CHAPTER 5
INTEGRATED WATER SUPPLY PLAN

This Chapter presents an integrated water supply plan for the City's contiguous water service area that will enable the City to meet projected demands through buildout of the City's adopted General Plan. As described in *Chapter 3 Water Demands*, the City's projected future water demands are anticipated to increase significantly in the future and the City's existing water supplies (described in *Chapter 4 Existing Water Supply*) may need to be supplemented in certain service areas to meet the projected demands during certain hydrologic periods.

Also described in this Chapter are potential additional surface water supply options, future groundwater supply considerations (including wellhead treatment and the potential for an ASR Program), recycled water opportunities and potential impacts of climate change and the on-going drought, anticipated Federal Energy Regulatory Commission (FERC) restrictions, and increasing unimpaired river flow requirements on future water supply availability and reliability to the City.

5.1 COMPARISON OF PROJECTED WATER SUPPLY AND WATER DEMAND

5.1.1 Projected Water Supply

As described in *Chapter 4 Existing Water Supply*, the City currently uses a conjunctive water use strategy with treated surface water and groundwater supplies to meet potable water demands within the City's contiguous service area. These available supplies include the following:

- Treated surface water purchased from MID
  - Available Supply
    - Phase One: 30 mgd (33,600 af/yr)
    - Phase Two Expansion: An additional 10 mgd (11,200 af/yr) starting in 2016 and continuing at 10 mgd through 2020, and then gradually increasing to an additional 30 mgd (33,600 af/yr) by 2050; and
  - Can only be used in the City's contiguous service area north of the Tuolumne River
- Groundwater pumped from City wells located throughout the City's service area
  - Modesto Subbasin
    - Location: North of Tuolumne River
    - Service Areas: North Modesto, South Modesto, Salida, Empire, Del Rio
    - Yield Estimate: 48,286 af/yr[1]
  - Turlock Subbasin
    - Location: South of Tuolumne River
    - Service Areas: South Modesto, Turlock, North Ceres, Ceres/Walnut Manor
    - Yield Estimate: 4,900 af/yr[2]

[1] See Chapter 4, Table 4-4. Preliminary Operational Yield Assumed for Each Subbasin.
[2] See Chapter 4, Table 4-4. Preliminary Operational Yield Assumed for Each Subbasin.

— Delta-Mendota Subbasin

- Location: West of San Joaquin River
- Service Area: Grayson
- Yield Estimate: 314 af/yr[3]

5.1.2 Projected Water Demand

Projected water demands for the City's water service areas are presented in *Chapter 3 Water Demands*. The projected demand for the City's contiguous service area was projected to increase to about 89 mgd (100,000 af/yr) by 2050, which includes a projected demand of about 82 mgd (92,300 af/yr) in North Modesto and a projected demand of about 7 mgd (7,700 af/yr) in South Modesto.

5.1.3 Projected Water Supply vs. Demand in Normal and Wet Years

Historical and projected water supplies and demands for the City's contiguous service area (including North Modesto, Salida, Empire and South Modesto) through 2050 are shown on 5-1 for normal/wet year supply and demand conditions (assumes an allotment of MID supplied surface water of 40 mgd from 2016 to 2020, then increasing to 60 mgd by 2050)[4]. As shown, the City's available treated surface water supplies from the MID MRWTP Phase One and Phase Two Expansion, together with groundwater supplies pumped from the Modesto and Turlock Subbasins, are sufficient to meet the projected demands within the City's contiguous service area through 2050. Under these assumptions, surplus groundwater supplies range from almost 40,000 af/yr in 2016 to about 15,000 af/yr in 2050.

However, as described in *Chapter 4 Existing Water Supply* and summarized above, the treated surface water supplies purchased from MID can only be used within the City's contiguous service area north of the Tuolumne River (not in South Modesto), so it is important to distinctly evaluate and understand the projected available supplies and projected demands for both North Modesto and South Modesto, separately.

Supplies available for use in North Modesto (including the treated surface water supplies purchased from MID and groundwater pumped from the Modesto Subbasin) are shown on Figure 5-2 along with the projected demand in North Modesto. As shown, with the available surface water supplies and groundwater supplies pumped from the Modesto Subbasin, the North Modesto supplies are sufficient to meet the projected North Modesto demands through 2050. In addition, Figure 5-2 shows that there are surplus groundwater supplies available in North Modesto, ranging from almost 40,000 af/yr in 2016 to almost 19,000 af/yr in 2050. These surplus groundwater supplies are available for transfer and use in South Modesto.

Supplies available for use in South Modesto (including groundwater pumped from the Turlock Subbasin and groundwater transferred from North Modesto) are shown on Figure 5-3. As shown, the quantity of groundwater required to be transferred from North Modesto to South Modesto

[3] See Chapter 4, Table 4-4. Preliminary Operational Yield Assumed for Each Subbasin.
[4] Demand projections are described in *Chapter 3 Water Demands*.

ranges from 12 af/yr in 2016 to about 3,600 af/yr in 2050. With the transferred groundwater from North Modesto, the South Modesto supplies are sufficient to meet the projected South Modesto demands through 2050. The transferred groundwater quantities are well within the quantities of surplus groundwater supplies available in North Modesto (see Figure 5-2), indicating that sufficient supplies are available to meet both the North Modesto and South Modesto demands through 2050 for normal/wet year supply and demand conditions (and adhering to the terms of the ARTDA).

This finding of sufficient water supplies for both North Modesto and South Modesto served as a key consideration for the City's November 2015 decision to not participate in the Stanislaus Regional Water Authority's Proposed Regional Surface Water Supply Project which would have provided the City with new treated surface water supplies for use in South Modesto (see additional discussion in Section 5.2.1 below).

5.1.4 Projected Water Supply vs. Demand in Dry Years

As described in Section 5.1.3, under normal/wet year supply conditions it is assumed that the City will receive an allotment of MID supplied surface water of 40 mgd from 2016 to 2020, then increasing to 60 mgd by 2050. As described in Chapter 4, the ARTDA between MID and the City includes a formula to reduce deliveries to the City in drier than average years based on the number of inches of water per acre allocated to its agricultural customers. In 2014 and 2015, the available supply from MID was reduced significantly due to drought conditions. Surface water supply reductions in 2014 and 2015 were as follows:

- In 2014, the available supply was 24 inches of water per acre of the total 42-inch allocation (equivalent to a 43 percent reduction), resulting in a treated water supply delivery to the City of approximately 17.1 mgd (19,200 af) for the 2014/2015 water year (May 1, 2014 through April 30, 2015).
- In 2015, the available supply was 16 inches of water per acre of the total 42-inch allocation (equivalent to a 62 percent reduction), resulting in a treated water supply delivery to the City of approximately 11.4 mgd (12,800 af) for the 2015/16 water year (May 1, 2015 through April 30, 2016).

The ARTDA does provide the opportunity for the City to purchase additional water from MID (at a higher rate) or to trade groundwater for agricultural use for treated surface water to achieve the full entitlement during drought years if such supplemental supplies are available (this may or may not be on a 'one-for-one' basis). However, the City did not purchase additional surface water supplies in 2014 or 2015. Instead, the City chose to increase groundwater production and implement an aggressive water conservation program to help reduce demands to match available supplies. Initial planning work is underway to develop a Water Exchange Program between the City and MID where groundwater from non-potable City wells within a one-half mile radius of candidate MID laterals is pumped to those facilities in exchange for additional treated surface water delivered from MID through the MRWTP to the City.

