Raw Water Supply Yield Analysis
2020 Update

Prepared For:

City of Loveland

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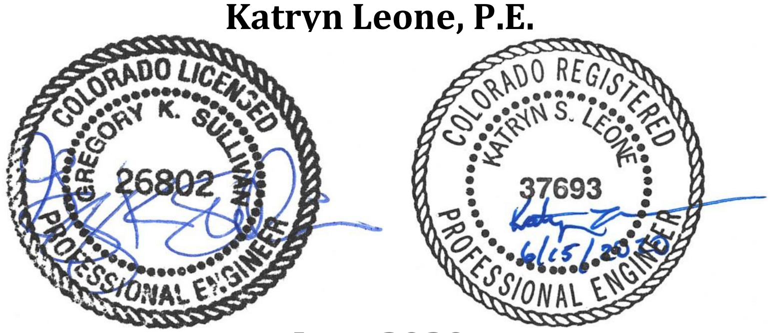

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Spronk Water Engineers, Inc.

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1.0 INTRODUCTION

The City of Loveland ("City" or "Loveland") is located along the Big Thompson River, a tributary of the South Platte River, in northern Colorado. Through its Department of Water and Power, the City provides treated water service to approximately 76,000 people located in a 33 square mile service area as shown in **Figure 1-1**. The City's water supply is derived from the Big Thompson River pursuant to water rights for the native supply, and contracts for transmountain water delivered to the Big Thompson River from the Colorado River basin through the facilities of the Colorado-Big Thompson ("CBT") Project and the Windy Gap Project.

Beginning in 2003, Loveland contracted with Spronk Water Engineers, Inc. ("SWE") to analyze and model the City's raw water supply system in response to concerns related both to the adequacy of the City's existing supply and to development credit given by the City for water that is put in the Loveland Water Bank ("Water Bank")[1]. The 2004 Raw Water Yield Study was performed in accordance with the City's 100-year drought planning policy and a report was prepared to summarize the results of SWE's analysis of the yield of Loveland's raw water supply. The report described the City's water supply system, the development and operation of a simulation model ("Yield Model") of that system, and presented the results of various analyses ("Yield Study" or "Yield Analysis") performed with the Yield Model, including (a) estimation of the reliable or firm yield of the City's current water supply and (b) estimation of the increase in the City's firm yield that would result from possible acquisition of various Big Thompson River and transmountain water sources, or development of additional raw water storage. The City used the results of these analyses to develop a Raw Water Master Plan ("RWMP") in 2005, and to modify its water rights dedication policies. The RWMP was adopted with the intention to reevaluate the plan at regular intervals of approximately five years to adjust the conclusions and recommendations for changes in population growth, the City's water portfolio, or other factors.

In 2011, SWE updated the 2004 Raw Water Yield Study to include analysis of the effects of changes in the City's raw water supply system and water supply portfolio that have occurred since the RWMP was developed. The City again contracted with SWE to update the Raw Water Yield Study to include analysis of the effects of changes in the City's raw

[1] See Section 2.6 for additional discussion of the Loveland Water Bank.

water supply system and water supply portfolio that have occurred since the 2011 Raw Water Yield Study Update.

This report was prepared to summarize SWE's updated analysis of the yield of Loveland's water supply. In order to serve as a stand-alone document, the report repeats some of the descriptive and explanatory material contained in the prior reports. It describes the City's water supply system and changes that have occurred since 2011, summarizes the updating of the Yield Model of the water supply system, and presents results of the analyses performed with the Yield Model. The City requested several analyses including (a) estimate the firm yield of the City's current supplies, including use of the Loveland Gard Right under the terms and conditions decreed in 2015 in Case No. 07CW325, (b) estimate potential uses and benefits of exchange of reusable wastewater treatment plant ("WWTP") effluent, (c) estimate potential volumes and uses of reusable lawn irrigation return flows, (d) estimate the increase in the City's firm yield that would result from possible acquisition of various Big Thompson River and transmountain water sources, or development of additional raw water storage, and (e) estimates of the potential impacts of future water supply reductions.

2.0 BACKGROUND

2.1 Municipal Water Supply and Drought

Drought is a normal and recurrent feature of the Colorado climate with which municipal water suppliers must contend. Climate records kept during the past century show that Colorado has been affected by numerous short-term and long-term droughts. The most well-known historical droughts in Colorado are the multi-year droughts of the 1930s and 1950s, the shorter but severe drought of the late-1970s and the most recent drought of the 2000s that began in 1999 and included the driest year of record in 2002 in the Big Thompson River and upper Colorado River basins.

The effect of drought on a municipal water supply depends on (a) the characteristics of the drought; i.e., the time of onset, duration and severity (departure from average) of the drought, and (b) the adequacy of the municipal water supply system to withstand the effects of drought. Short duration droughts (e.g., 6-months or less) occur more frequently than multi-year droughts. Municipal water suppliers with little or no raw water storage tend to be most affected by severe short-term droughts. Systems with significant raw water storage can withstand the effects of short-term droughts, and the yield of these systems is defined by the supply that can be provided through a prolonged drought period.

The yields of municipal water suppliers are often characterized by their firm yield. Firm yield is the maximum annual water demand that can be dependably supplied each year during a representative historical study period. Firm yield is distinguished from the drought yields of the individual sources available to a water provider by certain water supply enhancing features that allow a municipality to improve its supply during drought periods. For example, a municipal water supplier can increase its yield in drought years by storing excess water in average and wet years for use in the drought years or by exchanging legally reusable supplies for additional diversions.

Most large municipal water suppliers along the Front Range of Colorado have a variety of water sources and/or water rights from which their water supplies are derived. Loveland is typical in this respect as its water supply is derived from senior and junior water rights that are native to the Big Thompson River, and transmountain water from the Colorado River basin delivered pursuant to CBT and Windy Gap units owned by the City. Each of these sources has drought yields that can be characterized individually based on historical flow records or other procedures. However, the yield of the Loveland water supply is defined by how its various sources are integrated and delivered to meet the demands of the Loveland citizens. While the yields of individual sources in isolation are important (e.g., the yield of a ditch system as evidenced by historical diversion records), the City's yield is also affected by the capacity of its diversion facilities, the available physical supply at its points of diversion, the capacity of its water storage facilities, the timing of its water demand, the legal reusability of its water sources and other factors.

As the City contemplates acquisition of new water sources, it needs to consider what the new sources will contribute to enhancing its overall system yield. For example, if a new water source adds water only at times when the City already has excess supplies then the new source may not increase the overall system yield.

Three prior analyses of the Loveland water supply system have been conducted. They include the 1988 study by Camp, Dresser & McKee, Inc. ("CDM"), the 2004 Raw Water Supply Yield Analysis prepared by SWE, and the 2011 Raw Water Supply Yield Analysis Update prepared by SWE.

2.2 1988 Water Supply Analysis

A comprehensive analysis of the Loveland water supply was performed in 1988 by CDM.[2] CDM analyzed the City's water supply using a model that simulated the yield of the City's water rights based on one thousand year synthetic streamflow records for the Big Thompson River and for streams in the Colorado River basin that supply the CBT and Windy Gap Projects. The results of the CDM analysis indicated that the City's water supply in 1985 could supply an annual demand of 11,700 acre-feet per year ("AF/y") with an average one-in-100 year failure rate[3]. The City has acquired additional water sources and constructed additional water storage capacity since the CDM study was performed.

2.3 2004 Raw Water Yield Analysis

The 2004 analysis of yield considered the City’s water rights and facilities as they existed in 2003. Between the 1988 report and the 2004 analysis, Loveland expanded Green Ridge Glade Reservoir (“GRG”) to 6,785 acre-feet (“AF") and acquired additional ditch shares and CBT units. Using a study period of 1951 through 2003, the firm yield was estimated to be 22,400 AF/y and conformed to the City’s 1-in-100 year drought policy.

[2] Camp, Dresser & McKee, Inc., Phase I - Drought Study, City of Loveland Raw Water Supply System (August 28, 1986).

[3] Sum of the 1985 demand from Table 7-3 in the CDM report (7,575 AF/yr) plus the annual surplus for 1985 demand at 100-year recurrence interval (4,139 AF/yr)

In addition to estimating the firm yield of existing supplies, the 2004 Yield Study also evaluated various alternatives for additional water supply. Among the alternatives investigated were additional storage facilities without acquisition of additional ditch shares, storage needed to firm the yield of ditch shares acquired in the future, exchange and reuse of reusable WWTP effluent, participation in the Windy Gap Firming Project, and acquisition of additional CBT units and ditch shares.

The 2004 report was used as one of the bases for the RWMP that was developed by City staff and the Loveland Utilities Committee ("LUC"). The RWMP was the basis for several revisions to the City's water rights dedication policy in 2005.

2.3 2011 Raw Water Yield Analysis

The 2011 Yield Analysis considered the City's water rights and facilities as they existed in 2011. Between the 2004 and the 2011 analyses, the City acquired additional ditch shares, CBT units, and participation in the Windy Gap Firming Project ("WGFP"). The 2011 analysis also included the incorporation of the decreed return flow provisions decreed in Case No. 02CW392 ("392"), increased the modeled capacity of the Loveland Water Treatment Plant ("WTP") and Loveland Pipeline, modified the order of water supply use, modified free river diversions to be reusable, and included the addition of an augmentation demand of 590 AF/y to the modeled demands.

Using a study period of 1951 through 2006, the firm yield was estimated to be 27,390 AF/y and conformed to the City's 1-in-100 year drought policy.

As with the prior Yield Study, the 2011 Yield Study also evaluated various alternatives for additional water supply. Among the alternates investigated were additional storage facilities without acquisition of additional ditch shares, storage needed to firm the yield of ditch shares acquired in the future, exchange and reuse of reusable WWTP effluent, participation in the Windy Gap Firming Project, and acquisition of additional CBT units and ditch shares.

The 2011 Yield Study report was used as one of the bases for the RWMP that was updated by City staff and the LUC. The RWMP was the basis for several revisions to the City's water rights dedication policy in 2012.

2.4 2020 Raw Water Yield Analysis

The 2020 Yield Analysis considered the City's water rights and facilities as they existed in 2020. The 2020 analysis included the following:

- Extension of the study period through 2015
- Revision of the municipal water demand distribution based on 2005-2015 data
- Increased WGFP participation to 9,587 AF
- Increased CBT units from 11,786 to 12,190[4]
- Adjustment to South Side Ditch diversions related to conveyance of a portion (0.75 cfs) of the O'Hara private contract right back to the ditch company.
- Addition of the Loveland Gard Right[5]
- Addition of a 1,300 AF downstream gravel pit, Great Western Reservoir[6]
- Addition of unchanged ditch shares acquired since 2012.

Using a study period of 1951 through 2015 and a daily time step, the firm yield was determined as the total demand in acre-feet the City could have supplied each year without shortage. The firm annual yield was estimated to be 30,740 AF and conformed to the City's 1-in-100 year drought policy.

In addition to estimating the firm yield of existing supplies, the 2020 Yield Study also evaluated various alternatives for additional water supply. In addition to an evaluation of the impact of future water supply reductions and a modification to the calculation of reusable lawn irrigation return flows, the same alternatives from the 2011 analysis were also reevaluated in the 2020 analysis.

2.5 City Raw Water Planning Policy

On March 1, 1988, the Loveland City Council adopted the recommendations contained in the 1988 CDM study that the City's water supply be capable of meeting design demands during a one-in-100 year drought ("100-year drought"). A 100-year drought has a one percent chance of occurring in any one year and would be expected to recur on average

[4] The City of Loveland acquired an additional 20 CBT units after the yield modeling was completed. There are currently 12,210 CBT units in the City of Loveland's water rights portfolio.
[5] The Loveland Gard Water Right was decreed in Case No. 07CW325 and equates to 1.0 cfs from the beginning of the irrigation season until noon on July 14th each year and 0.5 cfs from noon on July 14th through August 31st each year. The City is in the process of implementing the Loveland Gard Water Right into its water rights portfolio.
[6] 1,300 AF was modeled as the preliminary operational storage capacity of Great Western Reservoir.

once every 100 years. The 100-year drought might occur more or less than one time in any particular 100-year period. According to the City staff, this planning policy requires developing sufficient supplies to meet the City's full water demand during the 100-year drought without water use restrictions. This planning policy remains in effect today.

As a result of the 2011 Yield Study Update and the subsequent RWMP developed by City staff and the LUC, on July 17, 2012, the City Council adopted Ordinance No. 5691, which modified the City's water right dedication policies. A copy of the ordinance can be found in **Appendix A**.

2.6 Loveland Water Bank

The City has operated the Water Bank since the mid-1980s, and deposits to the bank have been the source of most of Loveland's water acquisitions during recent years. Developers or other entities, who seek water supply service from the City, are required to provide additional water (e.g., ditch company shares, CBT units, or cash-in-lieu) and pay a native raw water storage fee if and when the ditch company shares are dedicated to a developing property. In exchange for depositing water in the Water Bank, the developer receives a credit that can be applied toward the water requirements for zoning or development anywhere the City serves treated water. Since April 1, 2006, a minimum of fifty percent of every raw water transaction to satisfy the requirements must include water bank credits received in exchange for CBT units transferred to the City, or water bank credits acquired from the City by cash purchase[7], or by paying the cash-in-lieu price ("50% Rule"). If the acre-feet requirement resulting from the 50% Rule results in a fractional requirement of less than one-half an acre-foot, it may be rounded down to the nearest acre-foot. The full amount is still required, but the percentages are allowed to be adjusted.

The development credit given for Water Bank deposits is determined when the credit is applied to meet zoning or development requirements based on the current conversion rate in effect. For example, a deposit to the Water Bank in 2005 that is used to meet the water requirements for a development initiated in 2020 would be converted to water supply credit based on the conversion rate in effect in 2020. The conversion rate in 2020 may be higher or lower than the rate that was in effect when the water was deposited. The conversion rates currently in effect were adopted with Ordinance No. 5691 in 2012. Depositors of native water (i.e., ditch company shares) are also required to pay a "Storage Fee" when the water is converted for water supply credit or accept a lower conversion rate. This fee is in recognition that raw water storage is necessary to firm up native water

[7] As of January 1, 2006, credit in the City's Water Bank may not be acquired from the City by cash purchase.

sources[8]. In addition to the water dedication/cash-in-lieu requirement, entities seeking treated water service must also pay "System Impact Fees", a "Raw Water Development Fee" and "Tap & Meter Fees."

The City has required water rights as a condition of development since 1960. The first such requirement is recorded in the form of an approved motion from a City Council meeting on August 16, 1960. Through 2005, credit for dedication of irrigation company shares was based on average annual diversions by each irrigation company over the past 20 years[9]. As a result of giving credit for average annual yield while needing to provide water supply during dry years, the Water Bank conversion policy resulted in erosion of the City's water supply drought cushion during this period. One of the purposes of the 2004 Yield Study was to estimate the actual increase in firm yield associated with addition of various water sources to the City's water portfolio for comparison with the then-current Water Bank conversion rates. As a result of the 2004 study, the Water Bank conversion rates were revised effective January 1, 2006. The Water Bank conversion rates were revised again after the 2011 Yield Study. A summary of the current water rights dedication and requirements for various irrigation company shares and transmountain sources is shown in **Appendix B**. One of the purposes of the current yield study is to review the current credits in the context of the City's current water portfolio and facilities.

[8] Ditch company shares yield water only during a typical May through October irrigation season. Storage is necessary to convert these sources to year-around supplies, as well as to increase dry year deliveries.
[9] See Ordinance No. 1053, Section 6, City of Loveland, October 21, 1969.

3.0 DROUGHT FREQUENCY

The City's policy of requiring that its water supply be capable of withstanding a 100-year drought is reasonable, but it raises a question about how to define the 100-year drought. Drought may generally be defined as a water supply deficiency relative to a long-term average condition. It may be determined based on precipitation records, streamflow records, soil moisture supply or other measures. Because the City's water supply is derived from both the Big Thompson River and the upper Colorado River, it is reasonable to assess the drought frequency of Loveland's water supply based on the combined flows of these sources.

3.1 Historical River Flows

The Big Thompson River is the source for Loveland's primary raw water supply derived from municipal transfers of native irrigation water rights. The flow of the Big Thompson River is measured at several locations including the Big Thompson River at Canyon Mouth gage, located west of Loveland and just upstream from Handy Ditch and the Hansen Feeder Canal, as shown in the schematic diagram in **Figure 3-1.** The Canyon Mouth gage provides a reasonable indication of the water supply available to water users in the basin as it is located downstream of the higher elevations that provide substantial snowmelt runoff and upstream of most of the significant diversions in the basin. However, the historical records of the Canyon Mouth gage are affected by the operation of the Colorado Big Thompson ("CBT") Project facilities. A better indication of the available native water supply is provided by estimates of the undepleted flow (also known as "virgin" flow) at the Canyon Mouth developed by the Northern Colorado Water Conservancy District ("Northern Water"). This is the flow that would have existed but for the operation of the CBT and Windy Gap Projects. Monthly undepleted flow estimates are available from 1947 - 2015.

The City relies on the CBT and Windy Gap Projects to supplement its primary native water supplies. The sources of water for these transmountain water projects include the Colorado River, Fraser River and Willow Creek in the upper Colorado River watershed. Northern Water prepares undepleted flow estimates for several upper Colorado River tributaries, and these data are available from 1950 - 2015.

The annual undepleted flows of the Big Thompson River at the Canyon Mouth gage and the Colorado River above Granby gage were analyzed to assess the frequency and magnitude of droughts affecting Loveland's raw water supply. The annual historical undepleted flows for these two gages are shown in **Figure 3-2**. During the period of concurrent record (1950 - 2015), the undepleted flow of the Big Thompson River averaged approximately 124,000 AF/y while the Colorado River averaged 270,000 AF/y. During this 66-year period the driest year at both locations occurred in 2002. Other dry years included 1954 and 1977. Flows at the two locations for these dry years are shown in the table below.

Annual Historical Undepleted Flows
Big Thompson River and Colorado River
(acre-feet)

	Big Thompson River at Canyon Mouth		Colorado River above Lake Granby	
Year	Undepleted Flow	% of Average Flow	Undepleted Flow	% of Average Flow
1950-2015 Average	124,000	---	270,000	---
1954	54,000	44%	154,000	57%
1977	71,000	58%	156,000	58%
2002	48,000	39%	120,000	44%

The Northern Water undepleted flow estimates provide information on the historical flows of the Big Thompson and upper Colorado Rivers. However, this data is not conclusive on the frequency of occurrence of very low flow events. For example, the most that can be said about the 2002 flow of the Big Thompson River from the virgin flow record is that it had a sample recurrence interval of one in 67 years. However, given the entire data set of Big Thompson River flows (including flows prior to the undepleted flow record), the 2002 flow could have an actual average recurrence interval of more or less than one in 67 years. Fortunately, there are methods that can be used to estimate the long-term frequency of low-flow events. One of these methods, involving the use of reconstructed flow through paleohydrologic analysis, is described in the following section.

3.2 Reconstructed Flows from NOAA Tree-Ring Study

The National Oceanic and Atmospheric Administration ("NOAA") has performed analyses of streamflows along the Front Range and in the Colorado River basin to extend the historical streamflow record using tree-ring data. These analyses involve developing a relationship between the thickness of annual tree rings in a watershed and the corresponding annual virgin streamflow during the period of the historical streamflow records. This relationship is then applied to earlier tree-ring data to estimate annual virgin streamflows prior to the period of record.

Reconstructed annual flows for the Big Thompson River at the Canyon Mouth gage are available for the period 1569 - 1999 and for the Colorado River above Granby from 1383 - 1999. A chart showing the historical and reconstructed annual Big Thompson River and Colorado River flows is shown in **Figure 3-3**. Historical undepleted flows are shown for the period 1947 through 2015 for the Big Thompson River at Canyon Mouth, and for the period 1950 through 2015 for the Colorado River above Granby reservoir. The reconstructed flows are used for the period 1569 through the start of the historical data.

3.3 Frequency of Big Thompson River and Colorado River Droughts

The combined historical and reconstructed undepleted flow record for the Big Thompson River indicates that 2002 was the 15th driest year in comparison to the 447 years of annual flows included in the record. An annual flow equal to or less than the 2002 flow occurred in 3.4 percent of the years. This corresponds to an average sample recurrence interval for the 2002 flow of one in 30 years. For the Colorado River above Granby, 2002 was the 5th driest year during the 633-year combined historical and reconstructed undepleted flow record. This indicates the sample recurrence interval for 2002 in the upper Colorado River basin was approximately one in 127 years.

In addition to the individual recurrence intervals for the Big Thompson River and upper Colorado River flows, the recurrence interval for both sources considered together is of interest to Loveland. The results of the yield analysis described in Section 8.1 indicate that approximately 55 percent of Loveland's water supply availability is from native Big Thompson River sources and 45 percent is from transmountain Colorado River sources, but approximately 69 percent of Loveland’s water supply firm yield is derived from the native Big Thompson River sources as illustrated on **Tables 8-1 and 8-2**. Based on this relative mix, the average recurrence interval for a composite supply comprised 60 percent from the Big Thompson River and 40 percent from the Colorado River was estimated as follows.

First, the composite reconstructed and historical undepleted flow records for each gage during the overlapping 1569 - 2015 period of record were normalized by computing the annual flow for each year as a percentage of average. **Figure 3-4** shows the normalized flows for the two gages over the 447-year period. Comparison of the normalized flows provides an indication of the degree to which droughts in the upper Colorado River basin have coincided with those in the Big Thompson River basin.

The next step was to compute a weighted composite annual normalized flow as 60 percent of normalized Big Thompson River flow plus 40 percent of the normalized Colorado River flow. A line chart illustrating the normalized historical and reconstructed annual virgin streamflow of the composite Big Thompson River and Colorado River over the 1569 - 2015 period is shown in **Figure 3-5**. The composite normalized 2002 flow is approximately 42 percent of average. Compared to the 447-year record, 2002 is the 6th driest year in the period. This corresponds to an average frequency of occurrence of approximately one in 75 years.

A frequency distribution of all the composite normalized gage flows was prepared and is shown in the solid line in **Figure 3-6**. The actual average recurrence interval of very low frequency events is difficult to assess from historical data because of the small number of these events in the sample. In consideration of this, a mathematical distribution can be fit to the sample data, and the fitted distribution may be used to characterize the low frequency events for the entire population of flows (i.e., the frequency of flows that would occur over a very long time period). One distribution that is commonly fit to streamflow data is the Log-Pearson Type III distribution ("LP-III"). The LP-III distribution was fit to the weighted combined normalized Big Thompson River and Colorado River annual flow data, and the result is shown in the dashed line in the **Figure 3-6**. Based on this fitted distribution, the 2002 weighted combined normalized flow has an average recurrence interval of approximately one in 90 years.

3.4 Historical Droughts and City Planning Policy

The one-in-90-year average frequency of occurrence of the combined normalized Big Thompson River and Colorado River flow in 2002 is close to the one-in-100-year frequency associated with the City's water supply planning policy. The 2002 combined normalized annual flow of 0.42 (42% of average) is only slightly greater than the normalized flow of 0.41 (41% of average) that corresponds to the one-in-100-year frequency of occurrence. This difference in flow is within the measurement accuracy of the Big Thompson River and Colorado River stream gages as well as the accuracy of the procedures used in the tree-ring streamflow reconstructions. As a result, water supply planning analyses based on the City's water supply being able to withstand the 2002 drought are consistent with the City's 1-in-100 year drought supply policy.

4.0 LOVELAND WATER USE

A summary of Loveland's historical annual potable water use since 1987 and the projected future potable water use is provided in **Figure 4-1**. The historical water use figures are based on the measured flow through the Chasteen Water Treatment Plant and do not include the non-potable water uses on certain of the City parks and other open space areas, which typically average approximately 800 AF/y. The non-potable irrigation uses are generally supplied by unchanged irrigation water rights and other sources not used to meet the City's potable water demands. The City's existing non-potable irrigation uses were not included in this yield study, except for about 90 AF/y of park irrigation demand that was assumed to be supplied from the potable water system for modeling purposes, as explained in more detail in Section 5.0.

The City also leases reusable water to other parties for augmentation use. As of 2020, the City provides reusable water for 19 leases totaling 390 AF/y. An extra 110 AF/y was incorporated into the future lease demand to allow for growth within the City's lease program. The leases are supplied by various sources including reusable water discharged to the river from the decant pond at the WTP and reusable treated wastewater effluent, and at times will compete with the supplies used to meet the City's potable water demands. The augmentation leases and park irrigation may be supplied by some of the sources used to meet potable demands, and have been included in this update of the yield study as an additional demand of 590 AF/y.

In 2020, the Loveland staff estimated the City's water demand through 2045 based on per capita water use and the population growth rates. The City's future water demand was projected from the 2018 population of 77,262 using annual growth rates of 1.5% and 2.0%. The 2018 per capita water use of 165 gal/person/day was applied to the future population for each of the years. The water demand estimates were then extended out to 2060 for the purposes of this analysis. A conservation factor of 0.5% was applied to the first 10 projected years (2020 to 2028)[10]. The anticipated municipal water demands at the various growth rates are presented below. The augmentation demand will increase the total demand by 590 AF.

[10] The conservation factor represents a reduction in the projected water demand associated with increased efficiency in water fixtures. The impact to the City's water supplies from the increased efficiency is anticipated to level out in the future.

**Anticipated City's Water Service Area Population
At Various Growth Rates**

Annual Growth Rate	1.5 %	2.0%
2040 Population	107,205	119,445
2040 Municipal Demand (AF)	19,478	21,635
2060 Population	144,390	177,490
2060 Municipal Demand (AF)	26,030	31,861

5.0 LOVELAND WATER SUPPLY FACILITIES

Loveland's water supply is diverted from the Big Thompson River at several locations. The City's direct flow diversions are made primarily at the Loveland Pipeline which is located immediately east of the canyon mouth at a diversion dam owned by the Consolidated Home Supply Irrigation and Reservoir Company ("Home Supply") that the City shares with Home Supply. The Loveland Pipeline has a capacity of 71.3 cubic feet per second ("cfs") and delivers water to the City's Chasteen Grove Water Treatment Plant ("WTP"). Loveland also diverts water from the Big Thompson River at the United States Bureau of Reclamation's ("USBR") CBT Project diversion facilities at Olympus Dam (on Lake Estes near Estes Park) and at the Dille Tunnel (approximately 2.5 miles west of the Loveland Pipeline). These facilities deliver CBT Project water through conveyance tunnels to the Charles Hansen Feeder Canal ("CHFC"). Loveland has a turnout from the CHFC that delivers water to its Green Ridge Glade Reservoir which is another source of raw water to the City's water treatment plant. Use of the USBR's facilities for delivery of the City's Big Thompson water supplies into Green Ridge Glade Reservoir is controlled by a long-term agreement that allows Loveland to divert water, using the excess capacity of the USBR facilities, up to a maximum rate of 75 cfs.

Green Ridge Glade Reservoir was constructed in 1977 and 1978 as a short-term regulation facility for the City's CBT supply and to provide a source of emergency water supply. The original usable capacity of approximately 600 AF provided minimal conservation storage to enhance the City's supply during a severe drought. The reservoir was enlarged in 2004 and now has a usable capacity of 6,785 AF.

Treated water is delivered to Loveland's customers through a looped distribution system that includes approximately 20.3 million gallons (62.3 AF) of treated water storage in tanks. Wastewater is collected and treated at the Loveland Wastewater Treatment Plant ("WWTP") and discharged to the Big Thompson River just upstream of the Hillsborough Ditch.

In 2019, Loveland purchased on downstream gravel pit, Great Western Reservoir ("GWR"). This lined gravel pit is also known as Great Western Pit No. 1 and/or Kauffman Reservoir. Great Western Reservoir is located downstream of the Loveland WWTP near the Hillsborough Ditch and the diversion from the Big Thompson River will be gravity-fed or pumped into the storage facility. In Case No. 18CW3215, Loveland filed a water court application to adjudicate a conditional water storage right for this facility. The pending application claimed 1,600 AF of storage[11] with subsequent refills and sources of water from the Big Thompson River, local tributary inflows, and precipitation. In addition to water stored under the conditional water right, Great Western Reservoir will also be used to store fully consumable water from Loveland's other water rights.

The Loveland Parks Department irrigates several parks within the City with raw water delivered from irrigation ditches and reservoirs located throughout the City. The sources of supply for these non-potable demands are private irrigation rights owned by the City that are delivered in area irrigation ditches, excess irrigation company shares that are not needed for potable water uses (e.g., in non-drought years) and spot rentals of CBT Project units. It was assumed these demands would continue to be met by either supplies not included in the yield analysis (e.g., private rights or rented CBT units) or excess yield from the City's transferred irrigation water rights. For purposes of the yield study, the City's current non-potable water uses were not explicitly analyzed except for 90 AF/y associated with irrigation from the Barnes Park pond that the Parks Department estimated would not be available from non-potable sources in a dry year. The 90 AF demand in the analysis was treated as a lease that would be met through the potable water system.

The reusable water that the City leases to other parties for augmentation use is currently delivered as WTP decant water, WWTP effluent, and releases from Green Ridge Glade Reservoir.

[11] Though 1,600 AF of storage was claimed in Case No. 18CW3215, 1,300 AF was modeled as the preliminary operational storage capacity of Great Western Reservoir.

6.0 LOVELAND WATER SOURCES

Loveland's water sources are derived from a combination of irrigation water rights from the Big Thompson River that have been transferred to municipal use and from deliveries of transmountain water from the Colorado River basin based on ownership of contracts for CBT and Windy Gap Project supplies. Summaries of these water sources follow.

6.1 Domestic Water Rights

The City appropriated two water rights for domestic and municipal uses from the Big Thompson River early in its history: 0.5 cfs in 1887 and 2.5 cfs in 1901. These water rights were assigned domestic priorities No. 2 and 3, respectively, in Case No. CA4862. There are unresolved issues regarding the priority and diversion season of these rights. Although it appears from the decree in CA4862 that the rights could be diverted year-round under domestic priorities 2 and 3, until the questions are resolved, the rights are conservatively simulated in the Yield Model using irrigation priorities 51 and 81 with a diversion season of April 1 through October 31. The manner of simulation used in the Yield Model is conservative and does not imply that the City is waiving its right to divert year-round under the domestic priorities.

6.2 Transferred Irrigation Water Rights

In the course of its development, Loveland has acquired shares in various irrigation companies that supply irrigation water in and around the Loveland area. These shares typically were associated with land parcels that were developed for residential, commercial or other uses. Loveland's early transfers of irrigation water rights included 3.44 cfs of the No. 1 Big Thompson River priority in 1907 and two shares (6.0 cfs when all the rights are in priority) of the Big Thompson Ditch and Manufacturing Company ("BTD&MC") in 1925. Together, these two early transfers and the domestic rights are generally referred to as the City's municipal rights, or the Loveland Pipeline rights. The 3.44 cfs right is diverted year-round, but the two shares of BTD&MC are diverted only during the irrigation season. Under current administration, the irrigation season is April 1 through October 31.

Following the early transfers, the City continued to acquire ditch shares as it grew. The first formal requirement for raw water as a condition of development was expressed as a motion by City Council in august 16, 1960. Portions of these shares were used informally for several years until an application was filed in Case No. 82CW202(A) ("202A") in 1982 to transfer a large block of shares in several ditch companies to municipal use by the City.

The 202A decree was entered by the Water Court in 1986. Since that time the City has made several additional irrigation water rights transfers under the terms and conditions of the 202A decree. The final 202A transfer was approved by the water court in Consolidated Case Nos. 00CW108 and 03CW354.

The 202A decree allows Loveland to divert its transferred irrigation water rights at the Loveland Pipeline, Dille Tunnel, and Olympus Tunnel for direct flow uses when the rights are in priority, less 15 percent of the City's pro-rata share of the diversion rate entitlement that is left in the original ditches for ditch losses. The City's diversions are limited by certain monthly, annual and long-term volumetric limitations. The City's use of its shares is restricted to certain starting and ending dates that vary by company, but generally correspond to a May - October season. Direct flow uses of the 202A water rights are limited to a one-time use meaning that the return flows (WWTP return flows and irrigation return flows) cannot be reused.

The 202A water rights may be stored provided that Loveland replicates the historical return flows associated with the prior irrigation use of its ditch shares, as specified in the decree. During the irrigation season, the return flow requirements for stored water are met by the City leaving a portion of its diversion entitlement in the stream. The decree contains monthly percentages that specify the amount of the City's pro-rata diversion entitlement that may be stored. During the non-irrigation season, the City is required to return to the stream 13 percent of the volume stored under the 202A water rights during the prior irrigation season. The winter return flow requirement may be met by WWTP discharges following municipal use of the stored water. Return flows from use of stored 202A water that are not required for the winter return obligation may be reused by the City. Such reuse may occur directly or by exchange (e.g., diversions at the Loveland Pipeline in exchange for release of reusable WWTP discharges).

Based on negotiations with other Big Thompson water users and a desire for increased flexibility in its water use, Loveland agreed to not make further transfers of ditch company shares under the terms and conditions of the 202A decree. Loveland's future transfers will follow a modern format that involve Loveland diverting its pro-rata share of the water rights in priority and replicating historical return flows with wastewater discharges, irrigation return flows, reservoir releases, and other sources. The water that remains after meeting the return flow requirements may be reused directly or indirectly to extinction. The City’s first transfer of this type was decreed on May 14, 2010 in Case No. 02CW392 (“392”), involving shares of several ditch companies.

Except for Loveland’s ownership in the Barnes and Chubbuck Ditches, which were transferred under terms similar to the 202A decree, the 392 decree allows Loveland to divert its transferred irrigation water rights at the headgates of the irrigation ditches and at the Loveland Pipeline, Dille Tunnel and Olympus Tunnel, for direct flow or storage uses when the rights are in priority, less 15 percent of the City's pro-rata share of the diversion rate entitlement that is left in the original ditches for ditch losses. The monthly, annual and long-term volumetric limitations, as well as the diversion starting and ending dates, differ somewhat from those in 202A but are similar. Historical return flows are replicated for all diversions, both for direct flow use and storage, through monthly return flow percentages specified in the 392 decree. All water that remains after the return flow requirements are met may be reused to extinction. Future transfers of shares in the same ditches that were included in the 392 decree will use the same per-share volumetric limits and similar terms and conditions.

Loveland also transferred the water rights associated with the Rist & Goss Ditch to the Loveland Pipeline in two separate proceedings in Case Nos. W-7412 and 86CW050. These transfer decrees include rate of flow and annual volumetric limits.

In Case No. 07CW325 ("Loveland Gard"), Loveland transferred a portion of the Big Thompson Ditch[12] referred to as the Loveland Gard Right that since 1903 has been carried in the Home Supply Ditch. This transfer decree included a rate of flow of 1.0 cfs through noon on July 14th and 0.5 cfs thereafter. Additionally, this decree includes monthly, annual, and long-term volumetric limitations and requirements to make return flow replacements to the Big Thompson River, the Little Thompson River, and two other locations.

A summary of the City's transferred irrigation water rights is provided in **Table 6-1**.

6.3 Transmountain Water Sources

Loveland's other major sources of water are derived from transmountain diversions from the Colorado River basin through the City's interest in the CBT Project and the Windy Gap Project. The following is a summary of these sources and the City's interest in each.

6.3.1 Colorado-Big Thompson Project

Water for the CBT Project is diverted from the headwaters of the Colorado River basin and stored in several reservoirs. CBT Project water is delivered to Lake Estes in the upper Big Thompson River basin through the Alva B. Adams Tunnel which conveys water beneath the Continental Divide in Rocky Mountain National Park. From there, the water

[12] The Big Thompson Ditch was the original No. 1 ditch in the basin. The Big Thompson Ditch no longer exists and was replaced by the Hillsborough Ditch. The Big Thompson Ditch is not the same as the Big Thompson Ditch & Manufacturing Company.

is distributed through a series of tunnels, reservoirs and canals to water users in the Northern Colorado Water Conservancy District which comprises approximately 1.5 million acres in the South Platte River basin of northeastern Colorado. The CBT Project was constructed by the USBR and began delivering water in the late 1940's. The project is jointly operated by the USBR and Northern Water.

