic spills – spills lasting more than 2-4 days that do not flush through the river channel.

6.3.3 Distribution System

The City relies upon state certified water treatment and distribution system operators who continually monitor water quality in the distribution system. All testing and monitoring are done in conformance with established federal and state health and safety standards. The City prepares an annual water quality Consumer Confidence Report which provides an overview of the previous year’s drinking water quality data. The City provides high quality water which meets and exceeds all US Safe Drinking Water Act standards and meets or exceeds US Environmental Protection Agency and Nevada State Health standards. The City also has a backflow prevention and cross-connection control program. The purpose of this program is to prevent backflow of pollutants or contaminants from customer plumbing systems into the City’s distribution system.
6.4 CONVEYANCE METHODS

On January 5, 2008, a breach occurred in the Truckee Canal which resulted in an uncontrolled flow of water onto irrigated lands and a portion of the City. Although TCID acted quickly and sealed the breach within hours, approximately 590 properties were affected, and surface water diversions were interrupted. This event shows the importance of regular canal monitoring and maintenance to prevent similar failures from occurring.

7.0 SUMMARY/RECOMMENDATIONS

The following recommendations should be considered in detail to ensure effective and sustainable potable water system operations.

1. Water Conservation & Water Audit – Water conservation measures are governed by City of Fernley Municipal Code Title 28.05 and state law. Assembly Bill (AB) 163 was approved by Governor Sisolak on June 3, 2019. AB 163 requires the adoption of a plan of water conservation which includes a water loss audit. The water audit should define revenue and non-revenue water in the system and make recommendations on how to cost-effectively reduce water losses and non-revenue water.

2. Groundwater Monitoring Plan – Aquifer water levels are currently monitored and measured on a regular basis. Water quality needs to be added to the plan to include both production wells and monitor wells. Strategic water quality monitoring will allow the water system to minimize costly water treatment. The plan should be revised based on the primary goals of the plan including but not limited to:
   a. Keep data collection costs low.
   b. Identify additional data gaps.
   c. Partner with other parties to the greatest extent possible.
   d. Provide straightforward process for evaluating data on frequent basis.
   e. Develop hydrographs and cross sections of aquifers, aquitards with their associated water quality data.

3. Utilization of Surface Water – The ability to utilize existing surface water resources as a potable water supply is the most beneficial project the City can currently pursue to ensure the sustainability of their system.

4. Upstream Storage – As the City becomes more reliant on surface water in the future, upstream storage should be actively managed to provide the City with the maximum volume of storage allowable. If available, additional upstream storage should also be pursued on a permanent or long-term lease basis. Finally, the City should support regulatory actions which would allow for the City to store credit water year-round.

5. Induction Wells – A detailed study into the feasibility of constructing a surface water induction well adjacent to the Truckee River should be pursued in the future. In addition to an induction well providing an alternative to surface water treatment costs, potential benefits of an alternative surface water diversion facility are discussed in Chapter 3 and Chapter 4.

6. Reuse of Treated Effluent – The City should begin planning for the management of their treated effluent as a future water resource. Whether the water is used to offset irrigation uses, basin recharge or as a potential Indirect Potable Reuse (IPR) project; proper management of treated effluent can provide significant benefits to a utility instead of a burden. At a minimum, the City should monitor or be engaged in the effluent management policy and developments in adjacent communities to be well positioned to meet the City’s future effluent management needs.
CHAPTER 3: MANAGEMENT OF WATER RESOURCES

1.0 PURPOSE

The purpose of this chapter is to provide analysis and recommendations related to how the City of Fernley (City) manages its groundwater and surface water resources to meet water service demands on an annual and long-term basis.

2.0 SURFACE WATER AND GROUNDWATER MANAGEMENT

As discussed in the prior chapters, the City will be constructing facilities to use the Truckee River as a surface water supply in conjunction with its current groundwater supplies. This section will analyze the relationship between the City’s water resources including the use and availability of Truckee River surface water rights, reservoir storage rights, and groundwater rights.

2.1 SURFACE WATER

The City has acquired approximately 9,700 AFA of water previously appropriated under Claim No. 3 of the Orr Ditch Decree. Claim No. 3 was originally appropriated for irrigation purposes and, although the rights are approved for municipal and industrial purposes, the diversion season under these rights is limited to periods “as decreed” by the Federal Water Master. To provide supply resiliency and drought storage, the City negotiated a Contract for Storage of Municipal Credit Water with the US Bureau of Reclamation (USBR) which allows use of the City’s Claim No. 3 water rights to establish Fernley Municipal Credit Water in upstream reservoirs. Once the surface water diversion facilities are constructed and all approvals are in place, the City will have Claim No. 3 water rights and Fernley Municipal Credit Water available for its use.

2.1.1 Truckee River Operating Agreement

On November 16, 1990, Public Law (PL) 101-618 enacted the Truckee-Carson-Pyramid Lake Water Rights Settlement Act. PL 101-618 provides for interstate allocation of the waters of the Truckee River, Carson River, and Lake Tahoe between the States of Nevada and California subject to a new operations agreement for the Truckee River (i.e., the Truckee River Operating Agreement (TROA)). TROA was signed by the five mandatory signing parties and other parties, including the City, on September 6, 2008. In November 2015, the parties completed all requirements to implement TROA, and it was officially implemented December 1, 2015. TROA is meant to provide for modified river and reservoir operations that result in multiple benefits for water users, endangered fish species, recreation, and additional drought storage in the upstream reservoirs.

In 2009, the City entered into an agreement with USBR which established the procedures the City will follow before using the Truckee Canal for delivery of its Claim No. 3 water rights. Further, in order for the City to take advantage of the benefits provided to it under TROA, the City must execute the negotiated Contract for Storage of Municipal Credit Water between the City and USBR, which will allow the City to store approximately 10,000 AF in Truckee River Reservoirs as permitted under TROA. This Contract was executed during 2017, and the City can establish (or collect to storage) Fernley Municipal Credit Water under the provisions of Section 7.F of TROA. When its Claim No. 3 water rights are in priority as decreed, the City will have the opportunity to directly divert up to 9,700 AF of water to the Truckee Canal or establish Fernley Municipal Credit Water in storage at Truckee River Reservoirs. Because the City has not yet exercised its Truckee River water rights, it is not known if the season of diversion will be limited to the irrigation season, typically about March 15 through November 15.
2.1.1.1 Surface Water Demand and TROA

Precision Water Resources Engineering performed a study to determine the amount of surface water that was reliably available to the City by exercising its 10,000 AFA\(^2\) of Claim No. 3 water rights in conjunction with its upstream storage capacity under TROA. The results of this study are documented in *City of Fernley Municipal Surface Water Demand – Firm Yield Study* (Gacek, 2016). There is seemingly conflicting direction between TROA Section 7.F.1 and the Nevada State Engineer’s Ruling No. 6102 regarding the periods in which diversion can take place; therefore, the Firm Yield Study considered two scenarios – one which permits the City to establish credit water throughout the entire calendar year and the other which only allows the City to establish credit water during the irrigation season.

Multiple surface water demand volumes were considered with the balance of the available surface water used to establish Fernley Municipal Credit Water in storage for each scenario. For example, the model with a surface water demand of 6,000 AF had a credit storage goal of 4,000 AFA. Over a 50-year period, including sustained periods of drought, the Firm Yield Study determined the yield of each scenario to be:

- Scenario 1. Credit storage through the year, firm yield of 6,250 AFA
- Scenario 2. Credit Storage only during irrigation season, firm yield of 5,750 AFA

The study defined the firm yield as the surface water demand in which the City is able to just meet its surface water demands throughout the run with no excess credit water in storage at the end of the most severe drought in the model period. The firm yield was limited to demand scenarios which had a zero balance of credit storage at the end of the drought sequence with no shortage, even if those shortfalls were less than 100 ac-ft. This is a conservative definition of firm yield and the study continues to state that a greater firm yield could be achieved through exchanges permitted under TROA. Further review of the modeled surface water demands indicates that the City could reliably meet a surface water demand of 6,500 AFA under both diversion season scenarios.