In 2014 and 2015 the City's water demands were significantly reduced as a result of water conservation. Water conservation measures included both voluntary actions implemented by the City's water customers and mandatory measures implemented by the City in response to the drought conditions and as mandated by the Governor's April 2015 Executive Order B-29-15 calling for a statewide reduction in urban water use of 25 percent (as compared to 2013). Each urban water supplier in California was assigned a conservation standard (a percent reduction as compared to 2013 water use) to achieve the statewide water conservation goal. The City's conservation standard was initially set at 36 percent, but was later revised to 33 percent in March 2016. From June 2015 to May 2016, the City achieved a cumulative savings of 29.8 percent (as compared to the same months in 2013)[5]. This is less than the conservation standard set for the City, but is still a very significant reduction in water demand. The success of these recent water conservation measures has shown that the City has the ability to reduce water demands if needed to respond to water supply shortages.

The City's increase in groundwater production in response to the recent shortage in treated surface water supplies is within the operational yield estimates for the Modesto and Turlock Subbasins, and is not anticipated to have any adverse effects on the underlying groundwater subbasins either through subsidence or diminished water resources.

In the future, if the City were to implement an ASR Program, the City may be able to seasonally inject surplus treated surface water supplies available in normal or wet years into the underlying groundwater subbasins and bank it for later extraction during dry years and/or use during peak seasonal demand periods. Such a program would provide the City with added supply reliability during dry years. Several other cities in California and across the country have implemented, or are in the process of implementing, ASR programs to inject and store wet year supplies for later extraction and use in dry years and/or seasonal demand peaking. A conceptual-level evaluation of the potential for an ASR program in the Modesto area has been performed in conjunction with this WMP and is described in Section 5.3.3 below. In addition, the City, in cooperation with the Stanislaus and Tuolumne Rivers Groundwater Basin Association, has recently completed a Modesto Groundwater Basin Characterization and Recharge Study which is described in Section 5.3.4 below.

5.2 POTENTIAL ADDITIONAL SURFACE WATER SUPPLY OPTIONS

As described in Chapter 4, the City's surface water supply from MID is a key component of the City's water supply portfolio. As described below, the City has investigated additional surface water supply options which may be available in the future.

The following potential additional surface water supply options are described below:

- Stanislaus Regional Water Authority's Regional Surface Water Supply Project; and
- MRWTP Phase Three Expansion Project.

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[5] May 2016 Supplier Conservation Compliance, SWRCB Water Conservation Portal, (http://www.waterboards.ca.gov/water_issues/programs/conservation_portal/docs/2016jul/suppliercompliance_070616.pdf)

5.2.1 Stanislaus Regional Water Authority's Regional Surface Water Supply Project

Additional water supply is needed in most of the cities throughout the southern Stanislaus County area (south of the Tuolumne River and within the Turlock Groundwater Subbasin) because the local groundwater supply, which is typically the sole or primary source of water supply in these areas, is neither sufficient nor reliable (due to water quality issues) to meet existing and/or future demands. For the City of Modesto, it is expected that the reliable groundwater production capacity will remain the same or continue to decrease as the City's water wells are taken out of service due to increasingly stringent water quality regulations. Additionally, the cost for wellhead treatment (including residual by-product disposal and management) has increased significantly, and this cost is anticipated to continue increasing due to regulatory requirements.

The proposed Stanislaus Regional Water Authority (SRWA) Regional Surface Water Supply Project (RSWSP) is being developed to provide a long-term, reliable water source for existing customers and help meet future development needs by pumping water from the Tuolumne River (using TID's surface water rights), treating it to drinking water standards and then delivering it to the participating cities. The proposed water treatment plant, to be constructed in phases, would be located east of the City of Hughson.

The City of Modesto's interest and participation in the RSWSP was solely to provide an alternative and/or supplemental water supply source for its South Modesto service area. The South Modesto service area is the portion of the City that lies south of the Tuolumne River, outside of MID's service area and within the TID service area. As described in Chapter 4, the groundwater supply in the South Modesto service area has water quality issues that threaten the availability and reliability of water supplies for South Modesto.

In 2015, West Yost conducted a water supply and demand study for the City for the South Modesto service area to evaluate the City's need to participate in the RSWSP. The Study evaluated the City's two primary options for meeting the future water supply needs in South Modesto:

- Option 1: Continue participation in the proposed RSWSP; or
- Option 2: Do not continue participation in the proposed RSWSP and instead construct the infrastructure necessary to pump and transfer more groundwater from North Modesto to South Modesto.

The Study's findings showed that the City did not need water from the RSWSP to meet the buildout water demands of South Modesto. With the now completed MID MRWTP Phase Two Expansion, adequate surface water supplies are available in the North Modesto service area to allow for supplemental groundwater supplies to be pumped from North Modesto to the South Modesto service area, all within the terms of the ARTDA. This is demonstrated in Figure 5-2 and Figure 5-3. Figure 5-2 shows that there is an adequate supply of groundwater available in the North Modesto service area to transfer to the South Modesto service area, and Figure 5-3 shows the future demands of South Modesto service area and how they will be met using groundwater supplies from the Turlock Subbasin together with groundwater transferred from North Modesto service area.

Furthermore, the estimated cost of the City's full participation in Phase One of the RSWSP is $40 million and the cost to construct the associated downstream infrastructure required to properly distribute this new surface water into the City's existing South Modesto water system is an additional $15 million, for a total cost of approximately $55 million. This does not include any costs related to the City providing "offset water" to be delivered to TID as a condition of the SRWA Water Sales Agreement with TID. In comparison, the estimated cost to construct only the infrastructure necessary to pump and transfer additional groundwater from North Modesto to South Modesto is significantly less at $20 million.

Based on these findings, in November 2015, the City decided to cease participation in the RSWSP and officially withdrew from the SRWA.

5.2.2 MRWTP Phase Three Expansion Project

A MRWTP Phase Three Expansion Project may be possible in the future if there is a sizeable future conversion of agricultural land to urban uses (requiring an accompanying change in water rights from agricultural to M&I uses), which would allow for a corresponding redistribution of MID's existing surface water rights. In addition, the City may also be able to purchase an additional surface water supply from another wholesale water agency (e.g., Oakdale Irrigation District). This additional surface water supply could then be treated at the MRWTP in conjunction with a future Phase Three Expansion for delivery to the City. However, at this time, this project is speculative, and the need for and timing of such an expansion has not been determined.

5.3 FUTURE GROUNDWATER SUPPLY CONSIDERATIONS

As described in Chapter 4, the City's groundwater supply is, and will continue to be, a key component of the City's water supply portfolio. The following sections describe key future groundwater supply considerations, including:

- New wells and replacement of existing wells;
- Groundwater quality issues and the need for and feasibility of wellhead treatment systems; and
- The feasibility of implementing an ASR Program consisting of injecting, storing, and recovering treated surface water from the groundwater aquifer beneath the City.

5.3.1 New Wells

Groundwater has been, and will continue to be, a critical part of the City's water supply portfolio. As described in *Chapter 9 Future Water System Evaluation*, in addition to maintaining the City's existing wells, a number of new wells will be needed in the future to help meet future projected demands within the City's service area. New wells should be planned in areas where new development is planned, primarily in the northern and western portions of the contiguous service area. Also, replacement wells should be constructed to replace older wells as needed, to maintain the City's groundwater pumping capacity.

5.3.2 Wellhead Treatment Evaluation

As described in *Chapter 4 Existing Water Supply*, the City has experienced some issues related to groundwater quality. As of October 2014, sixteen of the City's wells had been removed from service due to Title 22 MCL exceedances for nitrate, uranium, arsenic and perchloroethylene (PCE). These included thirteen wells in the North Modesto service area, two wells in the South Modesto service area, and one well in the Turlock service area. In addition, five of the South Modesto wells are blending wells that produce water of potable quality, but do not meet all Secondary MCL criteria for aesthetics[6].