There are 310,000 outstanding units in the CBT Project of which Loveland currently owns 12,210[13] units, or about 3.9 percent. The CBT Project was created to provide a supplemental irrigation supply to water users in the Northern Water service area. Each year in April, Northern Water sets a quota that establishes the amount of delivery entitlement for each CBT unit. The quota typically averages approximately 0.7 AF/unit. During years of low snowpack in the South Platte River basin, the quota may be increased depending on project water availability. Conversely, the quota may be set lower than 0.7 AF/unit during wet years when the demand for supplemental water is less, or during dry years when the project supply is limited. Municipal and industrial water users, who take delivery of project water during the non-irrigation season, generally have been permitted to receive up to approximately 50 percent of the annual quota during the November - March period before the annual quota was set. Beginning in November 2001, Northern Water began formally setting a winter quota for municipal and industrial water users.

Owners of CBT units may carry over a portion of their unused allocation for use during the subsequent year. The carryover is limited to the lesser of 0.2 AF/unit or 90 percent of the unused allocation remaining in the user's account on October 31. Return flows from initial use of CBT Project water may not be reused. Instead, these return flows accrue to the South Platte River and its tributaries to the general benefit of water users throughout the Northern Colorado Water Conservancy District.

6.3.2 Windy Gap Project

The Windy Gap Project was developed to provide additional water supply for municipal and industrial water users on the East Slope using unused capacity in the CBT Project facilities. Water for the project is diverted from the Colorado River immediately downstream of the confluence with the Fraser River and is pumped into the unused space in Granby Reservoir. The water is then delivered as needed through the Adams Tunnel for the use of the members of the Municipal Subdistrict of the Northern Colorado Water Conservancy District ("Subdistrict"). Loveland owns one-twelfth of the supply, or 40 units out of the 480 units in the project. Each unit was originally projected to yield an average of 100 AF/y, although actual yields have been less since the project began delivering water

[13] Only 12,190 CBT units were included in the yield modeling since an additional 20 CBT units were acquired after the modeling was completed.

in 1985 because full demands have not yet been placed on the system by most of the users. Unlike the CBT Project, return flows resulting from initial use of Windy Gap Project water may be reused to extinction.

Yield from the Windy Gap Project is quite variable as a result of the relatively junior water rights that supply the project and the reliance on the excess storage and conveyance capacity of the CBT Project facilities. During dry years the project yields little or no water because of upstream diversions by senior water rights, and by calls against the project water rights from senior downstream water users. During wet years, there may be insufficient capacity in Granby Reservoir to store water pumped from the project diversion facilities on the Colorado River. In addition, Windy Gap Project water stored in Granby Reservoir is subject to spill in wet years as a result of storage of CBT Project water.

As a result of the unreliability of the Windy Gap Project supply, efforts were undertaken by the Municipal Subdistrict several years ago to study potential ways to enhance the yield of this supply. The Windy Gap Firming Project ("WGFP") is being developed to enhance the project yield, particularly during dry years. The WGFP will involve an East Slope storage reservoir ("Chimney Hollow Reservoir") and revised operation and coordination with the CBT Project. Loveland is participating in the development of the WGFP, presently at the level of 9,587 AF of storage capacity. Studies of the benefits of the WGFP have been performed for the Subdistrict and are documented in a 2003 report[14]. Additional technical reports were prepared between 2005 and 2008. A Record of Decision on the final environmental impact statement ("EIS") was published on December 19, 2014[15] and the Record of Decision on the Section 404 Permit was finalized May 16, 2017[16]. Project construction is anticipated to begin in 2020.

6.3.3 Eureka Ditch

The Eureka Ditch was a hand-dug ditch that diverted water across the Continental Divide at Sprague Pass to the Big Thompson River basin. Loveland acquired the ditch in 1941 as a source of municipal supply and operated and maintained the ditch for many years. In 1995, the City entered an agreement with the National Park Service, the USBR and Northern Water whereby the City agreed to abandon the Eureka Ditch in exchange for 180 AF/y of firm CBT yield.

[14] Windy Gap Firming Project, Alternative Plan Formulation Report. Boyle Engineering, February 2003.
[15] Record of Decision Windy Gap Firming Project, Final Environmental Impact Statement, U.S. Bureau of Reclamation, Great Plains Region, December 2014.
[16] Record of Decision Windy Gap Firming Project, Section 404, U.S. Bureau of Reclamation, Great Plains Region, May 2017.

6.4 Exchanges

Loveland operates exchanges from its WWTP outfall to its various points of diversion on the Big Thompson River. By these exchanges, Loveland can deliver legally reusable treated effluent to the Big Thompson River and divert a like amount of water upstream. The exchanges can only operate to the extent that they do not interfere with the operation of senior water rights that divert within the exchange reach. This means that if a senior user within an exchange reach is diverting and drying up the stream, then Loveland cannot operate the exchange. Loveland's sources of reusable water include 392 water, stored 202A water, Loveland Gard Right water, free river, water diverted under Loveland's junior storage decree filed in 1984, Windy Gap water, and will include yield derived from future water rights transfers. The City adjudicated its exchange appropriations in Case Nos. 02CW393 and 02CW394.

6.5 Free River

During high flow periods when the demands of all downstream users on the Big Thompson River and the South Platte River are satisfied ("Free River"), Loveland may divert water as needed. In November 2015, the State Engineer issued Written Instruction 2015-02 - Instruction Concerning the Administration of Diversions of Water during Free River ("Free River Instructions"). During Free River conditions, if the diversion is for uses decreed by Loveland's water rights for either direct flow or storage purposes, the diversion will be credited to the volumetric limits for those water rights and must be consistent with the terms and conditions of those water rights. Subsequent diversions that exceed the volumetric limits during Free River are not subject to decree provisions. Diversions for undecreed uses are not subject to terms and conditions of Loveland's decreed water rights and are considered reusable. However, undecreed storage diversions result in Loveland's decreed water storage rights (at the same storage facility) being filled to an amount equal the amount diverted during free river ("paper filled") to avoid extending the period in which Loveland could divert under their decreed storage rights. These conditions occur infrequently, typically during the spring runoff of wetter than average years or following high rainfall events.

7.0 YIELD MODEL DESCRIPTION

A computer model of the Loveland water supply system was constructed to simulate the integrated yield of the City's various water sources. The Loveland Water Supply Yield Model is based on the historical records for the various Big Thompson River irrigation systems and the CBT Project over a study period from 1951 – 2015 using a daily time-step. Simulated yields for the Windy Gap Project developed as part of the planning for the WGFP are used in the Yield Model. Loveland's pro-rata share of the historical diversion records and simulated Windy Gap Project yields are computed based on ownership information input by the model user. Other user inputs include Loveland's annual potable water demand, leases of augmentation water to other entities, downstream non-potable water demand, and upstream and downstream raw water storage capacity. Descriptions of the model input data, assumptions and operation follow.

7.1 Historical Records

Daily diversion and monthly storage records for all the major irrigation companies on the Big Thompson River mainstem were downloaded from the Colorado Decision Support System database maintained by the Colorado Division of Water Resources. The daily diversion records generally include the total amount diverted as well as the disaggregated amounts associated with native water rights, transmountain sources, exchanges, and other categories. The monthly storage records generally consist of end-of-month reservoir storage content. The diversion and storage records were spot checked against paper copies of the historical water commissioner records.

Daily records of the operation of the CBT Project were obtained from the USBR. These records include a wide variety of information including streamflows, diversions, power production, reservoir stage, water orders, etc. Daily records were available in digital form from 1976 - 2015. Prior to 1976, the records are available only in paper form. Daily information was extracted from the digital data and input from the paper records for the Olympus Tunnel, Dille Tunnel, Charles Hansen Feeder Canal, Big Thompson Power Plant and Hansen Feeder Wasteway.

7.2 Municipal Water Demand

Loveland's annual potable and non-potable water demands are input by the model user. The potable water demand is the principal simulated water use in the Yield Model and is met by diversions at the Loveland Pipeline or from Green Ridge Glade Reservoir releases. Leases of potable water to other parties can also be included as part of the potable water demand. In the current Yield Model, 90 AF/y for parks irrigation is simulated as a potable lease, with a monthly distribution provided by the City. The annual potable demands specified by the model user are distributed to daily amounts based on the historical pattern reflected in the City's daily water use records for 2005 – 2015 as shown in **Figure 7-1.** A smoothed line was fit to the historical data to develop the daily water demand distribution used in the Yield Model. If desired, the model user may alter the daily water use distribution.

The non-potable irrigation demand of 90 AF/y represents potential future irrigation water uses located downstream of the City's WWTP. This demand may be satisfied in the Yield Model from the same sources used to supply the potable demand, as well as direct use (i.e., not by exchange) of reusable effluent and releases from downstream reservoir storage. The annual non-potable irrigation demand may be distributed to monthly and daily amounts in a pattern specified by the user. The current default distribution is based on the City's current irrigation demand pattern.

The augmentation demand is also a non-potable demand and represents leases of reusable water to other parties for augmentation purposes. This demand may be satisfied in the Yield Model from reusable WWTP effluent, the reusable portion of the WTP decant water, the reusable portion of 392 transfer water that is not diverted at the Loveland Pipeline or Green Ridge Glade Reservoir, and releases from Green Ridge Glade Reservoir or Great Western Reservoir. In the current Yield Model, an augmentation demand of 500 AF/y is simulated in addition to the 90 AF/y of park irrigation described above. Based on the relative locations of the current augmentation leases, 50 AF/y of the current lease demand is located higher in the basin can only by WTP decant water and releases from Green Ridge Glade Reservoir, and the remaining 450 AF/y is met by any of the available sources. The annual augmentation demand is currently distributed based on records of augmentation deliveries for 2005-2015, but the distribution may be changed by the user.

7.3 Simulated Water Supplies Currently Used by Loveland

All of Loveland's primary water sources described in Section 6 are simulated in the Yield Model. In addition, there are other irrigation companies that may be simulated for which Loveland currently has no shares transferred to municipal use. Loveland's yield of the irrigation company sources is determined as a pro-rata share of the historical diversions of the subject source limited by the estimated flow that is physically available at Loveland's point of diversion. Additional information regarding the simulation of each of Loveland's water sources follows.

7.3.1 Early City Transfers and Domestic Water Rights

Loveland's early water rights transfers included 3.44 cfs of the Big Thompson Ditch and two shares (6.0 cfs) of the BTD&MC which has four priorities. Loveland's 3.44 cfs of the Big Thompson Ditch may be diverted year around and, because this is the No. 1 priority on the Big Thompson River, it was assumed to always be available. The yield of Loveland's early transfer of the BTD&MC is determined based on the flow rate in priority during a diversion season specified by the user. Under current administration, the season is April 1 – October 31.

City also has water rights decreed to the Loveland Pipeline for domestic and municipal purposes in CA4862. These water rights, generally referred to as the "domestic rights", have two separate priorities: 0.5 cfs and 2.5 cfs. There are unresolved issues regarding the priority and diversion season of these rights. The yield of these water rights can be modeled based on days in priority during the year, or during a diversion season specified by the user. The priority can be based on the rights' relative priority with respect to irrigation ditches ("irrigation priority") or with "domestic priority" that is senior to irrigation rights and therefore assumed to be available every day. The user can also select the option to not use this water right in the Yield Model. Although it appears from the decree in CA4862 that the rights could be diverted year-round under domestic priorities 2 and 3, until the questions are resolved, the rights are conservatively simulated in the Yield Model using irrigation priorities 51 and 81 with a diversion season of April 1 through October 31. The manner of simulation used in the Yield Model does not imply that the City is waiving its right to divert year-round under the domestic priorities.

7.3.2 202A Transfers

The yield of Loveland's 202A water rights is determined as 85 percent of the City's pro-rata portion of the adjusted historical direct flow irrigation diversions associated with each ditch company. The historical diversions were adjusted to (a) exclude assumed diversions of private or contract water rights that are carried in certain ditches[17] and (b) to include the City's historical diversions of its transferred irrigation water rights. The diversions by private or contract rights were modified in the 2011 analysis to reflect the updated analyses that were performed for the 392 transfer. The simulated divertible yield to Loveland is limited to days between the starting and ending dates specified in the 202A decree. The volumetric limits from the 202A decree were not directly imposed on the simulated diversions. However, the simulated diversions were compared to the

[17] The 2020 Yield Model includes an adjustment to the South Side Ditch diversions related to conveyance of a portion (0.75 cfs) of the O'Hara private contract right back to the ditch company.

decreed volumetric limits and it was determined that the volumetric limits only rarely would have been violated[18].

During periods when there is 202A yield that is in excess of the City's demands, the excess supply is stored in the simulated upstream storage (i.e., Green Ridge Glade Reservoir) and/or downstream at Great Western Reservoir. The amount stored is limited to the direct flow yield multiplied by the monthly storage percentages in the 202A decree. Any simulated storage of 202A water also creates a winter return flow obligation of 13 percent of the amount stored. This obligation can be met by using the stored water through the City's water system during the winter and dedicating the return flows to the river.

7.3.3 Rist & Goss Transfers

Loveland's yield of its transferred Rist & Goss Ditch water rights is computed similarly to the yield of the 202A water rights. Loveland was assumed entitled to use approximately 84 percent of the Rist & Goss Ditch historical yield[19]. Diversions were limited to a daily total of 5.48 cfs and a total annual volume during the period April 1 – October 31 and were further limited by the monthly volumetric limits in the second transfer decree.

7.3.4 392 Transfers

Loveland's 392 case water rights transfer allows Loveland to reuse return flows resulting from any use of the transferred water once the return flow obligations are met. The yield of Loveland's 392 water rights is determined as 85 percent of the City's pro-rata portion of the adjusted historical direct flow irrigation diversions associated with each ditch company. The historical diversions were adjusted to (a) exclude assumed diversions of private or contract water rights that are carried in certain ditches[20] and (b) to include the City's historical diversions of its transferred irrigation water rights. The simulated divertible yield to Loveland is limited to days between the starting and ending dates specified in the 392 decree. For modeling purposes, the irrigation season return flows are assumed to be left in the stream, and only the reusable portion is diverted for use. In actual operations, the City could divert its entire pro-rata entitlement if the irrigation return flow requirements are met by other sources. The non-irrigation season return flow obligations are met by various reusable water sources. The volumetric limits from the 392 decree were not directly imposed on the simulated diversions. However, the

[18] This is expected as the volumetric limits were derived from the historical diversions during the 1920 - 1979 period.
[19] The combined annual diversion entitlement from the City's two Rist & Goss Ditch transfer decrees is 487.5 AF/y, of which 80 AF/y may be used for replacement of evaporation associated with a gravel pit on a portion of the lands historically irrigated by the ditch.
[20] The 2020 Yield Model includes an adjustment to the South Side Ditch diversions related to conveyance of a portion (0.75 cfs) of the O'Hara private contract right back to the ditch company.

simulated diversions, including the amount left in the stream, were compared to the decreed volumetric limits and it was determined that the volumetric limits only rarely would have been violated[21].

During periods when there is 392 yield that is in excess of the City's demands, the excess supply is stored in the simulated Green Ridge Glade Reservoir and/or in any simulated downstream storage. The amount stored is limited to the reusable portion of the available amount. Any simulated storage of 392 water also creates a winter return flow obligation as specified in the 392 decree.

7.3.5 Loveland Gard Right Transfer

The yield of the transferred Loveland Gard Right[22] follows a format similar to the 392 water rights that allows Loveland to reuse return flows resulting from any use of the transferred water once the return flow obligations are met. The Loveland Gard Right was changed for use by Loveland in Case No. 07CW325 which included return flow obligations to be replaced to five different return flow sectors. For modeling purposes, all the return flow obligations were assumed to impact the Big Thompson River; the five return flow sectors listed in the 07CW325 were aggregated into two sectors differentiated by their location above or below the Loveland Wastewater Treatment Plant. The City's ability to replace return flow obligations in the smaller return flow sectors could affect the City's yield from the Loveland Gard Right. The volumetric limits from the Loveland Gard Right decree were not directly imposed on the simulated diversions. However, the simulated diversions were compared to the decreed volumetric limits and it was determined that the volumetric limits only rarely would have been violated[23].

During periods when there is Loveland Gard Right yield that exceeds the City's demands, the excess supply can be stored in Green Ridge Glade Reservoir. The amount stored is limited to the reusable portion of the available amount.

7.3.6 Post-392 Transfers

Loveland's future water rights transfer(s) will follow a format similar to the 392 transfer. For future transfers of additional shares in irrigation ditches that were included in 02CW392, the decreed per-share volumetric limits and monthly return flow obligations will be used. The precise terms of future transfers of shares in ditches, that were not

[21] This is expected as the volumetric limits were derived from the historical diversions during the 1951 - 1979 period.
[22] Diversions of the Loveland Gard Water Right are limited to 1.0 cfs from April 17 through noon on July 14. From noon on July 14 through August 31, the diversion of the Loveland Gard Water Right is limited to 0.5 cfs.
[23] This is expected as the volumetric limits were derived from the historical diversions during the 1950 - 1998 period.

included in the 392 decree (Handy, Home Supply, Hillsborough and GLIC), are unknown. The yield of these transfers is computed based on a similar procedure used for the 392 transfers, using the average of return flow percentage values from the 392 decree. These values may be modified by the user.

7.3.7 Free River Diversions

There are no long-term records of historical priority calls on the Big Thompson River, and therefore the periods of free river (no priority call) were estimated based on the following criteria: (a) no call exists on the South Platte River downstream of the Big Thompson River confluence, (b) the flow in the Big Thompson River at La Salle is greater than 20 cfs and (c) exchange potential exists between the La Salle gage and the Canyon Mouth gage. It is assumed that Loveland could divert up to its daily water demand under the free river criteria and the Office of the State Engineer's Free River Instructions.

7.3.8 Exchanges

Exchanges are simulated in the Yield Model on days when exchange potential exists and there is reusable WWTP effluent and/or reusable water stored downstream in Great Western Reservoir in excess of augmentation and return flow demands. The exchanges are simulated to release reusable water from a downstream location such as the WWTP and/or Great Western Reservoir and to divert reusable water at an upstream location either at the Loveland Pipeline or the Olympus and Dille Tunnels to Green Ridge Glade Reservoir. Modeled sources of reusable water include 392 water, stored 202A water, Loveland Gard Right water, free river diversions, Windy Gap water, and WWTP effluent from these sources.

7.3.9 Decant Water from Water Treatment Plant

The treatment process at the Chasteen WTP generates a stream of water, known as decant water, that is returned to the Big Thompson River near the point of diversion. The reusable portion of the decant water may be used for augmentation and return flow demands and may also be stored downstream in Great Western Reservoir. Currently, Loveland uses the decant water under administrative approval from the State Engineers Office. The City has a pending water court application, Case No. 18CW3193, to quantify and use the return flows associated with the decant water. Although the amount of decant varies somewhat seasonally with the processes at the WTP and is expected to decrease over time, it is simulated in the Yield Model as 2.5% of diversions to the plant. This percentage may be changed by the user.

7.3.10 CBT Units

Loveland's CBT Project yield is simulated based on the historical annual quota set each year during the study period between 1953 - 2015. The quota for 1951 and 1952 is based on estimated CBT yields determined as part of the WGFP modeling (see Section 7.3.11). The quota is generally treated as a supply of water that Loveland could draw on at any time to meet its demands, similar to a reservoir. In accordance with Northern Water policy, one-half of the annual quota is assumed to be available for use beginning November 1. The remaining portion of the annual quota is assumed to be available for use beginning when the annual quota is set by Northern Water's Board at its April meeting each year. Carryover of CBT supply to the next year is limited to the lesser of 0.20 AF per simulated CBT unit or 90 percent of the amount of unused quota remaining on October 31. In addition to yield from its CBT units, 180 AF/y of firm CBT yield is simulated based on the City's Eureka Ditch agreement.

7.3.11 Windy Gap

The yield of Loveland's Windy Gap units is simulated differently in the Yield Model depending on whether the firmed or unfirmed yield is being analyzed. As described above, the yield of the current Windy Gap Project (i.e., unfirmed) is variable from year to year due to the relatively junior priority of the Windy Gap water rights and the availability of excess capacity in the CBT Project facilities. The West Slope yield of the Windy Gap Project was simulated by Boyle Engineering ("Boyle"), now AECOM, in 2003 and updated in 2008 as part of their modeling for the WGFP. This provided estimates of the project yield for the period from 1951 - 1996, when the Boyle study period ends. After 1996, a combination of the actual yields from Northern Water and the procedures used in the Boyle analysis was used to develop Windy Gap yield estimates for the Yield Model.

When simulating yields from the unfirmed Windy Gap Project, the Boyle yield estimates were totaled annually, and Loveland's pro-rata portion was assumed available for delivery any time after March. The exception to this was during years of Granby Reservoir spills when the Windy Gap yield was set to zero. After 1996, the actual Windy Gap yields were used for the simulated unfirmed Windy Gap yields. This was deemed reasonable as there was no Windy Gap yield from 1997 – 2000, 2011, and 2014 – 2015 because Granby Reservoir spilled in those years. In 2001 – 2008, 2010, and 2012 – 2013, the Windy Gap yields were generally limited by the available supply on the West Slope. In 2009, Windy Gap yields were limited to prevent Granby Reservoir from spilling.

The WGFP modeling was intended to estimate the increased yield reliability that could be available to the Subdistrict members who participate in the WGFP. The approach taken in the WGFP modeling was to estimate the firm annual yield that could be delivered from the Windy Gap Project to each participant. This implied a constant annual demand for water from the Windy Gap Project. However, Loveland will not likely use its Windy Gap supply in this manner. Instead, it will more likely use its Windy Gap supply as a supplemental water source to be drawn upon in dry years when its other native and transmountain water sources are in shorter supply. As a result, SWE discussed with Boyle Engineering an alternative modeling approach whereby Loveland's yield from the WGFP could be treated as a supplemental dry year supply.

As part of the WGFP, Loveland will be entitled to use a portion of the proposed Chimney Hollow Reservoir to regulate its Windy Gap Project yield. Loveland is currently proposing to participate in the WGFP to the extent of 9,587 AF of East Slope reservoir storage space. Loveland's pro-rata share of the Boyle estimates of the West Slope yields for the period 1951 - 1996 were assumed available for storage in Loveland's portion of the proposed Chimney Hollow Reservoir.

As described above, there was no yield from the Windy Gap Project in several years because Granby Reservoir spilled during those years. However, if there had been storage space available on the East Slope for project water, then water could have been pumped through Granby Reservoir directly to Chimney Hollow Reservoir. The potential Windy Gap yield during 1997 – 2000, 2011, and 2014 – 2015 was estimated based on the daily flow at the Colorado River at Windy Gap gage during the months of April - August, less 90 cfs for a downstream minimum flow water right. The resulting daily values were further limited by the daily unused capacity in the Adams and Olympus Tunnels[24]. During 2001 – 2009, 2010, and 2012 – 2013, the actual Windy Gap yields were assumed to represent the amount that could have been pumped to Chimney Hollow Reservoir.

The yield of the WGFP to Loveland was estimated in the Loveland Yield Model based on simulation of a separate reservoir of variable capacity intended to represent Loveland's pro-rata share of the proposed Chimney Hollow Reservoir space. Inflows to this separate reservoir were computed based on Loveland's pro-rata share (40 Loveland units / 480 Total units) of the total Windy Gap Project yield described above. The regulated Windy Gap yield is utilized in the Yield Model as necessary to supplement the other simulated water sources.

[24] In years when Granby does not spill, the capacity of the Adams and Olympus Tunnels is not a constraint to the Windy Gap Project yield due to Northern Water's instantaneous delivery and accounting policy. Under this policy, a water user may take delivery of Windy Gap Project water from any of the Northern Water's CBT supplies available on the Eastern Slope. Such deliveries are accounted for by a paper transfer of Granby Reservoir storage from Windy Gap to CBT.

The results of the Yield Model simulation of the WGFP supply were provided to Boyle who input the simulated variable Windy Gap Project water use as a demand schedule to their yield model. Boyle verified that the WGFP water use simulated in the Loveland Yield Model could be delivered in their simulation model.

7.3.12 Green Ridge Glade Reservoir

Loveland's Green Ridge Glade Reservoir is simulated to regulate all of Loveland's water sources for all municipal uses including potable uses and releases, when necessary, to meet return flow obligations. The simulated capacity in the Yield Model is the 6,785 AF capacity determined in the as-built survey of the reservoir. Simulated reservoir inflows are limited to the 75 cfs capacity of the turnout from the Hansen Feeder Canal and by the historical excess capacity in the CBT Project facilities. Evaporation losses are computed based on average unit evaporation losses determined in accordance with the State Engineer's procedures related to gravel pit reservoirs. These unit evaporation losses are multiplied by the surface area of the reservoir determined from the simulated reservoir content and the area-capacity table for the reservoir. There are no seepage losses from the reservoir simulated in the Yield Model.

The simulated reservoir storage contents are divided into reusable and non-reusable pools, with individual reservoir accounts for each water source. All sources stored in the reservoir are assumed to be reusable except for CBT Project deliveries. Releases from storage are assumed to be colored based on the concurrent mix of reusable and non-reusable in storage, except for releases to demands that require only reusable water. Simulated evaporation losses are applied pro-rata to the relative contents of the reusable and non-reusable pools [25].

7.4 Simulated Water Supplies Not Currently Used by Loveland

Loveland may acquire and transfer shares in other irrigation companies for which the City has not previously changed shares to municipal use. At the request of the LUC in 2004, the potential benefit to the City's water supply of shares for selected Big Thompson River irrigation companies was evaluated. The analysis was updated for this report. A description of these companies and the procedures used to evaluate the potential yield to the City's water supply follows.

[25] Loveland may operate to release water from the individual reusable and non-reusable accounts; however, this method of operation is not currently simulated except in the case of releases for return flow obligations and augmentation leases.

7.4.1 Handy Ditch Company

The Handy Ditch is the only irrigation ditch on the Big Thompson River that diverts upstream of the Loveland Pipeline. The ditch irrigates land on the south side of the Big Thompson River and in the Little Thompson River drainage. The City of Berthoud historically has taken delivery of its Priority No. 1 water through the Handy Ditch. Berthoud's diversions are accounted for separately from the agricultural diversions in the historical records for the Handy Ditch.

The potential yield of Handy Ditch Company shares to Loveland is estimated in the Yield Model assuming that Loveland would be entitled to a pro-rata share of the historical agricultural diversions by the Handy Ditch. It is assumed that Loveland would be required to leave 15 percent of its diversion entitlement in the Handy Ditch to replicate historical ditch losses and an average of 40 percent in the river to replicate historical return flows. The water remaining after paying the assumed return flow obligation is assumed to be fully reusable.

7.4.2 Consolidated Home Supply Irrigating and Reservoir Company

The Consolidated Home Supply Irrigating and Reservoir Company ("Home Supply") Ditch diverts from the south bank of the Big Thompson River. The City uses Home Supply's diversion dam for its Loveland Pipeline on the north bank of the river. Home Supply is primarily a storage-based irrigation company. The company owns and operates three water storage reservoirs that fill from the Big Thompson River. Lone Tree Reservoir is the No. 1 priority storage water right on the Big Thompson River and has a decreed capacity of approximately 9,180 AF. Mariano Reservoir is the No. 3 priority storage water right with a decreed capacity of approximately 4,130 AF. The storage water right for Home Supply's third reservoir, Lon Hagler Reservoir, is one of the most junior storage water rights in the basin. The Home Supply reservoirs are generally filled during the non-irrigation season from November - April. Lone Tree and Mariano Reservoirs fill almost every year while Lon Hagler Reservoir rarely fills under its own priority. Lon Hagler Reservoir is used by the shareholders primarily to store excess CBT water or leased water sources.

The company also has 56 cfs of direct flow water rights by virtue of acquisition and transfer of portions of the Big Thompson Ditch and Manufacturing Company in the early twentieth century. Most of this water may only be diverted by Home Supply during the irrigation season until July 14 of each year in accordance with the terms of the transfer decree. Home Supply also owns a relatively junior (1881 priority) direct flow water right for 279 cfs that is divertible only during periods of high streamflow.

During the early portions of the irrigation season when runoff is relatively high, Home Supply tends to rely more on its direct flow water rights. When the runoff ebbs, and after July 14 when its senior transferred water rights must be curtailed, Home Supply transitions to use of its storage water rights. Shareholders in some portions of the Home Supply service area cannot receive water directly from storage. These users are supplied water by exchange. Water is released from Home Supply's storage reservoirs to the Big Thompson River and a comparable amount of water is diverted upstream at the Home Supply Ditch headgate. The Home Supply exchange is decreed for 76 cfs and is the No. 2 exchange right on the river.

The annual "issue" (yield) to shareholders in the Home Supply Ditch Company is determined each year by the board of directors based on review of expected runoff, amount of water in storage and other factors. The annual issue is net of conveyance and evaporation losses and may be delivered by a combination of direct flow diversions and releases from storage. The potential yield of Home Supply shares to Loveland is computed based on historical records of the annual issue. It is assumed that the City could take delivery of the annual issue at any time during the irrigation season up to the historical annual amounts for each year. It was also assumed that the City could receive its deliveries as necessary under the Home Supply exchange right.

The Town of Johnstown has transferred Home Supply shares to municipal use in Case Nos. 98CW410 and 06CW224. The change decrees provided that an average of 60 percent of the direct flow deliveries and 65 percent of the storage yield was consumed, and the remainder returned to the stream. Based on these findings it was assumed that Loveland would have an average return flow obligation for any transfer of Home Supply shares equal to 40 percent of the annual issue.

7.4.3 Greeley - Loveland Irrigation Company

The Greeley – Loveland Irrigation Company ("GLIC") operates the Barnes Ditch and the Loveland and Greeley Canal (a.k.a. "Chubbuck Ditch"). Predecessors of the GLIC acquired the water rights of the Barnes Ditch and the Chubbuck Ditch pursuant to a series of contracts entered in the late-nineteenth century with the original water right holders. In exchange for the water rights, the GLIC agreed to deliver certain amounts of water expressed as "inches" to each of the contract holders. These contract rights are the source of the Barnes and Chubbuck inches that have been acquired by the City and transferred to municipal use over the years. To the extent that there is yield from the Barnes Ditch and Chubbuck Ditch water rights that is excess to the delivery requirements of the inch-holders, the excess yield accrues to the GLIC shareholders. In addition to the excess yield from the Barnes Ditch and Chubbuck Ditch water rights, the GLIC owns another large (297 cfs), but relatively junior (1881 priority), direct flow water right. The GLIC also owns and operates Boyd Lake which has a decreed capacity of 48,564 AF. Most of the yield to the GLIC shareholders is derived from the Boyd Lake storage water right. The largest GLIC shareholder is the City of Greeley. Loveland owns three GLIC shares that are used for non-potable irrigation use.

Each year, the GLIC sets a "storage dividend" and a "river dividend." These figures establish the annual per share yields before the 22 percent delivery shrink that is charged by the company. The storage dividend is the yield from Boyd Lake storage and the river dividend is the yield of the company's direct flow water rights. Historical records of the GLIC dividends for the period 1968 - 1985 are contained in the 1987 engineering report for the Greeley transfer of GLIC shares in Case No. 87CW329[26].

The GLIC is unique in the Big Thompson River basin, in that it allows shareholders to carry over to the next year any unused portion of their pro-rata share of the annual dividend in Boyd Lake. Any water that is carried over from December 31 to January 1 is subject to an 11 percent storage charge. Carryover of unused dividend water is termed "protected" carryover storage. Shareholders may also store other water in Boyd Lake on a space available basis. All foreign water and "protected" carryover storage is subject to spill as a result of diversions under the Boyd Lake storage water right. The foreign water is the first to spill followed by the "protected" carryover storage. However, due to its relatively junior storage priority, Boyd Lake rarely fills.

For purposes of estimating the potential benefit of GLIC shares to Loveland, the direct flow yield of the GLIC shares was simulated in the Yield Model based on a pro-rata share of the computed historical annual direct flow diversions that were excess to the delivery entitlements of the Barnes and Chubbuck inches less an assumed 22 percent shrink. The storage yield of the GLIC shares was determined from the 1968 - 1985 storage dividends contained in the 1987 Greeley engineering report. For the period prior to 1968 and after 1985, estimates of the GLIC storage dividends were made based on a relationship developed between the 1968 - 1985 storage dividends and the reported March 31 storage contents of Boyd Lake.

The annual storage dividend less a 22 percent shrink charge was assumed available for use at any time during the irrigation season. The GLIC carryover policy was also simulated by assuming that Loveland could carry over its unused storage dividend in its pro-rata share of the Boyd Lake storage space. Simulated carryover storage was assessed an 11 percent shrink charge in accordance with company policy. An average return flow

[26] W.W. Wheeler & Associates, Inc., City of Greeley and Public Service Company of Colorado. Water Use Study - Task B, Greeley and Loveland Irrigation and Associated Companies (September 1987).

obligation of 40 percent was estimated to apply to Loveland's computed diversion entitlement in addition to the shrink charge described above. Water remaining after the return flow requirement was assumed to be fully reusable.

7.4.4 Ryan Gulch Reservoir Company

The Ryan Gulch Reservoir Company ("RGRC") owns and operates a storage reservoir on Ryan Gulch, a tributary that joins the Big Thompson River approximately one-quarter mile upstream from the Farmers Ditch headgate. The reservoir has a decreed capacity of approximately 730 AF, and the decreed source of water to the reservoir is Ryan Gulch. The largest shareholders in the RGRC are the Town of Berthoud (34%) and private homeowners (30.5%). The City of Loveland currently owns 15.75 shares (15.75%) in the RGRC, and these shares are used for non-potable irrigation uses. Most or all the uses of water from Ryan Gulch Reservoir are diversions made from the Big Thompson River in exchange for releases from the reservoir to the river. In recent years, certain of the RGRC shares have been acquired by property owners near the reservoir who prefer to leave their share of the reservoir yield in storage for aesthetic purposes. The storage water right for Ryan Gulch Reservoir has a relatively junior 1904 priority date. Because the reservoir fills from Ryan Gulch, it does not compete with the other Big Thompson River reservoirs for supply. However, it is subject to priority calls from downstream storage water rights on the South Platte River.

The potential yield of RGRC shares to Loveland was estimated using the historical reservoir storage records. The historical annual yield was estimated as the historical increase in storage during the storage season less an assumed 15 percent evaporation and conveyance loss. Any of the annual yield not used was allowed to carryover in storage for use in the subsequent year.

7.4.5 Lawn Irrigation Return Flows

Loveland's lawn irrigation return flows ("LIRFs") originate from the irrigation of lawns, parks, golf courses, and other areas with fully consumable sources. In Case No. 18CW3193, Loveland filed a water court application to quantify and use its reusable return flows, including LIRFs, to the Big Thompson River for payment of return flow obligations associated with the prior change cases, as a substitute supply, and as replacement sources in decreed augmentation plans. Loveland seeks approval to use its reusable return flows for all municipal purposes, including reuse, and successive use to extinction and disposition to others by sale, lease, trade or other arrangement.

The LIRFs from the use of the various water sources can be tracked in the Yield Model, and the user may choose to use the reusable portion to meet augmentation and return flow demands. Because the LIRFs have not yet been quantified in a decree, the Base Run does not include simulation of this source. The LIRFs procedures from the preliminary engineering report prepared by SWE in support of Case No. 18CW3193 are included as a model run under an alternative water supply operation.

7.5 Diversion Constraints

The Loveland Yield Model includes several limitations on direct flow and storage diversions that are intended to mimic actual constraints on Loveland's water use. In addition to the water rights constraints described above, the following is a summary of the Yield Model limitations on direct flow and storage diversions:

Loveland Pipeline Diversions

- Actual diversion capacity of 71.3 cfs but increased to 90 cfs to simulate additional capacity that will be needed at higher demand levels.
- Historical available river flow at the point of diversion.
- Diversions of transferred irrigation water rights are limited to the exchange potential between the Loveland WWTP and the Loveland Pipeline.

Diversions to Green Ridge Glade Reservoir

- Available storage space.
- 75 cfs limit of USBR contract.
- Historical excess capacity in the Olympus Tunnel, Dille Tunnel and Charles Hansen Feeder Canal plus historical skim[27].
- Diversions of transferred irrigation water rights are limited to the historical available physical flow and the available river exchange potential.
- CBT water remaining unused in September and October.
- Windy Gap water, at times when Green Ridge Glade is less than half full.