Under Scenario 1, a shortage of 1,930 AF occurred in one year out of the 50-year model period (i.e., a supply shortage occurred in 2% of the years). Under Scenario 2, shortages of 573 AF and 16 AF occurred in consecutive years during the 50-year model period (i.e., a supply shortage occurred in 4% of the years). As mentioned above, the study used conservative assumptions. However, the City will have management options available to it, such as exchanges under TROA and imposing conservation requirements, to ensure that customer demands are met even through a prolonged drought. Figures and tables in this section referring to the Firm Yield Study are based on results of the RiverWare model provided by Precision Water Resources Engineering for a surface water demand of 6,500 AFA under Scenario 1. Figure 3-1 shows the average monthly use of Claim No. 3 water rights, credit water use, and surface water shortage.

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\(^2\) For the purpose of the Firm Yield Study, Precision Water Resources Engineering rounded the volume of water available to the City under its Claim No. 3 water rights to 10,000 AFA.
Figure 3-1: Average Monthly Use of Surface Water Under Scenario 1

The Firm Yield Study indicates that Fernley Municipal Credit Water will not be required to meet surface water demand in the majority of years. Table 3-1 summarizes the percent of years in the model period in which Fernley Municipal Credit Water was used to meet surface water demand. Fernley Municipal Credit Water was used in at least one month during 22 percent of the years. This table shows that Claim No. 3 water right supply is most likely to not meet the City’s modeled surface water demand of 6,500 AF during June through September; however, Fernley Municipal Credit Water is projected to make up the difference between demand and supply in all but 2 percent of years.

Table 3-1: Percent of Time Credit Water is Used Under Scenario 1

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
<td>8%</td>
<td>14%</td>
<td>20%</td>
<td>16%</td>
<td>0%</td>
<td>0%</td>
<td>22%</td>
</tr>
</tbody>
</table>

When the surface water facilities are in place, the City can reliably use 6,500 AF of surface water annually to meet its customers demand. The remaining portion of the City’s Claim No. 3 water rights available in a given year, up to 3,500 AFA, should be used to establish Fernley Municipal Credit Water in storage.

2.1.1.2 Management of Fernley Municipal Credit Water

The terms pertaining to Fernley Municipal Credit Water are in TROA Section 7.F. As discussed above, it is recommended that the City uses its Claim No. 3 water rights to establish up to 3,500 AFA in Fernley Municipal Credit Water after meeting its surface water demands. Key provisions of TROA that effect Fernley Municipal Credit Water are summarized below:

- When a drought does not exist, the amount of Fernley Municipal Credit Water in excess of 10,000 AF in storage on April 1 will be converted to Fish Credit Water.
- When a drought does exist, the City has the right to retain all of its Fernley Municipal Credit Water in storage, including that in excess of 10,000 AF and that established after April 1.
- Fernley Municipal Credit Water has the fifth lowest storage priority (i.e., the City’s credit water in storage is fifth in line to spill if a higher priority category of water requires space in the reservoir); however, the City may be able to use exchanges to move its water to a different reservoir prior to spill or divert the spilled water at the Truckee Canal if capacity and operations allow.
The City will need to closely manage its Fernley Municipal Credit Water in storage. This will include determining when to accumulate credit water instead of diverting it directly under its Claim No. 3 water rights and when to initiate release of the credit water.

It is important to note that Fernley Municipal Credit Water will accrue losses after being released from the upstream reservoir. As discussed above, Fernley Municipal Credit Water was needed during 22 percent of the years in the model period (i.e., 11 years out of the 50-year period). Figure 3-2 shows the average monthly use of Claim No. 3 water rights, credit water use, and surface water shortage for the 11 years in the model period during which the City would need to use Fernley Municipal Credit Water. These losses are accounted for in the Firm Yield Study and considered in the reliability of the surface water supply.

![Figure 3-2: Average Monthly Surface Water Use in Years with Credit Water under Scenario 1](image)

**Figure 3-2: Average Monthly Surface Water Use in Years with Credit Water under Scenario 1**

The average amount of Fernley Municipal Credit Water used in these 11 years is 1,196 AF. However, in order for this amount to be available for diversion to the City, an average of 2,596 AF is needed to be released from the upstream reservoirs to account for transportation losses. The losses associated with delivery of Fernley Municipal Credit Water will vary from year to year based on hydrologic conditions and the amount of other Credit Water currently in the system. Based on the assumptions used in the Firm Yield Study, losses averaged approximately 54 percent.

**2.1.2 Use of Surface Water**

The Truckee Canal is maintained and operated by the Truckee-Carson Irrigation District (TCID) for diversion of its Claim No. 3 water rights for use within the Newlands Project. Diversions to the Truckee Canal for water users within TCID occur during the irrigation season from March 15 through November 15. Therefore, even if the City’s Claim No. 3 water rights were decreed to be available outside of the irrigation season, the City may not be able to divert that water to the Truckee Canal. This limitation would also apply to the use of the City’s Fernley Municipal Credit Water in storage. For the purposes of this Plan, and consistent with assumptions in the Firm Yield Study, it is assumed that this diversion season limit exists. However, the City should coordinate with TCID and USBR to determine if there are options for the City to divert its surface water, whether Fernley Municipal Credit Water or Claim No. 3 water, year-round.

From July 2013 through June 2018, the City pumped an average of 3,934 AFA from its municipal groundwater supply wells. When the City begins using its surface water supply, it is unlikely that total system demands will be considerably greater than this, especially when considering that surface water use
will be limited to the irrigation season. It is assumed that the City will maximize use of its Claim No. 3 water rights from March 15 through November 15 and allow the remaining balance not needed to accumulate as Fernley Municipal Credit Water in storage. In dry years, when the flow in the Truckee River system is insufficient to meet the City’s surface water demand, the City should initiate releases of its Fernley Municipal Credit Water to meet the deficit. The City should continue to maximize its surface water diversions until it reaches 6,500 AFA.

2.2 GROUNDWATER

The City will continue to rely solely on its groundwater sources, with a current pumpage of approximately 4,000 AFA, until its surface water facilities have been constructed and all necessary approvals are in place. When the City is able to utilize its surface water source, the City should manage its surface water and groundwater sources in an integrated manner. Assuming that diversion of surface water to the Truckee Canal will be limited to March 15 through November 15, the City will need to use its groundwater supply source the remainder of the year. Demand during these months is typically lower because customers are not irrigating landscape. At a minimum, the City will continue to pump groundwater to meet wintertime (November through February) demands even after the surface water supply is in use. As the population and water demand increase, the wintertime demand supplied by groundwater will also increase. When future demands during March 15 through November 15 exceed the firm surface water supply of 6,500 AFA, then groundwater will also be pumped year-round to ensure customer demands are met.

2.3 INTEGRATED USE OF GROUNDWATER AND SURFACE WATER

With the addition of the surface water source, the City will be able to reduce its groundwater pumping from March 15 through November 15 until future population growth and associated future water demands require water in addition to the surface water supply. Using groundwater as a lower priority resource to supplement surface water resources will allow the aquifer to recharge. Using groundwater as a lower priority source to surface water will also result in greater well efficiency from reduced drawdown and may improve groundwater quality. Groundwater wells with higher TDS should be utilized concurrent with surface water to allow for blending of the higher TDS groundwater.

2.3.1 Current Demand

From July 2013 through June 2018, the City pumped an average of 3,934 AFA from its municipal groundwater supply wells. This current annual demand was distributed on the monthly pattern relied upon for the Firm Yield Study. Figure 3-3 uses this monthly demand pattern to provide an example water year supply using both surface water and groundwater. The monthly water demand was compared to surface water availability from the Firm Yield Study over the 50-year model period.
Figure 3-3: Average Monthly and Cumulative Water Use (Demand of 3,934 AFA)

As shown in Figure 3-3, the current demand can be supplied over the 50-year model period with no instances of surface water supply shortage. In this example, an average 3,261 AF of Claim No. 3 water rights would be used annually along with 145 AF of Credit Water\(^3\) and 528 AF of groundwater to meet customer demands. As mentioned above, groundwater will be needed to meet demand between November 15 and March 15.