It is important to maintain the City's existing well capacity, and return to service wells that are currently out of service. Therefore, in conjunction with this WMP, West Yost conducted a wellhead treatment evaluation to evaluate the range of wellhead treatment options available for removal of several specific contaminants of concern (including hexavalent chromium, nitrate, manganese, strontium and uranium) and recommend which processes would best suit wellhead treatment applications at the City's wells. A copy of the evaluation is provided in Appendix H.

The best technology for wellhead treatment depends upon both the target contaminant and the ambient water quality of the well water. The technologies considered included the following:

- Ion Exchange (IX)
- Reduction/Coagulation/Filtration (R/C/F)
- Sorptive Processes
- Biological Treatment
- Reverse Osmosis (RO)
- Nanofiltration (NF)
- Electrodialysis Reversal (EDR)
- Lime Softening

A series of recommended treatment approaches were developed based on the published literature, conversations with vendors, and the available water quality data. Some contaminants had different recommendations based upon the feed water quality. These conclusions are summarized in Table 5-1.

[6] Water from these blending wells is pumped into storage tanks and blended with water of better water quality so the water quality of these blended supplies meets all applicable SWRCB DDW Primary and Secondary MCL requirements.

Table 5-1. Summary of Wellhead Treatment Recommendations by Contaminant Type[a]

Contaminant	Recommended Process(es)	Rationale	Additional Notes
Hexavalent Chromium (with low nitrate)	Strong-base anion (SBA) exchange	Advances in brine minimization have greatly reduced waste management costs for at least one technology	If SBA or biological treatment cannot be used alone, biofiltration followed by SBA may be warranted to minimize expensive ion exchange brine disposal requirements.
Hexavalent Chromium (with high nitrate)	Biological treatment (if proven), anion exchange if not	Biological treatment is proven at bench-scale, pilot testing in progress	
Manganese	Greensand filtration	Simple to operate, low-cost alternative	Permanganate is a more effective oxidant but use of free chlorine may be simpler as it can also serve as a disinfectant residual post-treatment.
Nitrate	Biological filtration	Lowest-cost, simple operation, eco-friendly	A comparatively new technology but conditionally approved by DDW and does not produce a brine waste.
Uranium	Anion exchange with off-site regeneration	Long operating life if the nitrate concentration is low, no technically enhanced naturally occurring radioactive material (TENORM) waste production on-site	If nitrate is relatively high (so violation of the MCL is likely at breakthrough), pretreatment with biofiltration should be considered.
Strontium	Cation exchange and/or lime softening	Both proven efficacious	Dataset is limited. Cations like calcium can be a big problem for strontium removal with ion exchange so pretreatment may be warranted.

(a) Refer to the November 2017 Wellhead Treatment Evaluation Technical Memorandum included in Appendix H for additional information.

Additional contaminants of concern in groundwater include arsenic and 1,2,3-trichloropropane (TCP). Each of these is described further below.

Arsenic is ubiquitous in nature and is commonly found in groundwater sources in California. California's revised arsenic MCL of 0.010 mg/L (equivalent to 10 micrograms per liter, µg/L) became effective on November 28, 2008. A 10-µg/L federal MCL for arsenic has been in effect since January 2006. Previous California and federal MCLs for arsenic were 50 µg/L. Arsenic remediation is typically expensive because large volumes of groundwater must be treated. Best Available Technologies for the removal of arsenic include ion exchange, activated alumina, reverse osmosis, enhanced lime softening, enhanced coagulation/filtration, alternative adsorption media, coagulation-assisted microfiltration and point-of-use (POU) treatment.

1,2,3-TCP is a chlorinated hydrocarbon with high chemical stability. It is a man-made chemical that does not occur naturally, but is found at industrial or hazardous waste sites. It has been used as a cleaning and degreasing solvent and also is associated with pesticide products. Currently, there is no federal MCL for 1,2,3-TCP. The State has established a Public Health Goal of 0.0007 µg/L (or 0.7 parts per trillion), and the DDW has indicated that the MCL will likely be set at 0.005 µg/L. Over the last several years, the DDW has received input from affected water systems expressing concerns about the lack of a drinking water standard for 1,2,3-TCP. Local community groups and environmental justice groups have requested that the SWRCB set as one of its highest priorities the development of an MCL for 1,2,3-TCP. A presentation before the SWRCB on the status of the 1,2,3-TCP MCL is planned for early 2017. The most common wellhead treatment technology for removal of TCP is granular activated carbon (GAC). It is likely that the State will designate GAC as the Best Available Technology.

As the City moves forward with treatment at one or more of its well sites, site-specific details like water quality, available footprint, and access to waste disposal options may shift the preferred technology choice. Also, as technologies develop, new (and/or better proven) options may become available that warrant serious consideration.

5.3.3 Conceptual-Level Evaluation of Aquifer Storage and Recovery

Pueblo Water Resources (Pueblo) has conducted a conceptual-level evaluation for ASR within the groundwater basin underlying the City's contiguous water service area. The focus of this evaluation was to review existing data on the City's wells and groundwater basin hydrogeologic and geochemical characteristics to determine the conceptual feasibility of injecting, storing, and recovering treated surface water within the groundwater aquifer(s) beneath the City. The results of the evaluation provide input to the City regarding 'if' and 'how' to advance an ASR project in the City. Pueblo's evaluation is provided in Appendix I and is summarized below.

5.3.3.1 ASR Overview

ASR is a form of managed aquifer recharge that involves the seasonal banking of water in an aquifer during times when excess water is available (typically winter and spring), and subsequent recovery of the water from the aquifer when needed (typically fall and summer, and/or during drought periods). ASR can utilize dual-purpose or dedicated injection/recovery wells for the injection of treated, potable water for storage, and the subsequent recovery of this previously stored water by pumping. The advantage of ASR technology is that it allows recharge to be applied in those geographic areas or aquifer zones with the most need, or where available groundwater storage space is the greatest. In addition, ASR sites require minimal land use area, so they can be more easily located than spreading basins or other recharge facilities.

Conceptually, treated surface water purchased on a wholesale basis from MID could be used when a seasonally available surplus supply is available to develop an ASR program for the City. The ASR program, if determined to be feasible, could provide the City with the following benefits:

- Increasing the long-term reliability of the groundwater supply;
- Improving the ability to meet peak system demands;

- Minimizing the impacts of water shortages during drought periods;
- Enhancing groundwater operational yield; and
- Improving groundwater quality.

The success of an ASR project depends on the ability to physically place water into the aquifer and to effectively store and retrieve this stored water. The hydrogeology of the aquifer system controls the rate at which water can be injected, the amount that can be stored, and the ability to recover the stored water. The hydrogeologic factors affecting the feasibility of an ASR program include groundwater basin structure and geometry, hydrostratigraphy, aquifer hydraulic parameters, and water-level conditions. For example, aquifer transmissivity affects the ability to get water into and out of the aquifer. The lower the transmissivity, the more head (draw-up or mounding) will be required at the injection well to achieve a given injection flow rate. Not all of these factors must be maximized for an ASR project to be successful, as less than optimum conditions for a particular hydrogeologic criterion can be offset by another. For example, in a basin where the depth to water is great, lower transmissivities are acceptable as greater draw-up is available to convey more water into the target aquifer(s).