Diversions to Great Western Reservoir

- Available storage space.

[27] The USBR has historically diverted native water at the Olympus and Dille Tunnels for power generation and returned this water to the river upstream of the Loveland Pipeline so as not to affect diversions by senior water rights. This is termed the USBR's "skim" operation. In accordance with Loveland's contract with the USBR, Loveland may divert against the skim provided that it pays the USBR a power interference charge.

- 20 cfs assumed maximum inflow and outflow rates[28].
- Diversions of reusable treated effluent are limited to the amount remaining after paying winter return flow obligations and augmentation leases, direct non-potable uses and upstream exchanges.

7.6 Order of Simulated Water Use

The simulated order of use of Loveland's various raw water supplies to meet the City's daily water demands is patterned after the order in which the sources are actually used. Based on discussions with the City staff, the following is a summary of the simulated order of use of the City's raw water supplies to meet direct flow water demands and for diversions to storage:

Order of Simulated Water Use (First to Last)

Direct Flow Use	Pipeline Rights[1]	202A Transfers[2]	392 Transfers[3]	Loveland Gard Right	Future Sources[4]	Exchange[5]	Free River	CBT	From Storage	WG
To GRG Storage	202A Transfers[2]	392 Transfers[3]	Loveland Gard Right	Future Sources[4]	Exchange[5]	Free River	CBT	WG		
To GWR Storage	202A Transfers[2]	392 Transfers[3]	Future Sources[4]	Reusable Effluent	Reusable WTP Decant	Free River				
To Aug Leases	Reusable Effluent	Reusable LIRF	From D/S Storage	Reusable WTP Decant	From GRG Storage					
To NP Irrigation	202A Transfers[2]	392 Transfers[3]	Future Sources[4]	Reusable Effluent	From D/S Storage	From GRG Storage				

Notes:
1. Early transfers to municipal use and the City's domestic use right (when simulated).
2. Past transfers of irrigation water rights in Case No. 82CW202A, related cases, and Rist & Goss Transfers.
3. Transfer in Case No. 02CW392 and future related cases.
4. Transfers of Ditch and reservoir rights not included in 82CW202A and 02CW392.
5. Exchange of reusable effluent and water from terminal storage (when simulated).

Currently, the Yield Model diverts 202A water before 392 water. This may not be the way the water rights are operated in the future, and the Yield Model may need to be modified to divert in ditch order rather than decree order to better simulate actual operations. The order of use of the various transferred irrigation company shares

[28] Inflow and outflow rates to Great Western Reservoir are still under design and could be up to 40 cfs. For the 2020 Yield Analysis, the rates were conservatively modeled at 20 cfs.

relative to one another may be specified by the model user. However, the order of use in the above table maximizes use of the transferred irrigation water rights and provides a better basis for comparison of the yields from shares in the various irrigation companies. For the Base Run scenario (the model run used for comparison of other alternatives), the order of use of ditch company shares generally follows a junior to senior order.

7.7 Exchanges

The Yield Model simulates exchanges of reusable effluent discharged to the river at Loveland's WWTP and of reusable water release from downstream storage. In exchange for the reusable effluent or storage releases, water may be diverted at the Loveland Pipeline for direct flow uses or to storage in Green Ridge Glade Reservoir through the Dille Tunnel or Olympus Tunnel. The rate of exchange is limited by the available capacity of the diversion facilities and by the river exchange potential between the WWTP outfall or reservoir outlet and the upstream point of diversion.

The river exchange potential between the downstream point of discharge and the upstream point of diversion limits the amount of water that may be exchanged upstream. The exchange potential is defined by the minimum flow that exists in the river along the exchange reach. Exchange potential for the Loveland Yield Model was determined using a point flow model of the Big Thompson River. The Big Thompson River Point Flow Model ("Point Flow Model") was constructed using historical daily streamflow and diversion data. The Point Flow Model is simply an arithmetic determination of the flow that exists at various points along the river between known flows measured at streamflow gages. The flow at any point along the river is computed in the Point Flow Model as follows:

Flow at any point = Measured flow at the nearest upstream gage

+ Measured inflows or returns [(1)]

- Measured outflows or diversions [(1)]

+/- Unmeasured reach gains or losses [(1)]

<u>Notes:</u>

[(1)] between the upstream gage and the point of interest.

A schematic diagram illustrating the operation of the Point Flow Model is shown in **Figure 7-2**.

The unmeasured gains or losses between two streamflow gages are determined daily based on the difference between the flow at the downstream gage and the flow at the upstream gage plus and minus all the measured inflows and outflows between the two gages. Upstream of the Canyon Mouth gage, the unmeasured gains or losses were distributed proportionately based on the distance between various points. Downstream of the Canyon Mouth gage, the unmeasured gains or losses are primarily the result of irrigation return flows along the river, and therefore they were distributed along the river based on the relative width of the irrigated area lateral to the river. This procedure caused more of the unmeasured gains and losses to be shifted downstream.

The daily exchange potential along key reaches of the Big Thompson River was conservatively computed as the minimum flow from the Point Flow Model less 5 cfs. The resulting historical daily exchange potential estimates were input to the Loveland Yield Model and used as constraints on the simulated exchanges. A chart illustrating the operation of the Point Flow Model is provided in **Figure 7-3**. The chart shows the flows computed at various points along the Big Thompson River on July 4, 2002. The exchange potential (minimum flow minus 5 cfs) between the WWTP outfall and the Loveland Pipeline is shown by the pink line in the graph (84 cfs). The line extends from the WWTP outfall on the right to the Loveland Pipeline on the left. The exchange potential between the WWTP outfall and the Dille Tunnel is shown by the green line (33 cfs).

For illustration of the exchange conditions over the 1951 - 2015 study period, **Figure 7-4** shows average daily flows and exchange potential in a similar manner for the months of January and August. These months show some of the range in daily river flows and exchange potential that can exist over the year. Note that this summary of exchange potential is based on estimated flows from the Point Flow Model and does not consider the timing and location of local calls on the Big Thompson River. The existence of these calls, particularly reservoir calls in the non-irrigation season, may limit the number of days and river reaches for exchanges.

Table 7-1 summarizes the average simulated exchange potential in river reaches over which Loveland is likely to operate an exchange. The upper portion of the table shows the average daily cfs of exchange potential in each month. The lower portion of the table shows the average number of days that exchange potential existed during the 1951 - 2015 study period. Although the actual existence and amount of exchange potential will vary daily and may be limited by the existence of local calls, **Table 7-1** provides information on when the Point Flow Model indicates that exchanges could be performed. The months of May through July have the highest average exchange potential as well as the highest number of days.

7.8 Revisions to the Yield Model

A number of changes in the City's water supply portfolio and facilities between 2011 and 2020 necessitated revision to some of the assumptions and operations in the Yield Model. Some of the important Yield Model changes are listed below:

- Extension of the study period through 2015. The extended study period encompasses the September 2013 Flood on the Big Thompson River which directly impacted the City of Loveland by limiting diversions at Loveland facilities due to infrastructure damage. The two years following the September 2013 Flood where characterized by multiple extended periods of Free River which facilitated municipal diversions.
- Revision of the municipal water demand distribution based on 2005-2015 data.
- Incorporation of the WGFP at the 9,587 AF level.
- Increase in CBT units from 11,786 to 12,190[29].
- Addition of Loveland Gard Right to the water right portfolio and return flow obligations.
- Addition of future ditch shares currently deposited in Loveland's water bank.
- Adjustment to South Side Ditch diversions related to conveyance of a portion (0.75 cfs) of the O'Hara private contract right back to the ditch company.
- Addition of the ability to switch the order of use for CBT and Windy Gap water supplies.

Changes in the Base Run conditions are summarized on **Table 7-2** for several important parameters.

7.9 Yield Model Operation and Use

The Loveland Yield Model is a multi-tabbed Microsoft Excel spreadsheet that simulates the daily raw water supply yield for the City over the period from 1951 - 2015. The Yield Model is operated by the user specifying various input parameters on two input data sheets and then recalculating the spreadsheet to compute the model results. The user-defined inputs include the following:

[29] The City of Loveland acquired an additional 20 CBT units after the yield modeling was completed. There are currently 12,210 CBT units in the City of Loveland's water rights portfolio.

- Annual water demand: municipal, potable leases, augmentation, non-potable irrigation.
- WWTP return flow percent.
- Transferred irrigation company shares.
- Priority of irrigation company share use.
- CBT units.
- Windy Gap Project units.
- Upstream and downstream raw water storage capacity and starting contents.
- Loveland's WGFP storage capacity.
- Diversion facility capacities.

The user may also select from several alternate operational options on the second data sheet. A copy of the input data sheets from the Yield Model is shown in **Figures 7-5 and 7-6.**

The process of computing the firm yield of Loveland's raw water supply requires iterative runs of the Yield Model. After setting the various input parameters on the input data sheets, including the annual water demand, the spreadsheet is recalculated. Among the Yield Model outputs are summaries of the volume of any simulated water shortages. If a shortage occurs, then the annual municipal demand is reduced, and the Yield Model is rerun. If there is no shortage, then the demand may be increased. The process of increasing or decreasing the annual water demand is repeated until the maximum annual demand that can be satisfied in every year of the study period is determined. This maximum annual demand defines the firm yield for the particular set of input parameters.

When non-potable irrigation or augmentation lease demands are simulated, the annual shortage is calculated separately for each of these demands in order to allow shortage in, for example, the irrigation demand, while still meeting the municipal demand with no shortage. For this analysis, all demands were assumed to be met in order to determine the firm yield. A total of 590 AF/y of augmentation and potable park irrigation demand was kept constant and only the municipal demand was increased or decreased. The total firm yield is computed as the maximum municipal demand that can be satisfied each year plus the 590 AF of augmentation demand. If the augmentation demand is not simulated or is allowed to have a shortage, the municipal portion of the firm yield would be increased.

The Yield Model spreadsheet is linked to summary spreadsheets containing various graphs and tables that allow automatic summarizing, visualization and comparison of model runs. Additional tables and graphs can be generated from manual entry of firm yield results into a results spreadsheet.

8.0 YIELD MODEL RESULTS

Numerous runs of the Loveland Water Supply Yield Model were made to evaluate the yield of Loveland's current water supply and the increase in yield that would result from adding various additional water sources or from operating the water supply system in different ways. All Yield Model runs included 590 AF/y of augmentation demand, assumed to be fully met each year, in addition to the municipal demand. Firm yield is defined as the maximum annual water demand that can be dependably supplied each year of the 1951 - 2015 study period. The results are reported as the total firm yield, including both the municipal and augmentation portions of the total simulated demand.

The analysis of the increase in firm annual yield that would result from acquisition of various water sources was performed by comparing the results of a "Base Run" of the Yield Model that simulates Loveland's current water supplies against a "Test Run" that simulates Loveland's current supplies plus an additional increment of a particular water source or a change in operation. Subtracting the Base Run firm yield from the Test Run firm yield provides an estimate of the change in firm yield resulting from the water source or operational scheme being evaluated. The following is a description of these model runs and results.

8.1 Base Run Results

8.1.1 Yield of Current Water Supplies

Loveland's current average annual simulated water supplies and the amounts available in the dry year of 2002 are shown in **Table 8-1**. The average annual available supply totals approximately 36,895 AF, while the availability of these sources in the 2002 dry year totals only 16,980 AF. These figures do not include diversions during free river periods, exchanges of reusable effluent or the regulating benefits of Green Ridge Glade Reservoir.

Loveland's firm yield, assuming current water sources and facilities without the WGFP in place, was determined from the Yield Model to be approximately 25,160 AF/y (24,570 AF municipal and 590 AF augmentation). When the WGFP is constructed, Loveland's current participation level of 9,587 AF of storage will increase the firm yield to 28,960 AF (28,370 AF municipal and 590 AF augmentation). When both the WGFP and Great Western Reservoir storage are operational ("Base Run") the firm yield to 30,740 AF (30,150 AF municipal and 590 AF augmentation). This is the simulated annual demand that can be reliably delivered in each year of the 1951 - 2015 study period. The firm yield is greater than the 2002 dry-year yield of Loveland's direct flow sources shown in **Table 8-1** as a result of carryover storage in Green Ridge Glade Reservoir and Chimney Hollow Reservoir, and exchanges of reusable effluent and downstream storage at Great Western Reservoir. A comparison of the firm yield to the past and projected future water demands is provided in **Figure 4-1**. This figure shows that the current water supply would be adequate to meet City's water demands during the drought year, at the 1.5% growth rate, without water use restrictions through 2055. If the WGFP and Great Western Reservoir are constructed, assuming future drought yields are no worse than during the 1951 - 2015 period, the City could meet the water demand at the 2.0% growth rate until 2058. **Table 8-2** summarizes the relative contributions of the City's water sources to the modeled total Base Run firm yield on an average basis and during the dry year of 2002.

A chart illustrating the annual amounts of Loveland's various water sources simulated to meet the Base Run firm yield demand is provided in **Figure 8-1**. This chart shows that the amount of transferred irrigation water rights used to meet the City's demand varies from year to year depending largely on the yield of the in-basin water supplies. In drought years, when the in-basin yields are low, there are greater uses of transmountain supplies and releases from Green Ridge Glade Reservoir to meet the City's demand.

The simulated contents of Green Ridge Glade Reservoir and Loveland's Chimney Hollow Reservoir account are shown in **Figure 8-2**. Releases from the Chimney Hollow Reservoir account to Green Ridge Glade Reservoir are simulated as needed to try and maintain the latter reservoir at least half full. Both reservoirs are simulated to empty in the spring of 2005, and this is the constraint that establishes the firm yield of Loveland's water supply system. The drought of the late 1970s was another period in which there was a substantial draw on the reservoir contents in the Base Run. The drawdown seen in early 2014 is the result of Post-2013 Big Thompson Flood operations.

The study period contains several droughts. Charts illustrating the daily simulated water supply during the drought years of the mid-1950s, late-1970s and early 2000s are included in **Appendix C**. These charts show how the daily municipal water demands at the Base Run firm yield level are met with Loveland's various water supply sources. The top of the colored area in the charts corresponds to the daily simulated municipal water demands that vary from about 20 cfs during the winter to more than 80 cfs during the peak summer demand period. The different colors correspond to the various water sources simulated to meet the daily water demands. Superimposed on each chart are lines showing the current capacity of the WTP (read on the left axis), and the contents of Green Ridge Glade Reservoir, the contents of Great Western Reservoir, and Loveland's account in Chimney Hollow Reservoir (read on the right axis).

The daily supply charts show that the Loveland Pipeline Rights (a.k.a. Early Transfers and domestic rights) provide relatively continuous year-round base supply. During the winter season of most years, CBT Project yield provides the balance of the winter supply. During the irrigation season, the transferred irrigation water rights typically provide the majority of the water supply. In low water supply years, the irrigation supply is supplemented by CBT Project deliveries and releases from Green Ridge Glade Reservoir. When necessary, reservoir releases are simulated to meet any remaining unmet demand, typically in the latter portions of the irrigation season after the City has exhausted its annual CBT quota.

8.1.2 Base Run Generation of Reusable Return Flows

Reusable return flows from use of legally reusable water supplies reusable are simulated as releases from the WTP decant ponds, discharges of treated effluent at the WWTP, and as LIRFs (when simulated). Reusable decant pond releases and treated effluent discharges are simulated to meet return flow obligations, augmentation demands, and exchanged for diversions at the Loveland Pipeline and Green Ridge Glade Reservoir. An average of 170 AF/y of reusable decant pond releases and 3,025 AF/y of reusable treated effluent discharges are produced in the Base Run, mostly in the spring and fall months when free river diversions and releases of stored water are available. Reusable effluent is low in July when a large portion of the supply is from non-reusable 202A sources. On average, the simulated annual use of reusable return flows is comprised of 1,160 AF exchanged to the Loveland Pipeline, 50 AF exchanged to Green Ridge Glade Reservoir, 20 AF to pay winter return flow obligations, 210 AF to satisfy augmentation leases, and 460 AF stored in Great Western Reservoir. Excess unused reusable return flows average 1,110 AF/y in the Base Run. Excess unused reusable return flows occur during periods of free river call conditions, when reservoir storage is full, and/or there is no exchange potential on the Big Thompson River. **Figure 8-3** is a chart summarizing the simulated production and use of the reusable WWTP effluent discharges and decant pond releases in the Base Run.

Loveland is seeking to quantify its reusable LIRFs in a pending Water Court application. Because this quantification is uncertain, the reusable LIRFs were not simulated as a source in the Base Run. However, the reusable LIRFs may be simulated in alternative model runs to pay return flow obligations, meet augmentation demands, and for storage in Great Western Reservoir.

8.2 Changes in Firm Yield Due to Differences Between 2011 and 2020 Models

There were several modifications made to the Yield Model between 2011 and 2020 to reflect changes in Loveland's water supply portfolio and operating procedures, as described in Section 7.8. Some of the changes produced relatively small changes in firm yield, but others were more substantial and had a larger effect on use of the City's water supplies and the incremental firm yields of additional sources that were modeled in 2011. The table below summarizes the effect on the firm yield due to some of the major Yield Model changes. The table does not include the effect of every model change.

Yield Model Change	Effect on Firm Yield, AF
Add CBT Units (from 11,786 to 12,190[30])	270
WG Firming Project Participation (from 7,000 AF to 9,587 AF)	860
Add Great Western Reservoir (1,300 AF[31])	1,780

The additional simulated water supplies from municipal rights, ditch shares, CBT units, participation in the Windy Gap Firming Project, and Great Western Reservoir in the 2020 Yield Model Base Run resulted in a significant increase in Loveland's firm yield (30,740 AF/y in 2020 compared to 27,390 AF/y in 2011). The major change to the Yield Model was the addition of the 1,300 AF Great Western Reservoir to the Base Run. The downstream reservoir allows Loveland to store reusable return flows and exchange that water upstream when exchange potential exists, which increases the simulated firm yield.

Table 8-3 shows the differences in the use of the City's water supplies in the 2011 and 2020 Base Runs.

8.3 Increased Yield from Windy Gap Firming Project

Participation by Loveland in the WGFP by funding a portion of the construction and operation of the proposed Chimney Hollow Reservoir will increase the City's firm yield. The increased firm yield will vary with the level of Loveland's participation in the project, which is currently at a level of 9,587 AF of storage space. The WGFP increases the firm yield of Loveland's water supply by helping to maintain storage levels in Green Ridge Glade Reservoir and by providing a drought water supply to supplement the limited yield from the City's other water sources. Use of the WGFP as a drought supply in this manner will require filling Loveland's account in the proposed Chimney Hollow Reservoir through

[30] The City of Loveland acquired an additional 20 CBT units after the yield modeling was completed. There are currently 12,210 CBT units in the City of Loveland's water rights portfolio.
[31] 1,300 AF was modeled as the preliminary operational storage capacity of Great Western Reservoir.

the irregular yield available from the Windy Gap facilities on the West Slope and then drawing on the water stored in Chimney Hollow Reservoir in dry years.

Because the WGFP has not yet been constructed, it is conceivable that the City could change its participation from the current 9,587 AF level. The increase in Loveland's firm water supply yield was estimated at various assumed levels of project participation ranging from 0 AF to 20,000 AF of Chimney Hollow Reservoir capacity. In general, there is some benefit from additional project participation above the current level of 9,587 AF. The results of these model runs are shown in **Table 8-4** and in the chart in **Figure 8-4**.

The simulated Windy Gap supply available in the years subsequent to the drought year 2002 becomes the limiting factor in the firm yield provided by the WGFP. This is illustrated in the reservoir storage hydrograph for the 9,587 AF participation level run provided in **Figure 8-2**. In the years leading up to 2002 the reservoir fills to capacity. The limitation on the Windy Gap supply during the dry years immediately following 2002 is the lack of flows in priority on the West Slope.

Without Chimney Hollow Reservoir or other East Slope storage, the Windy Gap Project is generally considered to have no firm yield. This is due to the absence of yield from the project in very dry years when the Windy Gap water rights have no yield, and the lack of yield in very wet years when there is no excess capacity in Granby Reservoir to store pumped Windy Gap water. However, the Windy Gap Project does add firm yield to the Loveland water supply as a result of the City's other water resources. First, Green Ridge Glade Reservoir provides a place to store excess Windy Gap yield in average water supply years for carryover and use in subsequent dry years. In addition, the availability of Windy Gap supply in average years can also allow Loveland to save some of its CBT Project yield for carryover to subsequent dry years (up to the 0.2 AF per unit carryover limit).

Two runs of the Yield Model were made to estimate the amount of Loveland's current firm yield that is derived from the City's current Windy Gap supply without the proposed Chimney Hollow Reservoir. This was accomplished by first recomputing the City's firm yield without the WGFP, and then by another run setting Loveland's Windy Gap supply to zero and then recomputing the City's firm yield. The difference in firm yield with and without the City's Windy Gap supply is estimated at approximately 940 AF, and this is the estimated amount of firm yield provided by the City's current Windy Gap supply without the WGFP in place. The following table is a summary of current and potential firm yield provided by Loveland's Windy Gap supply.

Summary of Firm Yield
from Loveland's Windy Gap Supply

Description	Incremental Additional Firm Yield (AF/y)
Without WGFP	940
With WGFP (9,587 AF participation)	3,800
Total Firm Yield to Loveland from Windy Gap	4,740

8.4 Shortages at Greater Demands

Alternative Yield Model runs were made to estimate the amount and frequency of water shortages that would exist at simulated annual water demands in excess of the estimated firm yield of the City's current supplies. As the municipal demand is increased above the 30,150 AF/y Base Run level, shortages in the augmentation demands begin to occur, first in 2004 and then in other years. The following is a summary of magnitude of the shortages and the number of years of shortages in the 65-year study period at increased demand levels.

Volume and Frequency of Water Shortages
at Increased Annual Municipal Water Demand
In Excess of the Firm Yield of Loveland's Current Water Supply

Annual Municipal Demand (AF/y) [1]	Maximum Annual Municipal Shortage (AF)	Number Years of Municipal Shortage	Maximum Annual Augmentation Shortage (AF)	Number Years of Augmentation Shortage
30,150	0	0	0	0
30,500	288	1	7	1
31,000	1,176	2	8	2
32,000	2,916	9	14	8
33,000	6,246	14	17	13
34,000	7,099	22	17	20
35,000	9,256	26	102	23

Notes:
1 The annual total demand is equal to the sum of the municipal demand and the augmentation demand of 590 AF/y. The Base Run annual total demand shown on the first line of the table is 30,740 AF/y which is the municipal demand (30,150 AF/y) + augmentation demand (590 AF/y).

A chart illustrating the results of the increased demand runs is shown in **Figure 8-5**. These results show the amount and frequency of municipal demand shortages that occurred at greater demand levels during the simulated 1951 - 2015 period. The results can be used to assess the approximate increase in water supply that could be delivered in most years, provided that the City could reduce its demand in dry years (e.g., through water use restrictions). For example, the results show that Loveland could satisfy an annual demand of 32,000 AF/y in 56 years of the 65-year study period. Demand reduction would be required in the other 9 years, with a maximum required annual reduction of approximately 2,916 AF (9%). Although it can be effective, relying on water conservation to meet future water demands can reduce the City's ability to withstand droughts that are more severe than a 100-year drought. The City has chosen to plan to meet all demands during the 100-year drought without watering restrictions.

8.5 Effect of Competing Senior Conditional Exchanges

Loveland's exchanges from its WWTP outfall to various upstream points of diversion compete for the available exchange potential with exchanges by other Big Thompson water users. Many of the exchanges exercised by other Big Thompson River water users have operated for long periods, and their operation is already reflected in the historical streamflow and diversion records utilized in the Point Flow Model and the Yield Model. These are largely agricultural exchanges involving releases from storage in exchange for upstream diversions. Among the Big Thompson River water users with decreed agricultural exchanges are the Handy Ditch, Home Supply, South Side and the GLIC.

In addition to the exchanges that have operated historically there are several conditional exchanges for municipal purposes, including exchanges claimed by the Cities of Greeley[32] and Evans[33], that are senior to all or portions of Loveland's exchanges ("Competing Exchanges"). As the use of any Competing Exchanges are increased in frequency and amount, they may reduce Loveland's exchanges to amounts less than what are simulated in the historical 1951 - 2015 period.

The potential effect on Loveland's firm yield resulting from increased operation of Competing Exchanges was analyzed using the Yield Model. Model runs were made to assess the impact of Competing Exchanges over two different reaches of the Big Thompson River. The first category of runs assessed the potential impact of Competing Exchanges operated on the lower reach of the Big Thompson River from at or near the confluence with the South Platte River upstream to the Barnes Ditch and Loveland and

[32] In Case No. 99CW325, the City of Greeley agreed to limit the operation of their exchanges decreed in Case Nos. 87CW329, 95CW042, and 99CW325 to 30 cfs.
[33] In Case No. 98CW958, the City of Evans agreed to limit the operation of their exchange to 16 cfs.

Greeley Canal. This is the reach over which the Cities of Greeley and Evans operate their exchanges ("Lower River Exchanges"). The second category runs were made to estimate the impact of Competing Exchanges over the reach from the Loveland WWTP outfall to the Loveland Pipeline ("Middle River Exchanges"). The modeled increased Competing Exchanges were assumed to operate continuously during the irrigation season limited only by the river exchange potential. If the Competing Exchanges are operated for only part of the irrigation season in the future rather than continuously, the effect on the City's exchanges would be less than simulated.

The results of the impact of increased operation of Competing Exchanges on Loveland's firm yield are shown in **Figure 8-6** for exchange rates up to 50 cfs. The results show that the competing Lower River Exchanges would have less impact on Loveland's firm yield than would the competing Middle River Exchanges. For example, at an assumed additional Competing Exchange rate of 50 cfs, the Lower River Exchanges would reduce Loveland's firm yield by approximately 3,740 AF/y while Middle River Exchanges at the same rate would reduce the firm yield by approximately 6,260 AF/y. The reason for the difference in impact is that the exchange potential on the lower reaches of the Big Thompson River is typically less than on the middle reaches and the City has fewer existing facilities located in this reach. Exchanges in the lower reach do not contribute as much to the firm yield as exchanges in the middle river, where more of the City facilities are located. Competing Exchanges in the middle reach can affect more of the City's opportunities for exchange. While there are no known significant conditional exchanges on the middle river reach, the sensitivity of the results to increased middle river exchanges suggests that Loveland should be vigilant in protecting flow conditions upstream of the WWTP (e.g., through opposition to change water right applications, etc.).

8.6 Effect of CBT Project Supply on Exchange Yields

The exchange potential on the Big Thompson River has been enhanced by the operation of the CBT Project. Project deliveries to downstream users have increased the flow of the Big Thompson River, thus providing more opportunities for river exchanges. However, the historical operation of the CBT Project may not be representative of future conditions due to the changing character of ownership of the CBT Project from agricultural to municipal and industrial. As the CBT Project ownership changes there will likely be less transmountain water delivered down the Big Thompson River, and this will reduce the available exchange potential. A chart showing the historical deliveries of CBT Project water to Big Thompson River water users is shown in **Figure 8-7**. The chart shows there has been a general decline in CBT Project deliveries since the mid-1980s.

The Yield Model was used to estimate the potential effect of reduced agricultural CBT deliveries on Loveland's firm yield. Alternative runs were made for various levels of reduced deliveries of CBT Project. These runs included (a) reducing historical deliveries over the entire study period to approximate current levels, (b) further reductions to approximately one-half the current level and (c) no deliveries of CBT Project water. Reduced deliveries were subtracted from the historical diversions of the Big Thompson River ditches and the records of the Big Thompson River flow gages in the Point Flow Model resulting in lower simulated Big Thompson River exchange potential.

The results of the Yield Model runs for reduced agricultural CBT deliveries are shown in **Figure 8-8**. Reductions in historical CBT deliveries to current 5-year average levels have resulted in an estimated loss of 570 AF/y in the Base Run. However, further reduction of CBT deliveries to one-half the current 5-year average level would result in an estimated loss of 1,480 AF/y of firm yield while curtailment of all CBT deliveries down the Big Thompson River would reduce the firm yield by approximately 2,460 AF/y. These results may understate the actual impacts to Loveland's firm yield as the reductions in irrigation return flows that would result from reduced CBT Project deliveries were not evaluated.

8.7 Future Water Supply Variability

New to the Loveland Yield Study in 2020 is an analysis of the impact of future supply reductions to the City's firm yield. Several entities have undertaken examinations of future water supply impacts in northern Colorado due to climate variability. Those entities are the United States Bureau of Reclamation ("USBR"), the Water Research Foundation, and Western Water Assessment.

8.7.1 Climate Change and Future Water Supply Research

8.7.1.1 Western Water Assessment Report

In 2008, The Western Water Assessment ("WWA") prepared a report titled Climate Change in Colorado, A Synthesis to Support Water Resources Management and Adaptation for the Colorado Water Conservation Board. This report included several projections on future water supplies in Colorado including:

- Declines in snowpack with more declines at lower elevations
- Runoff shifting earlier in the season
- Reduction in Colorado River basin runoff ranging from 6% to 20%

- Increase in temperature leading to increased evapotranspiration ("ET") and higher water demands
- Increase in drought severity

The WWA report also identified key unresolved issues associated with climate implications on Colorado's water resources as follows:

> *"The current state of the science is unable to provide sufficient information to decision makers and stakeholders on a number of crucial scientific issues regarding Colorado's water resources. Often, there are insufficient data, in time or space, to assess long-term observational trends. In other cases, research is in progress, but the results may not be as robust as needed. Four overlapping areas with unresolved issues are climate models, research specific to Colorado, drought, and reconciling hydrologic projections."*

8.7.2 United States Bureau of Reclamation Report

In 2012, the USBR prepared the Colorado River Basin Water Supply and Demand Study Technical Report B – Water Supply Assessment. In this report, the USBR evaluated four climate scenarios:

- Observed Record Trends and Variability (Observed Resampled): Future hydrologic trends and variability are similar to the past approximately 100 years.
- Paleo Record Trends and Variability (Paleo Resampled): Future hydrologic trends and variability are represented by reconstructions of streamflow for a much longer period in the past (nearly 1,250 years) that show expanded variability.
- Observed Record Trends and Increased Variability (Paleo Conditioned): Future hydrologic trends and variability are represented by a blend of the wet-dry conditions of the longer paleo reconstructed period (nearly 1,250 years), but magnitudes are more similar to the observed period (about 100 years).
- Downscaled General Circulation Model ("GCM") Projected Trends and Variability (Downscaled GCM Projected): Future climate will continue to warm with regional precipitation and temperature trends represented through an ensemble of future Downscaled GCM Projections and simulated hydrology. The downscaled GCM model is a basin-wide model which incorporates 112 climate predictions and runs using a 30-year timestep.

The USBR report projects Upper Colorado River basin precipitation will increase during November-March and decrease during April-June, with an overall increase. Increased temperatures are projected to increase ET during April-June, and runoff and cause snowmelt runoff to occur earlier.

Collectively, the four climate scenarios in the USBR report show a projected reduction of 2.0% to 8.7% in the mean flow of the Colorado River at Lee's Ferry by 2060. The GCM scenario projects the average reduction in streamflow will reach 12.4% by 2095.

The USBR cautions that *"…climate projections are used to generate projections of future streamflow, contains a number of areas of uncertainty."* In particular, *"The GCMs were applied at relatively coarse scales (~150- to 200-km resolution) in relation to what is required for watershed assessments, and therefore are not likely to capture important regional phenomena."*

Future refinement of the USBR analyses was presented in two reports published in 2016: Technical Memorandum No. 86-68210-2016-01 West-Wide Climate Risk Assessments: Hydroclimate Projections and the SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water 2016. These reports echo the findings of the 2012 USBR report.

8.7.3 Water Research Foundation Report

Also, in 2012 the Water Research Foundation ("WRF") published a Joint Front Range Climate Change Vulnerability Study in collaboration with the following entities:

- City of Aurora
- City of Boulder
- City of Cheyenne
- City of Colorado Springs
- City of Fort Collins
- City of Longmont
- City of Westminster
- Colorado Water Conservation Board
- Denver Water
- National Center for Atmospheric Research
- Northern Colorado Water Conservancy District
- Principal Investigators
- Riverside Technology Inc
- Western Water Assessment

The objective of the WRF study was to analyze the sensitivity of streamflow to climate change for the headwaters of the Arkansas, Colorado, and South Platte Rivers and to develop projected streamflow scenarios that represent the effects of climate change.

Of the 112 climate projections available, the WRF analysis used five projections (hot and dry, hot and wet, warm and dry, warm and wet, and median) which were selected to represent the range of climate models. The five projections were repeated to evaluate 30-year periods surrounding 2040 and 2070. The WRF study also incorporated undepleted stream flows at 18 gage locations distributed within the three watersheds. The undepleted streamflows are the historical streamflow records adjusted to remove diversions, reservoir storage releases, and return flows.

The WRF study used two climate models, the Water Evaluation and Planning ("WEAP") model from Stockholm Environmental Institute and the Sacramento model from the National Weather Service River Forecast System, to simulate the impact of climate change on streamflow. They also used a two-stage approach to test the sensitivity of each model and gauge locations: a simple sensitivity analysis and a GCM-based sensitivity analysis.

- Simple Sensitivity Analysis – Tested the effect of uniform temperature increases (excluding precipitation changes) and uniform precipitation adjustment (excluding temperature changes) on each of the models and streamflow gauge locations.
- GCM-base Sensitivity Analysis – Test the effect of the five climate projections (which had temperatures and precipitation amounts that varied spatially over the study area and temporally over the study period) each of the models and streamflow gauge locations.

The following table presents the range of projected annual percent change in streamflow volumes for the Big Thompson River and the upper Colorado River across the two climate models and the five climate projections.

Projected Annual Percent Change in Streamflow Volumes
(% Change from Model Baseline)

Sacramento Model	*Big Thompson River at Canyon Mouth near Drake, CO*	*Colorado River near Granby, CO*
Simple Analysis	-21% to +17%	-24% to +16%
2040	-21% to +16%	-24% to +16%
2070	-17% to +17%	-19% to +11%
WEAP Model	*Big Thompson River at Canyon Mouth near Drake, CO*	*Colorado River near Granby, CO*
Simple Analysis	-16% to +18%	-22% to +8%
2040	-18% to +25%	-10% to +13%
2070	-20% to +19%	-15% to +10%

The key takeaways from this study for water providers include:

- Future streamflow may decrease as a result of increased ET due to increased temperatures and decreases in precipitation.
- Future streamflow may increase as a result of increased precipitation offsetting the impact of increased temperatures.
- Runoff is expected to occur earlier during the season.
- *"There is substantial variability in projected future streamflow based on the range of climate model projections that were used for streamflow simulation."*
- *"Spatial and temporal distribution of temperature and precipitation changes across multiple sub-basins and over the twelve-month period has considerable influence on hydrologic model results."*
- *"While increased temperatures are shown to reduce simulated average annual streamflow, the reductions are not uniform across the study area, with the driest basins, such as those in the South Platte, experiencing the greatest percent reduction in streamflow due to warmer conditions, while the wetter basins, including the upper areas of the Colorado, show a smaller percent reduction."*

- Water providers should monitor climate change indicators, encourage climate science research to aid in hydrologic assessments, and incorporate updated climate models in their planning processes.

8.7.4 Potential Colorado River Compact Call

The State of Colorado is a party to the Colorado River Compact, signed in 1922, which apportions the Colorado River streamflow between the Upper Basin and Lower Basin states. The Upper States (Colorado, New Mexico, Utah, and Wyoming) are obligated to provide 7.5 million AF of water, on a 10-year rolling average, to the Lower Basin states. Since 2000, an extended drought within the Colorado River basin and low storage in Lake Mead and Lake Powell have led to concerns that the Lower Basin states will place the first ever call for their portion of the compact streamflow. A Colorado River Compact call could result in curtailment of upstream water diversions in order to deliver water downstream. Curtailment would likely occur by priority, with post-compact water users curtailed first, unless the upstream water users develop a different curtailment scheme. The parties to the Colorado River Compact recently undertook collaborative efforts to manage water supplies through drought contingency plans with the hope of heading off a compact call. The drought contingency plans are still in the planning stages.