### 2.3.2 Future Demand

Scenario 1 of the Firm Yield Study considered a total demand of 10,000 AF based on 6,500 AF surface water and 3,500 AF groundwater. Based on the annual demand distributed over the monthly pattern, groundwater would be pumped in every month of the year with surface water supplementing the supply from March 15 through November 15. Figure 3-4 shows the monthly surface water delivery from Figure 3-1 with the monthly groundwater supply.

---

\(^3\) Credit Water is only needed to meet demands during seven of the 50-year model period. During these seven years, the average amount of Credit Water used to meet customer demands is 1,016 AFA.
Figure 3-4: Average Monthly and Cumulative Water Use (Scenario 1 Demand of 10,000 AFA)

As demands within the City approach 10,000 AFA as illustrated in Figure 3-4, the City should review its monthly demand pattern and perform a new delivery study to model integrated management of groundwater and surface water considering an annual demand in excess of the current Firm Yield Study. An updated model run could also include TCID operations and deliveries under TROA which were not known at the time of the Firm Yield Study.

As discussed in Chapter 1, the City holds municipal water rights to approximately 11,000 AFA of groundwater, 8,900 AFA of which is appropriated within the Fernley Hydrographic Area and has infrastructure in place. The remaining 2,100 AF is within the Brady’s Hot Springs Hydrographic Area and there is not currently infrastructure in place to utilize these water rights. Based on an analysis dated March 2018, there are 7,315 lots within the City which have 4,665 AF committed (Stanka Consulting, 2018). This equates to an average dedication of 0.638 AF per equivalent dwelling unit (EDU). The current volume being dedicated per lot is based on the following equation:

\[
\text{Demand} = 1.4 \times \left( \frac{1.0}{1.1 + \left(\frac{10,000}{\text{Lot Size}}\right)} \right)
\]

Table 3-2 summarizes the total number of EDU’s which can be served by each water source. Based on the current average dedication rate of 0.638 AF per EDU, 20,117 additional EDU’s can be dedicated with the City’s existing water rights. Adding this number to the existing customer base results in a total system size of 27,432 EDU’s. As shown in Chapter 2, the average day demand is 480 gallons per day per EDU or 0.55 AFA per EDU. The annual volume of water needed to serve 27,432 EDU’s is estimated to be 15,088 AFA, which is slightly less than the 17,500 AFA of water rights volume available for dedication. The difference between the volume dedicated and the projected demands provides a factor of safety or safe yield in water supplies which help ensure adequate water resources during dry periods.

---

4 This number of additional EDU’s will change based on the type of development that is proposed and permitted in the future. Because the dedication rate is based on lot size, any deviation from historical average residential lot sizes will affect this estimate.
Table 3-2: Potential EDU’s per Water Supply Source

<table>
<thead>
<tr>
<th>Water Supply Source</th>
<th>Groundwater Fernley Area (In Use)</th>
<th>Groundwater Fernley Area (Future)</th>
<th>Groundwater Brady’s Hot Springs Area</th>
<th>Surface Water Truckee River Firm Yield</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumes Available for Dedication (AFA)</td>
<td>4,665</td>
<td>4,235</td>
<td>2,100</td>
<td>6,500</td>
<td>17,500</td>
</tr>
<tr>
<td>EDUs Served using Current Dedication Rate (EDU)</td>
<td>7,315</td>
<td>6,638</td>
<td>3,291</td>
<td>10,188</td>
<td>27,432</td>
</tr>
<tr>
<td>Projected Demands Using 0.55 AFA/EDU (AFA)</td>
<td>4,023</td>
<td>3,651</td>
<td>1,810</td>
<td>5,603</td>
<td>15,088</td>
</tr>
</tbody>
</table>

i Italics indicate the current volume which has already been dedicated by the City along with the associated EDU’s and demands. All other values in the table represent potential or buildout EDU’s based on the current average dedication rate.

ii The number of additional EDU’s includes 900 will serves currently issued by the City.

3.0 UPDATED WATER BUDGET

A current water budget, through 2018, for the Fernley Hydrographic Area is presented in Chapter 2. This water budget was developed based on review of multiple studies and reports prepared for the area. The 2018 water budget is presented in Table 3-3 along with an estimated future water budget. The explanation column described changes between the 2018 and future water budget, which considers land use within the Fernley area and the City’s water supply and refers to sources in Chapter 2.

The future water budget relies on information and relationships presented in previous studies. For example, it was assumed that the volume of surface water outflow to the Brady’s Hot Springs Hydrographic Area is related to irrigation deliveries and tailwater within the Fernley area. Similarly, Appendix H of a Desert Research Institute (DRI) modeling study provides water budgets for 1993 and 1996. These water budgets estimate that approximately 40% of the irrigation diversions are used by the crops for evapotranspiration. This percentage was applied to both the 2019 and future water budgets conditions. The City should support agriculture and irrigation in the area so that water is not moved out of the Fernley Hydrographic Area.
### Table 3-3: Fernley Hydrographic Area Future Water Budget

<table>
<thead>
<tr>
<th>Components</th>
<th>Estimate of Basin Water Budget, AFA</th>
<th>2018</th>
<th>Future</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inflow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Recharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater</td>
<td>Inflow</td>
<td>2,475</td>
<td>2,475</td>
<td></td>
</tr>
<tr>
<td>Importation (Brady's HSA 75)</td>
<td>0</td>
<td>2,100</td>
<td></td>
<td>City of Fernley Groundwater Permit</td>
</tr>
<tr>
<td>Treated Effluent</td>
<td>Re-use of Groundwater</td>
<td>1,088</td>
<td>3,543</td>
<td></td>
</tr>
<tr>
<td><strong>Surface Water (Truckee River Diversion)</strong></td>
<td>Truckee Canal Seepage</td>
<td>11,000</td>
<td>11,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irrigation Diversions in Basin</td>
<td>3,360</td>
<td>3,360</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City of Fernley Diversions</td>
<td>0</td>
<td>6,500</td>
<td></td>
</tr>
<tr>
<td><strong>In Basin Subtotal:</strong></td>
<td></td>
<td>17,923</td>
<td>28,978</td>
<td></td>
</tr>
<tr>
<td><strong>Outflow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater Discharge</td>
<td>Truckee River Basin</td>
<td>4,200</td>
<td>4,200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brady Hot Springs Basin</td>
<td>1,000</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carson Desert</td>
<td>800</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td><strong>Surface Water Outflow</strong></td>
<td>Brady Hot Springs Basin</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Evapotranspiration</strong></td>
<td>Reservoir/Lake Evaporation</td>
<td>1,796</td>
<td>1,560</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phreatophytes and Playa</td>
<td>2,900</td>
<td>2,900</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cropland</td>
<td>1,360</td>
<td>1,360</td>
<td></td>
</tr>
<tr>
<td><strong>Basin Groundwater Use</strong></td>
<td>City Municipal Use</td>
<td>3,796</td>
<td>7,674</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Domestic</td>
<td>472</td>
<td>472</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commercial/Industrial Use</td>
<td>1,210</td>
<td>1,210</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irrigation</td>
<td>389</td>
<td>389</td>
<td></td>
</tr>
<tr>
<td><strong>Municipal Surface Water Use</strong></td>
<td>Surface Water</td>
<td>-</td>
<td>5,603</td>
<td></td>
</tr>
<tr>
<td><strong>Municipal Imported Water Use</strong></td>
<td>Importation (Brady's HSA 75)</td>
<td>-</td>
<td>1,810</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal:</strong></td>
<td></td>
<td>17,923</td>
<td>28,978</td>
<td></td>
</tr>
<tr>
<td><strong>Imbalance (Inflow minus Outflow):</strong></td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
4.0 **LONG-TERM WATER RIGHTS STRATEGY**

Long-term water rights strategy should be considered to protect and maximize the water supply. These strategies will allow the City to manage water rights proposed to be dedicated, acquire strategic water rights and maintain beneficial use, and develop new water resources to supply users within the service area. Such strategies may include water right purchase and long-term leasing, water importation, effluent water distribution, and conjunctive use strategies.