5.3.3.2 ASR Feasibility Evaluation for Existing City Wells

A screening-level analysis of the City's existing wells was performed to identify existing City wells with the highest initial estimated injection capacities. The three wells that were identified are as follows:

- Well 65 in the Unconfined Aquifer;
- Well 38 in the Confined Area – Shallow Aquifer; and
- Well 33 in the Confined Area - Shallow/Deep Aquifers.

Based on Pueblo's review of the Well Completion Reports for these wells, no apparent problems or limitations with regards to their as-built conditions were found that would preclude them as potential candidate ASR testing sites (e.g., screen consists of torch-cut slots, missing or incomplete information regarding well completion, lithology, etc.). Therefore, these wells were selected as potential candidates for ASR testing and were analyzed further utilizing a more in-depth site-specific methodology compared to the above initial screening-level methodology. The following factors were evaluated:

- **Well Response to Injection** - One method of estimating the injection capacity limits of an ASR well is to determine the amount of draw-up available within the well casing for injection, and calculate the maximum injection rate based on the theoretical water level response to injection.
- **Backflushing Capacity** - Periodic, vigorous backflushing is absolutely necessary to maintain injection capacity. The ability to adequately backflush ASR wells while maintaining a flooded perforated section is, therefore, a critically important consideration when designing and operating ASR well facilities.

- **Downhole Velocity** - Experience at other injection wells has shown that excessive downhole velocities can lead to the entrainment of air bubbles, sweeping them into the well screen and formation, which results in air binding and plugging of the well.
- **Hydro-Fracturing** - During injection, the injection heads must not exceed pressures that would create vertical cracks in the confining layers (hydraulic fracturing) through which injected water may flow upward into overlying sediments or to the ground surface ('daylighting'). The pressure in the confined aquifer must not exceed vertical grain pressures of the materials overlying the confining layer to avoid hydraulic fracturing.
- **Offsite Impacts** - This constraint is based on estimates of the maximum injection rate that can be achieved without causing water levels in the aquifer system offsite to rise above some level that would cause undesirable results. Typically, this means raising water levels above the ground surface at an offsite well and causing it to become artesian and start flowing at the surface (i.e., daylighting).

A summary of the site-specific injection capacity constraints presented above for the three ASR candidate City well sites is presented in Table 5-2.

Table 5-2. Injection Capacity Constraints Summary[(a)]

Well	Injection Capacity (gpm) vs. Constraint					
	Well Response[(b)]					
	Minimum Response (Water Level @ Ground Surface)	Maximum Response (30 psi of Wellhead Pressure)	Backflushing Capacity	Downhole Velocity	Hydro-Fracturing	Offsite Impacts
65	1,170	2,616	3,785	**793**	1,650	16,250
38	**732**	2,196	2,112	793	800	9,000
33	**225**	642	5,163	627	250	975

(a) Primary limiting factors for each well are highlighted in blue. See additional discussion in text below.
(b) Well response is the resulting injection rate that would raise water levels within the well casing to ground surface (minimum response) or result in 30 pounds per square inch (psi) of wellhead pressure (maximum response).

In summary, the evaluation of the various hydrogeologic and operational factors that constrain the injection capacities of the three-identified potential candidate ASR testing sites reveals that the primary limiting factor on the injection capacity of Well 65 is the downhole velocity criterion (i.e., limited by the 18-inch diameter casing), which limits the injection rate to approximately 790 gpm (1.14 mgd), regardless of the theoretical capacity as constrained by any other criteria.

The evaluation also reveals that the well response to injection (without pressurized casing injection) criterion is the primary limiting factor at Wells 38 and 33, which limits injection rates to approximately 730 gpm and 225 gpm (1.05 mgd and 0.324 mgd), respectively. This finding is not surprising given the relatively shallow depths to water in the area (both of these wells are located in the Confined Area in the western portion of the service area). If pressurized casing injection is determined to be an acceptable practice, then the downhole velocity criterion becomes the limiting factor at Well 38 and the hydrofracturing criterion becomes the limiting factor at Well 33, with injection rates of approximately 790 gpm and 250 gpm (1.14 mgd and 0.360 mgd), respectively.

5.3.3.3 Conceptual ASR Injection Quantities

Based on the preliminary injection rates described above, conceptual ASR injection quantities can be estimated as shown in Table 5-3.

Table 5-3. Conceptual ASR Injection Quantities

Assumed Injection Rate for Each ASR Well, gpm	Daily Injection Quantity, mgd[(a)]	Monthly Injection Quantity, gallons/month[(b)]	Monthly Injection Quantity, af/month	Winter Months Injection Quantity, af[(c)]
500	0.72	21,600,000	66.3	265
700	1.01	30,240,000	92.8	371

(a) Assumes continuous injection (24 hours per day) at the injection rate shown.
(b) Assumes 30 days per month.
(c) Assumes four months of injection (December through March).

As shown, with a single ASR well with an assumed injection rate of 500 to 700 gpm (0.7 to 1.0 mgd), the monthly injection quantity would be about 66 to 93 af per well. Assuming a four-month injection period, December through March when demands are low and surplus treated surface water supplies are typically available (in normal or wet years), approximately 265 to 370 af of treated surface water supplies could be injected into a single ASR well. If a number of ASR wells were constructed, the total injection quantities could be increased. For example, if ten ASR wells were constructed, and operated as shown in Table 5-3, the ASR injection potential over a four-month injection period could be approximately 2,650 to 3,700 af, or about 10 percent of the City's annual surface water allocation from Phase One of the MRWTP. This injected water could then be later extracted in the summer months to help meet peak demands, or stored from year to year and later extracted in dry years when surface water supplies may be limited. As previously stated, the injection of seasonally available surplus treated surface water into the groundwater basin would also improve the quality of the subsequently extracted groundwater, increase the groundwater operational yield in specific areas of the subbasin, mitigate some of the drought impacts to the City's potable water supply, better meet peak demand periods, and improve the reliability of the City's groundwater supply.

5.3.3.4 ASR Conclusions and Recommendations

The overall conclusion of Pueblo's evaluation is that ASR appears to be a viable water supply management tool available to the City. It is recommended that the City further advance the establishment of an ASR program with a focused evaluation of the various components integral to ASR operations such as: evaluating its fiscal feasibility, analyzing the source water's availability and source water quality; investigating the geochemical interactions between the source water and the native groundwater; and understanding the regulatory issues associated with ASR operations. Pilot ASR testing (ASR Demonstration Test Program) is also recommended to empirically verify the conclusions of the focused evaluation and to develop site-specific test program data regarding the expected effectiveness, impacts, and economics of a potential ASR program. If the results are favorable, this would form the basis for evaluating, planning, permitting and implementing a full-scale ASR program within the City. The City may choose to perform the demonstration project using an existing well, or by upgrading a new well (such as the upcoming Tivoli Well slated to be designed as a municipal extraction well).

The goals of the ASR Demonstration Test Program would include the following:

- Demonstrate/verify the beneficial impacts to water levels in the basin from ASR operations;
- Demonstrate/verify that beneficial injection rates can be maintained for sustained periods of time (i.e., with no significant loss in well efficiency);
- Demonstrate/quantify the effectiveness of periodic well flushing on well performance (i.e., specific capacity);
- Verify/quantify that the recovered water meets all Title 22 drinking water standards;
- Verify/quantify that the recovered water does not create or exacerbate any consumer acceptance issues (i.e., taste, odor, visual clarity, effervescence, etc.);
- Verify/quantify that injected water remains geochemically stable during storage and recovery; and
- Quantify the benefits to aquifer water quality (including stability and salt balance issues) from ASR operations.