In March 2019, the Colorado Water Conservation Board voted to explore the feasibility of a demand management program to help assure compliance with the Colorado River Compact and to avoid a priority-based compact call. The CWCB and State of Colorado seek to avoid the implementation of additional water right priority administration to in order to fulfill the Upper Basin's compact obligation. As a step in that direction, CWCB has adopted a policy stating that a demand-management program would be a voluntary, temporary and compensated. Key components of this strategy are to share the water shortages among water users and to pay water users who volunteer to not divert their water.

The potential impacts of a Colorado River Compact call on Colorado water users are uncertain and the effects of a call on Loveland's CBT and Windy Gap water supplies cannot be presently quantified. Loveland should continue to monitor the developments on the Colorado River Compact compliance negotiations and drought contingency plans.

8.7.5 Reduced Water Supplies in Loveland Yield Analysis

Given the information presented in the foregoing studies and recognizing the current uncertainties in climate modeling, Loveland has chosen to take a conservative approach in the 2020 Yield Model update by focusing on potential reductions to the water supply.

Several alternative model runs were made with reductions in the yields of Loveland's water sources and Big Thompson River flows for exchange ranging from 5% to 20%, with the results shown in **Figure 8-9**. A 5% reduction in supply results in a projected decrease in firm yield of 1,250 AF while a 20% reduction in supply would cause a 3,850 AF reduction in firm yield. Additional analysis of future reductions in the CBT water supply can be found in Section 8.6. These results should be considered approximate as the potential future reductions in streamflow would not likely uniformly reduce the yield of Loveland's water sources. Assuming that water will continue to be administered in Colorado based on the prior appropriation doctrine, flow reductions will likely have a disproportionately greater impact on the yields of junior water rights rather than senior water rights.

8.8 Increased Firm Yield from Additional Sources

One of the purposes of the Loveland Yield Study was to estimate the increase in the City's firm yield resulting from the addition of various water supply sources; namely irrigation company shares, CBT Project units and Windy Gap Project units. In addition, estimates were made of the increase in firm yield resulting from increased upstream storage capacity (e.g., increased capacity in Green Ridge Glade Reservoir or construction of other upstream storage) and increased downstream storage (e.g., increased capacity in Great Western Reservoir or construction of other gravel pit reservoirs). Selected amounts of each of these water sources or storage capacities were added individually to the simulated Loveland water supply and the resulting increase in firm yield was estimated using the Yield Model. In order to make the results comparable among the various water sources, 500 AF/y of average annual yield of each source was added in each of the alternative model runs. A summary of the results of the incremental firm yield analysis is provided in **Table 8-5** and in **Figures 8-10, 8-11, and 8-12**. Descriptions of the model results for the various categories of water sources potentially available to the City follow.

8.8.1 Additional Direct Flow Irrigation Sources

Acquisition of additional shares in the various Big Thompson River irrigation companies would have varying benefit to Loveland's firm yield. In the 392 case, Loveland agreed to not transfer any more Barnes or Chubbuck inches except in certain limited circumstances; therefore, no acquisitions from these ditches were simulated. The increase in firm yield resulting from adding 500 AF/y of average annual yield in each irrigation company is shown in **Table 8-5** and **Figure 8-10**, and ranges from 30 AF/y for George Rist (Buckingham) shares to 330 AF/y for GLIC shares with storage.

The increased firm yield tends to be greater for irrigation companies with more senior water rights and companies that have storage. The greater yield for the GLIC shares is due in large part to the company's carryover policy that allows excess storage yield to be carried over from one year to the next in a pro-rata share of the available storage capacity of Boyd Lake. The GLIC yield depends on the continued availability of sufficient exchange potential to exchange releases from Boyd Lake upstream to the Loveland points of diversion. Note that the results for Ryan Gulch Reservoir are for acquisition of the entire reservoir for municipal uses (the average annual yield of Ryan Gulch Reservoir is less than 500 AF/y).

The results of the incremental firm yield analyses depend on the particular hydrologic conditions and irrigation company operations during the recent drought. In the Base Run, the first year a shortage appears as demands are increased is 2004 (“critical year”). In order to assess the sensitivity of the analyses to the drought conditions, alternative model runs were made to estimate the incremental benefit to Loveland's water supply during other drought periods. One set of these alternative runs was made by increasing the simulated annual water demand until just before a shortage occurs in a second year (2003). This established an alternative baseline condition. Then, incremental yield runs were made for each source against the new baseline condition (i.e., adding 500 AF/y of average annual yield and then increasing the demand until just before a shortage occurs in 2003).

A second set of alternative runs was made by further increasing the annual demand to establish another baseline condition that includes failures in both 2003 and 2004, with 2002 becoming the critical year. Then, the incremental runs for each source were made as described above. The results of the original and alternative incremental yield runs are shown in **Figure 8-11**. The results show that the incremental firm yield added in the original and alternative runs is similar for most sources (e.g., the yields for George Rist (Buckingham) shares are less than 50 AF/y in each of the three critical periods, while the yields of the BTD&MC shares range from 170 - 180 AF/y).

In addition to the incremental yields from addition of direct flow irrigation sources, the City also requested a tabulation of the “portfolio yield” of ditch shares it currently owns. The portfolio yield is defined as the contribution of a particular ditch to the total firm yield, divided by the total number of shares in the City’s portfolio. **Table 8-6** summarizes the incremental yield of the ditch shares in the 2011 and 2020 Yield Models.

Differences in the incremental firm yield between the 2011 and 2020 Yield Models resulting from adding 500 AF/y of average annual yield in each irrigation company are due to many of the same factors that affect the overall yield described in Section 8.2. For example, the ditch shares have a variable yield based on historical diversions that may not be as well-matched to the revised demand pattern.

8.8.2 Additional CBT Units

Adding additional CBT units generally has more benefit to Loveland's firm yield than does adding shares in the various irrigation companies due to (a) the more dependable yield of the CBT Project, (b) the flexible timing of CBT deliveries, (c) the ability to carryover excess yield to the next year and (d) the upstream location that avoids having to exchange water for delivery to Loveland. When an additional 668 units (500 AF/y average yield) are added to Loveland's water supply, the simulated annual water demand throughout the study period can be increased by 600 AF/y above the demand in the Base Run before a shortage occurs as shown in **Figure 8-12**. Therefore, an incremental firm yield of 600 AF/y is attributed to the additional 668 units, or 0.90 AF/y per unit.

Table 8-7 shows the contribution of Loveland's water supplies to the increased firm yield from addition of CBT units from 2000 through 2006. The values in the table illustrate the effect of the reduced availability of excess supply at the overall higher firm yield level in the 2020 Yield Model.

The results of the CBT firm yield analysis have prompted questions about how the incremental firm yield can exceed the average annual yield (0.75 AF/unit) and maximum annual yield (1.00 AF/unit) available from the CBT Project. These questions can be answered by examination of (a) how yield from the additional CBT units is enhanced by the carryover storage available in the CBT facilities, (b) how the 2020 Yield Model differs from the 2011 version and (c) how use of the CBT units interacts with the City's other water supplies. These factors are explained below:

- Carryover Storage in CBT Project - CBT Project owners may carry over yield from one year to the next if there is space available in the project facilities. CBT carryover is limited to the lesser of 0.2 AF per unit owned or 90 percent of the amount of allocated supply remaining at the end of the year (October 31)[34]. Based on modeled ownership of 12,190 CBT units, Loveland's maximum CBT carryover is 2,438 AF. With the simulated addition of 668 CBT units, the maximum CBT carryover would increase to 2,570 AF.
- As noted above, in most years, Loveland has water supplies that are available in amounts greater than the City can use. As a result of these excess supplies available from Loveland's other water sources in most years, portions of the simulated additional CBT supply can increase Loveland's carryover in the CBT

[34] CBT owners are assessed a 10% storage charge to carry over water to the next year.

facilities, subject to the limitations described above. **Figures 8-13 and 8-14** contain bar graphs that illustrate the simulated available CBT supply that results from adding CBT units to provide 500 AF/y on average to Loveland's current water supplies for the 2011 and 2020 CBT Test Runs[35]. The information shown in **Figures 8-13 and 8-14** is expressed on a per-CBT-unit basis. The two bar graphs summarize the annual supply from the declared quota and from the simulated carryover of water in Loveland's CBT account. The upper graph shows that the annual available CBT supply, including simulated carryover, exceeds 1.0 AF/unit in three years of the study period for the 2020 Yield Model runs. The second graph shows that in the 2011 Yield Model runs, the CBT quota plus simulated carryover exceeded 1.0 AF/unit in five years of the study period.

- Differences Between 2011 and 2020 Models - Because of the dynamic interaction of the water supplies in the model, changes in model assumptions and operations can affect the yield estimated for the various water supplies. As discussed in Section 8.2, the model changes and additional simulated water supplies in the City's current portfolio allow a higher level of demand to be met than in 2004 and 2011. The higher 2020 demand reduces the excess supply that can contribute to increased firm yield from incremental additions of other supplies. Additionally, the reusable water exchanged from Great Western Reservoir up to Green Ridge Glade reduces the available local storage space for CBT supplies. Another factor in the reduced CBT yield from the addition of CBT units compared to 2011 is that part of the total demand in the 2011 and 2020 Yield Models is the augmentation demand that must be met with reusable water supplies. CBT units are not reusable and are therefore not used for this purpose.

- Interaction of CBT Units and Other Loveland Water Supplies - Loveland utilizes its CBT supply to supplement the yield from its native Big Thompson direct flow water rights. In the Yield Model, the supplemental nature of the CBT supply is simulated by diverting it after all the native ditch and exchange supplies. Other supplemental supplies include Windy Gap Project deliveries and water stored in Green Ridge Glade Reservoir. The Windy Gap Project deliveries include the simulation of Loveland's current participation level of 9,587 AF in the planned WGFP. At the simulated firm yield demand of 30,740 AF/y in the 2020 Base Run, the Yield Model simulates use by the City of nearly all available yield from its native and transmountain water sources, use of all the water in Loveland's account in the WGFP reservoir (Chimney Hollow Reservoir, simulated as full entering 2001 and empty at the end of 2002), and use of all water stored in Green Ridge Glade

[35] The study period in the 2011 Yield Model ended in October 2006 while the study period for the 2020 Yield Model ended in October 2015.

Reservoir (the reservoir is simulated as full entering 2000 and is drawn down to empty in April 2005). **Figure 8-2** shows the daily contents of both Green Ridge Glade Reservoir and Chimney Hollow Reservoir in the 2020 Base Run. However, even in the critical period, there are some days when excess supply exists because the transferred ditch shares yield amounts greater than the simulated daily municipal demand and the available exchange potential.

When 668 CBT units are added to Loveland's water system, this allows the simulated annual water demand to be increased to a greater firm yield amount. In most years, this increased demand can be met in part by the excess supplies that the City has available during certain times of the year. As described above, the excess supplies are primarily transferred ditch shares and reusable exchanges that are simulated to be used before the CBT units in the Yield Model. **Figure 8-15** shows the simulated annual use of water from each source. The sum of all increased or decreased use of supplies in each year equals 600 AF of increased firm yield attributed to the simulated CBT units. Note that due to the interaction of the various water sources in the Yield Model, use of some sources declines in certain years as a result of simulating the additional CBT units. For example, in several years, releases from Green Ridge Glade Reservoir decline as a result of the additional CBT supply, and this is indicated by the yellow areas shown as negative on the chart. In other years, the increased use of CBT due to the addition of the 668 units reduces the amount of reusable water exchanged from the Loveland WWTP to the Loveland Pipeline, because the CBT units are not reusable. These types of supply interactions are typical of dynamic simulation models.

Table 8-7 shows the contribution of Loveland's water sources to the additional yield of 600 AF/y from the 668 CBT units during 2000-2006. In the modeled critical year of 2005, there is no CBT carryover available, and the CBT yield from the 668 additional simulated units is limited to the annual quota of 468 AF which are used on a direct flow basis. An additional 132 AF are able to be delivered from other direct flow and exchange sources resulting in the 600 AF/y of firm yield attributed to the 668 CBT units. Any further increases in demand result in Green Ridge Glade Reservoir emptying earlier in 2005, thereby causing a water shortage. The reservoir remains above empty during other years of the study period, and there is excess direct flow yield that can't be exchanged to storage. This means that more than 600 AF of additional supply could be delivered in most other years.

8.8.3 Additional Windy Gap Units

The benefit to Loveland's firm annual yield from additional Windy Gap units varies depending on whether the WGFP is in place. Without the proposed Chimney Hollow

Reservoir of the WGFP, additional Windy Gap units would not add any firm yield to Loveland's water supply. While Loveland's current Windy Gap units add some firm yield to Loveland's system as a result of enhancing Loveland's carryover supply going into the critical drought period, the addition of more Windy Gap units would not increase the carryover supply as it is already maximized by Loveland's current supplies.

On the other hand, additional Windy Gap units with the WGFP in place would increase Loveland's firm yield depending on the level of WGFP participation. At the current proposed 9,587 AF level of participation, the benefit of the WGFP to Loveland's firm yield is limited by the amount of storage space (recall that at the 9,587 AF participation level, Loveland's Chimney Hollow Reservoir storage space fully refills prior to entering the critical drought and additional units could not be stored). At lower WGFP participation levels (e.g., less than 9,587 AF), the benefit of additional Windy Gap units to Loveland's firm yield is less. At a higher participation level, Loveland's Chimney Hollow Reservoir storage space does not fully refill prior to entering the critical drought. Therefore, by adding more Windy Gap units, the carryover storage in Chimney Hollow Reservoir leading into the drought can be enhanced which in turn increases the potential firm yield to Loveland. A summary of the incremental firm yield from 500 AF/y of average annual Windy Gap yield is shown in **Figure 8-12** without the WGFP, and with the WGFP at assumed participation levels of 9,547 and 12,000 AF.

8.8.4 Additional Upstream Storage

The benefit of increasing Loveland's upstream storage capacity was simulated using the Yield Model by increasing the capacity of Green Ridge Glade Reservoir from its current 6,785 AF capacity. Storage capacity was added in varying amounts up to an additional 30,000 AF. The additional storage could be at Green Ridge Glade Reservoir or at other potential sites in the general vicinity. The availability of potential storage sites was not evaluated as part of the yield study.

The estimated benefits of additional upstream storage capacity to Loveland's firm yield are shown in **Figure 8-16**. By adding 10,000 AF of storage capacity, Loveland's estimated firm yield would increase by approximately 1,930 AF/y. As storage capacity is added, the incremental benefit to Loveland's firm yield declines. It should be noted that results shown in **Figure 8-16** are relevant for the City's current water supply sources. As the City acquires additional sources, the benefit of increased storage may increase.

In addition to analyzing the effects of increased storage by itself, the benefit of adding storage in combination with the various irrigation company water sources was also evaluated. This analysis supplements the analysis of the irrigation company shares that is described in Section 8.8.1 above. In this supplemental analysis, estimates were made of how much additional storage, in combination with the 500 AF/y of average annual yield from the ditch company shares, would be necessary to produce 500 AF/y of additional firm yield to Loveland. The amount of required additional storage is shown by the dots above the bars in **Figure 8-10** (read on the right axis).

For comparison purposes, the amount of additional storage alone that would provide 500 AF/y of additional firm yield is shown by the blue line near the top of **Figure 8-10** (1,720 AF). For sources that add little firm yield by themselves to Loveland's water supply (e.g., George Rist (Buckingham) shares), it is necessary to add almost the full amount of storage that it would take when adding storage alone to increase the firm yield by 500 AF/y. For other sources with better dry year yields, the required amount of additional storage is less. Note that when adding storage in combination with the irrigation company shares, the additional storage helps not only to firm the particular additional shares that are being simulated, but also helps to firm all of Loveland's existing unfirmed supply.

8.8.5 Additional Downstream Storage

Adding additional downstream gravel pit storage to Loveland's water system would increase the City's firm yield by providing a place to store more reusable effluent and other reusable water sources when the exchange potential is limited for later exchange when the river conditions improve.

The benefit of increasing Loveland's downstream storage capacity was simulated using the Yield Model by increasing the capacity of the Great Western Reservoir from its current 1,300 AF capacity. Storage capacity was added in varying amounts up to an additional 1,000 AF and increasing the fill and release rates. The additional storage could be at the Great Western Reservoir or at other potential sites in the general vicinity. The availability of potential storage sites was not evaluated as part of the yield study.

The increases in Loveland's firm yield resulting from various amounts of additional downstream storage are shown in **Figure 8-17**. The results indicate that the City's firm yield could be increased by adding additional downstream storage and that the increase is dependent on the fill / release rates selected. The exchange potential during the critical period becomes the limitation on how much additional firm yield can be added to the Loveland supply.

8.9 Operational Changes

When making the model runs described in the preceding sections, it was observed that the firm yield results could change substantially depending on how the various existing water sources were used, even without additional amounts of ditch shares or storage. For example, if the City's domestic rights could be operated year-round with a domestic priority that is senior to irrigation priorities, the firm yield would increase to 32,350 AF (31,760 AF municipal plus 590 AF augmentation). In contrast, operating the CBT water supply in a different order relative to Green Ridge Glade Reservoir could reduce the firm yield by up to 8,050 AF. **Table 8-9** summarizes the results of various Yield Model runs simulating changes in the City's operations or the assumptions about the water sources. The "All Max" run incorporates all the operational changes that increase the firm yield into a single model run.

9.0 CONCLUSIONS AND RECOMMENDATIONS

The analysis of Loveland's raw water supply system described in this report indicates that the City's water supply should be adequate to withstand a 100-year drought during approximately the next two decades based on the two growth projections described in Section 4. Additional water supplies will be necessary to meet projected water demands in 2060 under both growth scenarios. However, the gap between the firm yield of the City’s water supplies and the projected demand varies depending on the growth rate considered. The conclusions from the updated yield study are summarized as follows:

1. Drought Frequency - Analysis of 447 years of historical streamflow records and reconstructed streamflows from NOAA tree-ring analyses indicates that the 2002 drought in the Big Thompson and upper Colorado River basins has an estimated average composite recurrence interval of approximately 90 years. The one-in-90-year average frequency of occurrence of the combined normalized Big Thompson River and Colorado River flow in 2002 is close to the one-in-100-year frequency associated with the City's water supply planning policy. The 2002 combined normalized annual flow of 0.42 (42% of average) is only slightly greater than the normalized flow of 0.41 (41% of average) that corresponds to the one-in-100-year frequency of occurrence. Given the accuracy of streamflow measurements and the drought analysis methodology, this average frequency of occurrence generally corresponds with the City's planning policy that requires the City's water supply be able to withstand a 100-year drought. Therefore, it is concluded that analyses showing that the City's water supply can withstand the 2002 drought conform reasonably well to the City's planning policy.
2. Yield Model - The Loveland Water Supply Yield Model was developed to assess the adequacy of the City's raw water supply and to assess the potential benefits to the City from acquisition of additional water sources and development of additional storage. The Yield Model simulates daily water supply and demand over a study period from 1951 - 2015 using historical records of streamflows, diversions and transmountain water supplies. Modeled water supply yields to the City are generally determined based on a pro-rata share of historical yields for the simulated ownership of irrigation company shares, CBT Project units, etc. The simulated municipal water use is limited by available physical flow, capacities of diversion facilities, available raw water storage capacity, estimated river exchange potential and other factors. The Yield Model is intended to be a tool that can be used to assist the City in its current and future water supply planning efforts.

3. Firm Yield of Current Loveland Supply Without the WGFP - The Yield Model was used to estimate the firm yield of Loveland's current water supply without the WGFP in place. The firm yield is defined as the maximum annual demand that can be dependably supplied through the 1951 - 2015 simulated study period without shortage. The estimated firm yield of Loveland's current water supply is approximately 25,160 AF/y (24,570 AF municipal and 590 AF augmentation). The City's firm yield was increased by about 880 AF/y through the acquisition of 404 CBT units, the Loveland Gard Right, and additional ditch shares since the 2011 Yield Study update.
4. Increased Yield with the Windy Gap Firming Project - Loveland is one of several area municipalities participating in a project to increase the reliability of the Windy Gap Project supply. The cornerstone of the WGFP will be construction of an East Slope reservoir, known as Chimney Hollow Reservoir, in which to store the variable Windy Gap yield so that it can be delivered more reliably when needed. Loveland is currently participating at a level of 9,587 AF of storage capacity, which would increase the total firm yield to 28,960 AF/y (28,370 AF/y municipal and 590 AF/y augmentation). Since the project has not been constructed, model runs were made to evaluate the increase in firm yield that will result from different levels of participation ranging from 6,000 AF to 20,000 AF of Chimney Hollow Reservoir space. The results of the model runs are shown in **Figure 8-4** and indicate that participation at a 12,000 AF storage level would increase Loveland's firm yield by approximately 670 AF/y over the firm yield at the current participation level. Loveland's firm yield could be increased further under the WGFP through acquisition of more Windy Gap units.
5. Increased Yield with the Windy Gap Firming Project and Great Western Reservoir - The Yield Model was used to estimate the firm yield of Loveland's current water supply with the WGFP and 1,300 AF of raw water storage in the Great Western Reservoir that was recently acquired by Loveland downstream of the Loveland WWTP near the Hillsborough Ditch headgate. Loveland plans to use the Great Western Reservoir to store fully consumable water not needed to meet return obligations as well a water diverted under a new conditional storage right. Once Great Western Reservoir after completion of improvements to the inlet and outlet facilities it will increase the total firm yield to 30,740 AF/y (30,150 AF/y municipal and 590 AF/y augmentation).
6. Reduction in Firm Yield from Increased Competing Senior Exchanges - The Yield Model is generally based on historical water supply operations on the Big Thompson River. It is likely that the historical river conditions will change with increased operation of municipal water exchanges, and this change may affect

the operation of Loveland's exchanges. The Cities of Greeley and Evans both operate exchanges that are mostly senior to Loveland's exchanges. The potential impact of increased Competing Exchanges was evaluated with the Yield Model and the results are shown in **Figure 8-6**. The results indicate that Competing Exchanges on the lower reach of the Big Thompson River, such as those by the Cities of Greeley and Evans, could reduce Loveland's firm yield by 3,740 AF/y from the Base Run based on an assumed exchange rate of 50 cfs and continuous operation of the exchange over the irrigation season. Exchanges at greater rates on the lower river, or more moderate Competing Exchanges on the middle reach of the river could have even greater impacts on Loveland's firm yield. The impact of increased Competing Exchanges would be less than shown on **Figure 8-6** if the exchanges were not operated continuously, leaving more opportunity for Loveland to operate its own exchange.

7. Reduction in Firm Yield from Decreased Agricultural CBT Project Deliveries - Another change in historical practices that may affect Loveland's exchanges is the ongoing reduction in the use of CBT Project water by agricultural users as the ownership of the CBT Project becomes increasingly municipal and industrial. Historical deliveries of CBT water to agricultural users have augmented the natural flow of the Big Thompson River and have enhanced the river exchange potential. The potential impact of further reductions in agricultural CBT Project deliveries and corresponding reductions to exchange potential was evaluated with the Yield Model. The results shown in **Figure 8-8** indicate that complete cessation of agricultural use of CBT water on the Big Thompson River and the resulting decreased exchange potential would reduce Loveland's firm yield by at least 2,460 AF/y from the Base Run. The actual impact from such a change is likely to be greater due to the coincident loss of irrigation return flows from use of CBT Project water. The effect of the reduced return flows was not evaluated.

8. Increased Firm Yield from Acquisition of Irrigation Company Shares - The Yield Model was used to evaluate the potential increase in Loveland's firm yield by the addition of shares of various Big Thompson River irrigation companies, including shares of selected companies in which Loveland has not previously transferred shares to municipal use. In order to facilitate comparison of the yields from shares in various companies, the increase in firm yield resulting from transfer of 500 AF/y of average annual historical yield in each company was evaluated. The results of the analysis, shown in **Table 8-5** and **Figure 8-10**, indicate that the estimated increase in Loveland's firm yield is typically much less than the average annual historical yield of these shares. The principal reasons for the low firm yield to average yield ratios are (a) the lower than average yields from most sources in dry years and (b) the necessity of the City providing year-around municipal water

deliveries with sources that only yield water during the irrigation season. In general, irrigation companies with senior water rights or significant storage provide more potential firm yield than those companies with more junior water rights and minimal storage. However, because Loveland could generally use storage releases only by exchange, the yield of ditch shares from companies that include storage could be affected by conditions that reduce exchange potential. The estimated yields for additional irrigation company shares acquired by the City are based solely on the modeling described herein and do not consider the uncertainty in the transferrable yield that is inherent in the process of changing irrigation water rights to municipal use.

9. <u>Increased Firm Yield from Acquisition of CBT Units</u> - Analyses of the potential benefit of additional transmountain water sources were made with the Yield Model. The results provided in **Table 8-5** and **Figure 8-12** show that acquisition of additional CBT units will substantially benefit Loveland's firm yield. The principal reasons for this are (a) CBT deliveries are generally available on demand, (b) additional yield comes essentially firmed with additional storage and (c) no exchange is necessary to utilize the supply. In addition, the source of CBT supply is from a different watershed that may not be affected by drought in the same degree or timing as the Big Thompson River basin supplies. This helps to diversify Loveland's water supply and provides additional drought reliability.

10. <u>Increased Yield from Windy Gap Units</u> - The benefit to Loveland of additional Windy Gap units depends on the extent of participation in the WGFP as shown in **Table 8-5** and **Figure 8-12**. Without the WGFP, additional Windy Gap units will add no firm yield to Loveland's water supply due to the absence of dry year yield from the project. However, additional Windy Gap units, in conjunction with participation in the WGFP, adds firm yield to Loveland's water supply depending on the level of participation. For example, at the current participation level of 9,587 AF, the increase in firm yield would be approximately 45 AF/y per additional Windy Gap unit, while participation at 12,000 AF of WGFP storage capacity would result in an increase in firm yield of 85 AF/y per unit. These results are pertinent to the next 500 AF/y of average annual Windy Gap yield added to the City's current number of Windy Gap units.

11. <u>Increased Firm Yield from Additional Storage Capacity</u> - The addition of more upstream water storage capacity would increase the City's firm yield based on results of the Yield Model runs shown in **Figure 8-16**. Additional storage capacity would allow the City to store more of its excess supplies during average and wet periods for use in dry years. If the City acquires more direct flow water sources, additional upstream storage could be more beneficial. As shown in **Figure 8-17**,

the City would also benefit from downstream storage in addition to the 1,300 AF in Great Western Reservoir, although the extent of this benefit depends on increasing the fill and release rates to take advantage of the exchange potential during critical periods.

12. Effect of Alternative Water Supply Operations - Even without acquisition of new water supplies or additional storage capacity, the firm yield of the City's water supplies can change with different modes of operation of its existing supplies and facilities. Some alternative operations are summarized in **Table 8-8**. Maximizing the yield of existing supplies may be an alternative to developing new supplies.

13. Water Supply Planning Recommendations - Based on the analyses of Loveland's raw water supply described herein, the following recommendations are offered regarding the City's water supply planning.

    a. The City should continue its policy of maintaining a water supply that can withstand a 100-year drought. Given that the 1951 - 2015 study period was found to generally comply with this policy, the City might consider refining the policy to specifically require planning to be based on a study period that includes the droughts of the 1970s and early 2000s. This would avoid the uncertainty that exists about how to define the 100-year drought.

    b. The reliability of the City's water supply will be enhanced by not depending on reduced water use as a planning strategy to withstand severe droughts. This would allow the City to keep the benefits of water use restrictions as a hedge against potential future droughts that are worse than the 100-year drought.

    c. The City should use the results described in this report and the Yield Model to develop and refine water acquisition strategies to meet its future water demands. These strategies may include alternative water supply operations, acquiring irrigation company shares, acquiring transmountain water supplies, development of additional storage, greater participation in the WGFP, development of non-potable water supply systems, and other measures.

    d. As the City acquires more water, the incremental firm yield from various water sources and the benefits of additional storage may change from the figures presented in this report as a result of the dynamic interrelationships among the City's water supply components. However, the Yield Model will continue to provide a basis to evaluate potential additions or changes to the City's water supply.

Figures

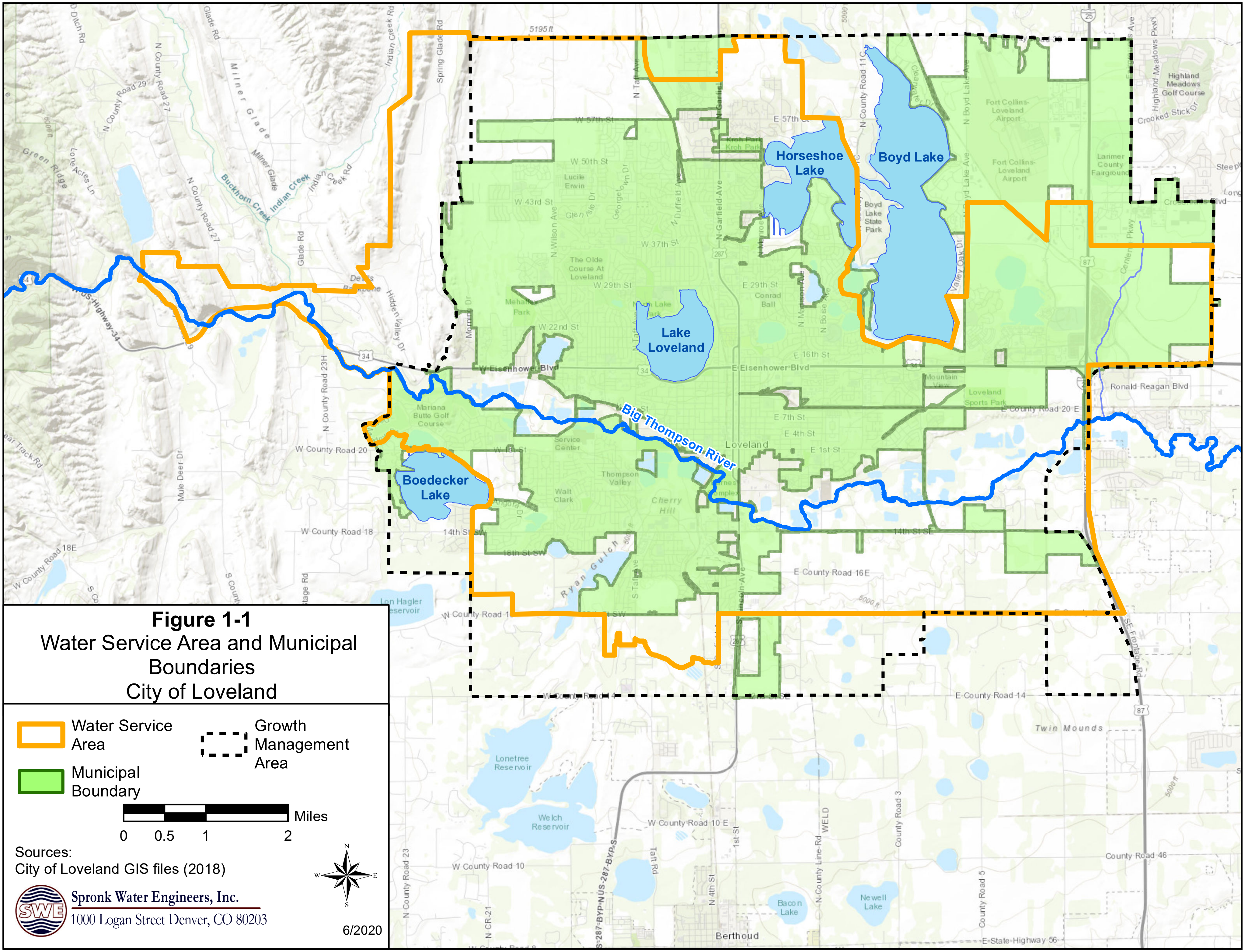
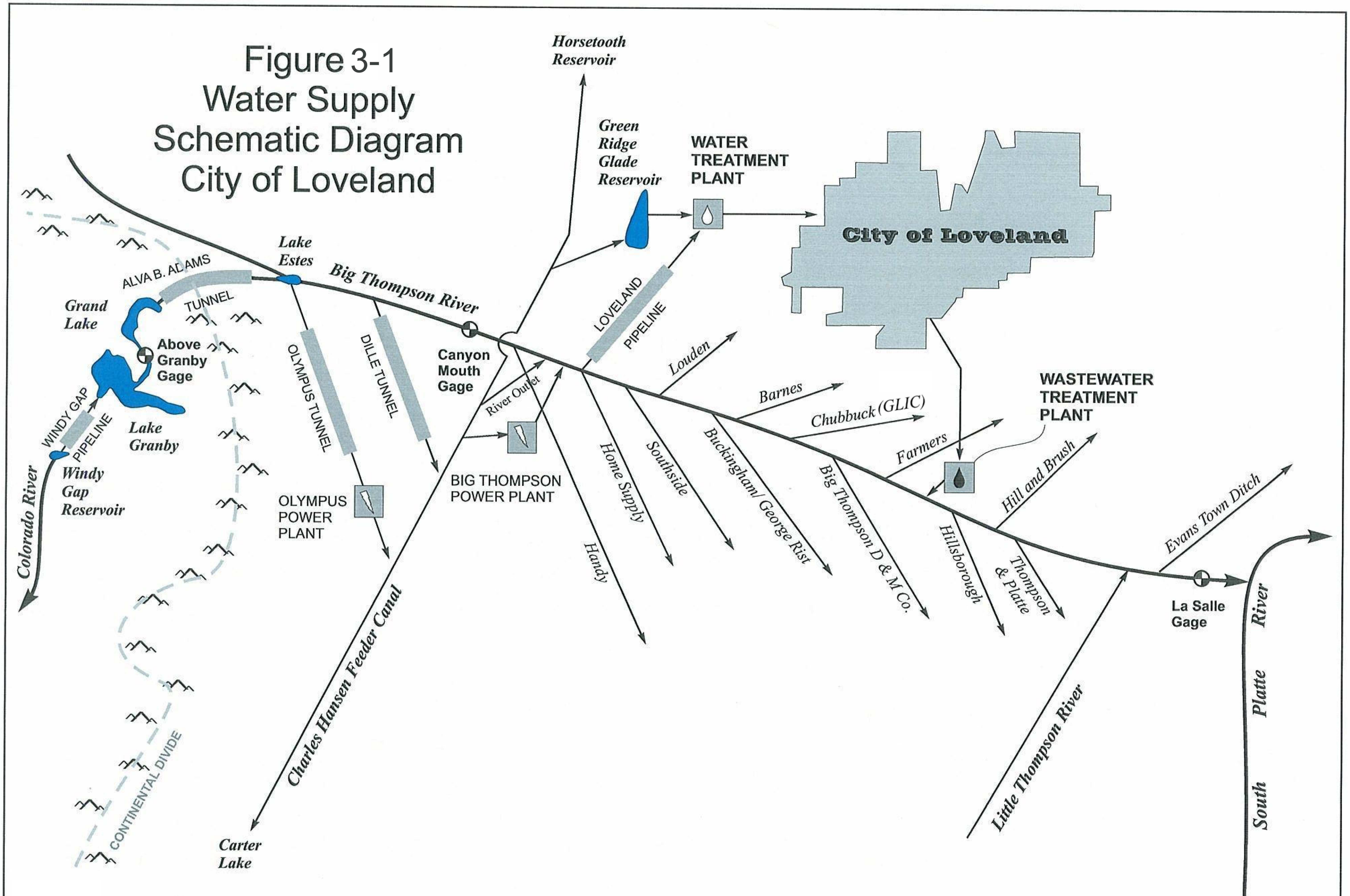


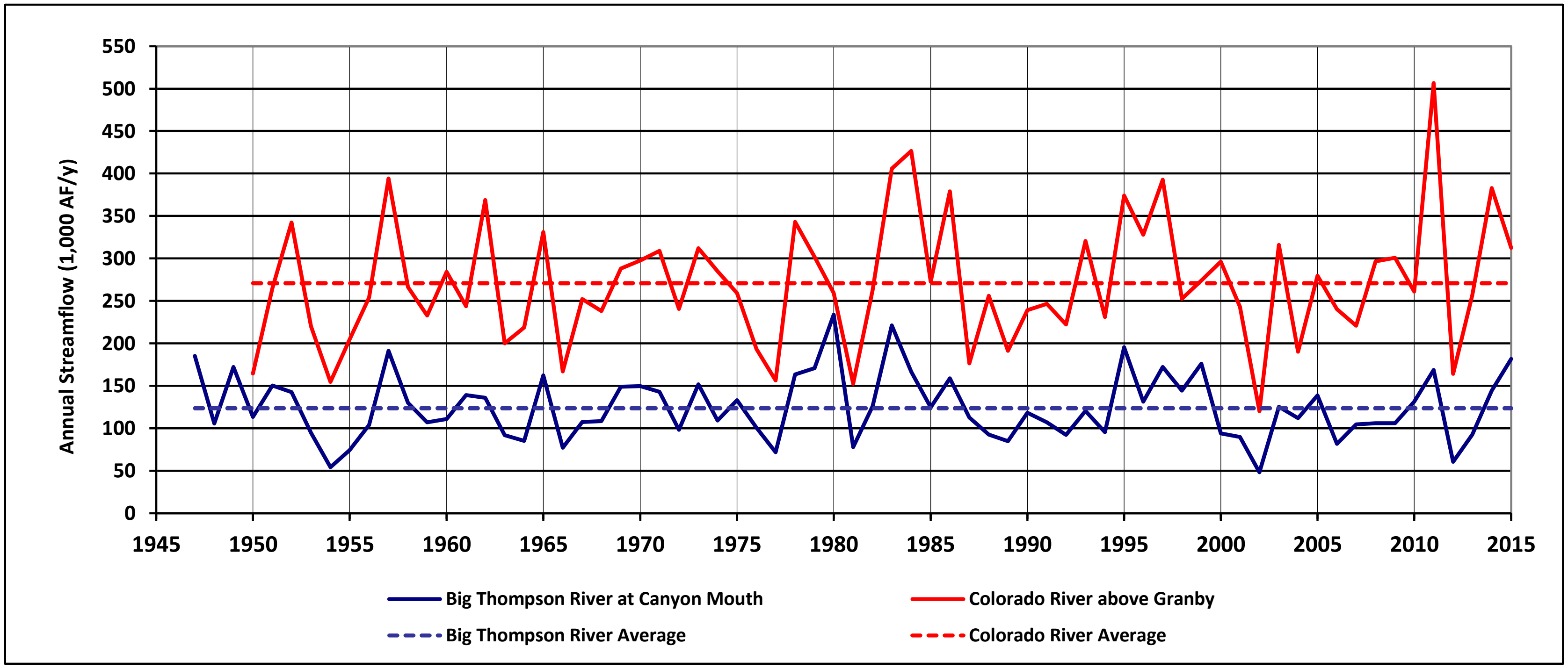
Figure 1-1
Water Service Area and Municipal Boundaries
City of Loveland
Water Service Area
Growth Management Area
Municipal Boundary
0
0.5
1
2
Miles
Sources:
City of Loveland GIS files (2018)
Spronk Water Engineers, Inc.
1000 Logan Street Denver, CO 80203
6/2020
Horseshoe Lake
Boyd Lake
Lake Loveland
Boedecker Lake
Big Thompson River
Loveland
Berthoud
E Eisenhower Blvd
W Eisenhower Blvd
Fort Collins-Loveland Airport
Larimer County Fairgrounds
Boyd Lake State Park
Lonetree Reservoir
Welch Reservoir
Twin Mounds
Ronald Reagan Blvd
Highland Meadows Golf Course
W County Road 20
W County Road 18
E County Road 16 E
E County Road 14
W County Road 10
W County Road 10 E
County Road 46
E State Highway 56



Spronk Water Engineers, Inc.