4.1 **ESTABLISH DEDICATION RATE POLICY**

Senate Bill (SB) 250 was approved by Governor Sisolak on June 5, 2019. SB 250 resulted in changes to Nevada Revised Statutes to require that before a water supplier can require the dedication of a right to appropriate water to ensure a sufficient water supply certain parcels, the dedication requirement must be:

1. Required pursuant to an ordinance, rule, regulation, or any other requirement adopted by the water supplier;
2. Based on reliable data and procedures estimating demand;
3. Consider any requirements for a sustainable water supply; and
4. Consider historic usage by similar existing water services.

The analyses presented in this Water Resources Plan could be used as the support for adopting a dedication requirement. The City should present its dedication rate analysis to the Nevada State Engineer.

4.2 **WATER RIGHT BANKING AND LEASING AGREEMENTS**

Banking agreements are tools that can be utilized to acquire water rights in advance of the dedication process, thereby allowing additional time to perform due diligence and water right permitting.

The City is currently holding water rights under various agreements in order to maintain and develop the water supply to allow for additional development. These tools allow for the City to acquire water rights and manage the development of those resources as growth occurs within the service area. These can, and have, provided the City the ability to utilize these water rights while other water sources are in development.

4.3 **PROTECTION OF GROUNDWATER SOURCES**

As detailed in Section 2.3 and Table 3-2, the City will require utilization of all water right holdings to maximize future dedications. Additionally, projected groundwater demands at buildout are assumed to peak at 7,673 AF within the Fernley Hydrographic Area. Any unforeseen condition or regulatory action which would impact the City’s ability to dedicate up to 8,900 AF of water and meet the average demand of 7,673 AF of water should be considered a significant threat to the sustainability of the water system.

Sufficient water rights should be strategically positioned at wells to optimize pumping energy efficiency and water quality. The inability to position water rights for optimal production efficiency and water quality may require additional infrastructure including production wells, waterlines, and treatment for TDS compared to if water rights are optimally located.

4.4 **CREDIT WATER AND SPILL**

Long-term, the City will need to determine how best to manage its Credit Water. In the event that the City has more than 10,000 AF of Fernley Municipal Credit Water in storage in a non-drought year, then the City should take delivery of as much of the water in excess of 10,000 AF as possible prior to it converting to Fish Credit Water on April 1. There may also be years during which the City has 10,000 AF or more of Fernley Municipal Credit Water in storage during the March 15 through November 15 period. It may be more beneficial for the City to take delivery of its Claim No. 3 water instead of establishing additional Credit Water. In other words, the City may want to divert its entire amount of Claim No. 3 water available,
up to 9,700 AF. New water storage facilities, including those resulting in groundwater recharge, could allow for full use of these water rights.

Section 5.C.3 of TROA states that water spilled may be used by its owner. For the City, the use of spilled Fernley Municipal Credit Water must be in accordance with Section 7.F2 which allows use of Fernley Municipal Credit Water to include:

- Municipal and industrial use,
- Temporary use for re-vegetation of former agricultural lands,
- Dilution flows or other measures to satisfy the water quality standards for effluent-based wetlands, and
- For purposes of a project for recharge, storage, and recovery of water permitted pursuant to Nevada Revised Statutes.

The *Firm Yield Study* indicates that Fernley Municipal Credit Water spills during 58 percent of the years under Scenario 1. Table 3-4 summarizes the percent of months and years in the model period during which Fernley Municipal Credit Water spilled from upstream reservoirs. This table shows that Credit Water spill may occur during any month of the year, with spill most commonly occurring during January.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>24%</td>
<td>16%</td>
<td>22%</td>
<td>20%</td>
<td>18%</td>
<td>12%</td>
<td>6%</td>
<td>4%</td>
<td>4%</td>
<td>10%</td>
<td>10%</td>
<td>18%</td>
<td>58%</td>
</tr>
</tbody>
</table>

Based on the current assumption that the City’s diversions to the Truckee Canal can only occur from March 15 through November 15, the City will not be able to use the spilled water without additional infrastructure. However, spills which do occur during this time period should be rediverted at the Truckee Canal for use by the City. Depending on the City’s future water demands, it may be beneficial for the City to construct an alternative surface water diversion facility, so that all surface water, including spill, can be used at any time throughout the year. Such a facility would not be necessary until the City’s demands exceed 10,000 AFA at which time new demand and diversion scenarios should be modeled as discussed in Section 2.3.2. Projected growth and water demands are discussed in Chapter 4.

It is possible that spill of Fernley Municipal Credit Water will occur at times when the City does not have demand for the volume spilled. This may lead to the development of an aquifer storage and recovery (ASR). Future ASR projects will be discussed in more detail in Chapter 4.

### 5.0 REMAINING FACILITY CAPACITY

As the City grows, it will be important to know the limiting factors of its water facilities. This section provides an estimate of remaining capacity, in number of EDU’s, for each component of the water system in its current condition. This section considers the remaining capacity of the water production, storage, and transmission facilities.

#### 5.1 WATER PRODUCTION FACILITIES

The firm pumping capacity of the City’s potable supply wells is 6,010 gpm\(^5\). In Chapter 2, it was determined that the maximum day demand (MDD) is 5,108 gpm or 0.70 gpm per EDU. Therefore, considering approximately 7,300 EDU’s are currently served, the remaining supply capacity of the groundwater wells is 1,289 EDU’s at MDD.

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\(^5\) The firm pumping capacity is defined in Chapter 2 as the combined production capacity of the City’s municipal wells with the largest well out of service.
The other system component which complements production or supply capacity is storage capacity. This plan’s recommended requirements for storage capacity are as follows:

- **“Fire Storage”** – Fire demand is assumed to be 2,000 gpm for 2-hours. Typical residential dwellings (under 3,600 ft$^2$) have a fire demand of 1,000 gpm for 1-hour. However, a higher fire demand was assumed to compensate for larger dwellings, commercial properties, and industrial properties. Ultimately, fire demand should be determined by the Fire Department.
- **“Operating Storage”** – Operating storage was assumed to be equivalent to the average day demand (ADD) for 24-hours.
- **“Emergency Storage”** – Emergency storage was calculated to be 75% of the operating storage.

The City currently has 6.86 million gallons of potable storage capacity. Considering the above requirements and an ADD of 480 gallons per day, this storage is adequate for 7,886 EDU’s. The remaining storage capacity can supply an additional 586 EDU’s. However, as discussed in Chapter 2, NAC 445A allows for a combination of water supply wells and storage to satisfy water system capacity requirements. This analysis determined that the existing well pumping infrastructure and potable storage tank system could theoretically support an additional 2,956 EDU’s, or 10,256 total EDU’s, without system expansion or improvement.

The final consideration in water supply production capacity is the water treatment plant. The City’s water treatment plant has a design capacity of 20 MGD. The current MDD is estimated to be 7.36 MGD. The treatment plant’s remaining capacity of 12.64 MGD could serve an additional 12,548 EDU’s or a total system size of 19,848 EDU’s.

The limiting factor of the current water production facilities are the water supply wells and storage facilities, combined, which limit the capacity of the system to 10,256 EDU’s. As the City develops its surface water facilities and water use approaches 10,256 EDU’s, it will also need to construct adequate potable water storage tanks to meet its demands. It is also important to consider system configuration and pipe capacities, as some areas of the City may be more conducive to additional EDU’s than others.

### 5.2 WATER TRANSMISSION FACILITIES

The City’s water transmission facilities consist of over 125 miles of pipeline, three pressure reducing valve (PRV) vaults, four storage tanks, and the water treatment plant. The current capacity of the storage tanks and the water treatment plant is described in Section 5.1. Capacity of the transmission facilities was determined by evaluating the maximum flow through key pipelines in the system before the NAC 445A velocity requirement (8 ft/s) is exceeded. The key pipelines include:

- the high-pressure transmission main from the water treatment plant to the system,
- the 18-inch pipeline connecting the Ricci tank to the distribution system,
- the 18-inch pipeline connecting the Sage tank to the distribution system, and
- the 18-inch pipeline connecting the Northeast tank to the distribution system.