5.3.4 Modesto Groundwater Basin Characterization and Recharge Study

The City received a grant from DWR's FY2012-2013 Local Groundwater Assistance (LGA) Program to conduct a Groundwater Basin Characterization and Recharge Study[7] to explore opportunities to improve conjunctive management of its groundwater and surface water resources in the Modesto Subbasin, including MAR. Specifically, this study included a hydrogeologic characterization, identification of potential recharge locations, and numerical model simulations of recharge alternatives. The study had the following objectives:

- To develop a comprehensive characterization of the basin hydrogeology, especially the deeper aquifers where domestic (potable) water is typically extracted via municipal production wells, with a focus on future augmentation of these aquifers;
- To identify future studies and projects that can be implemented to further the development of a groundwater banking, augmentation and management program for the Modesto Subbasin; and

[7] City of Modesto Groundwater Characterization and Recharge Study: Modesto LGA Program, prepared by RMC and Todd Groundwater, June 2016.

- To analyze the feasibility of pursuing a pilot study and subsequent demonstration project regarding potential groundwater recharge in the basin.

Potential recharge locations were identified based on the hydrogeologic conceptual model, a previous surface recharge analysis, and existing infrastructure, land use, and well locations. Seven potential MAR locations were identified and evaluated: Creekside Golf Course, Sutton Park, South of Mary Grogan Community Park, Sanders Park, Freedom Park, Orchard Park, and Ustach Park. The potential recharge method (i.e., surface and/or subsurface recharge) and recharge rates were estimated at each location.

A numerical model was used to simulate recharge alternatives. A refined local model was created from a regional steady-state USGS model and used to simulate a "No Project" Baseline scenario and three alternative scenarios with both surface recharge (i.e., ponds) and subsurface recharge (i.e., injection wells). Alternative A simulated recharge from ponds and injection wells at seven potential locations identified as part of this Study. Alternative B simulated recharge from an additional 10 injection wells along the eastern edge of the Study Area. Alternative C simulated recharge from an additional five injection wells in the eastern Study Area, but without ponds. Alternative A simulated 8,294 af/yr of recharge, while Alternatives B and C simulated 13,850 af/yr of recharge.

Simulations show groundwater mounding resulting from recharge at the ponds and injection wells. The maximum simulated mounding is approximately 15 meters (49 feet) in the vicinity of Grogan Park and Sanders Park in Alternatives B and C. Based on April 2015 measurements, the depth to water in this region is between 50 and 55 feet. Due to the observed mounding relatively close to the ground surface, results indicate that subsurface storage may be a limiting factor for large recharge volumes and/or closely-spaced wells. It appears that recharge volumes of about 8,294 af/yr could be accommodated. Enhanced recharge of 13,850 af/yr results in excessive mounding for the distribution of recharge ponds and wells simulated. However, simulations were conservative in that recovery pumping was not simulated in the recharge wells as would occur for ASR strategies. The MODPATH particle tracks show that most of the recharge water is extracted by City wells, or, in some cases, by nearby wells operated by MID. Most of the water is recovered within 25 years, while some of the water remains in the aquifer for longer time periods. The simulated particle pathlines and travel times are conservative (e.g., less recovery); injected water travels farther than would occur with operation of the injection wells as ASR wells. In addition, ASR operations would result in more available aquifer storage, as the injection wells also extract recharge water.

Overall, this study indicates that MAR is feasible and that the eastern and southeastern portions of the Study Area are most promising, with significant potential for recharge and for recovery by City wells.

The study will be submitted for inclusion in the East Stanislaus Integrated Regional Water Management Plan, currently under development, and will be incorporated in updates to the *Integrated Regional Groundwater Management Plan for the Modesto Subbasin*.

5.4 RECYCLED WATER OPPORTUNITIES

5.4.1 Regional Wastewater Treatment

The cites of Modesto, Turlock, Ceres, and Hughson each operate a wastewater treatment plant(s), providing services to their respective service areas. Treatment of the City of Modesto's raw wastewater occurs at the Sutter Avenue Primary Treatment Plant and Jennings Road Treatment Plant, located on two sites within the City of Modesto. The Sutter Avenue Primary Treatment Plant provides pumping, screening, grit removal, flow measurement, primary clarification and sludge digestion. The primary effluent is then conveyed to the City's Jennings Road Treatment Plant where it is treated further and either discharged or stored until it can be discharged. The Jennings Road Treatment Plant has recently been upgraded to a tertiary treatment system with the implementation of Phase 1A of its Tertiary Treatment Project, providing up to 2.3 mgd of tertiary treated water. Phase 2 of the project is currently under construction and will add 12.6 mgd of tertiary treatment, allowing for compliance with the City's National Pollutant Discharge Elimination System Permit and permitting year round discharge to the San Joaquin River.

Additionally, the Salida Sanitary District operates a wastewater treatment plant and provides wastewater collection, treatment, and disposal for the unincorporated community of Salida. The City of Turlock produces tertiary-treated recycled water. The cities of Hughson and Ceres treat wastewater to secondary standards.

5.4.2 Potential Recycled Water Uses

Recycled water is recognized as a beneficial water supply due to its many advantages including:

- Providing a reliable water source that is consistently available regardless of droughts or climate change;
- Offsetting potable water for other uses; and
- Diversifying agencies' and cities' water supply portfolios.

The cities of Modesto, Turlock and Ceres have historically worked together to identify regional opportunities for wastewater treatment and recycled water production. An example of a recent cooperative project is the North Valley Regional Recycled Water Program (NVRRWP), an effort to regionalize recycled water use in Stanislaus County. As envisioned, the NVRRWP could produce and deliver up to 30,600 af/yr of disinfected tertiary treated recycled water to western Stanislaus County by 2018. By 2045, NVRRWP could deliver up to 59,900 af/yr of recycled water. The source of recycled water includes treated wastewater from the Cities of Turlock, Ceres, and Modesto. As part of the project, the City of Turlock would install an additional 5.7 miles of conveyance pipeline to convey water directly from its Regional Water Quality Control Facility's tertiary treatment plant to the Delta-Mendota Canal (DMC). The canal would be used to convey the blended canal-recycled water to users in the west side of the County. Funding from the USBR has been pursued for completion of feasibility studies related to the NVRRWP; however, no funding has been secured to date.

The City analyzed opportunities to reuse the tertiary recycled water with the completion of a feasibility study in 2005[8]. The feasibility study assessed recycled water markets, reviewed regulatory requirements, and developed and evaluated alternatives for regional water recycling and wastewater treatment. As part of the study, stakeholder workshops were conducted to discuss and gain input on recycled water opportunities. Seventeen local communities and agencies were invited to participate in the workshops and nine cities and agencies participated.

This work has been refined, and the City is currently moving forward with this project to supply tertiary treated recycled water to the Del Puerto Water District (DPWD), as well as other potential users in western Stanislaus County, with the implementation of the NVRRWP. DPWD is located along the west side of the San Joaquin Valley and extends from Vernalis to Santa Nella. Currently, DPWD's only source of water is through a contract with U.S. Bureau of Reclamation for Central Valley Project (CVP) supply. Since the 1990s, DPWD has experienced reduction in CVP deliveries due to drought conditions and regulatory restrictions imposed on CVP operations. The geographic proximity of DPWD to the City of Modesto's wastewater treatment facilities provides an opportunity for recycled water to supplement DPWD's existing water supply and improve water reliability. Although the NVRRWP would not provide a potable water offset directly to the City of Modesto service area, the treated wastewater would be used beneficially and would provide water supply reliability, public safety, enhanced property values and increased educational opportunities.