Figure 3-2

Historical Annual Virgin Streamflow [1]
Big Thompson River at Canyon Mouth and
Colorado River above Granby
1947 - 2015
(1,000 acre-feet per year)



Note:
[1] Historical "virgin"(undepleted) flow data provided by the NCWCD for the Big Thompson River at the Canyon Mouth (1947-2015) and the Colorado River above Granby (1950-2015).

Figure 3-3

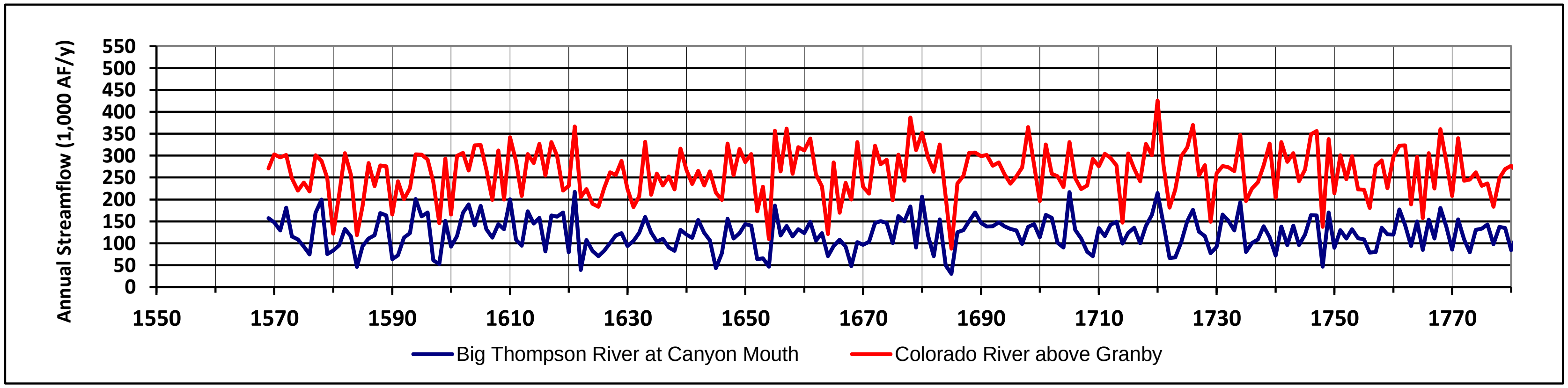
Historical and Reconstructed Annual Virgin Streamflow [(1)]

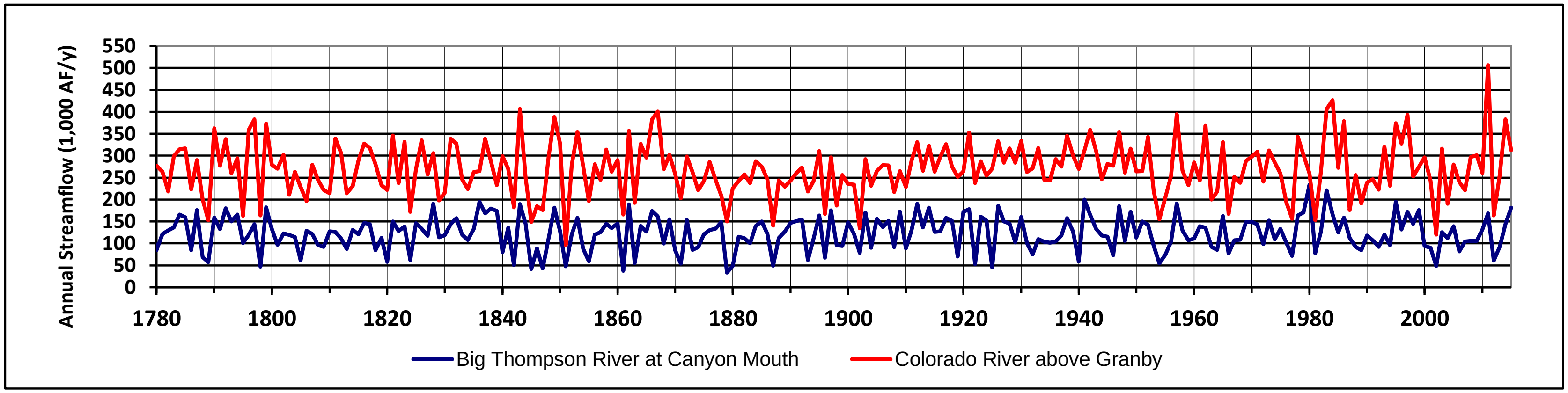
Big Thompson River at Canyon Mouth and

Colorado River above Granby

1569 - 2015

(1,000 acre-feet per year)





Notes:

(1) Historical "virgin" flow data provided by the NCWCD for the Big Thompson River at the Canyon Mouth (1947-2015) and the Colorado River above Granby (1950-2015). Reconstructed "virgin" flows obtained from the World Data Center for Paleoclimatology, Boulder and the NOAA Paleoclimatology Program for the period prior to the historical data.

Figure 3-4

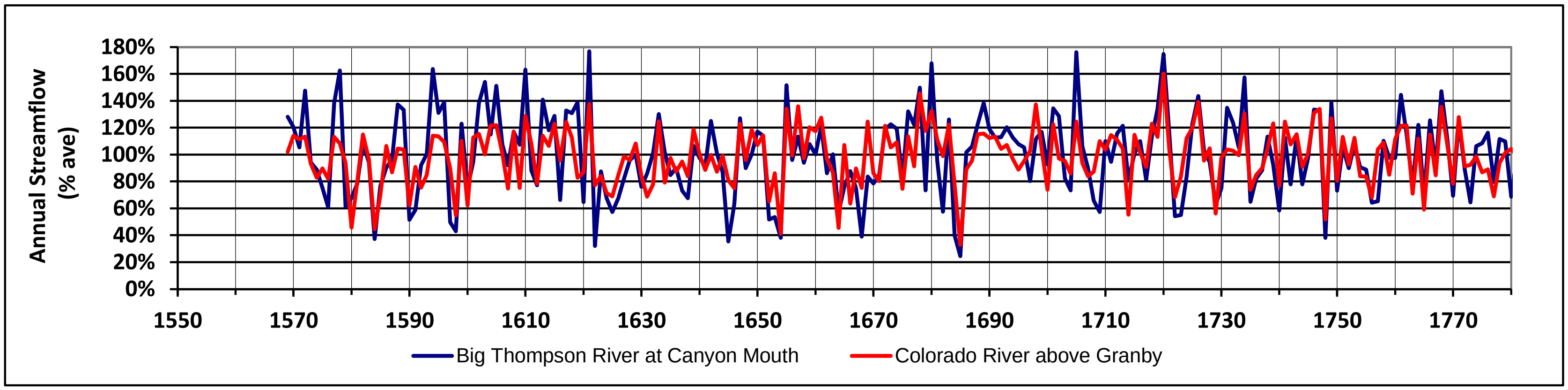
Normalized Historical and Reconstructed Annual Virgin Streamflow [1]

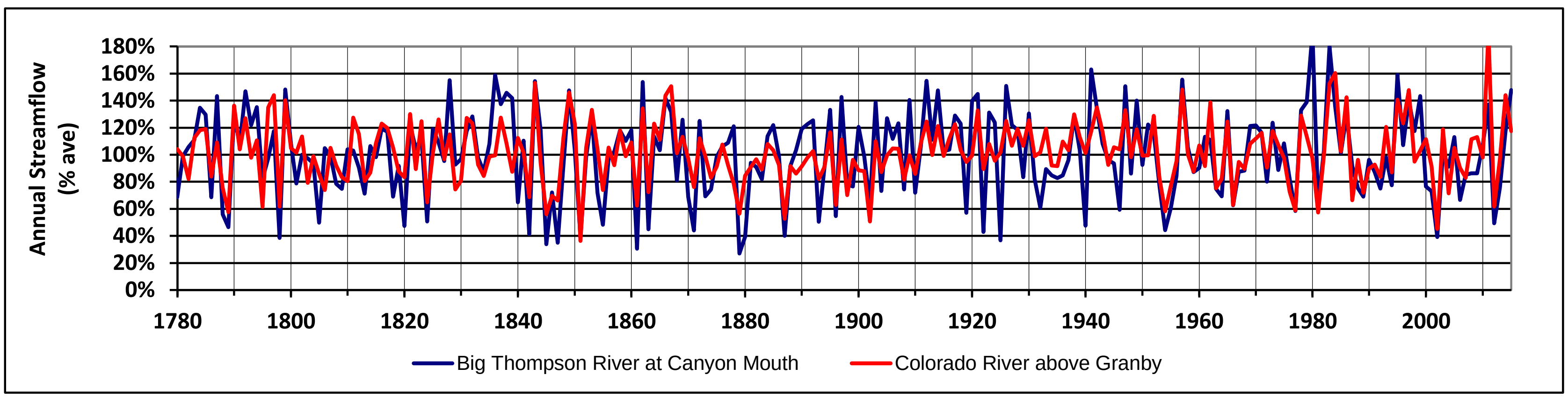
Big Thompson River at Canyon Mouth and

Colorado River above Granby

1569 - 2015

(% annual average flow)



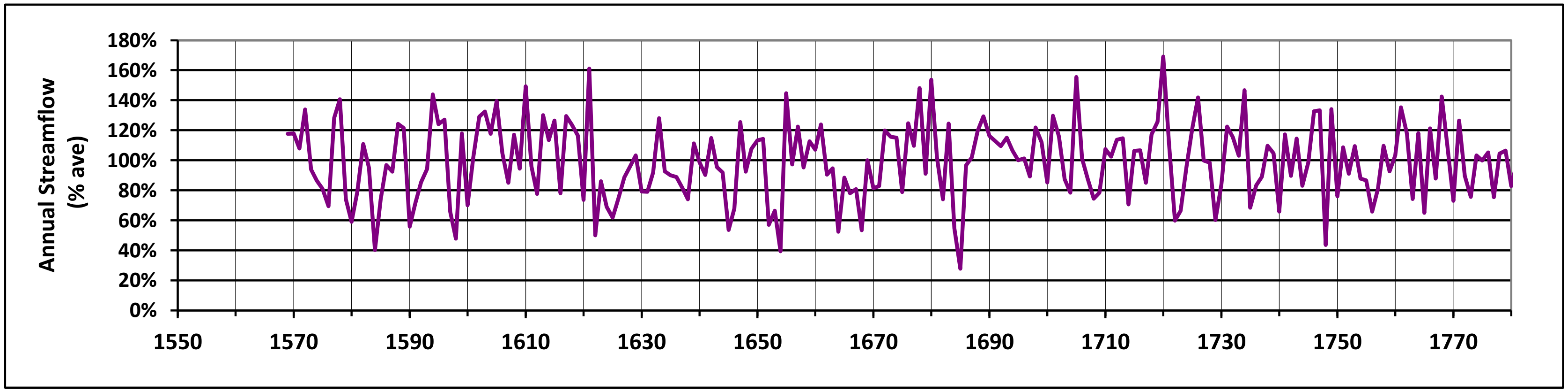


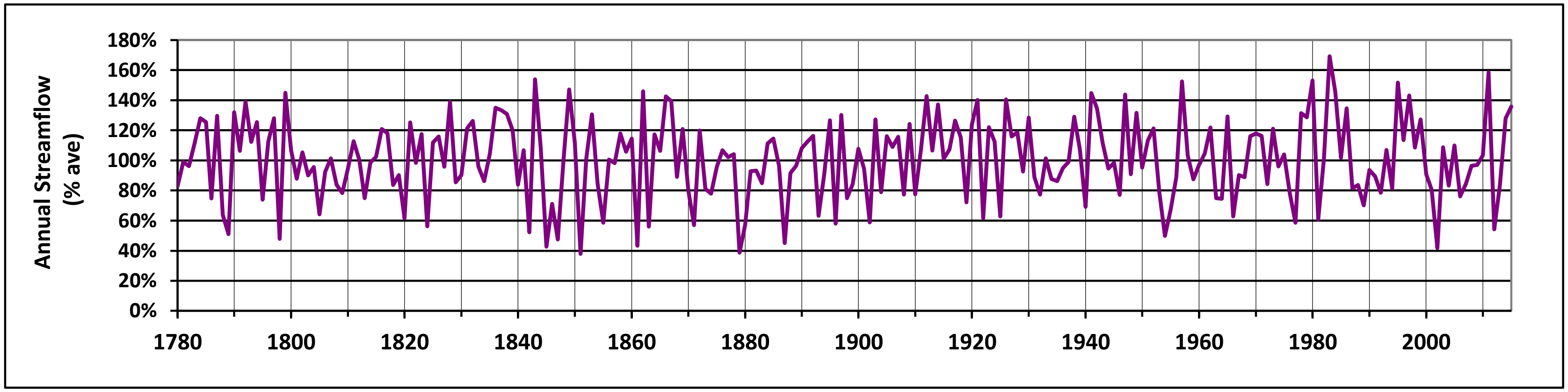
Notes:

[1] Normalized flows computed as annual flows divided by 1569 - 2015 average flow. Historical "virgin" flow data provided by the NCWCD for the Big Thompson River at the Canyon Mouth (1947-2015) and the Colorado River above Granby (1950-2015). Reconstructed "virgin" flows obtained from the World Data Center for Paleoclimatology, Boulder and the NOAA Paleoclimatology Program for the period prior to the historical data.

Figure 3-5

Normalized Historical and Reconstructed Annual Virgin Streamflow [1]
Composite of Big Thompson River and Colorado River [2]
1569 - 2015
(% annual average flow)





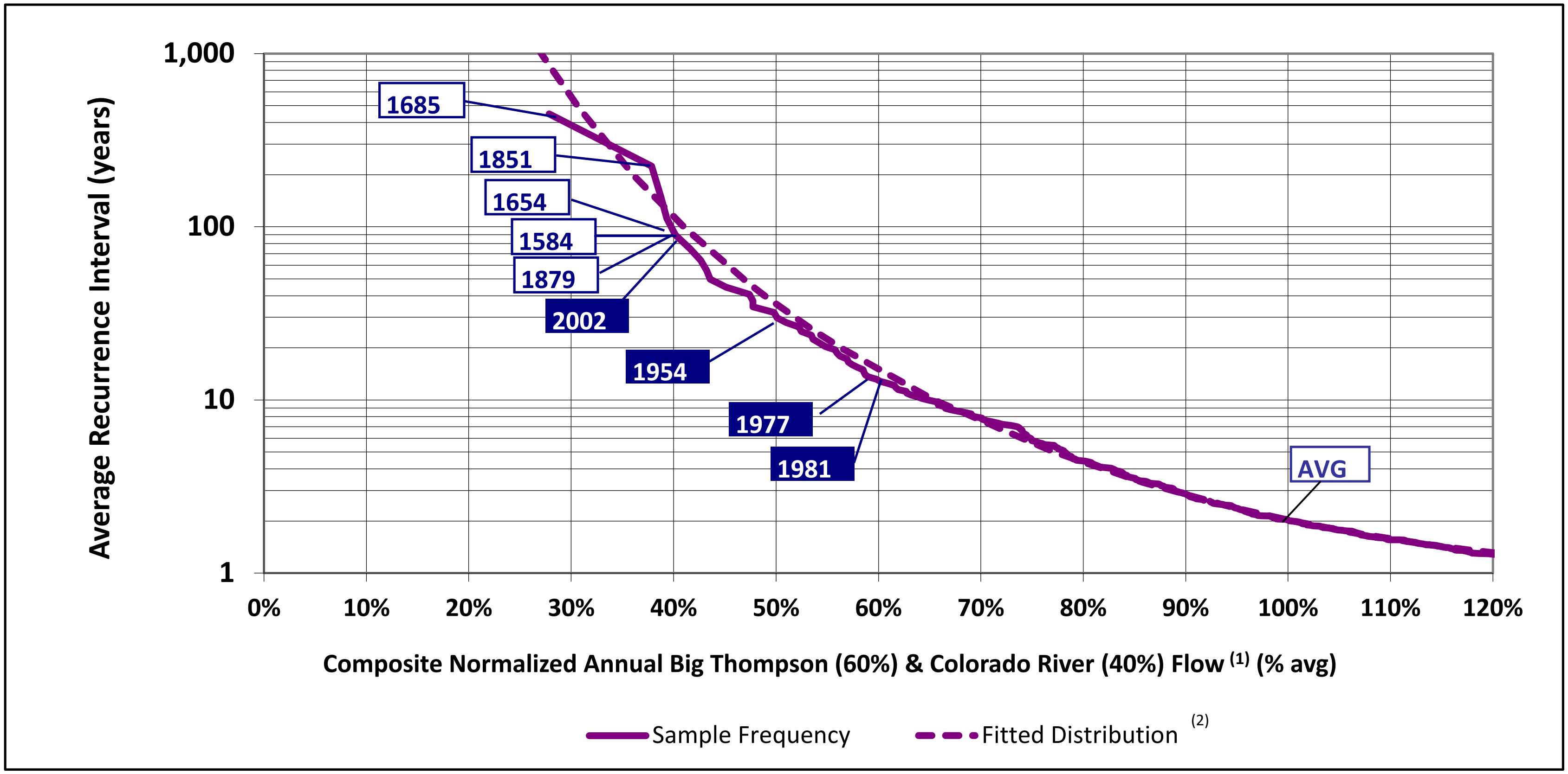
Notes:

[1] Normalized flows computed as annual flows divided by 1569 - 2015 average flow. Historical "virgin" flow data provided by the NCWCD for the Big Thompson River at the Canyon Mouth (1947-2015) and the Colorado River above Granby (1950-2015). Reconstructed "virgin" flows obtained from the World Data Center for Paleoclimatology, Boulder and the NOAA Paleoclimatology Program for the period prior to the historical data.

[2] Composite flows computed as 60% of the normalized Big Thompson River flow plus 40% of the Colorado River flow (approximate split of current Loveland water supply).

Figure 3-6

Frequency Distribution of Normalized Annual Virgin Flows
Composite of Big Thompson River at Canyon Mouth and Colorado River Flow above Granby [1]
from Historical and Reconstructed Data
(% annual average flow)



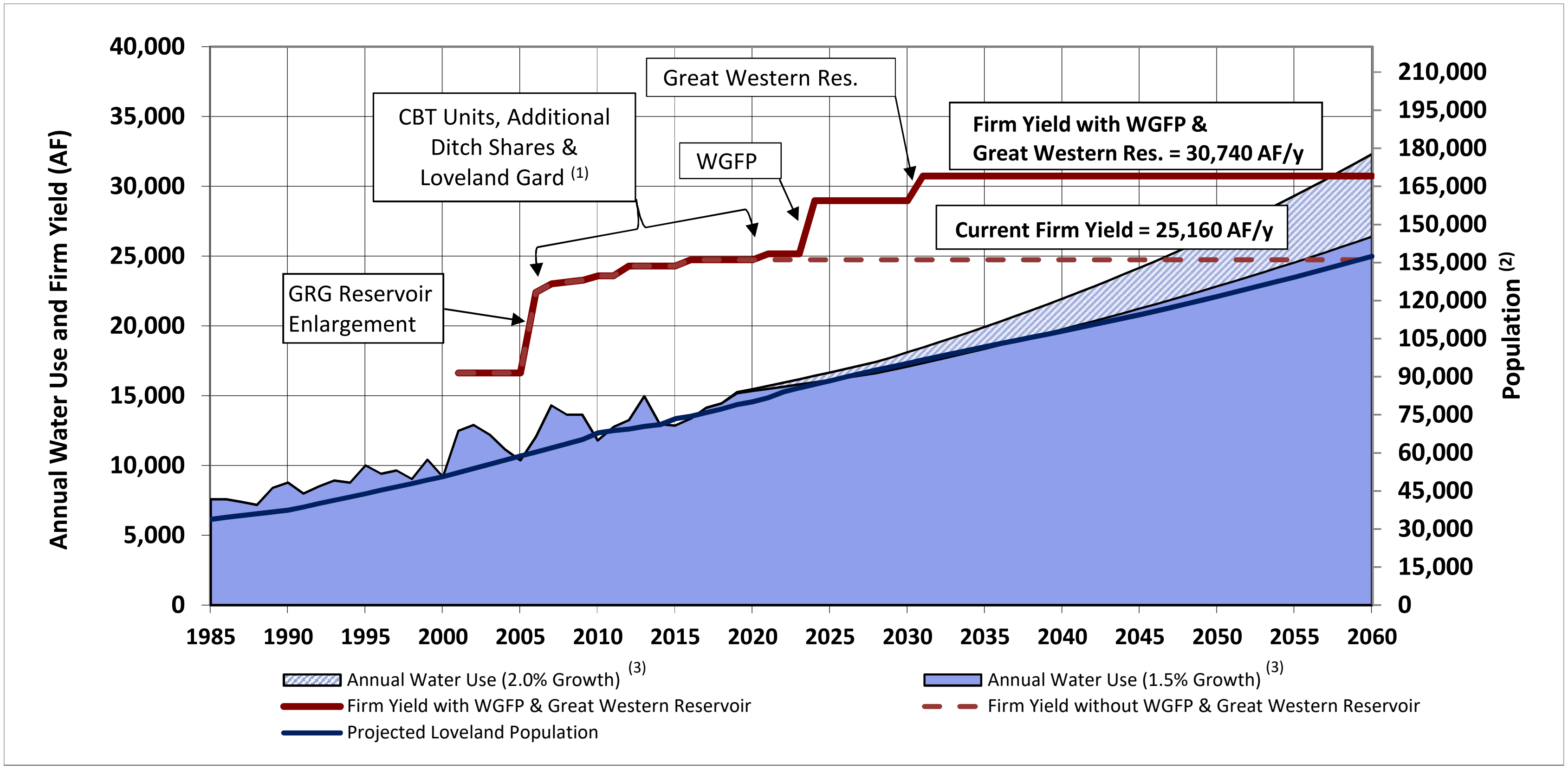
Notes:

[1] Annual streamflows were normalized by computing the annual flow as a percentage of average. The composite annual flow was computed as 60% of the Big Thompson normalized flow plus 40% of the Colorado River normalized flow based on the approximate long-term split of Loveland's current water supply.

[2] Log Pearson Type III Distribution fit to data.

Figure 4-1

Historical and Projected Water Demand
vs. Estimated Firm Water Supply Yield
City of Loveland
1987 - 2060
(acre-feet per year)



Notes:
[1] The Loveland Gard Right has not been implemented yet.
[2] Population values through 2045 from the City of Loveland Community and Strategic Planning Annual Data and Assumptions Report 2018. Population values from 2046 - 2060 were estimated using the average % increase (1.23%) from the last 15 years of data listed in the 2018 report.
[3] Actual water use through 2017 and projected by City staff using a two growth rates through 2060 with conservative conservation rate (0.5%) for 10 years and then a conservation rate of (0%). Projected use includes augmentation demand of 590 AF/y.

Figure 7-1

City of Loveland
Simulated Daily Water Demand Distribution 2005-2015

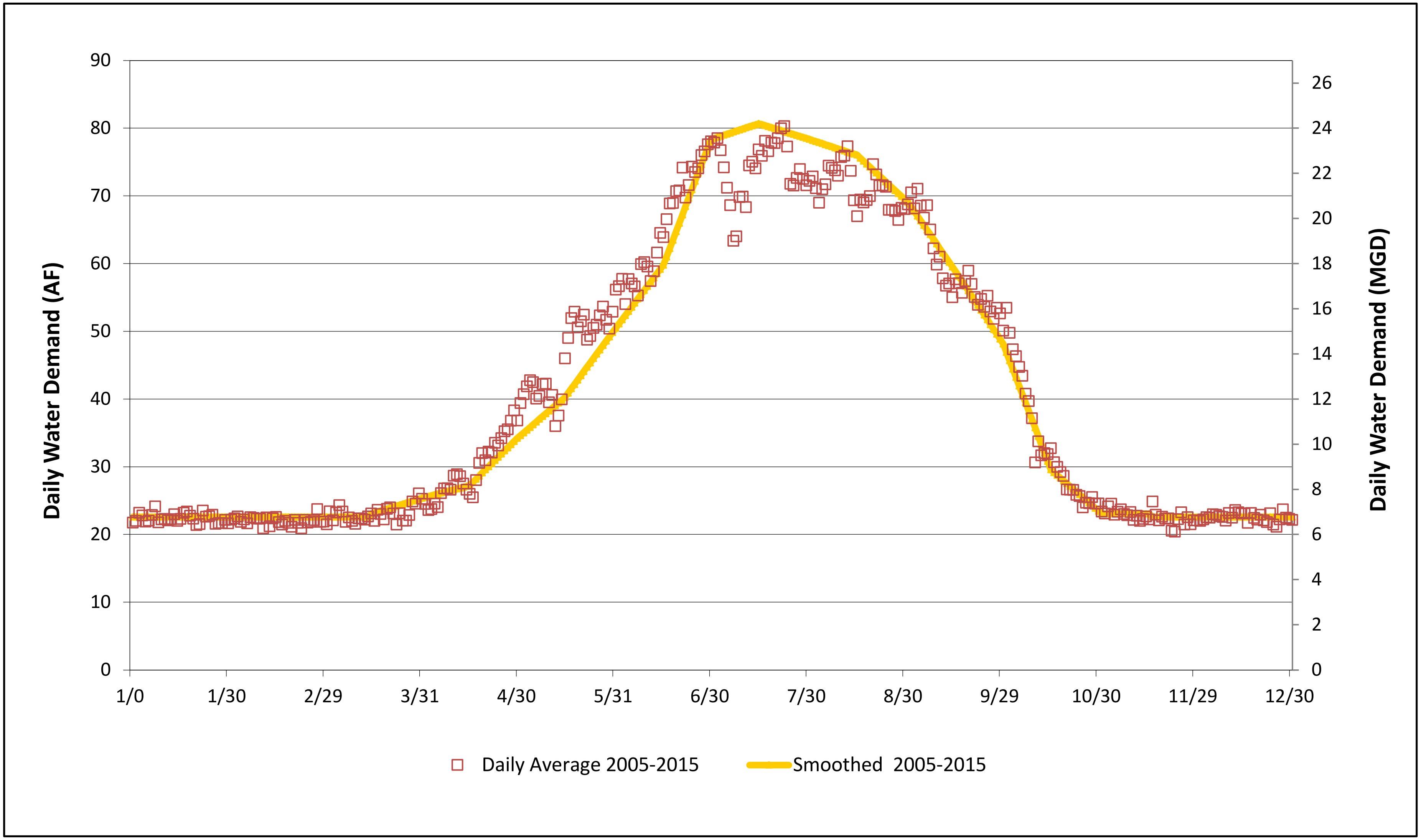
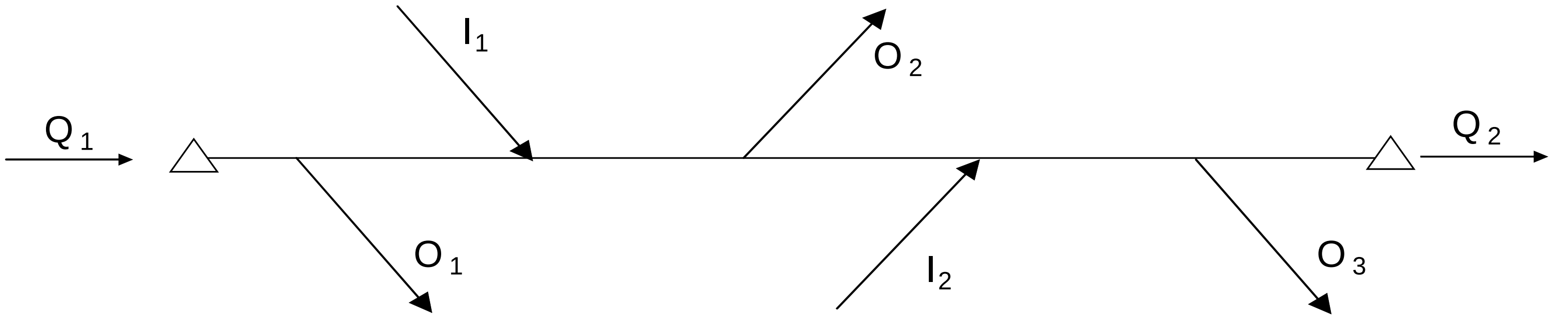


Figure 7-2

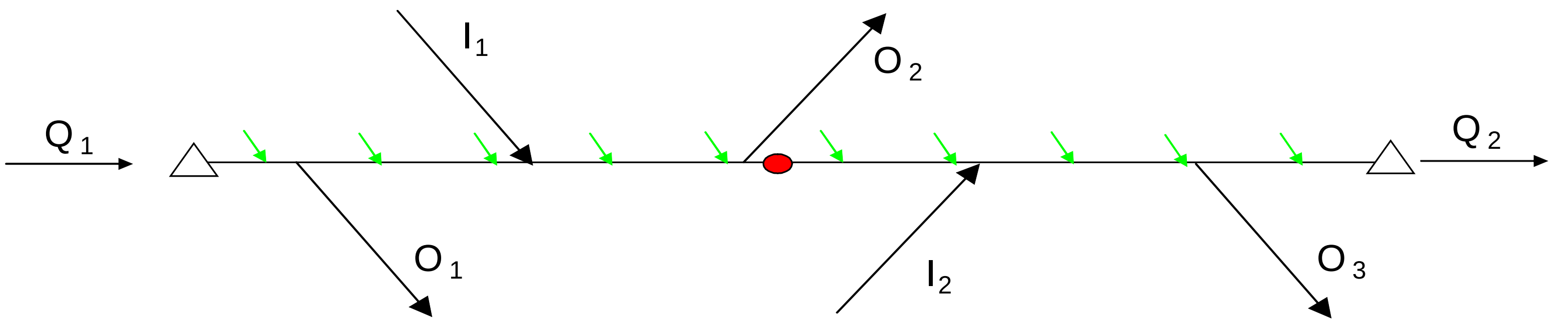
Point Flow Model Illustration

1. Compute Unmeasured Gain/Loss



Unmeasured Gain/Loss = $[\ Q_1 + I_1 + I_2 - O_1 - O_2 - O_3\ ] - Q_2$

2. Distribute Unmeasured Gain/Loss Along River Reach



3. Compute Flow at Any Point Along the River

Point Flow = Q_1 + Measured Inflows (I) - Measured Outflows (O) +/- Unmeasured Gains/Losses

e.g., Point Flow Below $O_2 = Q_1 - O_1 + I_1 - O_2$ + Unmeasured Gains between Q_1 and O_2

Figure 7-3

Point Flow Model Example
Point Flow Estimates for July 4, 2002
(cfs)