The water treatment plant is connected to the City’s distribution system by a single 42-inch diameter main. The main can convey up to 34,500 gpm of flow before reaching 8 ft/s. This equates to a total capacity of 49,339 EDU’s. With the treatment plant being able to produce a maximum of 19,841 EDU’s, the transmission main can convey all water produced by the existing water treatment plant.

Theoretically, all the pipelines connecting the storage tanks should reach 8 ft/s at a flow of 6,350 gpm which would equate to a maximum day demand of 27.4 MGD or a system size of 27,214 EDU’s. However, due to system hydraulics and the water treatment plant’s ability to meet demands throughout the day, the hydraulic model was required to run multiple demand scenarios in order to identify the specific system demand scenario which resulted in each tank’s connection main exceeding the 8 ft/s criteria. It was found that the Ricci tank main exceeds the criteria at a system demand of 41 MGD or 40,700 EDU’s, the Sage...
tank main reaches 8 ft/s at 50 MGD or 49,400 EDU’s, and the Northeast tank main exceeds this capacity criteria at 66 MGD or 65,000 EDU’s. Using this criteria it is appropriate to limit the maximum capacity of the existing water transmission system to 40,700 EDU’s, attributable to the Ricci tank connection main.

Additionally, there were specific locations or assets in the model which appeared to be out of regulatory compliance during high flow, Peak Hour Demand (PHD) scenario. More specifically, the section of the system downstream of the Mull PRV station appears to be a current chokepoint. These capacity issues should be able to be resolved with minor improvements and should not be considered the limiting component of the water distribution system as part of a water resource plan. Table 3-5 provides a summary of existing and remaining capacity for water system infrastructure.

Table 3-5: Remaining Water System Facility Capacity

<table>
<thead>
<tr>
<th>Component</th>
<th>Total Capacity (EDU)</th>
<th>Remaining Capacity (EDU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply (Groundwater Wells) ii</td>
<td>8,589</td>
<td>1,289</td>
</tr>
<tr>
<td>Storage ii</td>
<td>7,886</td>
<td>586</td>
</tr>
<tr>
<td>Storage + Supply (NAC 445A)</td>
<td>10,256</td>
<td>2,956</td>
</tr>
<tr>
<td>Water Treatment Plant</td>
<td>19,841</td>
<td>12,548</td>
</tr>
<tr>
<td>Water Transmission System</td>
<td>40,700</td>
<td>33,400</td>
</tr>
</tbody>
</table>

i Remaining capacity estimate uses a current EDU count of 7,300.

ii Remaining capacity estimate provided for informational purposes only. The remaining capacity estimate generated by the storage plus supply analysis should be used in place of these more limited evaluations since regulations (NAC 445A) allow for both systems to be assessed together. However, the analysis indicates that storage is more limited than supply.

The remaining capacity values in Table 3-5 for supply (1,289 EDU’s) and storage (586 EDU’s) should not be used to determine remaining system capacity, but rather provide an indication of how storage and supply relate within the system. Because less connections could theoretically be supported by the current storage capacity than by the current supply infrastructure, this indicates that additional storage capacity will be needed to support new customers. As additional customers are added to the system, it is recommended that the City evaluate the associated tank zone(s) and consider constructing additional storage.
CHAPTER 4: FUTURE WATER RESOURCES

1.0 PURPOSE

This chapter presents projected population and water demands and discusses water resource management strategies that can be considered or pursued in order for the City of Fernley (City) to meet these water demands.

2.0 FUTURE POPULATION GROWTH AND WATER DEMANDS

The City’s population has more than doubled since becoming incorporated in 2001. The Fernley area transitioned from a rural agriculture and ranching community to what is now a bedroom community or commuter town. The expansion and growth of industrial development in the City itself and the nearby Tahoe-Reno Industrial Center, located approximately 15 miles away, has resulted in significant growth for the region. In August 2018, the City prepared its third update to the City of Fernley Comprehensive Master Plan (2018 CMP) which discusses how the City can use its strategic physical location to become a community where people live and work.

2.1 PROJECTED POPULATION

The 2018 CMP is the best source of information for future growth and land use within the City. It considers how the City can rely on its strategic location to drive economic expansion and growth in the area through diverse and balanced land uses. This will include improved employment opportunities by encouraging commercial land uses within master planned communities and supporting new industrial and manufacturing development. The Comprehensive Master Plan states: “Based on current projections, the City of Fernley is likely to double its current residential population, growing from approximately 20,000 people today to approximately 40,000 people over the next 20 years.” For consistency between the plans, the projected water demands will rely on this assumption. However, because of the length of time it takes to identify, permit, and construct infrastructure to bring new water resources on line, the planning horizon for this Plan extends beyond the 20-year timeframe.

2.2 PROJECTED WATER DEMANDS

Future water demand projections provide the basis for assessing the capacity of the existing system and assist in the planning for future water infrastructure. The following assumptions were used in this analysis:

- The average household size is 2.79 people (Comprehensive Master Plan),
- The current average day demand (ADD) is 2,433 gpm or 3.50 MGD (Chapter 2), and
- The maximum day demand (MDD) is 2.1 times the ADD (Chapter 2).

Based on a review of the City’s billing and usage information for 2015 – 2018, commercial and industrial (C/I) customers represent approximately 34% of the City’s water demand. The City’s water treatment plant has a capacity of 20 million gallons per day (MGD). Table 4-1 shows the current water demand and the water demands for two future scenarios: (1) the 20-year demand using the City’s population estimate of 40,000 residents, and (2) the population at which customer demands are 20 MGD.
Table 4-1: Projected Water Demand

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Population</th>
<th>Residential Households</th>
<th>ADD Residential + C/I (MGD)</th>
<th>MDD Residential + C/I (MGD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Demand</td>
<td>19,000</td>
<td>7,090</td>
<td>3.50</td>
<td>7.36</td>
</tr>
<tr>
<td>(1)</td>
<td>40,000</td>
<td>14,337</td>
<td>7.21</td>
<td>15.14</td>
</tr>
<tr>
<td>(2)</td>
<td>52,839</td>
<td>18,939</td>
<td>9.52</td>
<td>20.00</td>
</tr>
</tbody>
</table>

The City’s current water demand is approximately 4,000 acre-feet annually (AFA). Based on a future population of 40,000 people, the City’s demand is projected to increase to approximately 8,100 AFA. Additionally, the City’s currently held water rights can support a system size of 27,432 EDU’s (Chapter 3).

2.3 WATER TREATMENT CAPACITY

As shown in Table 3-5 of Chapter 3, the total capacity of the water treatment plant (WTP) is 19,841 EDU’s. Once the surface water delivery infrastructure is connected, the WTP capacity will become the limiting component of the water distribution system. The water treatment plant has enough capacity to meet the 20-year growth projection of 40,000 people and more. If more C/I water demands occur in the future, then the water treatment plant’s 20 MGD capacity may be reached before the population is 52,839 people.

The current water treatment plant was designed to be expanded to 30 MGD. Based on the current MDD, a 30 MGD water treatment plant could supply approximately 29,760 EDU’s. This would be sufficient to provide water to the maximum number of EDU’s of 27,432 based on the City’s current water supplies as summarized in Table 3-2.

3.0 FUTURE WATER RESOURCES

The City is currently relying on groundwater rights within the Fernley Hydrographic Area. As demands increase, the City will also need to develop and utilize its surface water supply from the Truckee River and additional groundwater rights in the Brady’s Hot Springs Hydrographic Area.