5.5 OTHER POTENTIAL IMPACTS ON FUTURE WATER SUPPLY AVAILABILITY AND RELIABILITY

5.5.1 Climate Change

An extensive evaluation of the impacts of climate change is included the East Stanislaus Integrated Regional Water Management (East Stanislaus IRWM) Plan[9]. The City of Modesto is included in the East Stanislaus Regional Water Management Partnership (ESRWMP), the official Regional Water Management Group for the region, along with the cities of Hughson, Ceres and Turlock. Key findings from the climate change evaluation are summarized below.

The East Stanislaus IRWM region lies within the San Joaquin River Hydrologic Region and contains the Stanislaus, Tuolumne, Merced and San Joaquin Rivers, and Dry Creek. The Stanislaus, Tuolumne and Merced Rivers are all tributaries to the San Joaquin River, with the Tuolumne having the largest watershed in the San Joaquin River system. At present, all major tributaries to the San Joaquin River are being studied with respect to anticipated impacts from climate change. Studies currently underway include the following:

- Changes in snow cover patterns in the Sierra Nevada (University of Washington);
- The role of atmospheric rivers in extreme events in the Sierra Nevada (USGS);

[8] Northern San Joaquin Valley Regional Recycled Water Project Feasibility Study, prepared by RMC, 2005.
[9] East Stanislaus Integrated Regional Water Management (ESIRWM) Plan, December 2013.

- Impacts of climate changes on soil properties and habitats in the Sierra Nevada (University of California (UC) Merced and USGS);
- Study of the effects of climate change on hydrology and stream temperatures in the Merced and Tuolumne River watersheds (Santa Clara University); and
- Study of 2013 Rim Fire (UC Davis Center for Watershed Sciences).

In general, these studies are multi-year endeavors and are either in progress or have yielded data that are currently being evaluated. While preliminary study reports appear to support other climate change impact observations and modeling simulations, the final published conclusions of these studies are, for the most part, not currently available.

Climate change is adding new uncertainties to already existing challenges in water resources planning within the East Stanislaus IRWM planning region. There is not a widely-diversified water supply portfolio in the region. Water supplies are derived from multiple subbasins of the San Joaquin Valley Groundwater Basin (Modesto and Turlock Subbasins) and primarily from the Tuolumne River. Climate change will impact groundwater and surface water differently, but the region’s vulnerabilities are the same regardless of the source:

- Reduced surface water availability;
- Reduced water supply reliability as a result of reduced groundwater recharge and runoff;
- Potential increase in groundwater overdraft;
- Declining water quality;
- Loss of riparian habitat, wetlands and other sensitive natural communities; and
- Reduced hydroelectric generation capacity.

The identified vulnerabilities within the East Stanislaus Region are summarized in Table 5-4.

Table 5-4. East Stanislaus Region Climate Change Vulnerabilities

Vulnerability	Description
Water Demand	Vulnerable to increased agricultural demands due to longer growing season, increased temperatures and evapotranspiration rates, and more frequent/severe droughts. Vulnerable to increased urban and commercial, industrial, and institutional (CII) demand due to increased outside temperatures.
Water Supply and Quality	Vulnerable to decreased snowpack in the Sierra Nevada, shifts in timing of seasonal runoff, increased demands creating groundwater overdraft, degraded surface and groundwater quality resulting from lower flows, exaggerated overdraft conditions, a reduction of meadows which can provide contaminant reduction, and more frequent/severe droughts and storm events increasing turbidity in surface supplies.
Flood Management	More severe/flashier storm events and earlier springtime runoff leading to increased flooding, and a reduction of meadows which help reduce floods in the winter.
Hydropower	Vulnerable to increased customer demand combined with changes in timing of seasonal runoff and flashier storm systems affecting reservoir storage.
Ecosystem and Habitat	Vulnerable to decreased snowpack, more frequent/severe droughts and wildfires, shift in seasonal runoff, increased low flow periods and increased water temperatures (degraded water quality).

Source: Table 3-4, East Stanislaus IRWMP, December 2013

Considering the amount of uncertainty associated with climate change projections, a prudent approach to addressing climate change incorporates a combination of adaptation and mitigation strategies. Climate adaptation includes strategies (policies, programs or other actions) that bolster community resilience in the face of unavoidable climate impacts, where mitigation strategies include best management practices (BMPs) or other measures that are taken to reduce GHG emissions.

The Proposition 84 IRWM Guidelines require consideration of the *California Water Plan* (CWP) Resource Management Strategies (RMSs) in identifying projects and water management approaches for the region. RMSs are being considered in the East Stanislaus IRWM planning process to meet the region's objectives. Application of various RMSs diversifies water management approaches, and many of the RMSs apply to climate change adaptation and mitigation. Categories of applicable RMSs include:

- Reduce Water Demand
- Improve Operational Efficiency and Transfers
- Increase Water Supply
- Improve Water Quality
- Urban Runoff Management

- Practice Resource Stewardship
- Improve Flood Management
- Other Strategies

For the City, the implementation of its overall water conservation program, particularly the completion of the residential metering program, will help to reduce water demands, and also conserve energy as a result of decreased treatment, conveyance and pumping requirements. The City's compliance with SBx7-7 and its interim and final per capita water use targets will also ensure continued water conservation and energy conservation in the future. The City's increased use of surface water supplies from MID's MRWTP Phase Two Expansion will help to further diversify the City's water supplies and enhance the City's water supply reliability to "adapt" to the changing hydrologic conditions associated with climate change.

5.5.2 Anticipated FERC Restrictions

The Don Pedro Project is a federally-licensed water storage and hydroelectric generating facility located on the Tuolumne River in the Sierra Nevada foothills approximately 130 miles east of San Francisco. The Don Pedro Project was constructed as a water storage project and is operated to provide a safe, reliable source of water. It supplies water to approximately 300,000 acres of Central Valley farmland, which is among the most productive in the world. The water stored behind Don Pedro also supplements the drinking water supply for the City of Modesto, La Grange and, through a "water banking" arrangement with the City and County of San Francisco, supports the Bay Area's water supply for more than two million people. As a multi-purpose project, Don Pedro provides water storage for irrigation and domestic use, as well as energy from a renewable resource. Don Pedro operations also benefit fish, wildlife, and recreation resources, as well as providing flood control benefits through cooperation with the U.S. Army Corps of Engineers.

Owned 31.54 percent by MID and 68.46 percent by TID, the project was placed into service in 1971. It consists of a 2,030,000 acre-foot reservoir and a 203 megawatt powerhouse. The project operates under a 50-year license granted to the Districts by the FERC. The current license extends through April 30, 2016. The Districts intend to obtain a new license, and will be relicensing Don Pedro using FERC's Integrated Licensing Process. The relicensing process is an intricate and lengthy undertaking which will stretch over several years and will be open to public participation. Upon license expiration, FERC will begin issuing annual licenses for the Project until the relicensing process is complete. It is not unusual for larger projects to have their existing license expire while the relicensing proceeding is still underway.

MID and TID took the first step in this multi-year process by filing a Notice of Intent and Pre-Application Document in February 2011, which summarized existing information relevant to the relicensing process. Since then, numerous studies have been conducted. MID and TID filed the Draft License Application (DLA) in November 2013. The purpose of the DLA is to provide an opportunity for public review and comment on the application prior to filing the Final License Application (FLA). MID and TID filed the FLA for the Don Pedro Project with FERC in April 2014. The FLA contains a number of new proposed measures to protect the environment and promote recreational use of the Project area. The FLA may be modified in 2017, or sooner, awaiting completion of the last of the studies.