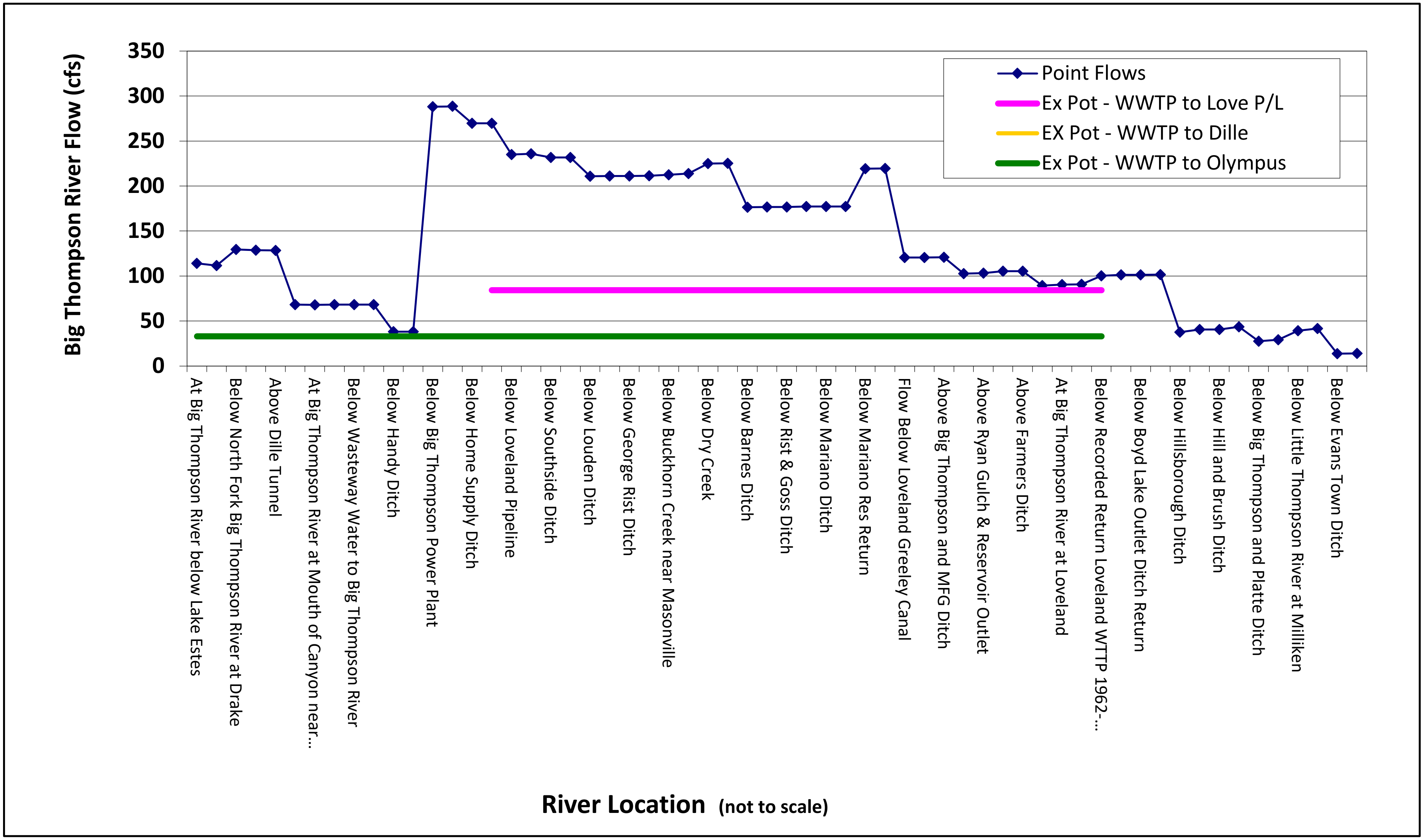
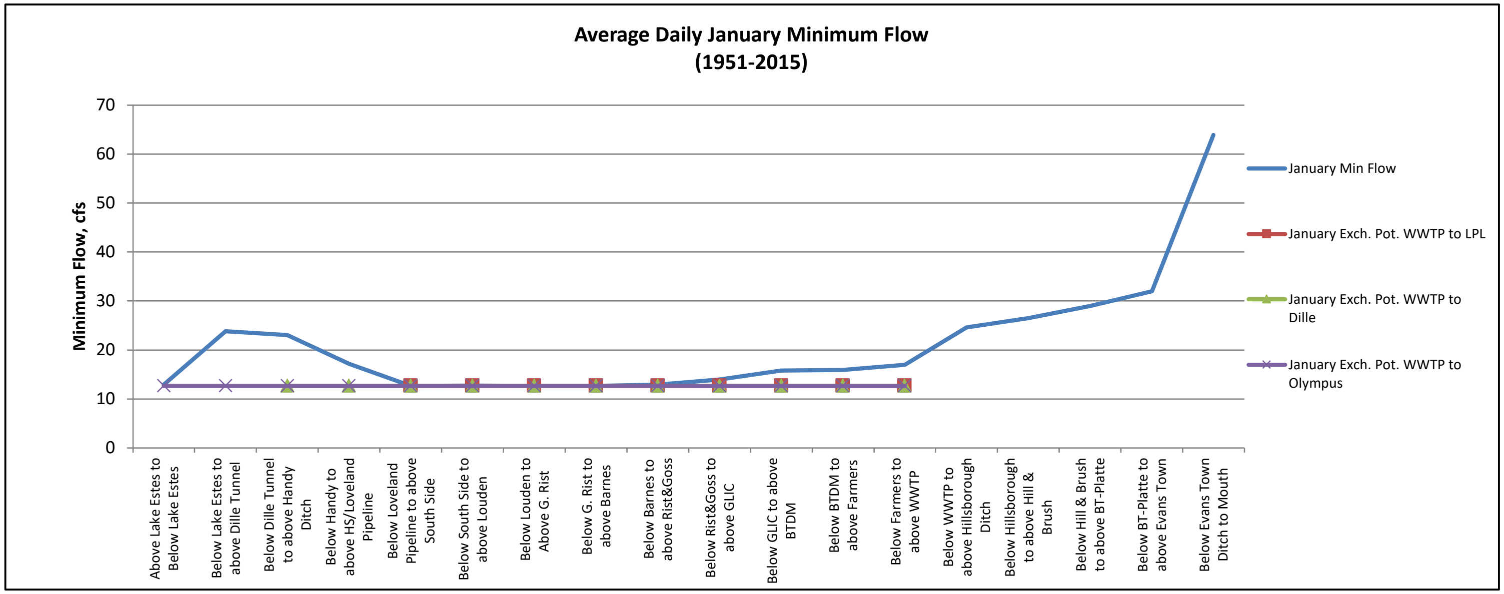


Figure 7-4

Average Daily Flows and Exchange Potential in Loveland Exchange Reaches - Big Thompson River



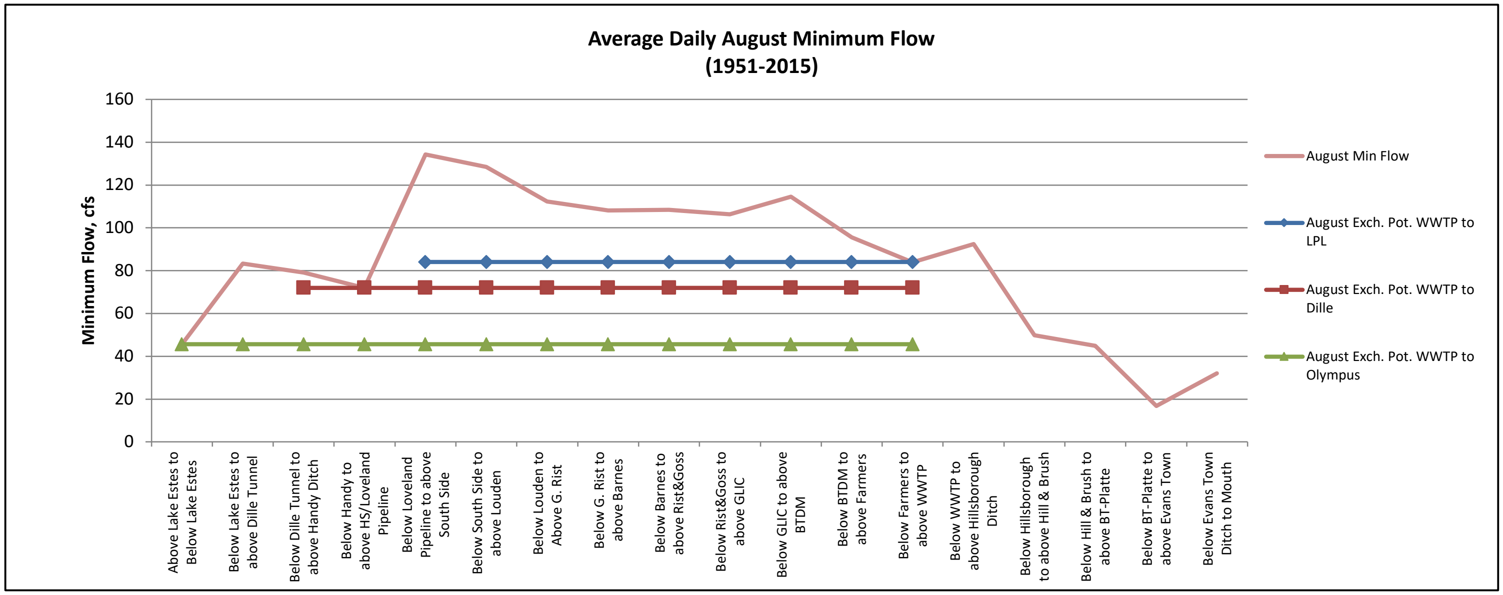


Figure 7-5

Loveland Water Supply Yield Model
Example Input Data Sheet 1

Sheet A1 - Main Input Page

Increase annual water demand (C16-C20) until a shortage occurs. The demand at which a shortage is impending is the firm yield

WATER SHORTAGE SUMMARY

	Shortage	GRG Min	Critical Yr	Shortage	Aug Short	Critical Yr	Shortage	Aug Short	Critical Yr	Shortage	Aug Short
51-15	0.0	19.8	1954	0	0	1987	0	0	2002	0	0
51-65	0.0	3292.8	1972	0	0	1988	0	0	2003	0	0
66-75	0.0	3279.4	1973	0	0	1989	0	0	2004	0	0
76-85	0.0	3289.4	1977	0	0	1990	0	0	2005	0	0
86-95	0.0	3302.3	1978	0	0	1991	0	0	2006	0	0
96-05	0.0	19.8	1979	0	0	1992	0	0	2012	0	0
06-15	0.0	1278.4	1981	0	0	1993	0	0	2013	0	0
All Demands Met?	OK		1982	0	0	1994	0	0	2014	0	0

	Muni	Aug	NP Irr	Ret Flow	
Average Annual Shortage (af)	0.0	0.0	0.0	0.0	OK
Maximum Annual Shortage (af)	0.0	0.0	0.0	0.0	OK
No. of Years of Shortage	0.0	0.0	0.0	0.0	OK

Titles For Summary Workbook

Run Description: **2019 BASE RUN, All Municipal and Augmentation Demands Met**

Summary Title: 0.00 shares added

User-Defined Inputs (Yellow Shading)

Gray-shaded boxes are not required inputs, but may be changed if necessary.

DEMANDS

OK

TOTAL DEMAND

Annual Municipal Demand, AF	30,150	
Annual Potable Leases to Others, AF	90	
Annual Non-Potable Irr Demand, AF		OK
Aug. Leases above WWTP, AF	50	OK
Aug. Leases below WWTP, AF	450	
Windy Gap Lease, AF	300	
Sum of Demands, AF	**30,740**	

Change Lease Distribution on Sheet D

IRRIGATION USE	
Municipal Irrigation Demand, % of Total Municipal Use	44%

RETURN FLOWS	
WWTP Returns,% of Indoor Use	95%

Notes:

Flow Condition:	Normal - Input 2020
Date Modified:	9/1/19

WATER SUPPLY

CBT Supply

Number of Units	12,190		**New Acquisitions**

Windy Gap Supply

Number of Units	40		**New Acquisitions**
WGFP Condition	2 Firmed	9,587	**WGFP Res. Participation, AF**
(set on Sheet A2)		1	Apply Re-introduction charge ? 1=yes

Ditch Shares

Ditch Name	Total Company Shares	202A Shares Owned	Calculated % Ownership	392 Case Shares Owned	Calculated % Ownership	No. of Shares Unchanged	Calculated % Ownership	Priority of Use	Include in analysis ? (1=Yes, 0 = No)
Barnes	1944.230	1306.750	67.2%	24.500	1.3%		0.0%	3	
Big T Ditch & Mfg.	20.792	2.583	12.4%	3.811	18.3%	5.26	25.3%	5	
Chubbuck	1590.400	596.579	37.5%	815.001	51.2%		0.0%	2	
Buckingham-George Rist	200.000	6.050	3.0%	89.250	44.6%	24.75	12.4%	1	
Louden	600.000	191.537	31.9%	61.547	10.3%	13.99	2.3%	6	
South Side	265.000	57.500	21.7%	23.000	8.7%	33.75	12.7%	4	
Rist & Goss	N/A	N/A	100.0%					12	
Loveland Gard Right						N/A	100.0%	13	
Farmers	30.000			-	0.0%		0.0%	11	0
GLIC	1636.000	-		-	0.0%		0.0%	7	0
Handy	900.000	-		-	0.0%		0.0%	9	0
Hillsborough	118.000	-		-	0.0%		0.0%	8	0
Home Supply	2001.000	-		-	0.0%	30.00	1.5%	10	0

* Loveland Gard Right is a portion of the Gard private right in the Home Supply Ditch.

RESERVOIR SOURCES

	Boyd L	Lake Loveland	Horseshoe	Rist Benson	Ryan Gulch	Mariana/Lon Hagler/ Lone Tree
	GLIC		7 Lakes	Louden?	Independent	Home Supply
Ownership% from Ditch Shares	0%				100%	1.5%
Include in analysis? 1=yes						0

CAPACITIES, ETC.

TOTAL UPSTREAM STORAGE

Green Ridge Glade Reservoir

Capacity, AF	6,785
Initial Contents, AF	4,500

New Storage, Upstream Location

(New Storage simulated with additional GRG capacity)

Capacity, AF	
Initial Contents, AF	
Total U/S Capacity, AF	6,785
Total Initial Contents, AF	4,500

DOWNSTREAM GRAVEL PIT STORAGE

Capacity, AF	1,300
Initial Contents, AF	
Fill Rate Limit, cfs	20
Release Rate Limit, cfs	20

New Storage, Downstream Location

(New Storage simulated with additional D/S Gravel Pit capacity)

Capacity, AF	
Initial Contents, AF	
Fill Rate Limit, cfs	
Release Rate Limit, cfs	
Total D/S Capacity, AF	1,300
Total Initial Contents, AF	-
Fill Rate Limit, cfs	20
Release Rate Limit, cfs	20

Evap and Area-Capacity, see Sheet C
Other Options, see Sheet A2

Figure 7-6

Loveland Water Supply Yield Model
Analysis Options Input Flags

Sheet A2 - User-Defined Input Options for Sources

Input Flag Options

Domestic and Municipal Rights	Selected	Other	0	1	2	3	4
Domestic Rights 1887 and 1901	1		0=OFF	1=Apr 1-Oct 31 in irrigation priority	2=All Year in irrigation priority	3=All Year, Domestic Priority Superior to Irrigation Rts	
6cfs early BTDM transfer	2		0=OFF	1=In Priority only on days when BTDM Diverts	2=Specified Irr Season in Priority		
6 cfs BTDM Start Date	4/24	Date					
6 cfs BTDM End Date	10/30	Date					

CBT	Selected	Other	0	1	2	3	4
CBT (Direct) Order of Use	1			1=Before GRG All Yr	2=After GRG All Yr	3=50/50 Winter with GRG	4=All Yr 50/50 with GRG
CBT Used after Windy Gap	0			0=NO	1=YES		

Windy Gap	Selected	Other	0	1	2	3	4
Windy Gap Simulated Yields Condition:	2			1=Unfirmed	2=Firmed	3=Test Data	
Windy Gap (Direct) Order of Use	1			1=Last after GRG	2=At LPL after CBT		
Windy Gap to GRG storage, when GRG <	50%	% full threshold to store WG in GRG					
Only after Month # (0= all year)	0	Month #					
Chimney Hollow contents below which no WG is sent to GRG storage	-	AF					

Free River	Selected	Other	0	1	2	3	4
Free River diverted into GRG?	1		0=NO	1=YES			
Only after Month # (0= all year)	0	Month #					
Free River diverted into Gravel Pit?	1		0=NO	1=YES			
Only after Month # (0= all year)	0	Month #					

Other Sources	Selected	Other	0	1	2	3	4
WTP Decant Water, % of WTP	2.5%	% of WTP					
Rist & Goss Order of Use	1			1=Before Other Ditches	2=After Other Ditches		
Loveland Gard Right Order of Use	2		0=Ignore, Not Diverted	1=Before Other Ditches, After Rist & Goss (direct)	2=After Other Ditches, After 392		
Exchange Potential Season (FLOWS page)	1			1=Irr Season Only	2=All Year		

LIRF Uses (See lagging Factors on Sheet C)	Selected	Other	0	1	2	3	4
Reusable LIRF used for Augmentation	0		0=NO	1=YES			
Reusable LIRF used for Return Obligations	0		0=NO	1=YES			
Reusable LIRF stored in Gravel Pit?	0		0=NO	1=YES			

Reservoirs-Other Inputs	Selected	Other	0	1	2	3	4
Replace Non-reusable in GRG when possible?	1		0=NO	1=YES			
Use Gravel Pit for non-potable irrigation in addition to other uses?	1		0=NO	1=YES			

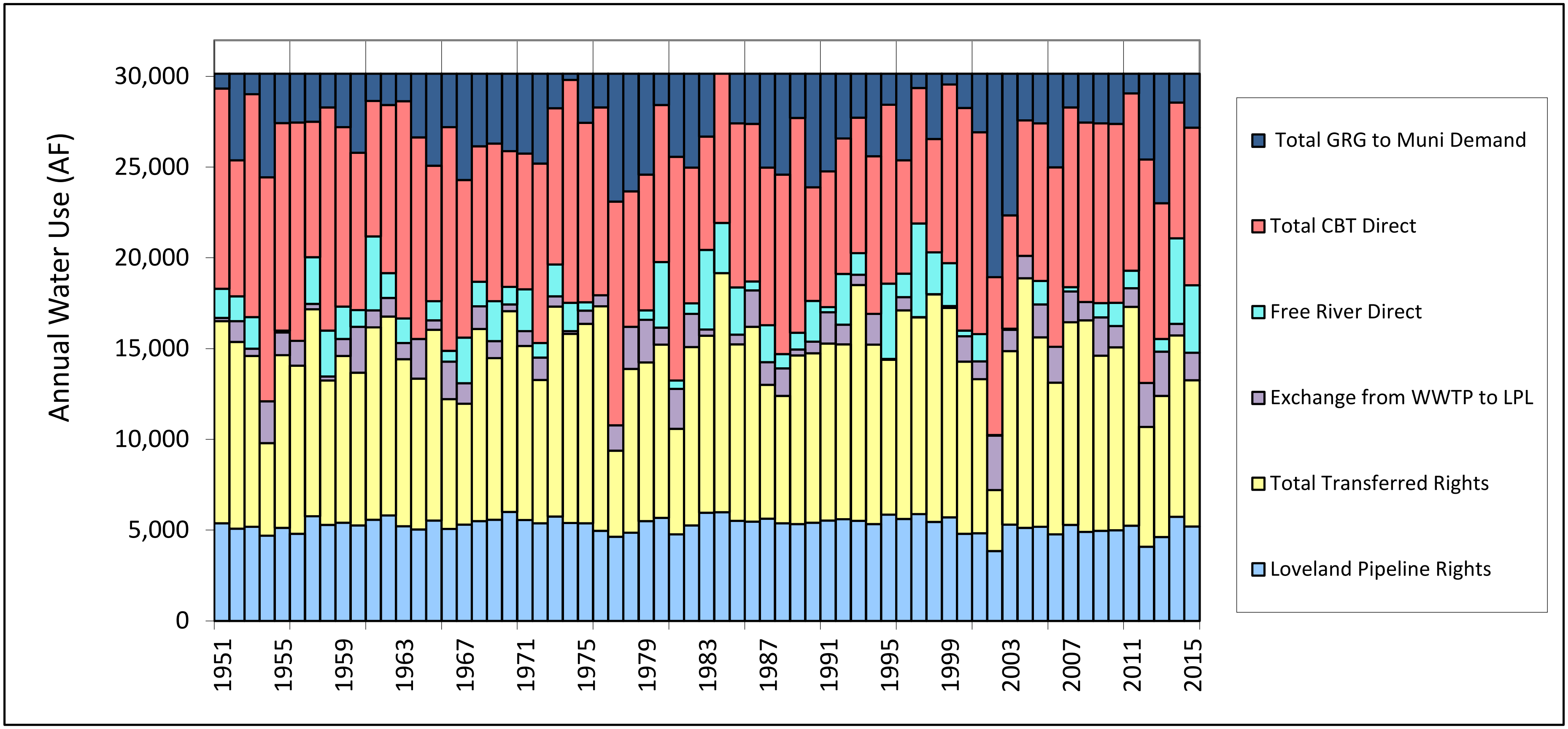
Augmentation Leases	Selected
Meet Every Day (0), Not during Free River (1)	0

Exchange Potential Lagging	Selected	Other	0	1	2	3	4
Lag Exchange Potential Due to Potential Administrative Approval Delay?	0		0=Same Day	1=Delay 1 Day	2=Delay 2 Days	3=Delay 3 Days	

Supply Reductions	Selected	Other	0	1	2	3	4
Reduce East Slope Supplies	15%	% Reduction					
	0		0 = no reduction	1 = East Slope Reduction		Note: Reduced East Slope Supplies does not include a reduction to Non-Base Run reservoir sources.	
Reduce West Slope Supplies	15%	% Reduction					
	0		0 = no reduction	1 = Windy Gap Reduction Only	2 = Both Windy Gap & CBT Reductions		

Figure 8-1

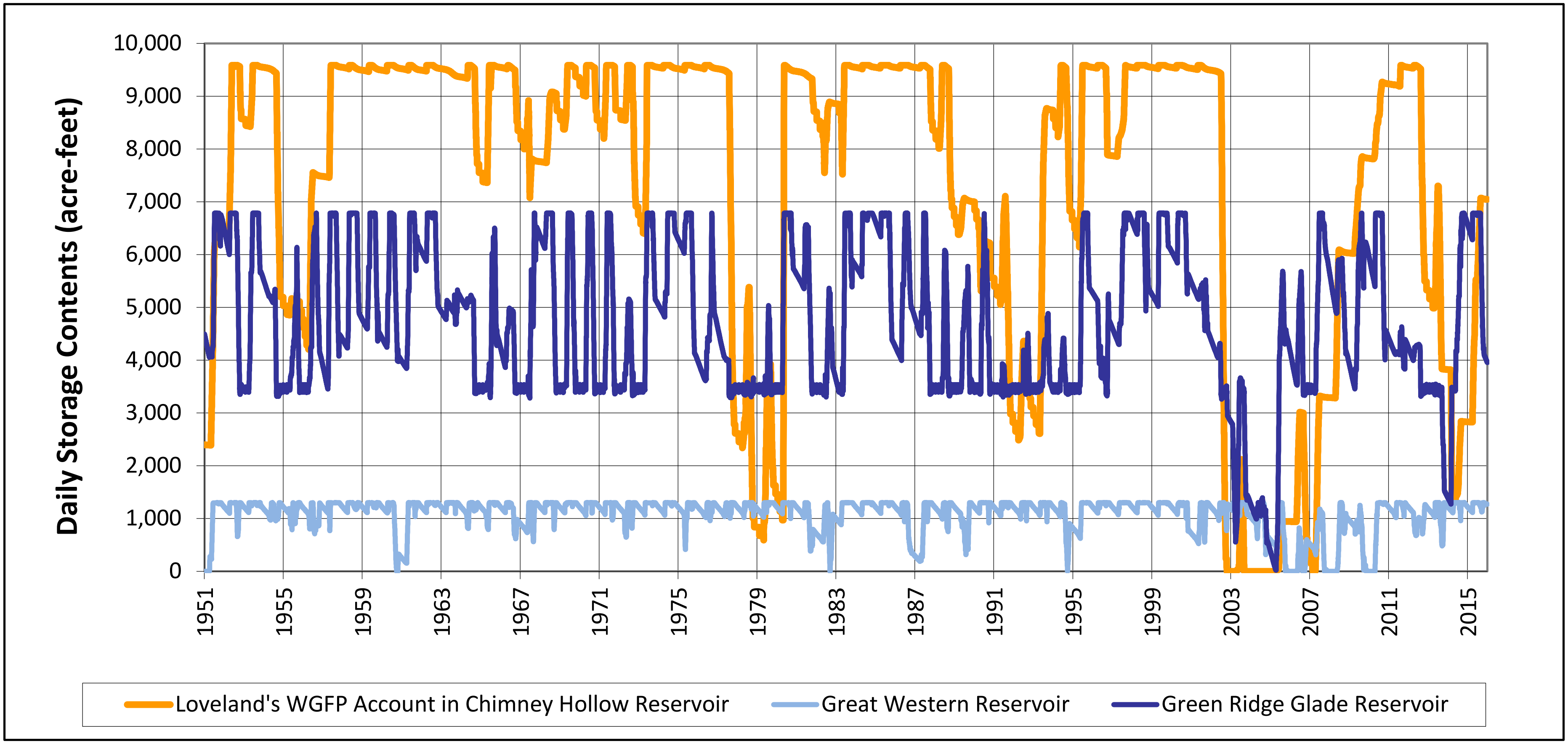
Annual Municipal Firm Yield Summary
City of Loveland
Municipal Firm Yield = 30,150 AF (Base Run)



2019 BASE RUN, All Municipal and Augmentation Demands Met

Figure 8-2

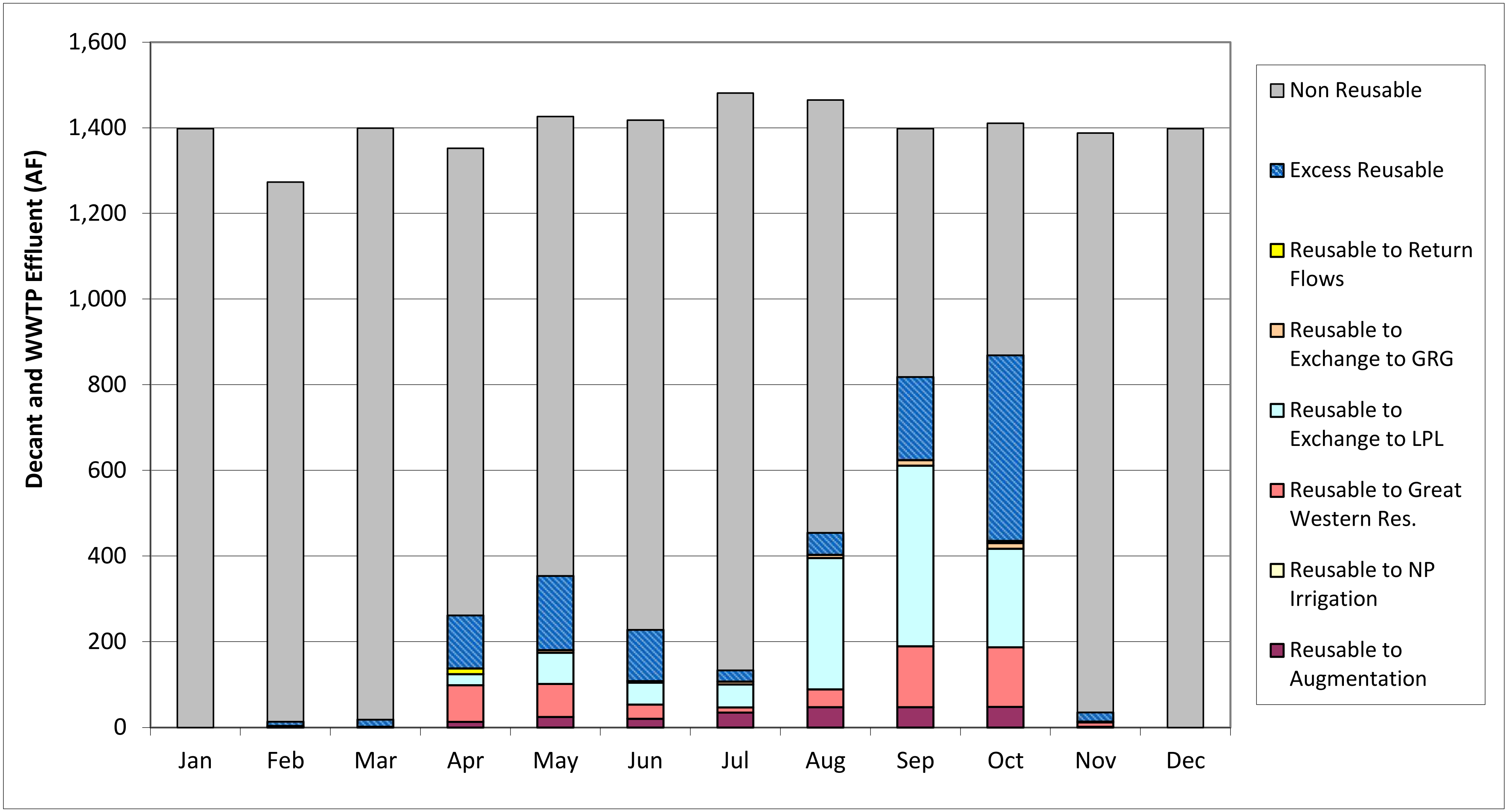
Daily Simulated Reservoir Contents
Green Ridge Glade Reservoir, Chimney Hollow Reservoir, and Great Western Reservoir
City of Loveland



2019 BASE RUN, All Municipal and Augmentation Demands Met

Figure 8-3

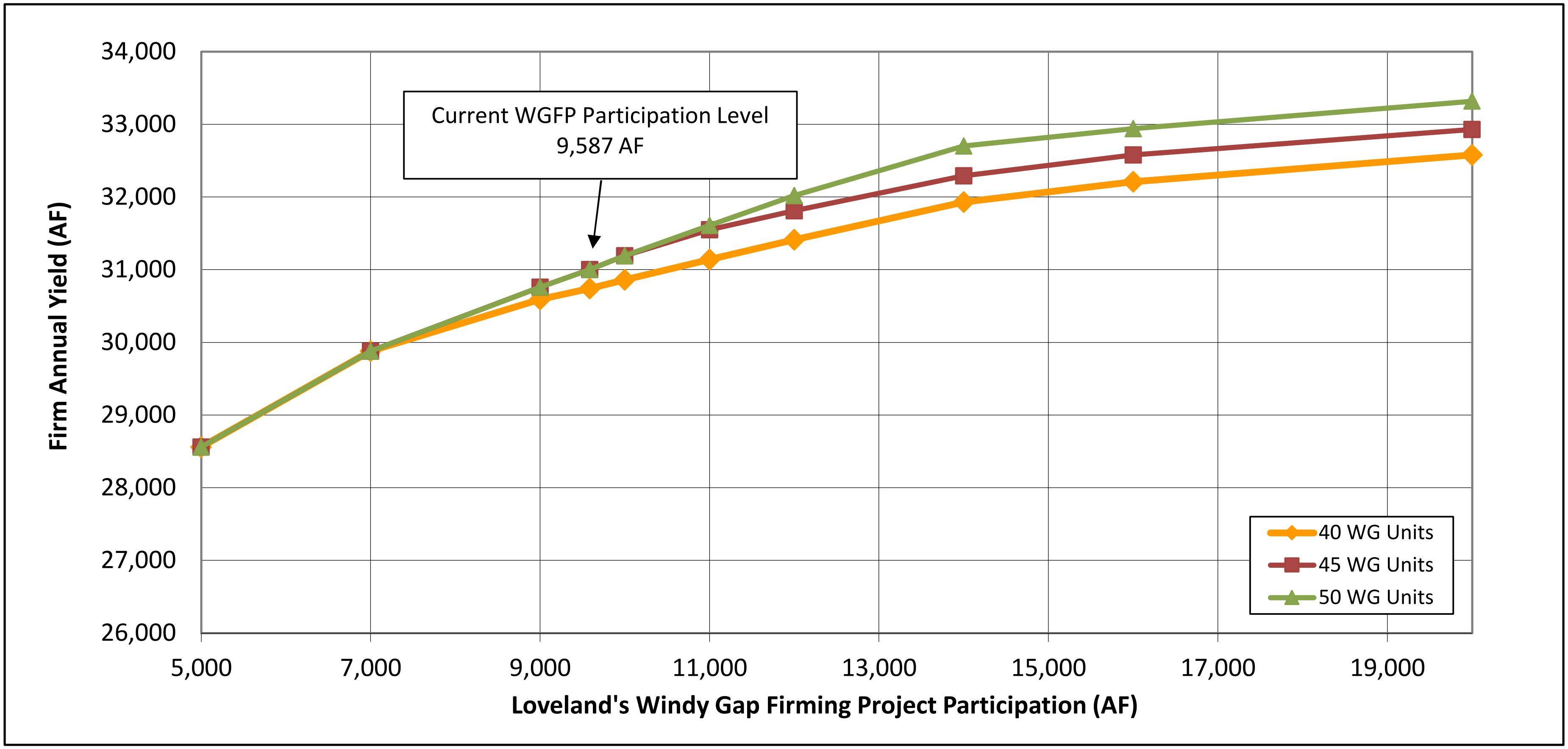
Simulated Average Monthly Production and Use of WWTP Effluent and Decant Pond Discharge
Firm Annual Yield = 30,150 + 590 = 30,740 AF (Base Run)



2019 BASE RUN, All Municipal and Augmentation Demands Met

Figure 8-4

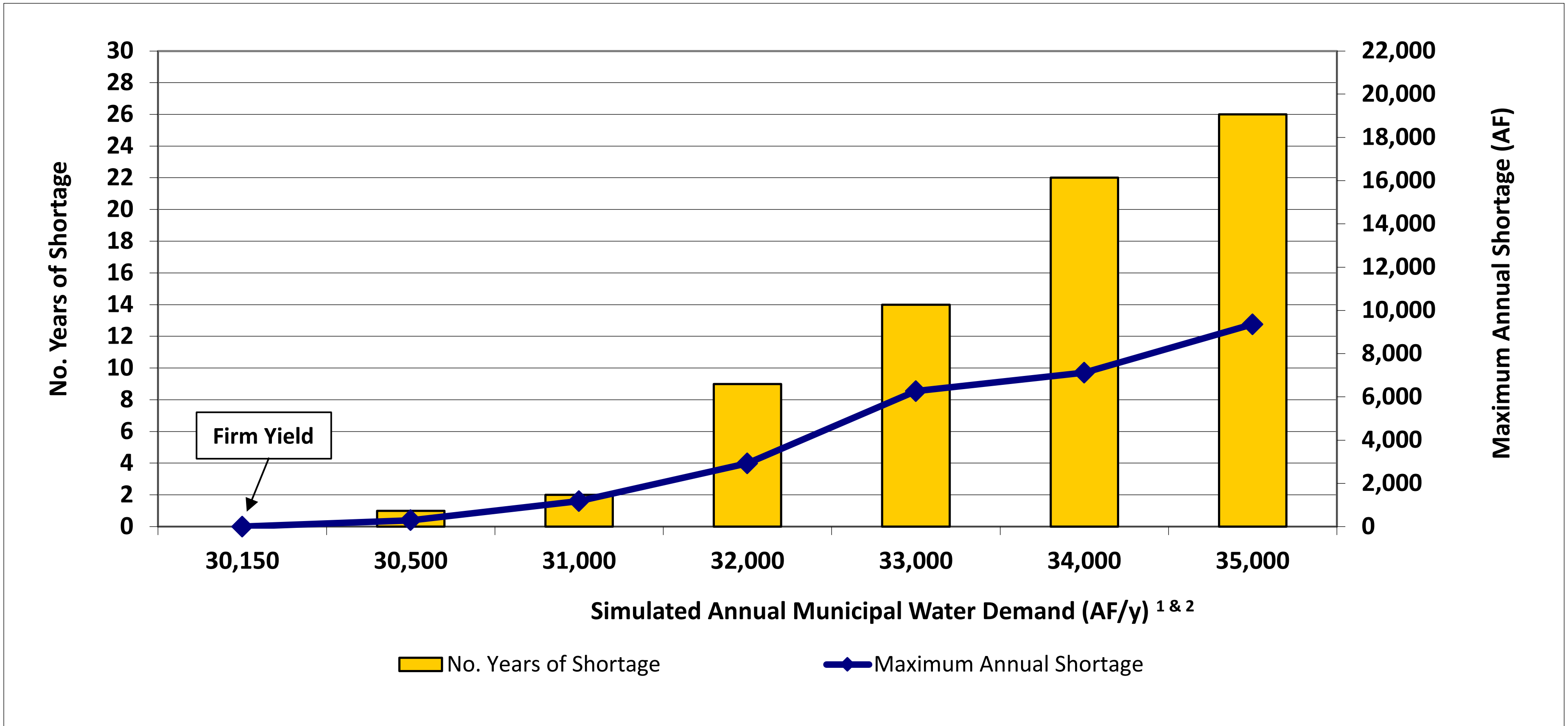
Firm Yield vs. Windy Gap Firming Project Participation and Windy Gap Units
City of Loveland



Note:
Loveland owns 40 Windy Gap Units and is currently participating in the Windy Gap Firming Project in the amount of 9,587 acre-feet of storage.