3.1 SURFACE WATER SUPPLY

As discussed in Chapter 3, the estimated firm yield of the City’s Truckee River rights is 6,500 AFA. This surface water supply is projected to support 10,188 EDU’s. Based on the assumptions of the City of Fernley Municipal Surface Water Demand – Firm Yield Study (Gacek, 2016), July is anticipated to have the highest monthly demand. The July demand is estimated to be 1,244 considering an annual demand of 10,000 AFA. This is an average demand of about 9,100 gpm per day. Because the amount diverted each day will fluctuate, the surface water diversion facilities should be designed to accommodate a higher flow rate. It is estimated that approximately 9,800 gpm or 22 cubic feet per second (cfs) would be adequate for future demands.

3.2 GROUNDWATER SUPPLIES

The City has water rights to use groundwater resources from both the Fernley Hydrographic Area and Brady’s Hot Springs Hydrographic Area. It is important that both resources are developed and available for use as part of the City’s future water supply portfolio as these two sources are considered in the 20-year projected and the buildout demand. The City should protect its ability to rely on groundwater as a sustainable supply.

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6 Value includes approximately 900 EDU’s to account for future commercial and industrial (C/I) uses.
As shown in Table 2-1 of Chapter 2, the Total Pumping Capacity and Firm Pumping Capacity of existing groundwater facilities are 8,560 gpm and 6,010 gpm, respectively. The production capacity of each well was based on the initial aquifer test and estimated production capacity. However, if groundwater levels decline within the aquifer, the production capacity may change. For the City to protect its groundwater supply, it must fully understand the resource which includes potential changes to production capacities. The following section discusses recommendations for monitoring the groundwater resource, testing well performance, and potential measures to strengthen the resource to meet future demands.

4.0 GROUNDWATER RECOMMENDATIONS

This section focuses on groundwater resources since groundwater is the City’s only active water supply. For a water resource to continue to meet customer demands, the system must be redundant, sustainable, and energy efficient. Redundancy allows for alternative production facilities which can be used in the short term to prevent disruption to a water system, which can have severe impacts to water users. The sustainability of water resources includes many aspects such as water rights, water availability, and equipment to provide water into the future. Energy efficiency is important to keep the water supply affordable for residents and businesses. In order to achieve these objectives for the City’s groundwater resources, the following tasks should be completed on an ongoing basis and as new resources are developed:

- Characterization
- Monitoring
- Strategic Management of Water Rights
- Well Maintenance
- General Aquifer and Well Guidance
- Specific Site Recommendations
- Aquifer Storage and Recovery

4.1 CHARACTERIZATION

A thorough understanding of the groundwater basin is a key to proper and effective management. Although significant efforts have been undertaken to model the Fernley Hydrographic Area in 2001, 2007, and 2015, limited efforts have been conducted to document the extent and characteristics of the aquifers.

The purpose of the previously conducted numerical models was to forecast water changes in the groundwater discharge to the Truckee River from Fernley area. The numerical modeling was based primarily on limited groundwater level data from shallow monitor wells, and in some models, the simulated future pumping occurred at a location approximately 2.5 miles northwest of active wells in the basin. Simulated drawdown results from the numerical model underestimate actual groundwater level declines even though the estimated future production rate was three times greater than the actual rate. The numerical modeling completed in 2015 appears to address the lack of correlation between earlier simulations and observed drawdown. While providing improved correlation, this model did not consider increases to pumping rates to correspond to forecasted demands; and therefore, results showed that water levels would stabilize after 2020.

The City and its water system will benefit from increased knowledge of the Fernley Hydrographic Area through the data collection efforts summarized below.

New Data Efforts
- Exploration drilling should include a greater suite of calibrated geophysical logs.
- Additional surface geophysics be identified in downhole logs.
- Down well flow (i.e., spinner) surveys should be completed to quantify flow contributions with depth in existing wells.
- Water quality sampling:
o Expand the area (areas upgradient of production wells typically do not have monitoring wells to characterize water quality).
o Complete discrete interval down hole sampling.

**On-going Data Efforts and Evaluations**

- Obtain and utilize data from available research and other Bureau of Water Pollution Control permitted facilities:
  - United States Geologic Survey – Canal Research
  - United State Bureau of Reclamation studies
  - Wastewater Facilities
  - Geothermal Facilities
- Plot data quarterly
  - Water level
  - Water quality
  - Production pumping

These characterization efforts are relatively inexpensive to implement and can be budgeted as part of an on-going program. Exploratory and production well drilling provides an opportunity to cost effectively collect additional data for water resource characterization. Having the funds budgeted for additional data collection at the time other work is being performed is critical. The result of this data collection and characterization effort can be detailed in a hydrogeologic conceptual model.

### 4.2 MONITORING

Water resource monitoring allows recurring characterization of water levels and water quality to evaluate changes to the groundwater resource over time. Understanding fluctuations and trends of the aquifer potentiometric level and water quality will help the City prepare for future conditions. Conceptual and numerical groundwater models provide a starting point, although routine monitoring can be used to more accurately characterize model results. Collection of additional data is important before additional modeling could be beneficial.

The City has routinely measured groundwater levels since January 1988. This monitoring effort improved in May 2012, and the City currently obtains more than 25 groundwater level measurements monthly. Groundwater level monitoring is important and continuing the effort can identify potentially changing conditions. Monthly water level data is typically adequate to characterize the change in groundwater levels. Characterization of shallow recharge effects and short-term responses to groundwater pumping will likely require more specific and frequent monitoring, which could be streamlined with the installation of pressure transducers capable of measuring and logging water level data. It would still be necessary to retrieve the data from the pressure transducers and perform manual measurements periodically to confirm water levels.

The recent approval of Permits 81398, 81399, 81400, and 81401 will result in additional monitoring requirements which may justify installation of pressure transducers in some groundwater wells. Terms in the new permits require the City to:

1.) Collect monthly records and report annually the effect of that well on other previously existing wells that are located within 2,500 feet of the wells receiving additional water right duties,
2.) Collect monthly records and report annually the amounts pumped from the wells receiving additional water right duties, and
3.) Submit and receive approval from the Division of Water Resources of a groundwater monitoring plan.

These permit terms should be incorporated into the City’s groundwater monitoring program. The City may also consider undertaking efforts to connect residences with domestic wells within 2,500 feet of the
permitted points of diversion into the water system, as this would reduce monitoring requirements due to domestic wells.

Water quality monitoring can also assist the City with meeting the water resource goals when developing and operating water resources. Understanding trends in water quality within the aquifers is important for managing groundwater production and reducing water production costs. Water quality sampling should occur at both production wells and monitor wells. Quarterly sampling of all production wells is recommended for the first year, after which sampling can be reduced to annual or less frequent sampling. The objective of water quality monitoring is to improve operations which requires understanding the causes for water quality differences throughout the aquifers used by the City. Understanding why certain production wells have anomalous constituents will assist in locating new wells.

Ideally, water quality monitoring includes typical field parameters (e.g., temperature, pH, and electrical conductivity) and laboratory analysis which could include parameters that typically can exceed primary or secondary maximum contaminant levels (MCLs), hinder treatment, or are undesirable. These parameters typically include total dissolved solids (TDS), manganese, iron, arsenic, phosphate, radon, sulfate, gross alpha uranium, and sodium. Radon does not currently have an MCL but should be avoided for public health and potential future regulatory action.

The periodic evaluation of monitoring data will also assist with water resource planning. The data could also be used to re-evaluate and update hydrographic area water budgets. The duration between measurement and sample data collection points can be modified based on water production trends. For example, if production from the City’s production wells is anticipated to increase or if recharge is anticipated to decrease from reduced irrigation, monitoring schedules should be adjusted to observe and document any resulting change.

The State of Nevada and United States Geological Survey (USGS) do not currently conduct any monitoring of the aquifers utilized by the City. The City could coordinate with either or both of these agencies to begin collecting groundwater data within the Fernley Hydrographic Area. Although this would result in greater cost to the City, it provides known quality assurance of the data that will be used by others. Development of a standard operating procedure (SOP) for City staff to conduct groundwater level measurements along with regular evaluation of the SOP would help ensure data quality and provide an alternative to requesting monitoring by an outside agency or consultant.