Federal law requires that MID and TID obtain a Water Quality Certificate from the State attesting that the Don Pedro Project, as proposed, complies with water quality objectives applicable to the Tuolumne River. Through this process, the State can impose requirements on MID and TID to increase river flows or implement non-flow measures beyond those ordered by FERC. These restrictions may be influenced by the SWRCB's recent draft revised Substitute Environmental Document (SED) in support of potential changes to San Joaquin River flow and southern Delta water quality objectives and program of implementation included in the *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* (Bay-Delta Plan) (see discussion in Section 5.5.3 below).

5.5.3 Increased Unimpaired River Flow Requirements

On September 15, 2016, the SWRCB released the draft revised SED in support of potential changes to San Joaquin River flow and southern Delta water quality objectives and program of implementation included in the Bay-Delta Plan.

The proposal by the SWRCB would require the Merced, Tuolumne, and Stanislaus rivers to dedicate a significant percentage of unimpaired flow from February through June annually to improve fish populations and the Delta ecosystem. According to the SWRCB, the proposed new flow requirements for the San Joaquin River's major tributaries recognize the vital role upstream water flows provide for habitat and migratory signals for native fish species. In summary, the draft proposes increasing flows for fish and wildlife and adjusts the salinity requirements to a slightly higher level to reflect updated scientific knowledge.

Specifically, the recirculated Draft SED recommends increasing flow on the San Joaquin River and its tributaries to a range of 30 to 50 percent, with a starting point of 40 percent of unimpaired flow from February through June. Unimpaired flow represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. Historical median February through June flows from 1984 to 2009 in the Merced, Tuolumne, and Stanislaus Rivers were, respectively, 26, 21, and 40 percent of unimpaired flow. In other words, half of the time more than 60 or 70 percent of each river's flow is diverted out of the river during these months.

If the SWRCB approves this proposal, it will undoubtedly have significant and unavoidable impacts on Don Pedro's water supply and, ultimately, all those who benefit from that water. Many water agencies, including MID and TID, are opposed to the proposal and believe there are less drastic, non-flow-based alternatives that warrant the serious consideration of the SWRCB. They believe that that the proposal lacks the best available science and will negatively impact both water and power customers, and will also cause significant harm to the region's economy, agriculture operations and water supply.

Written comments on the draft revised SED are due to the SWRCB on March 17, 2017. After receipt of comments, the SWRCB will make any needed changes to the SED and prepare written responses to comments along with a final draft SED and final draft changes to the Bay-Delta Plan for consideration by the SWRCB. Changes to the Bay-Delta Plan must be approved by the SWRCB and the Office of Administrative Law before becoming effective.