Figure 8-5

Simulated Water Shortages at Demands Greater than Firm Yield
City of Loveland



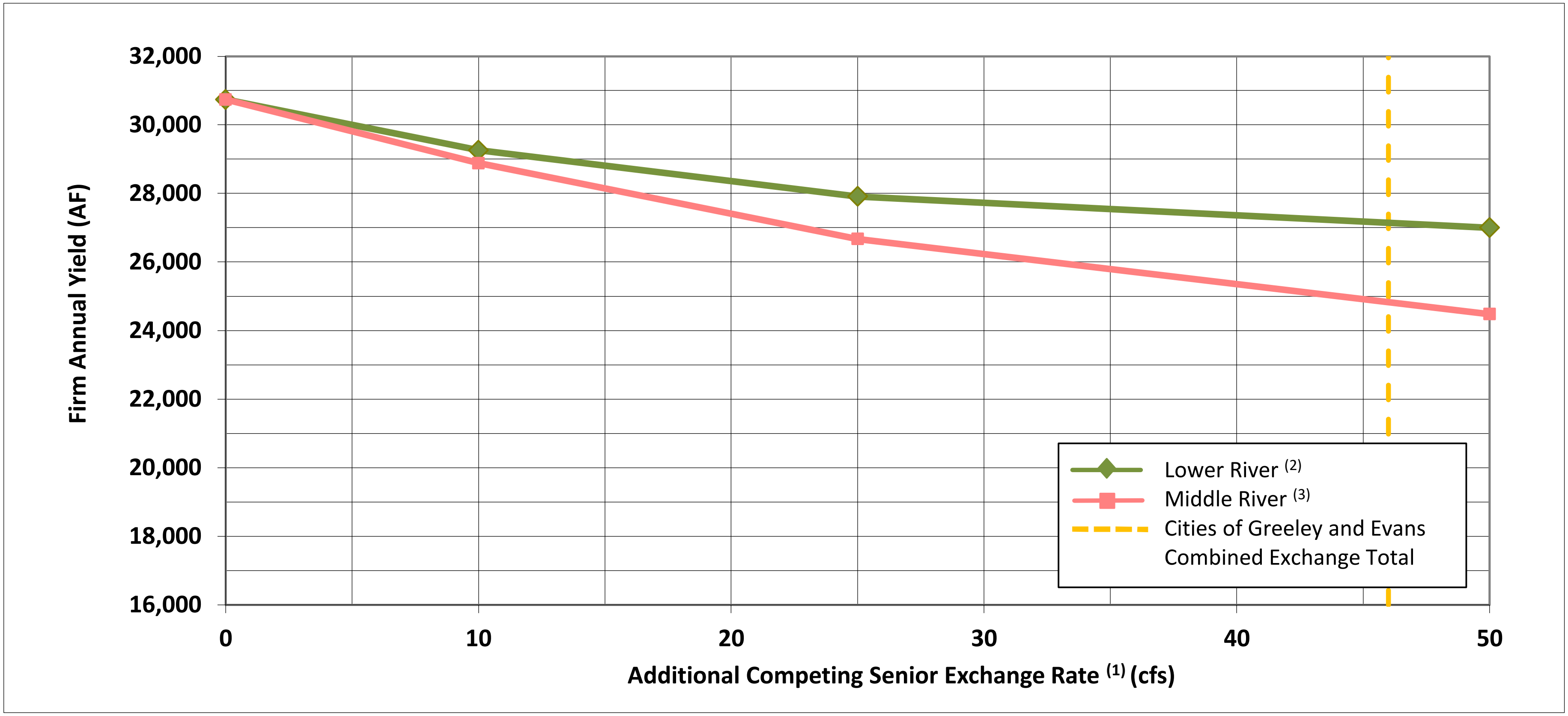
Notes:

(1) Bars read on left axis and line read on right axis.

(2) The simulated municipal firm yield is based on the 1951- 2015 study period. The total firm yield includes 590 AF of augmentation demand in addition to the municipal demand.

Figure 8-6

Effect of Increased Competing Senior Big Thompson River Exchanges on Firm Annual Yield City of Loveland



Notes:

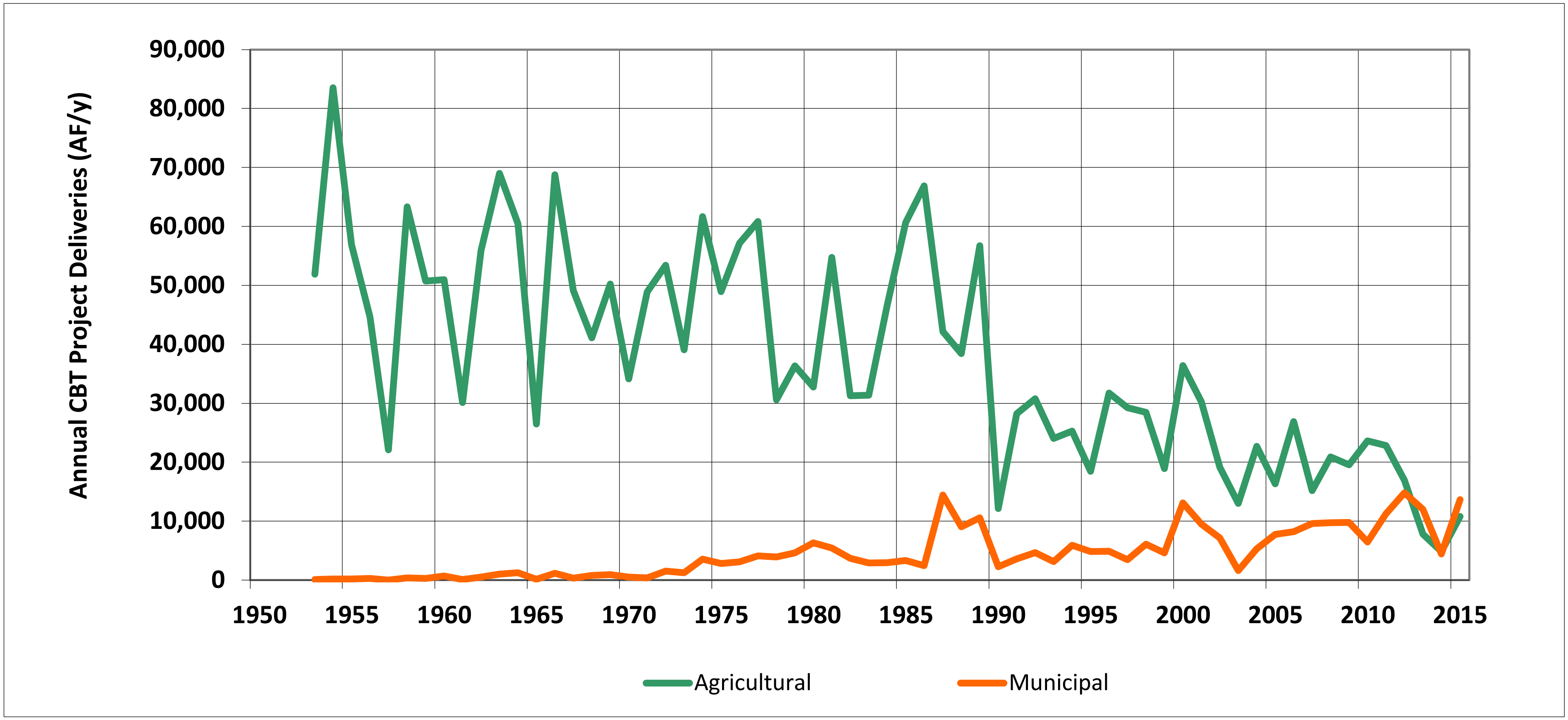
[1] Effect of historically operated exchanges (largely agricultural) are included in the baseline firm yield estimate (i.e., with additional senior exchanges = 0).

[2] Competing exchanges from other entities in the reach from the confluence with the South Platte River to Barnes Ditch headgate. The Cities of Greeley and Evans have decreed exchanges in the Lower River reach at the rates of 30 cfs and 16 cfs, respectively.

[3] Competing exchanges from other entities in the reach from above the Hillsborough Ditch to the Loveland Pipeline.

Figure 8-7

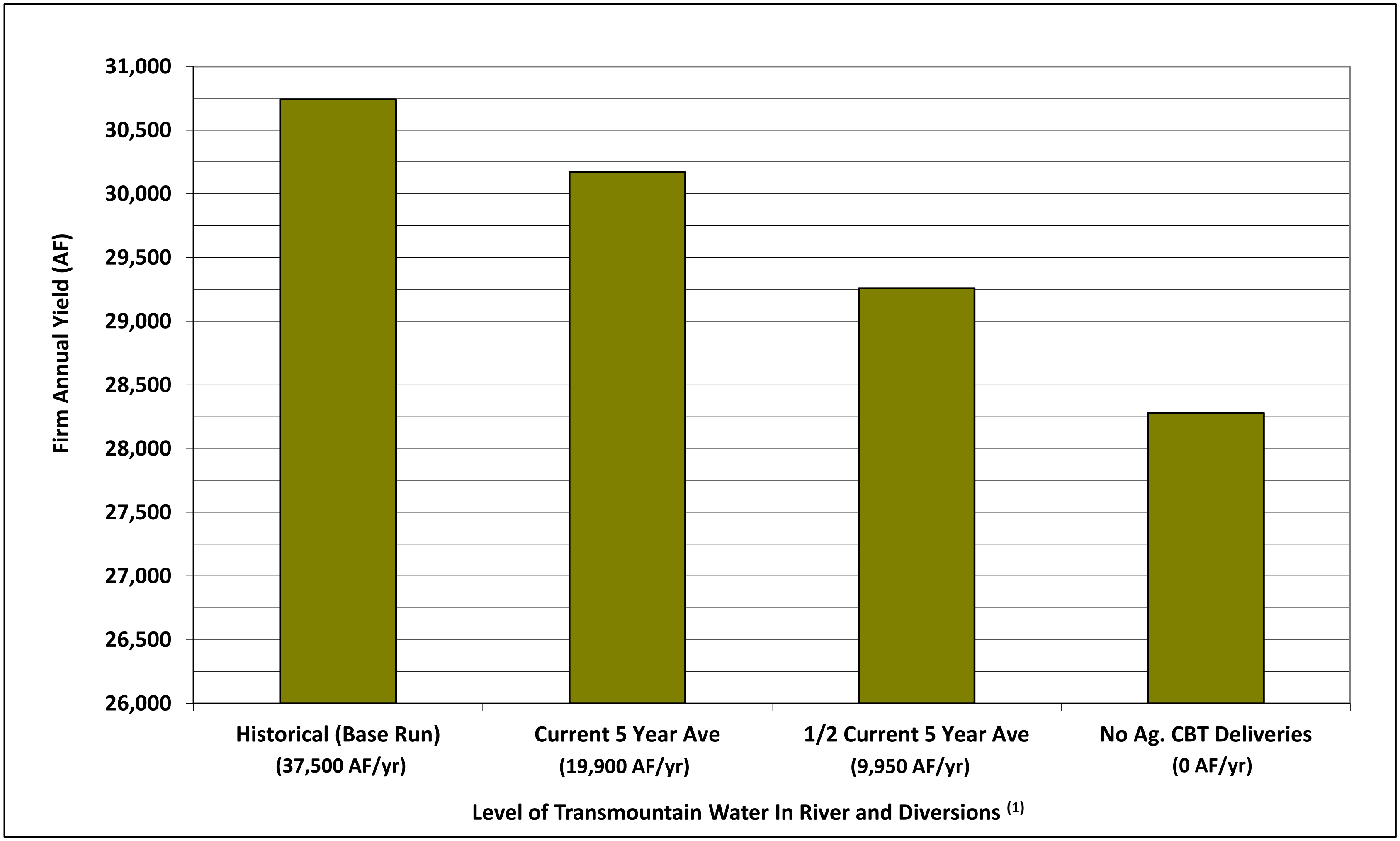
Historical Annual Agricultural and Municipal Deliveries of CBT Project Water to Big Thompson River



<u>Note:</u>
Data from the Northern Colorado Water Conservancy District.

Figure 8-8

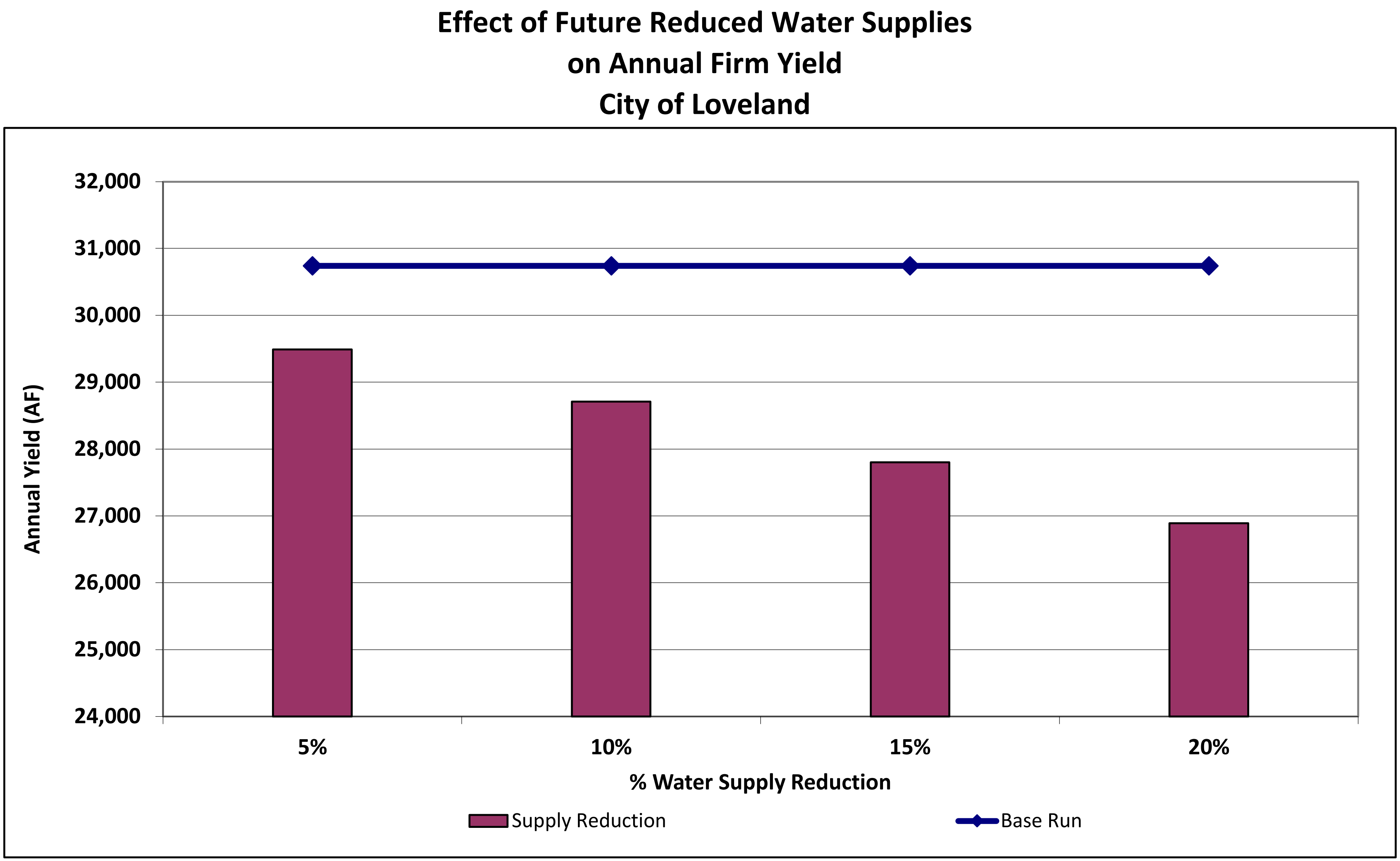
Effect of Reduced Agricultural CBT Project Deliveries and Decreased Exchange Potential on Annual Firm Yield City of Loveland



Note:

(1) Exchange potential adjusted to remove all or portions of the reported historical transmountain water deliveries from the streamflow and diversion records.

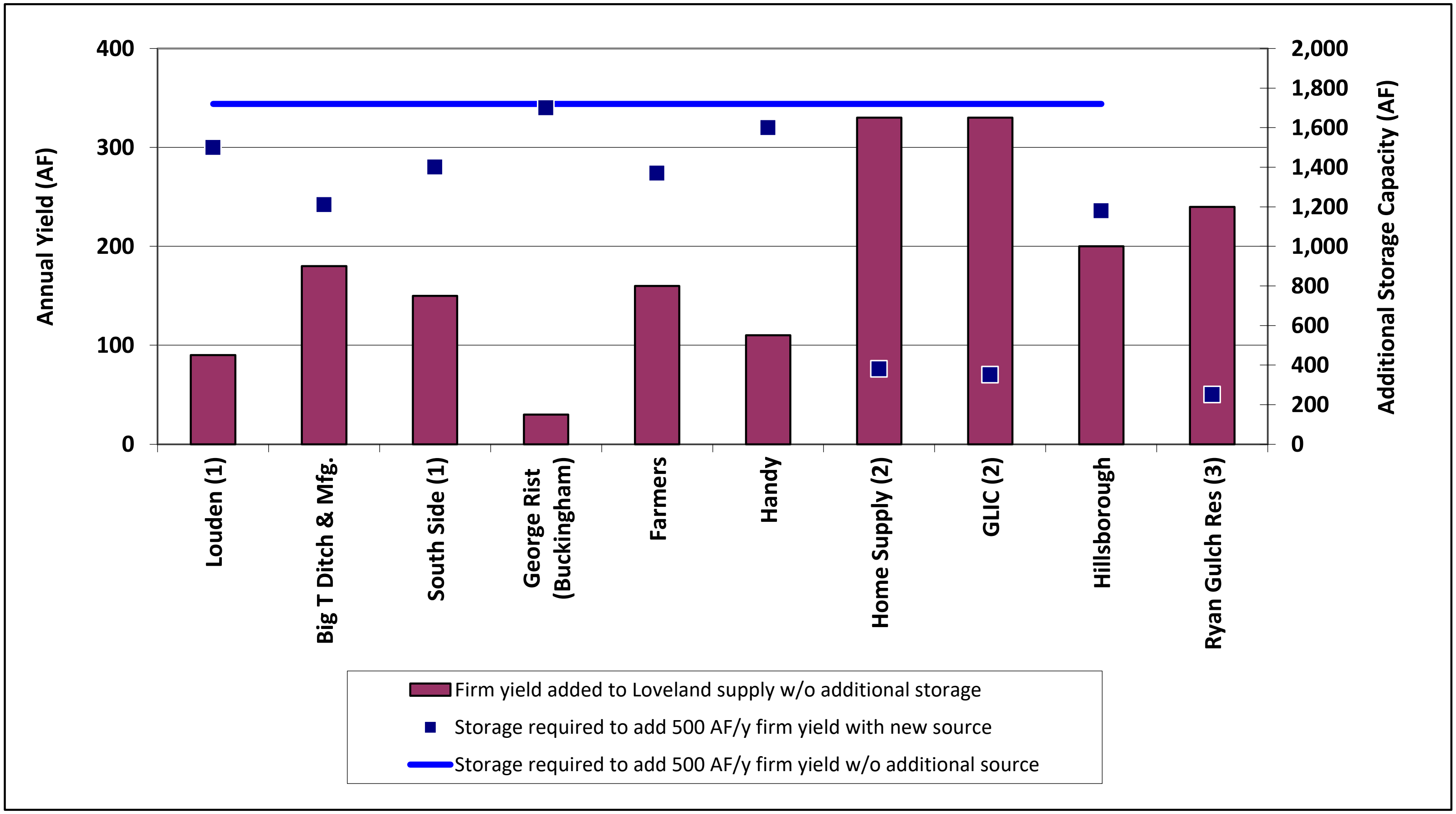
Figure 8-9



Note:
The % water supply reduction applies to all East and West slope water supplies.

Figure 8-10

Incremental Additional Firm Yield
from 500 AF/y of Average Annual Yield of Irrigation Company Supplies
City of Loveland



Notes:

(1) Louden and South Side results do not include yield from storage in those systems.

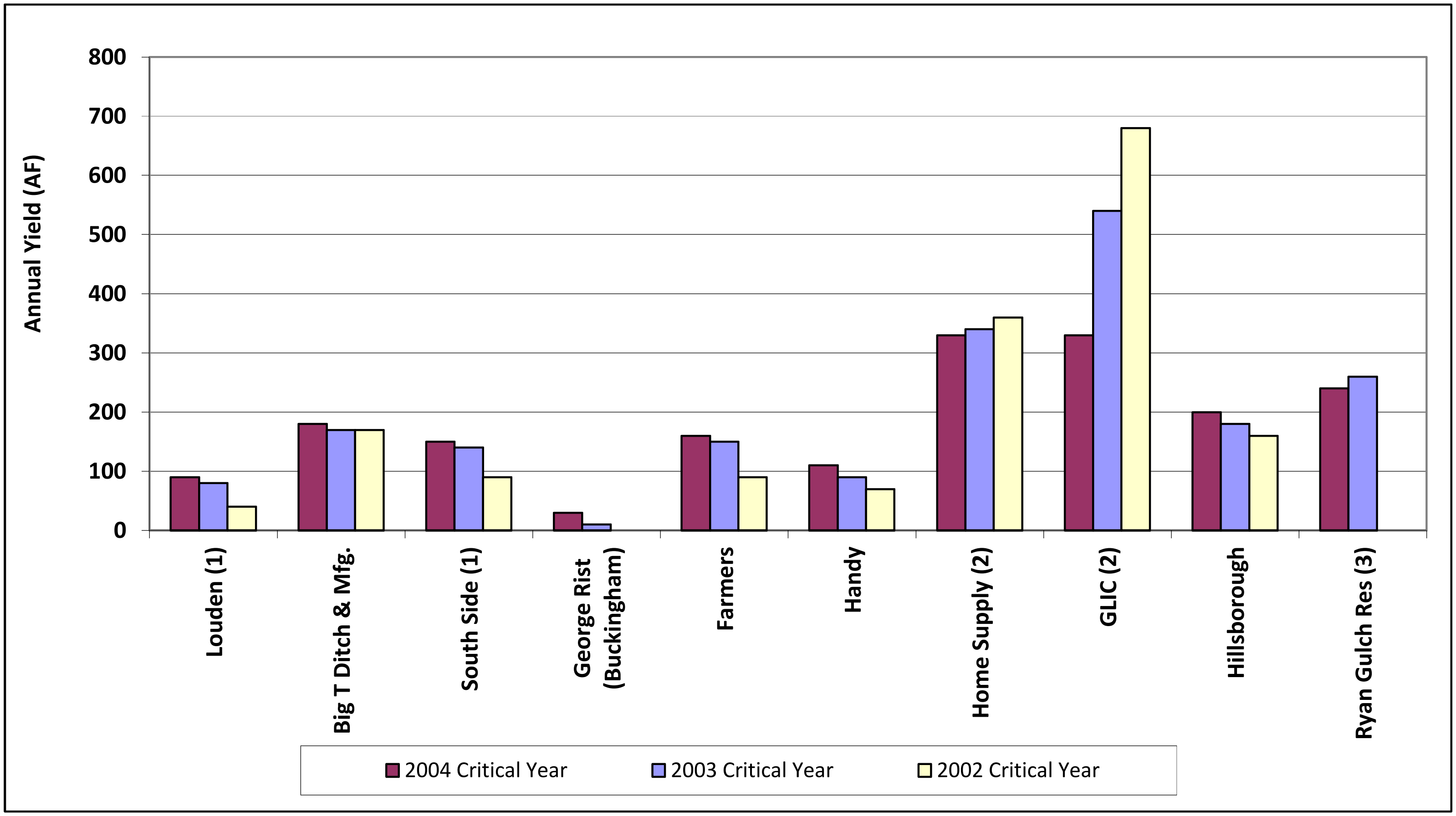
(2) Home Supply and GLIC results include yield from storage.

(3) Ryan Gulch Reservoir yield is based on use of the reservoir for municipal supply during drought periods.

The average annual total yield of Ryan Gulch Reservoir is estimated at 320 AF/y, which is less than the 500 AF/y of additional average annual yield simulated for the other companies.

Figure 8-11

Incremental Additional Firm Yield
from 500 AF/y of Average Annual Yield of Irrigation Company Supplies
for Various Critical Drought Years
City of Loveland



Notes

(1) Louden and South Side results do not include yield from storage in those systems.

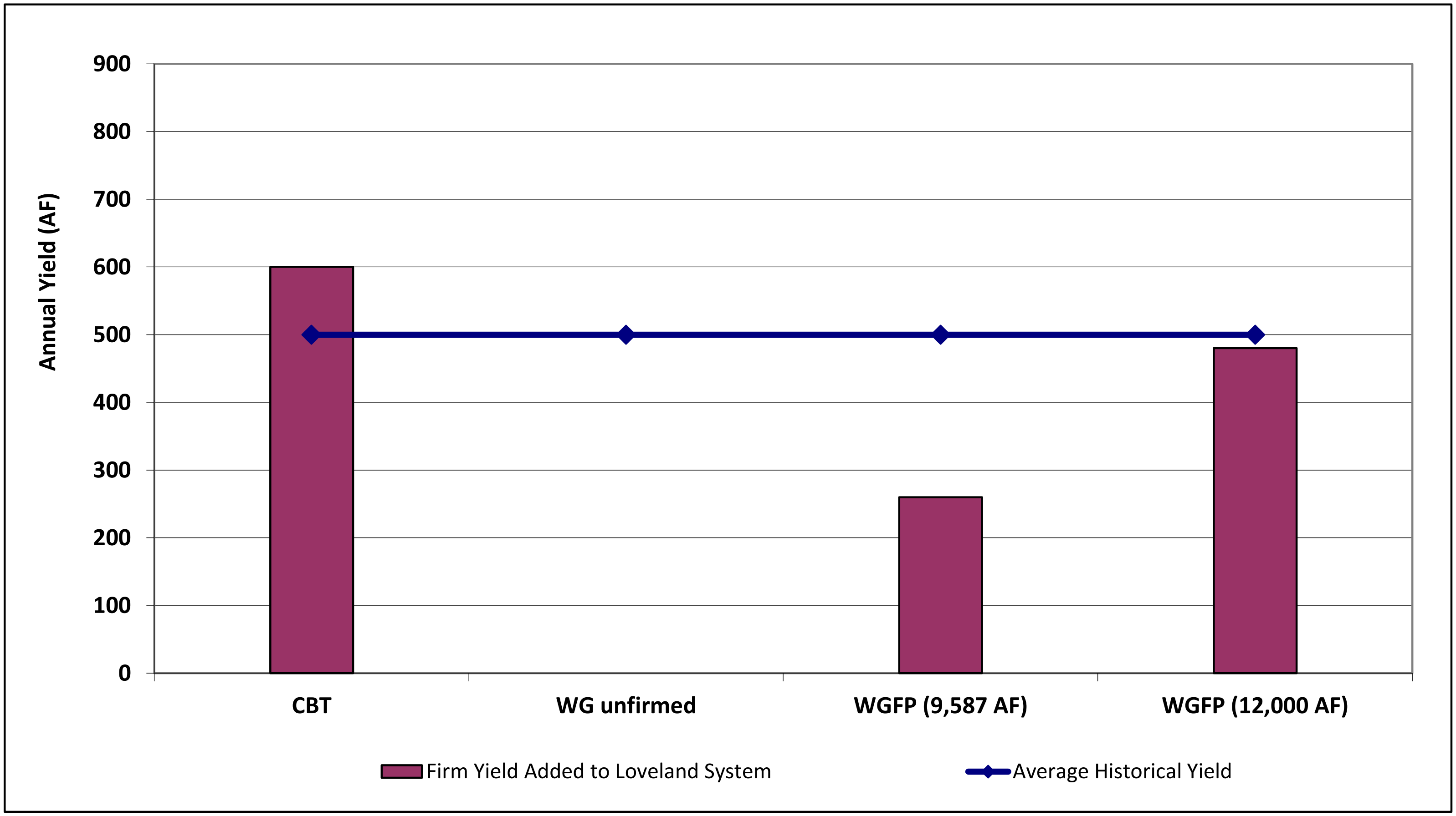
(2) Home Supply and GLIC results include yield from storage.

(3) Ryan Gulch Reservoir yield is based on use of the reservoir for municipal supply during drought periods.

The average annual total yield of Ryan Gulch Reservoir is estimated at 320 AF/y, which is less than the 500 AF/y of additional average annual yield simulated for the other companies.

Figure 8-12

Incremental Additional Firm Yield
from 500 af/y of Average Annual Yield of Transmountain Sources
City of Loveland



Note:

Based on Loveland participation in the Windy Gap Firming Project (WGFP) at 9,451 AF and 12,000 AF of East Slope storage capacity.

Figure 8-13

Simulated CBT Supply - 2020 Yield Analysis
For Additional CBT Units (500 AF/y average annual yield)
City of Loveland (1952-2015)

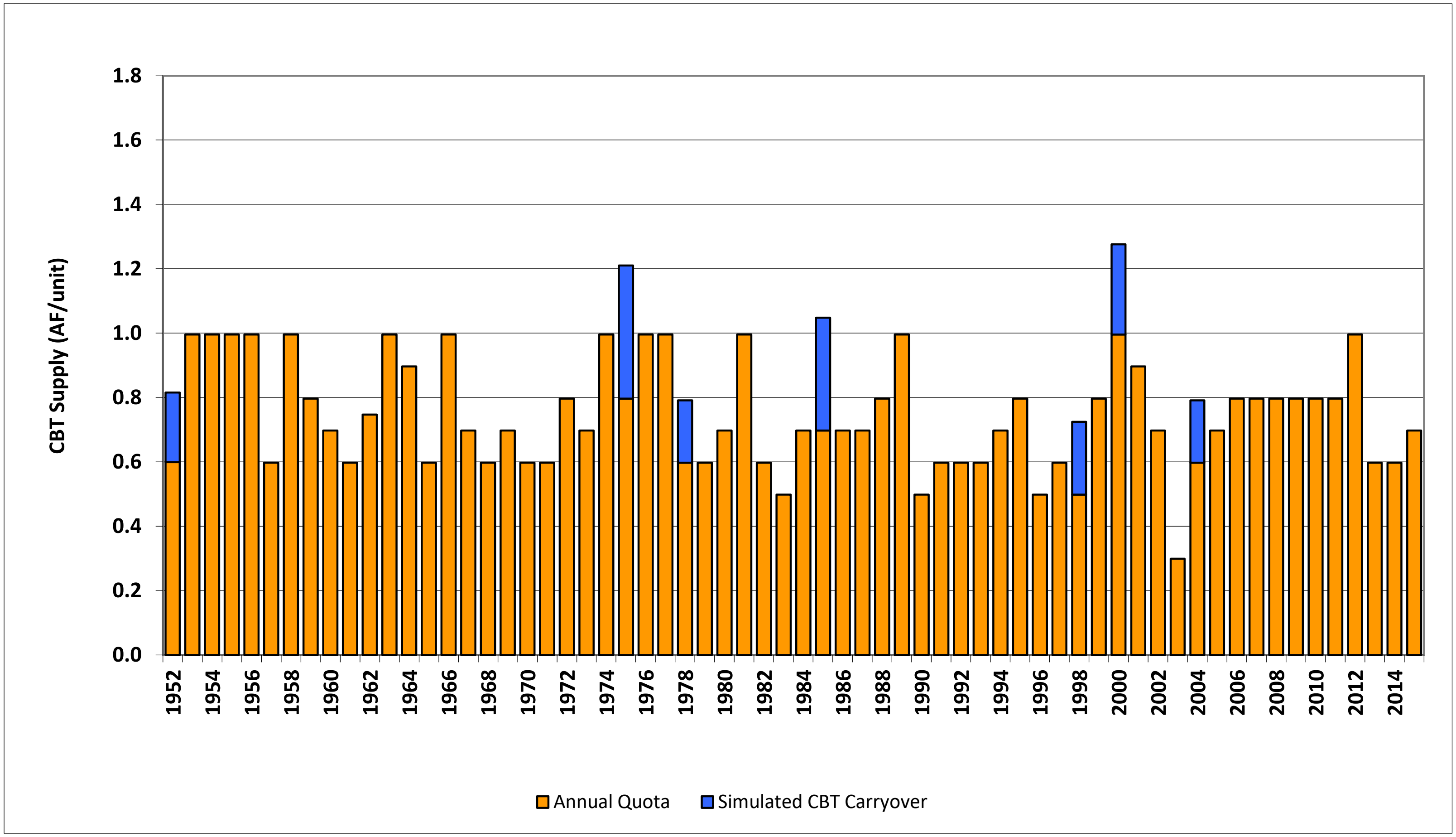


Figure 8-14

Simulated CBT Supply - 2011 Yield Analysis
For Additional CBT Units (500 AF/y average annual yield)
City of Loveland (1952-2006)

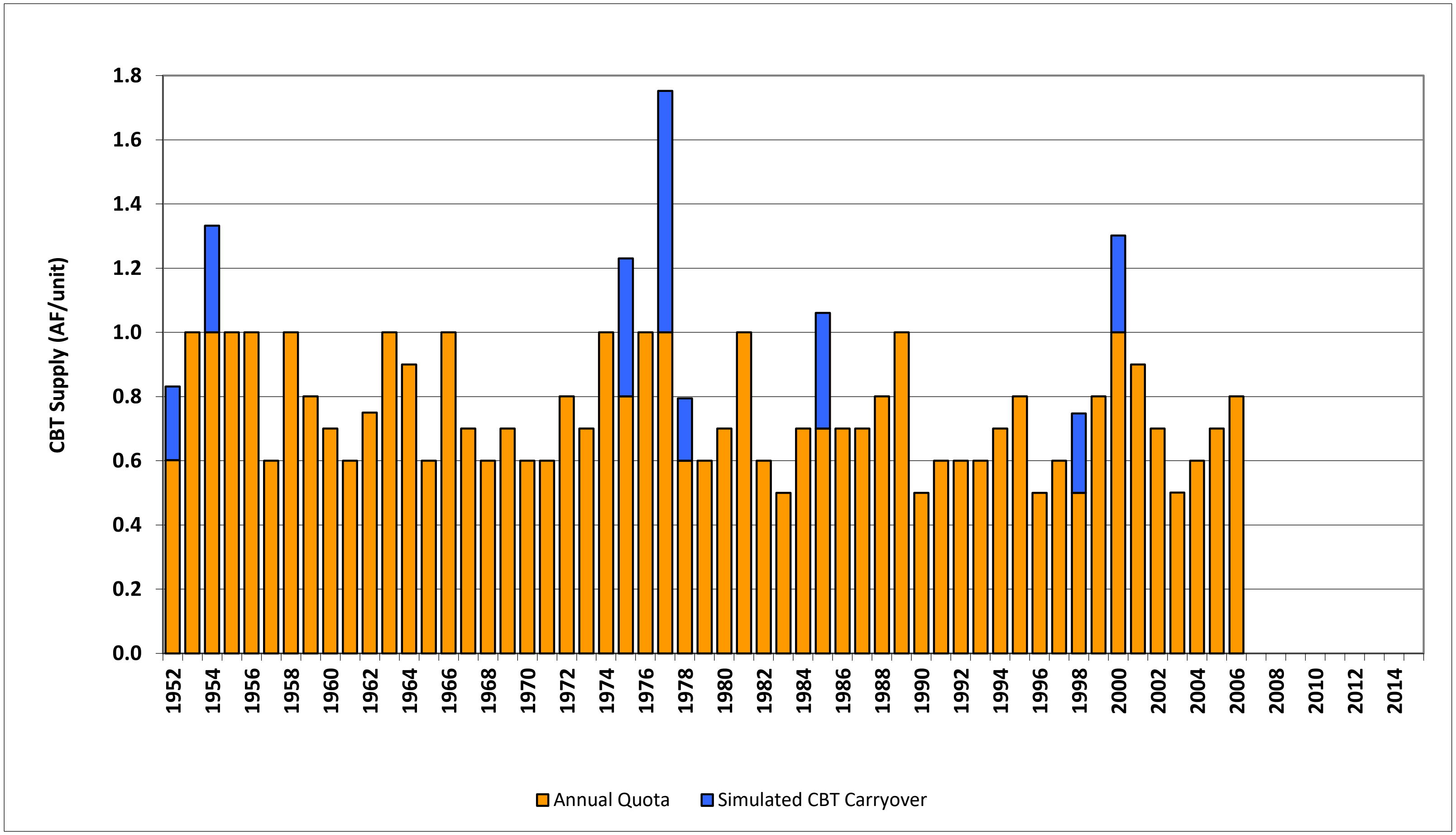


Figure 8-15

Change in Annual Simulated Water Supply
with 668 Additional CBT Units (500 AF/y average annual yield)
City of Loveland (1952-2015)