4.3 STRATEGIC MANAGEMENT OF WATER RIGHTS

Managing water rights in conjunction with water production is critical to achieve maximum water resource benefit. Currently, some of the City’s water right points of diversion within the Fernley Hydrographic Area are located at groundwater wells with low production potential or non-operable water production wells. This reduces flexibility in system water production. Moving water rights to locations with adequate production/pumping potential, or increasing the allowed diversion points, would provide greater flexibility to the system. In addition, improving water production capacity at existing sites can be pursued to ensure each groundwater well can produce the rate and volume of water rights assigned to it.

4.4 WELL MAINTENANCE

Well maintenance is required for efficient and dependable well field operation and should continue to be implemented by the City. Well maintenance includes downhole inspection, regular testing, and well rehabilitation. The benefits of well maintenance include reliable and dependable well operation, energy efficient operations, and earlier planning/budgeting for replacement of well and pumping equipment.
4.4.1 Well Inspection

Regular inspections are important for understanding the service life of a well and allow repairs to be completed before a well fails. Knowing that a well will need to be replaced based on multiple inspections allows for the long-range budgeting of a replacement well. Inspections can include video surveys prior to and after well rehabilitations. The video(s) collected prior to well rehabilitation should be used to identify any significant casing problems that could fail during a well rehabilitation.

4.4.2 Well Site Testing

Groundwater levels at some wells in the area have declined approximately 50 feet during the period from 1990 to 2005. Production wells completed in shallower aquifers may experience greater decreases in production than wells in deeper aquifers. Depending on the occurrence of aquifers at greater depths, it may not be possible to deepen a well to restore production capacities. Factors that can result in decreased production capacity include, but are not limited to, general decline of static water level in a groundwater basin, increased production in an aquifer, decreased recharge to an aquifer, interference between wells, scaling of the well screen and/or filter pack, and decline in aquifer production capacity with depth.

Well tests can be performed to confirm current production capacities. As discussed in Chapter 2 and Chapter 3, the Total Pumping Capacity and Firm Pumping Capacity of a system are critical to determining the total number of EDUs which can be served by the current water supply facilities. Well tests should include the following four components:

1. **Fifteen Minute Reconnaissance Step Tests:** Reconnaissance tests should consist of at least three, 15-minute constant rate tests. Each “step” is at an increasingly higher flow rate. The flow rates selected should span the capabilities of the pump.
2. **Several Day Step Tests:** The several day step tests should repeat the reconnaissance tests except each step will be for a greater duration. Ideally, the rate is kept constant during the entire step to provide the best data. This condition will require greater oversight during the testing. Discrete depth flow rate testing (i.e., spinner) should be included with one of the three step tests.
3. **Several Month Constant Discharge Tests Minimizing Well Interference:** These tests will provide greater confidence for the long-term capacity of each production well and identify hydrologic boundaries that may impact the well. Testing individual wells allows for increased stress at each well.
4. **Production Pumping Evaluation:** The production pumping evaluation should be an ongoing process to evaluate the impacts of several wells to the local aquifer. Aquifer water level responses are evaluated in regard to production pumping rates and other conditions including but not limited to recharge.

4.4.3 Well Rehabilitation

Regular well rehabilitation can be important to either repair a well or increase the energy efficiency of a well to decrease ongoing energy costs. Well rehabilitation typically includes removing scale and other material that can plug the well casing and make the well less efficient. A combination of chemical and physical treatments is typically required and should be selected based on the specific well conditions. Well rehabilitation also includes repairs that could include swaging a patch, installing a liner, or other well mitigation task. Utilizing a consultant to oversee the well contractor is strongly advised since some well rehabilitation methods provide little benefit, well work is typically expensive and required maintenance should be grouped together to reduce costs.
4.5 GENERAL AQUIFER AND WELL GUIDANCE

The following recommendations are provided as general guidance for further development within the Fernley Hydrographic Area and the Brady’s Hot Springs Hydrographic Area. Guidelines for selecting aquifers and design of wells should include but not be limited to:

**Aquifer Characteristics**

- **Materials**
  - The possibility of developing an aquifer within bedrock is unlikely because of the local geologic units but should be considered when evaluating well sites and depths.

- **Depth**
  - Deeper aquifers provide more protection from contaminants and allow for greater drawdown without cascading water from dewatered aquifers. The depth of the aquifer is of greatest importance to provide drought tolerance assuming the aquifer thickness is sufficient for providing efficient withdrawal and possibly injection of water resources. Wells should be in areas with the greatest possible aquifer depth. Alluvial aquifers have been screened to approximate depths of as great as 1,000 feet for the City of Fernley.

- **Thickness**
  - Greater aquifer thickness provides greater storage and efficiency for removing groundwater. Locating wells in thick aquifers, where screen thickness and well capacity can be maximized, will reduce operation and maintenance costs by reducing the number of wells in the system.

- **Aquifer material**
  - Aquifers comprised of well-sorted, coarser grained materials provide greater storage and efficiency. Groundwater wells in finer grained aquifers can result in subsidence and loss of aquifer storage.

- **Water quality**
  - Drinking water wells serving communities should ideally produce water with constituent concentrations below the MCLs. The aquifers within the Fernley area exceed the MCL for arsenic. TDS is also a constituent of concern. Treating for TDS is costly, so blending water from wells with high TDS with lower TDS surface water will result in lower treatment costs. Future well locations should target lower MCL aquifers.

- **Aquifer Storage and Recovery (ASR)**
  - Aquifer characteristics that are optimal for a water production well supplied by natural recharge may be different than characteristics needed for ASR programs. For example, ASR wells have the greatest efficiency in undersaturated aquifers which allow for additional water to be stored. Designing wells for ASR requires screen intervals across all aquifers. The most significant difference is the requirement to screen the uppermost aquifers for groundwater storage. The uppermost screens can be problematic for production by the occurrence of air entrainment from cascading water. As with standard municipal production well designs, efforts to maximize well efficiency for injection is prioritized.

**Well Characteristics**

- **Efficient Design**
  - There should be no aquifer damage during well construction. Drilling can plug and decrease the permeability of an aquifer. Specification and verification of the drilling method is required to maximize well efficiency.
  - The well casing and screen need to be properly designed. Well screens must be designed to prevent movement of filter pack into the well casing, prevent plugging of the well screen,
maintain their integrity with long term production or rehabilitation activities, withstand corrosion, and allow for well rehabilitation using acid.

- Filter packs must be designed to hold back the formation but allow for effective removal of drilling fluids and fine material from the aquifer adjacent to the filter pack.

**Proximity to Infrastructure:**

- **Other Wells**
  - The spacing between wells in the system should minimize interference to maximize energy efficiency and well capacity. Nearby domestic wells should not be impacted as required by NRS 534.110(b).

- **Treatment Plant**
  - Proximity of production wells to treatment plants reduces the construction of additional infrastructure and reduces energy losses from the movement of water to the plant.

- **Existing raw water lines**
  - Locating new wells near existing pipelines reduces cost for the construction of water lines and reduces costs for future production pumping.

- **Power**
  - The location of existing power lines should be reviewed when considering a well location. This reduces cost for construction of power transmission to well sites.

### 4.6 SPECIFIC SITE RECOMMENDATIONS

As noted in Chapter 2, pipeline configuration restricts the amount of water which can be produced from Wells 9 and 9A when they are operated simultaneously. Infrastructure improvements may be made to allow increased flow from these wells which would change the pumping capacity of the City’s system. Alternatively, if well tests identify that the production capacity of one or more of the wells has decreased, then this would reduce the total pumping capacity of the system. This would result in a reduction in the number of EDU’s which can be served by the existing water supply facilities.

To ensure that the City’s current volume of groundwater rights can be fully utilized, the City will need to consider new production wells or modifications to current production wells. Recommendations provided below are based on information obtained from existing data and reports, and the accuracy of the data was not fully verified. Therefore, the recommendations serve as a starting point for consideration.