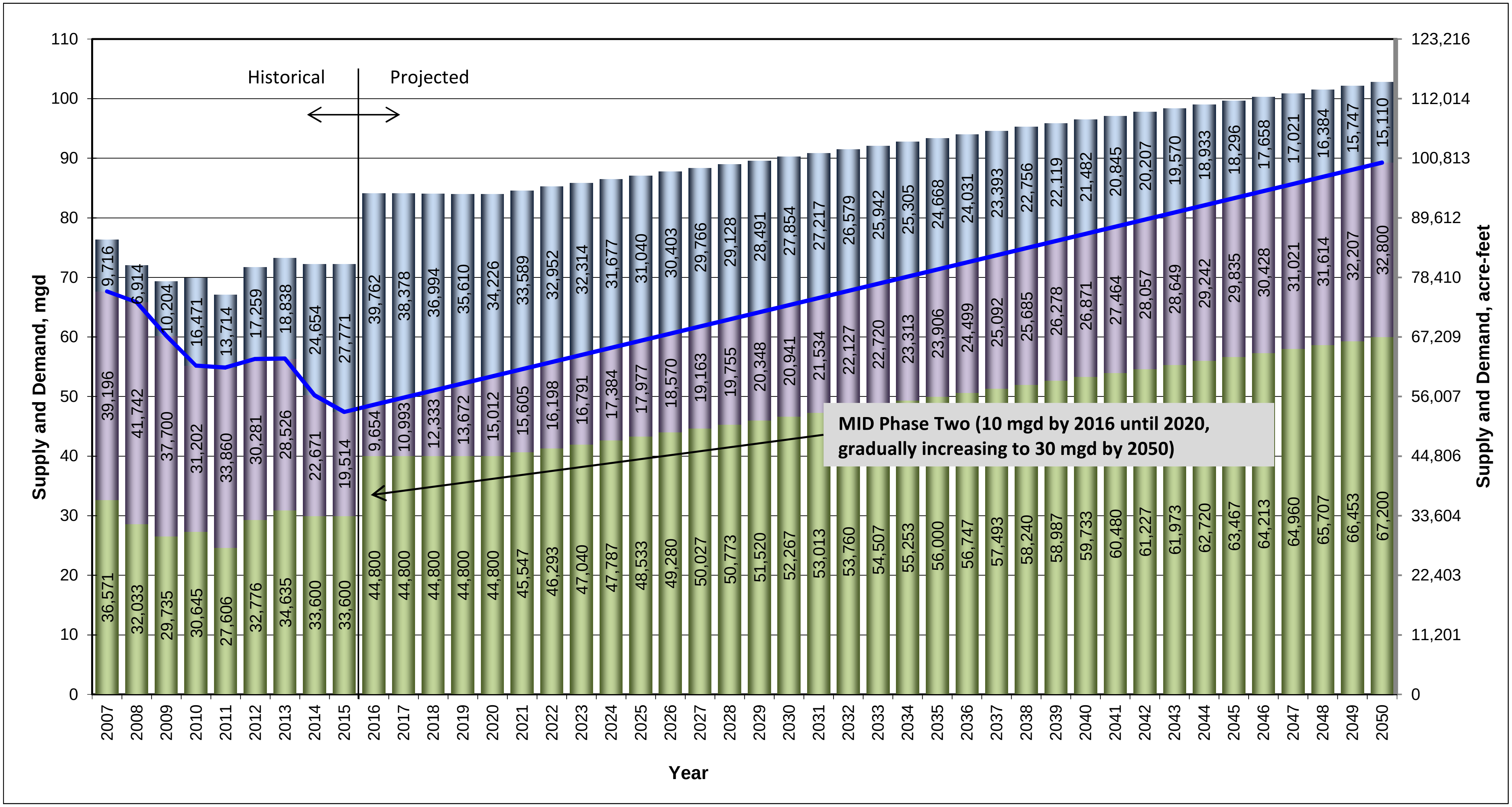


Figure 5-1
Modesto Contiguous Area - Comparison of Supply and Demand

City of Modesto
Water Master Plan

Last Revised: 10-01-15; o\c\418\02-13-34\e\TMTablesandFigures

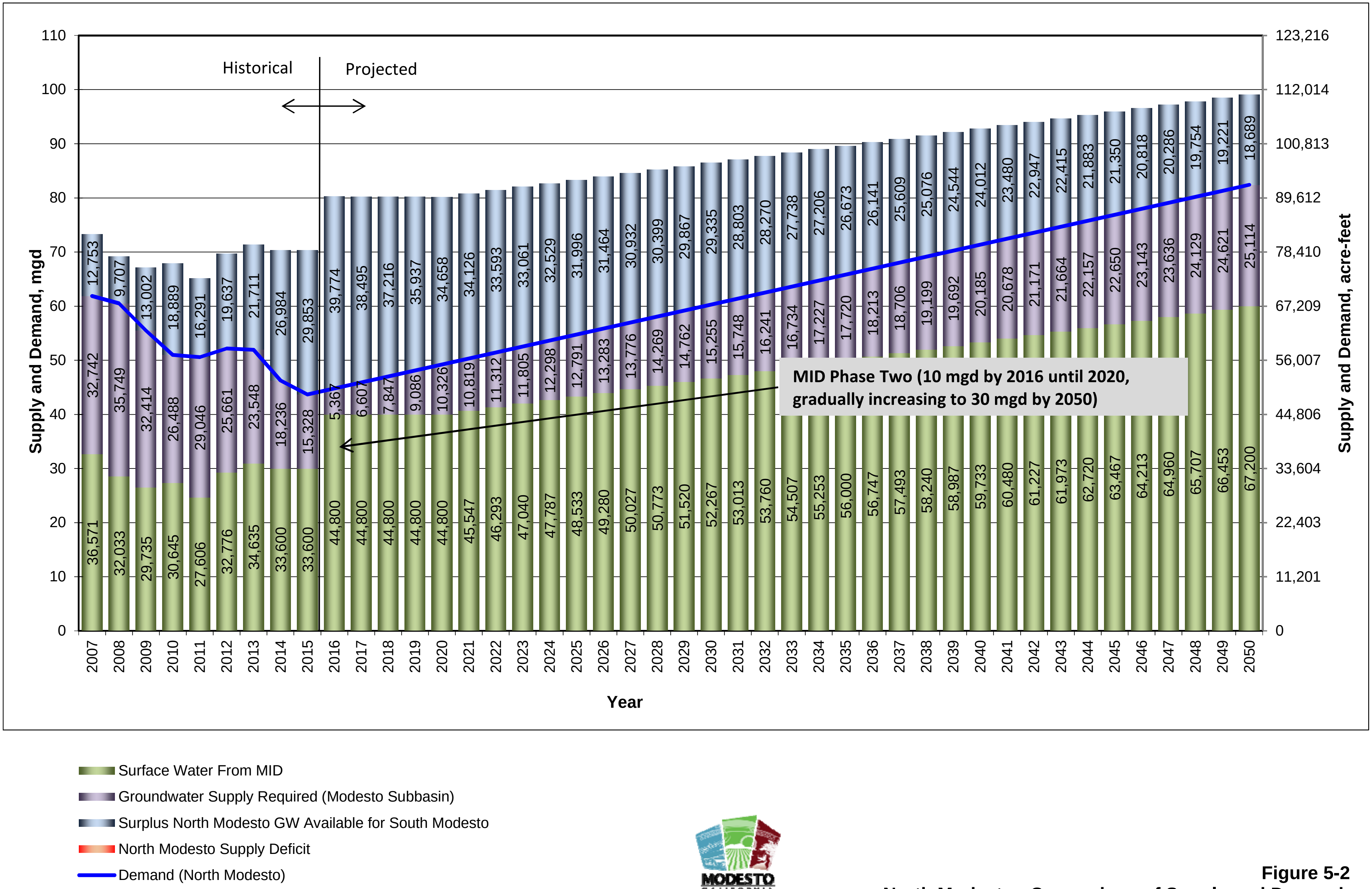
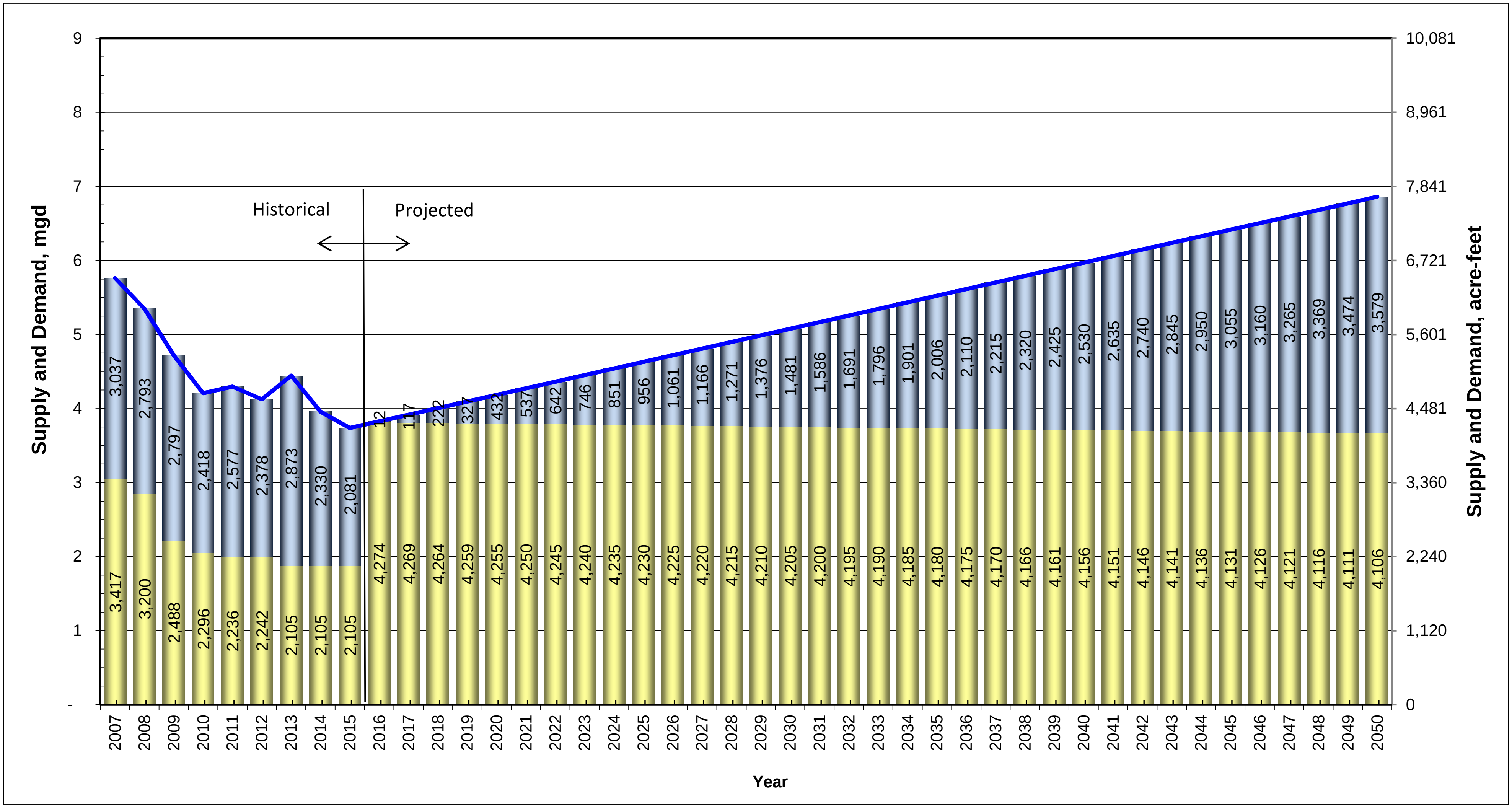


Figure 5-2
North Modesto - Comparison of Supply and Demand: Showing Impact of MID Phase Two on Groundwater Pumping

City of Modesto
Water Master Plan

Last Revised: 10-01-15; o\c\418\02-13-34\e\TMTablesandFigures



Water Supply Deficit

Groundwater Supply Required (Turlock Subbasin)

Transferred Groundwater Supply Required (Modesto Subbasin)

Demand (South Modesto)

Figure 5-3

South Modesto - Comparison of Supply and Demand: Showing Continued Use of Groundwater Supplies from the Turlock and Modesto Subbasins

City of Modesto
Water Master Plan