#### 4.6.1 Fernley Hydrographic Area

The conditions which limit pumping from Wells 9 and 9A prevent pumping of the full volume of water rights assigned to each well. If water rights cannot be moved from one or both of these wells to allow the City to pump the full permitted volume, then a deeper well could be constructed which has a greater pumping capacity. This would need to be coupled with a change in the transmission pipe configuration to eliminate the downstream restriction.

Similarly, Well 8 could also be replaced with a deeper well. The site is anticipated to have higher TDS than other wells, but in order to pump the full volume of water rights associated with this well, it may be necessary to increase the production capacity. Currently, this well is only used for construction water and additional raw water infrastructure would be needed before this well could provide water to the water treatment plant.

Well 26, identified by Well Log No. 18560 (also referred to as Sage, Armstrong, and Johnson), is a potential option for a future production well. Currently, there are water rights located at this point of diversion which the City cannot utilize. The site also appears favorable as the area tends to have water with lower TDS. Well 5 also has water rights assigned to it even though it is out of service. The City needs to evaluate this
location and change the point of diversion to a usable well. This well could then be abandoned following the permit change.

For new or reconstructed wells within the Fernley Hydrographic Areas, the well depth and screened intervals should extend into the deeper aquifers which extend from approximately 3,200 feet to 3,750 feet above mean sea level. Evaluation of the well site and exploratory drilling should occur concurrently with efforts to change the permitted point of diversion. If moving the water rights to a more beneficial, existing facility is successful, then construction efforts may not be required.

### 4.6.2 Brady’s Hot Springs Hydrographic Area

Development of all water resources available to the City of Fernley is critical to meet future demand projections. Groundwater resources provide the benefit of production at any time throughout the year and are not dependent on other agency water resources. With limited water in Northern Nevada, it is important that the City develops its Brady’s Hot Springs resource which, as shown in Chapter 1, represents approximately 20 percent of the groundwater volume available under the City’s water rights.

The Brady’s Hot Springs permit represents a majority of water rights in the basin, and the basin is appropriated below the perennial yield as recognized by the Division of Water Resources. Therefore, the potential for curtailment or other action that could limit the use of the permit is unlikely. The permit in the Brady’s Hot Springs Hydrographic Area has yet to be perfected and is subject to regulatory action. The permit, approved December 1, 2017, requires that work be prosecuted with reasonable diligence and proof of completion filed by December 1, 2020. There is only about one year to complete exploratory drilling, production well construction, and connection to the water system without the granting of an extension. It is recommended that these activities commence as soon as possible.

It is likely that the point of diversion associated with this water right will need to be moved to the ideal location in terms of water quality, proximity to power, available right-of-way, etc. There may also be a need for additional points of diversion under the water right so the City can optimize groundwater production and quality.

### 4.7 AQUIFER STORAGE AND RECOVERY

Aquifer storage and recovery (ASR) is the injection of water into an underground aquifer for later withdrawal and use. Depending on the source, treated or raw water is typically infiltrated into the ground or injected with wells into the aquifer. ASR programs are typically most efficient at recharging depleted aquifers to minimize natural water loss from the aquifer. Recharge into aquifers that exceed maximum contaminant levels may also result in future MCL exceedances.

In 2016, the City submitted an ASR permit application that was subsequently withdrawn. The City eventually chose not to proceed with an ASR project, due to various reasons including protests to the application and estimated costs. As the City’s water resource demand increases, it may want to re-explore ASR as an option to increase its water resource capacity.

One benefit of a successful ASR program is the ability for the City to fully utilize its surface water supply under the Truckee River Operating Agreement (TROA). As discussed in Chapter 3, Fernley Municipal Credit Water which is spilled from upstream reservoirs can be diverted by the City and used for meeting annual water demands. These spills can be large quantities of water (up to the amount currently held in storage which may be greater than 10,000 AF) and will likely occur at a time when the City’s demands are typically being met by other sources. The diversion of spilled credit water and/or Claim No. 3 water rights for an ASR program would help support the health of the aquifer and provide an additional water supply for the City.
5.0 REDUNDANT WATER SUPPLIES AND REGIONALIZATION

With the construction of the surface water intake and development of its water rights in the Brady’s Hot Springs Hydrographic Area, the City will have a much more robust water supply portfolio. The ability to rely on more than one source of water will provide redundancy and resilience within the system. This will not only help the City manage its supply in times of dry hydrologic conditions but will also provide flexibility to use a different source in the event of a water quality concern.

As population and water demands increase, so will wastewater generation. Treated effluent is another water source the City can consider for use. Chapter 3 estimates the maximum number of EDU’s which can be supported by the City’s water rights as 27,432. Assuming that treated effluent is equivalent to 60% of water use, this would result in as much as 9,000 AFA of treated effluent being produced/discharged at the City’s wastewater treatment facility at buildout. This volume of water could be used to offset future potable demands or could be used to maintain the health of the aquifer.

Another option the City might pursue is regionalization of water infrastructure with neighboring areas. The nearest water systems include Wadsworth (2.5 miles Northwest), Fallon (27 miles East), the Tahoe-Reno Industrial Center (15 miles West), and Silver Springs (13 miles South). Although these systems, with the exception of Wadsworth, are significant distances from the City, changing economic conditions and local needs could justify construction of a waterline. Currently, an effluent water line is being installed between Sparks and the Tahoe-Reno Industrial Center which is a similar distance as the City is to several nearby water systems.

There may be opportunities to connect to one or more of these water systems. Lyon County is currently pursuing a study of a regional system along Highway 50, including Silver Springs. The existence of this system could increase the opportunity for the City to connect to a larger, more regional utility.

6.0 ACTION ITEMS TO SUPPORT FUTURE WATER RESOURCES

Action items presented in this chapter are prioritized below. Due to regulatory uncertainty, concurrent tasks should be pursued so the City is not reliant on a single approach for the development of water resources to meet projected demand.

1.) Construct surface water facilities.

Constructing the facilities needed to use Truckee River surface water will provide considerable resiliency within the water system and allow for the City to fully utilize their water right holdings.

2.) Evaluate well development in Brady’s Hot Springs Hydrographic Area.

Development of a production well in the Brady’s Hot Springs Hydrographic Area provides the only groundwater source from a basin which is below the perennial yield recognized by the Division of Natural Resources available to the City. The opportunity to prove up on the COF permit could be limited by Legislative or State Engineer actions.

3.) Perform well maintenance (testing, inspection and well rehabilitation).

Verifying estimated production capacity at current water levels and updating future production capacity estimates is needed to accurately forecast system capacity to meet anticipated demand.

4.) Evaluate well sites and complete exploratory drilling.

Moving water rights from Wells 8, 9, and/or 9A to a site with better water quality and production capacity is unlikely, so the City should consider a new well at one of the sites which uses the full depth of the aquifer. Construction of a new well at Well 26 would provide redundancy and minimize interference of production wells within the water system. The well
sites should be explored and prioritized based on anticipated production capacity and water quality.

5.) **Change water right points of diversion to coincide with active and proposed well sites.**

Moving water rights with points of diversion at sites without active wells, or well sites with poor water quality or production capacity, should be evaluated concurrently to well site developments. Moving of water rights can be a lengthy process and should be initiated soon. If changing the points of diversion is successful, then well site development at Wells 26, 8, 9, and 9A may not be necessary.

6.) **Monitor groundwater levels and evaluate water level and water quality quarterly.**

Development of compliance monitoring plan and strategic monitoring to increase useful data and optimize data collection efforts. A standard operating procedure, with a quality assurance/quality control component, will assist with consistent, quality data collection. Measurement of groundwater levels should be obtained at least quarterly and adjustments to water system operations made, as needed, based on operational needs and consideration given to minimizing interference between production wells or sources of recharge.

7.) **Initiate long-term planning for regionalization and use of reclaim water.**

Regionalization of water resources requires long range planning that considers various approaches and needs to be started before individual project feasibility is analyzed. Although water system consolidation or reuse of effluent water may not be needed at this time, planning efforts can be undertaken to develop future alternatives.
REFERENCES


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