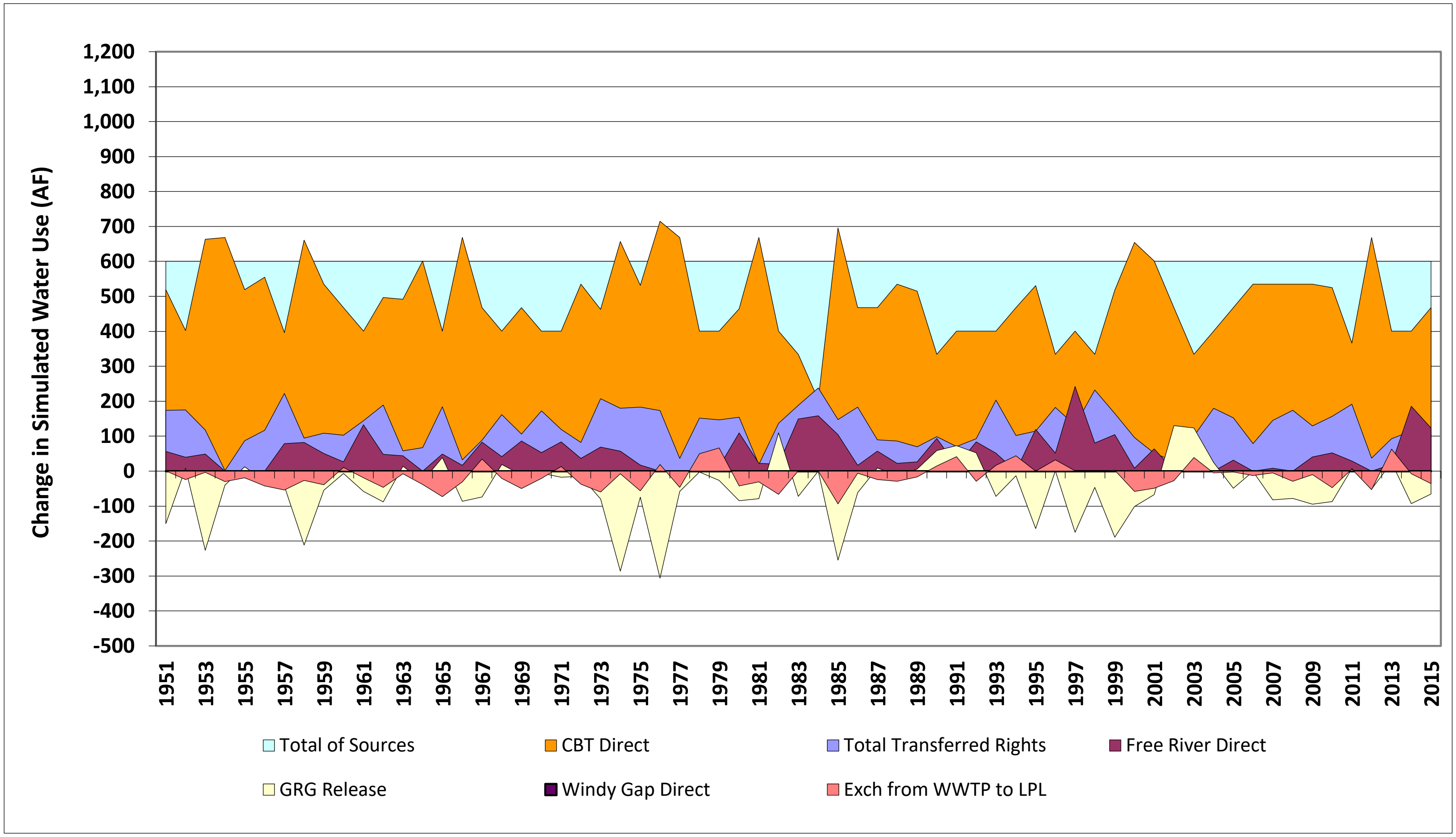
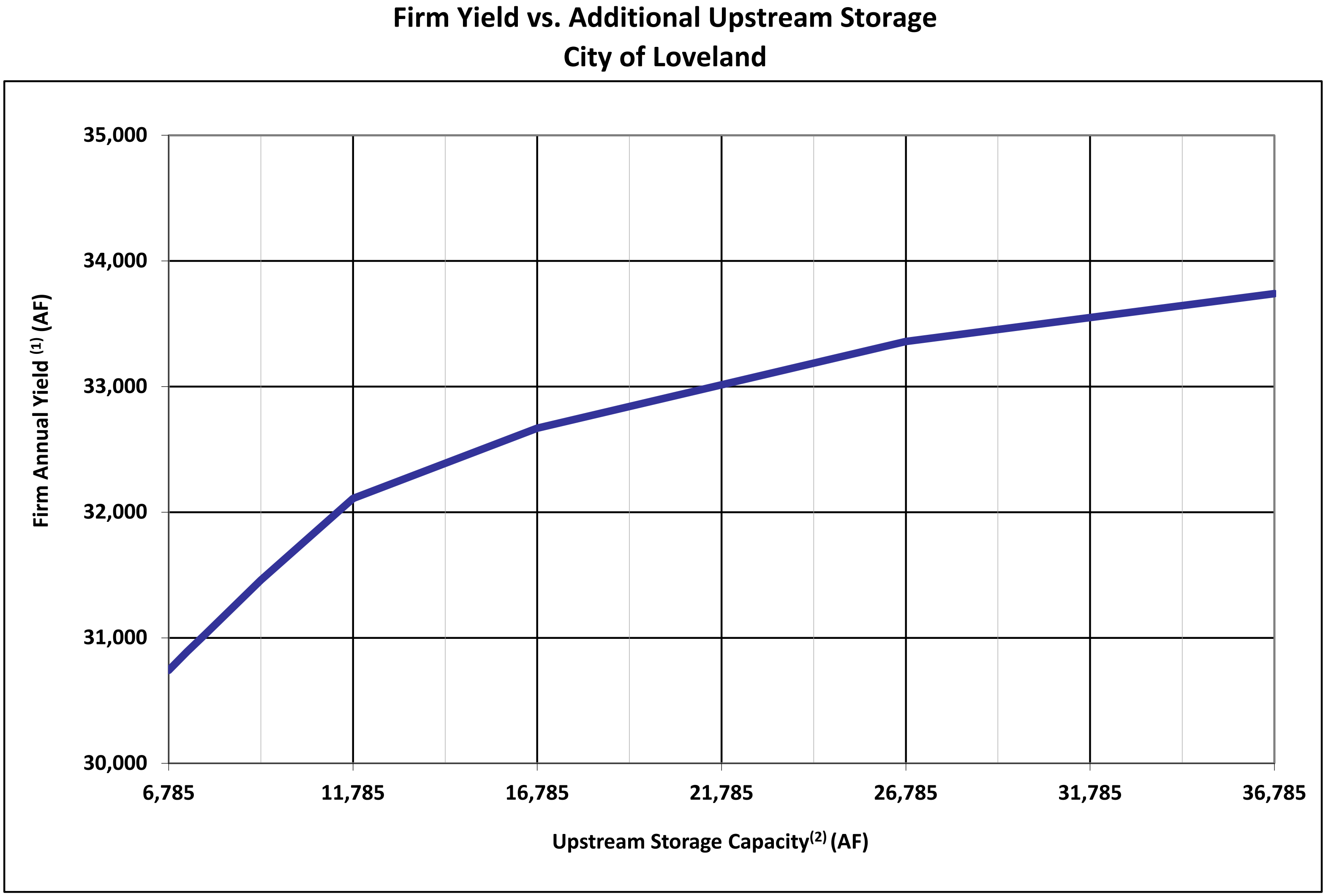


Figure 8-16



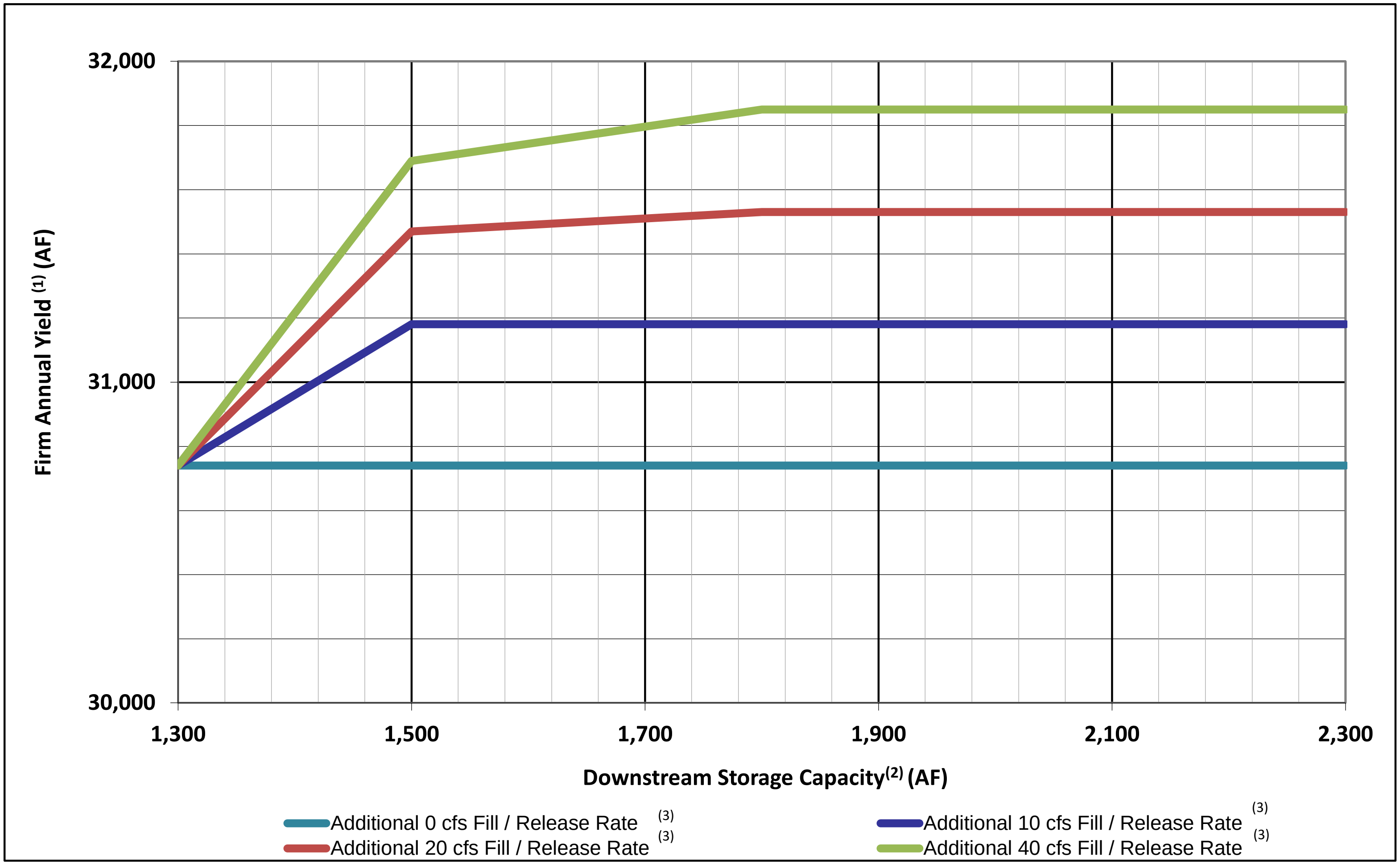
Notes:

[1] Firm Yield includes municipal and augmentation demands.

[2] Includes the existing 6,785 AF of storage in Green Ridge Glade Reservoir.

Figure 8-17

Firm Yield vs. Additional Downstream Storage
City of Loveland



Notes:

[(1)] Firm Yield includes municipal and augmentation demands.

[(2)] Includes the conservatively estimated 1,300 AF of storage in Great Western Reservoir. The inflow and outflow rates to Great Western Reservoir are still under design and could be up to 40 cfs. For the 2019 Yield Analysis, the rates were conservatively modeled at 20 cfs.

[(3)] The fill / release rates shown are in addition to the 20 cfs fill / release rates modeled in the Base Run (e.g. an additional 40 cfs fill/ release rate would total a 60 cfs fill / release rate).

Tables

Table 6-1

Summary of Irrigation Company Shares/Inches/Rights[1]
City of Loveland

Ditch	202A Transfers	392 Transfers	Other Transfers	Untransfered	Loveland Total	Ditch Company Total	Loveland % Total
Big Thompson Ditch & Mfg Co.	2.583	3.811	0.0	5.262	11.66	20.8	56.1%
Barnes Ditch	1306.750	24.500	0.0	0.000	1331.25	1944.2	68.5%
Chubbuck Ditch	596.600	815.001	0.0	0.000	1411.60	1590.4	88.8%
George Rist (Buckingham) Ditch	6.100	89.250	0.0	24.750	120.10	200.0	60.1%
Louden Ditch	191.500	61.547	0.0	13.992	267.04	600.0	44.5%
Rist & Goss	0.000	0.000	W-7412 & 86CW50 [2]	0.000	N/A	N/A	N/A
South Side Ditch	57.500	23.000	0.0	33.750	114.25	265.0	43.1%
Home Supply Ditch	0.000	0.000	Loveland Gard Right [3]	30.000	30.00	2001.0	1.5%

Notes:

(1) Shares changed to municipal use (rounded to nearest tenth).

(2) The W-7412 decree (adjusted to account for Loveland Ready Mix's use) equates to 3.74 cfs and 323.8 AF annually. The 86CW50 decree equates to 2.136 cfs and 117.5 AF annually, which is further limited by monthly volumetric limits.

(3) Loveland is the successor in interest to a one-fifth interest in the Gard Water Right ("Loveland Gard Right") that was historically carried in the Home Supply Ditch. The Loveland Gard Right may be diverted at 1.0 cfs from the beginning of the irrigation season until noon on July 14 and 0.5 cfs from noon on July 14 through August 31. Loveland has not yet begun using the Loveland Gard right.

Table 7-1

Summary of Exchange Potential
Big Thompson River
1951 - 2015

Average Exchange Potential (cfs)

Month	Between WWTP and: Olympus Tunnel	Between WWTP and: Dille Tunnel	Between WWTP and: Loveland Pipeline	Between LaSalle Gage and: Olympus Tunnel	Between LaSalle Gage and: Dille Tunnel	Between LaSalle Gage and: Loveland Pipeline
January	7.3	10.0	13.8	7.2	9.4	13.0
February	6.9	9.0	13.8	6.8	8.7	13.1
March	8.3	10.6	15.6	7.8	9.4	13.3
April	24.5	27.0	43.1	18.5	20.4	32.3
May	64.2	64.5	120.4	55.8	58.0	131.0
June	137.3	136.5	194.4	121.4	121.5	188.4
July	82.3	77.7	91.7	57.1	57.1	64.0
August	45.1	38.0	50.0	33.2	35.1	40.8
September	23.9	19.0	22.8	19.0	18.9	19.7
October	22.1	24.1	30.6	20.7	24.2	31.1
November	17.0	19.8	26.5	16.8	19.4	25.4
December	9.4	12.7	18.7	9.4	11.8	16.6

Average No. Days of Exchange Potential

Month	Between WWTP and: Olympus Tunnel	Between WWTP and: Dille Tunnel	Between WWTP and: Loveland Pipeline	Between LaSalle Gage and: Olympus Tunnel	Between LaSalle Gage and: Dille Tunnel	Between LaSalle Gage and: Loveland Pipeline
January	16	16	17	16	16	17
February	14	14	15	14	14	15
March	15	15	15	15	15	15
April	16	17	17	14	14	14
May	25	26	27	18	18	18
June	28	28	28	21	21	21
July	25	30	30	13	14	14
August	15	27	29	9	10	11
September	8	18	21	6	6	7
October	10	12	13	9	10	10
November	16	16	17	16	16	16
December	16	16	16	16	16	16
Annual (1951-2015)	204	235	245	166	169	173

Table 7-2

Summary of Differences in Base Run Conditions
Between 2004, 2011, and 2020 Yield Analyses

Simulated Firm Yield (AF/yr)	**2004**	**2011**	**2020**
Municipal Demand	22,440	26,800	30,150
Augmentation Demand	0	590	590
Total Supply	22,440	27,390	30,740

Yield Model Assumptions	**2004**	**2011**	**2020**
Municipal Demand Distribution Basis	1997-2001 average	2000-2010 average	2005-2015 average
Last Year of Study Period	2003	2006	2015
Call Revisions	No	Yes	Yes
LPL Capacity (cfs)	71.3	90	90
WGFP Participation (AF)	Off	7,000	9,587
Updated WG Inflows	No	Yes	Yes
WG Order	Before GRG	Last (after GRG)	Last (after GRG)
CBT Units	10,538	11,786	12,190 (1)
Municipal 6 cfs (BTDM)	When BTDM diverting	In Priority; Apr 24-Oct 30	In Priority; Apr 24-Oct 30
Domestic 3 cfs	Off	In Irrigation Priority; Apr-Oct	In Irrigation Priority; Apr-Oct
Ditch Source Order	Senior to Junior	Junior to Senior	Junior to Senior
Rist & Goss Order	After other ditches	Before other ditches	Before other ditches
392 Conditions Modeled	No	Yes	Yes
Free River Diversions	Not Reusable	Reusable	Reusable
WWTP Exchange	To GRG	Also to LPL	Also to LPL
WTP Decant	n/a	Used as source	Used as source
Loveland Gard Right Included	No	No	Yes (2)
Great Western Reservoir (AF)	0	0	1300 (3)

Notes:

(1) The City of Loveland acquired an additional 20 CBT units after the yield modeling was completed. There are currently 12,210 CBT units in the City of Loveland's water rights portfolio.

(2) The Loveland Gard Right has not been implemented yet.

(3) 1,300 AF was modeled as the preliminary operational storage capacity of Great Western Reservoir.

Table 8-1

Simulated Average and Dry Year Yield[1]
City of Loveland Water Sources
(AF/yr)

	Source	1951 - 2015 Average	Dry Year (2002)
	LPL (3.44 cfs)	2,490	2,490
	Early BTDM (6cfs)	2,180	1,242
(2)	Domestic (3 cfs)	679	117
(3,4)	202A Transfers	9,458	2,720
(4)	392 Transfers	5,963	2,012
	Loveland Gard Right Transfer	156	149
	CBT	9,077	8,250
(5)	Windy Gap	6,891	0
	Total	36,895	16,980

Notes:

(1) Values reflect the simulated available yield from Loveland's water sources prior to regulation in Green Ridge Glade Reservoir, and does not include free river diversions and exchanged of reusable effluent.

(2) Diverted April - October with irrigation priority. There are unresolved issues regarding the priority and diversion season of these rights. Although it appears from the decree in CA-4862 that the rights could be diverted year-round under domestic priorities 2 and 3, until these questions are resolved, the domestic water rights are simulated using irrigation priorities 51 and 81 with a diversion season of April 1 - October 31.
The manner of simulation used in the model does not imply that the City is waiving its rights to divert year round under the domestic priorities.

(3) Includes Rist & Goss Ditch transfer yield.

(4) Loveland's pro-rata portion of historical diversions, less 15% left in ditch.

(5) Average of Loveland's portion of the simulated Windy Gap Project yield prior to regulation in Chimney Hollow Reservoir through the Windy Gap Firming Project as set forth in a 2003 Boyle Engineering report (updated in 2008) and in the NCWCD records.

Table 8-2

Simulated Average and Dry Year Base Run Yields[(1)]
City of Loveland
(AF/yr)

Source	Municipal Use 1951 - 2015 Average	Municipal Use Dry Year (2002)	Augmentation and Potable Leases 1951 - 2015 Average	Augmentation and Potable Leases Dry Year (2002)
Loveland Pipeline Rights[2]	5,286	3,838	16	11
202A Transfers	7,712	2,350	23	7
Rist & Goss Transfer	269	126	1	0
392 Transfers	1,501	805	4	2
Loveland Gard Right Transfer	45	98	0	0
Free River	1,409	34	4	0
WWTP Effluent[3]	1,161	2,994	213	254
CBT	9,240	8,687	28	26
GRG Release	3,527	11,219	43	51
Windy Gap (Direct)[4]	0	0	-	-
WTP Decant	-	-	26	33
Downstream Gravel Pit Release	-	-	232	205
Total	30,150	30,150	590	590

Notes:

(1) Simulated yield of Loveland's water supplies under Base Run conditions.
(2) Includes municipal and domestic rights.
(3) WWTP effluent used by exchange for municipal uses and directly for augmentation uses.
(4) No Windy Gap water is diverted directly at the Loveland Pipeline in the Base Run, but it is diverted into Green Ridge Glade Reservoir and is part of the total reservoir releases.

Table 8-3

Difference in Simulated Annual Yields
of Loveland Water Sources
During the 2000 - 2006 Drought Period
Between the 2011 and 2020 Yield Analyses
(acre-feet)

Source	2000	2001	2002	2003	2004	2005	2006	Avg
Loveland Pipeline	0	0	0	0	0	0	0	0
Transferred Rights	1,161	781	494	807	1,231	1,014	708	885
Free River	48	255	3	10	0	175	0	70
WWTP Exchange	763	548	572	151	547	586	623	541
CBT Direct	-104	364	283	202	242	432	323	249
Windy Gap Direct	0	0	0	0	0	0	0	0
GRG Release	1,486	1,375	1,871	1,987	1,098	915	1,422	1,451
Total	3,355	3,323	3,223	3,157	3,118	3,122	3,075	3,196

Note:
(1) Differences computed as 2020 Model results minus 2011 Model results.

Table 8-4
Increased Firm Yield vs.
Windy Gap Firming Project Participation
and Windy Gap Units
City of Loveland

Windy Gap Firming Project Storage (af)	Windy Gap Units		
	40	45	50
0	26,100	26,100	26,100
2,000	26,790	26,790	26,790
5,000	28,560	28,560	28,560
7,000	29,880	29,880	29,880
9,000	30,590	30,760	30,760
9,587	**30,740**	31,000	31,000
10,000	30,860	31,190	31,190
11,000	31,140	31,550	31,610
12,000	31,410	31,810	32,020
14,000	31,930	32,290	32,700
16,000	32,210	32,580	32,940
20,000	32,580	32,930	33,320

Note:
Loveland owns 40 Windy Gap Units and is currently participating in the Windy Gap Firming Project in the amount of 9,587 acre-feet of storage.

Table 8-5

Summary of Incremental Firm Yield Analysis
City of Loveland

Water Source	Added Supply	Total Yield of Additional Supply: Average Historical Yield (1) (AF/yr)	Total Yield of Additional Supply: Firm Yield (AF/yr)	Unit Yield (e.g., yield per share): Unit Average Historical Yield (AF/yr)	Unit Yield (e.g., yield per share): Unit Firm Yield (AF/yr)	Unit Yield (e.g., yield per share): Storage to Firm 500 AF	Unit Yield (e.g., yield per share): Firming Ratio
(2) & (3) Additional Ditch Supply (shares or inches)							
Louden	41.962	500	90	11.92	2.14	1,500	3.0
Big T Ditch & Mfg.	2.644	500	180	189.11	68.08	1,210	2.4
South Side	100.520	500	150	4.97	1.49	1,430	2.9
Barnes	151.040	500	100	3.31	0.66	1,800	3.6
Chubbuck	172.337	500	50	2.90	0.29	1,720	3.4
(4) George Rist (Buckingham)	86.789	500	30	5.76	0.35	1,700	3.4
Farmers	7.817	500	160	63.97	20.47	1,370	2.7
Handy	55.202	500	110	9.06	1.99	1,600	3.2
Home Supply	50.310	500	330	9.94	6.56	680	1.4
GLIC	58.423	500	330	8.56	5.65	350	0.7
Hillsborough	4.594	500	200	108.84	43.53	1,260	2.5
Ryan Gulch Res	100%	320	240	320.00	240.00	310	1.0
(2) Additional Transmountain Supply (units)							
CBT	668.1	500	600	0.75	0.90		
WG Unfirmed	6.98	500	0	71.63	0.00		
WGFP (9,587) (5)	5.67	500	260	88.18	45.86		
WGFP (12,000) (5)	5.67	500	480	88.18	84.66		
(6) Additional Transmountain Supply (storage, AF)					Firming Ratio (7)		
WGFP	500		140		3.6		
WGFP	1000		280		3.6		
(7) Additional Storage Capacity (af)					Firming Ratio (8)		
Upstream	1,000	--	290	--	3.4		

Notes:
(1) Historical average based on 1951 - 2015 average.
(2) Increase in Loveland's current firm yield resulting from addition of 500 AF/yr of average annual yield.
(3) Ditches currently accepted into the Water Bank with proper analysis and documentation include: Louden, Big Thompson Ditch & Mfg, South Side, and George Rist (Buckingham). The City no longer accepts shares from the Barnes or Chubbuck.
(4) For the George Rist (Buckingham) Ditch, it is not possible to obtain more than 86 shares. The City currently owns 120.4 shares out of the total 200 shares.
(5) Based on Loveland participation in the Windy Gap Firming Project (WGFP) at 9,587 and 12,000 AF of East Slope storage.
(6) Increase in Loveland's current firm yield resulting from additional WGFP storage participation above the current 9,587 AF level (at 40 WG units).
(7) Increase in Loveland's current firm yield resulting from addition of upstream storage.
(8) Firming ratio computed as the increased storage capacity divided by the firm yield.

Table 8-6

Historical Simulated Available Supply and Firm Yield
Comparison of 2011 and 2020 Yield Study Results [1]

Simulated Ditch Company Shares		Simulated Average Available Supply				Water Bank Credit (AF/share)	Simulated Firm Yield			
		Total Supply (AF)		Unit Supply (AF/share)			Total Yield (AF)		Unit Yield (AF/share)	
Simulated Incremental Yield of 500 af of Additional Supply										
392 Transfer Conditions	2011	2020	2011	2020	2011	2020	Current	2011	2020	2011	2020

392 Transfer Conditions	Shares 2011	Shares 2020	Total Supply 2011	Total Supply 2020	Unit Supply 2011	Unit Supply 2020	Water Bank Credit Current	Total Yield 2011	Total Yield 2020	Unit Yield 2011	Unit Yield 2020
George Rist (Buckingham)	78.66	86.79	500	500	6.36	5.76	6.36	30	30	0.38	0.35
Chubbuck [2]	170.10	172.34	500	500	2.94	2.90	2.94	70	---	0.41	---
Barnes [2]	150.68	151.00	500	500	3.32	3.31	3.32	130	---	0.86	---
South Side	109.84	100.52	500	500	4.55	4.97	4.55	160	150	1.46	1.49
Big T Ditch & Mfg.	2.68	2.64	500	500	186.57	189.11	186.57	190	180	70.90	68.08
Louden	41.09	41.96	500	500	12.17	11.92	12.17	100	90	2.43	2.14

Note:

(1) The study period for the 2011 Yield Model ended in 2006 while the 2020 Yield Model study period ended in 2015.

(2) Ditches currently accepted into the Water Bank with proper analysis and documentation include: Louden, Big Thompson Ditch & Mfg, South Side, and George Rist (Buckingham). The City no longer accepts shares from the Barnes or Chubbuck.

Table 8-7

Comparison of Simulated Annual Water Supplies
Municipal and Potable Lease Demand
Base Run and CBT Test Run
(acre-feet)

Base Run	2000	2001	2002	2003	2004	2005	2006	Avg
Loveland Pipeline	4,816	4,840	3,849	5,314	5,141	5,199	4,773	4,847
Transferred Rights	9,537	8,511	3,389	9,601	13,829	10,471	8,389	9,104
Free River	311	1,500	34	53	0	1,293	0	456
WWTP Exch / Release	1,412	994	3,003	1,175	1,243	1,828	1,977	1,662
CBT Direct	12,319	11,151	8,713	6,275	7,494	8,713	9,932	9,228
Windy Gap Direct	0	0	0	0	0	0	0	0
GRG Release	1,892	3,245	11,252	7,822	2,579	2,735	5,170	4,957
All Sources	30,287	30,240	30,240	30,240	30,287	30,240	30,240	30,254

CBT Test Run	2000	2001	2002	2003	2004	2005	2006	Avg
Loveland Pipeline	4,816	4,840	3,849	5,314	5,141	5,199	4,773	4,847
Transferred Rights	9,633	8,562	3,417	9,702	14,009	10,624	8,468	9,202
Free River	319	1,563	36	56	0	1,325	0	471
WWTP Exch	1,355	944	2,975	1,214	1,239	1,826	1,964	1,645
CBT Direct	12,974	11,752	9,181	6,609	7,895	9,181	10,466	9,723
Windy Gap Direct	0	0	0	0	0	0	0	0
GRG Release	1,791	3,178	11,382	7,946	2,604	2,686	5,169	4,965
All Sources	30,887	30,840	30,840	30,840	30,887	30,840	30,840	30,854

Difference	2000	2001	2002	2003	2004	2005	2006	Avg
Loveland Pipeline	0	0	0	0	0	0	0	0
Transferred Rights	96	51	28	101	180	152	79	98
Free River	9	64	2	3	0	32	0	16
WWTP Exch	-58	-49	-28	39	-5	-3	-13	-17
CBT Direct	655	601	468	334	401	468	534	494
Windy Gap Direct	0	0	0	0	0	0	0	0
GRG Release	-101	-67	130	124	25	-49	-1	9
All Sources	601	600	600	600	601	600	600	600
Sources other than CBT	-54	-1	132	266	200	132	65	106

Note: The 2002 total of all sources (30,240 AF) is comprised of 30,150 AF for municipal use and 90 AF for potable lease use.

Table 8-8

Simulated Additional Annual Water Supply
During 2000 - 2006 Drought Period
from Addition of 668 CBT Units
Resulting in 600 Acre-Feet of Firm Yield
(acre-feet)

Water Source	2000	2001	2002	2003	2004	2005	2006	Avg
Loveland Pipeline	0	0	0	0	0	0	0	0
Transferred Rights	96	51	28	101	180	152	79	98
Free River	9	64	2	3	0	32	0	16
WWTP Exch	-58	-49	-28	39	-5	-3	-13	-17
CBT Direct	655	601	468	334	401	468	534	494
Windy Gap Direct	0	0	0	0	0	0	0	0
GRG Release	-101	-67	130	124	25	-49	-1	9
All Sources	601	600	600	600	601	600	600	600
Sources other than CBT	-54	-1	132	266	200	132	65	106

Table 8-9

Additional Firm Yield from Alternate Water Supply Operations
Loveland Water Supply Yield Model

Run Type	Run Description	Firm Yield (AF/y)	Incremental Firm Yield (AF/y)
Base Run	Base Run with current water supply operations	**30,740**	----
Test Runs with Alternate Water Supply Operations			
Domestic	Diverted year-round with irrigation priority	31,450	710
Domestic	Diverted year-round with domestic priority	32,350	1,610
CBT	CBT used after GRG	22,690	-8,050
CBT	CBT and GRG used 50/50 in winter	29,510	-1,230
CBT	CBT & GRG used 50/50 year-round	30,380	-360
Exchange All Year	Allow exchanges all year, not just April - October	30,830	90
Windy Gap	Windy Gap used before CBT	26,880	-3,860
LIRFs	LIRFs included (1)	30,960	220
Ditch Lease	Long Term Lease of ditch shares to other entities (2)	30,660	-80
CBT Lease	Long Term Lease of CBT units to other entities (2)	30,270	-470
WG Lease	Long Term Lease of WG Units to other entities (2)	30,330	-410
Ditch Lease	Short Term Lease of ditch shares to other entities (3)	30,670	-70
CBT Lease	Short Term Lease of CBT units to other entities (3)	30,610	-130
WG Lease	Short Term Lease of WG Units to other entities (3)	30,330	-410
Alt CBT Lease	Long Term Lease of CBT units to other entities with Loveland receiving the water in 3/10 years (4)	30,610	-130
All Max Conditions	Simulated conditions that maximize the firm yield	32,780	2,040

Note:
(1) Due to the Yield Model limitations, the LIRFs are not represented at their full beneficial use.
(2) Ditch share / CBT Unit/ WG Unit lease of 500 af of average annual yield for entire study period.
(3) Ditch share / CBT Unit/ WG Unit lease of 500 af of average annual yield for 5 years during the critical 2000-2006 period.
(4) CBT Unit lease of 500 af of average annual yield for randomly selected 3 years out of every 10 years during the entire study period.

Appendix A

FIRST READING July 3, 2012

SECOND READING July 17, 2012

ORDINANCE #5691

AN ORDINANCE AMENDING THE LOVELAND MUNICIPAL CODE AT CHAPTER 19.04 CONCERNING WATER RIGHTS IN ACCORDANCE WITH THE 2012 RAW WATER MASTER PLAN

WHEREAS, on June 5, 2012, the City Council adopted Resolution #R-46-2012 adopting the 2012 Raw Water Master Plan of the City of Loveland; and

WHEREAS, the City Council desires to amend the Loveland Municipal Code at Chapter 19.04 in accordance with 2012 Raw Water Master Plan.

NOW, THEREFORE, BE IT ORDAINED BY THE CITY COUNCIL OF THE CITY OF LOVELAND, COLORADO:

Section 1. That Section 19.04.018 of the Loveland Municipal Code is hereby amended to read as follows:

19.04.018 Value of water bank credit.

A. The value of water bank credit received in exchange for water rights transferred to the city shall be determined at the time such water bank credit is applied to satisfy the city's water rights requirements.
B. The current value of ditch water rights shall be as follows:

Ditch/Ditch Company	Value	
	With Payment of the Native Raw Water Storage Fee	Without Payment of the Native Raw Water Storage Fee
Barnes	3.32 acre-feet of water per inch	0.86 acre-feet of water per inch
Big Thompson Ditch & Manufacturing Company	186.57 acre-feet of water per share	70.90 acre-feet of water per share
Buckingham Irrigation Company (George Rist Ditch)	6.36 acre-feet of water per share	0.38 acre-feet of water per share
Chubbuck Ditch	2.94 acre-feet of water per inch	0.41 acre-feet of water per inch
Louden Irrigating Canal and Reservoir Company	12.17 acre-feet of water per share	2.43 acre-feet of water per share
South Side Ditch Company	4.55 acre-feet of water per share	1.46 acre-feet of water per share

The values set forth in the table above represent the historical average yield of each ditch as stated in Spronk Water Engineers' Raw Water Supply Yield Analysis Update dated January 2012. These values are subject to change at any time by ordinance of city council. The value of water bank credit received in exchange for transferring to the city ditch water rights not set forth in the table above shall be determined by city council by resolution on a case-by-case basis at the time such water bank credit is applied to satisfy the city's water rights requirements. The native raw water storage fee applicable to each ditch or ditch company is set forth in Section 19.04.045.

C. The current value of Colorado-Big Thompson Project units shall be one (1) acre-foot per unit.

__**Section 2**__. That Section 19.04.040 of the Loveland Municipal Code is hereby amended to read as follows:

19.04.040 Satisfying water rights requirements.

To satisfy the city's water rights requirements, the applicant must apply water bank credit in an amount sufficient to satisfy the city's water rights requirements. A minimum of fifty percent (50%) of every transaction to satisfy such requirement must include water bank credits received in exchange for Colorado-Big Thompson Project units transferred to the city or water bank credits acquired from the City by cash purchase, or by paying the cash-in-lieu price ("50% Rule"). If the acre-feet requirement resulting from the 50% Rule results in a fractional requirement of less than 0.50 acre-feet, it may be rounded down to the nearest acre-foot.

__**Section 3**__. That Chapter 19.04 of the Loveland Municipal Code is hereby amended by addition of a new Section 19.04.041 to read as follows:

19.04.041 Cash-in-lieu price.

The cash-in-lieu price shall be equal to the market price of one (1) Colorado-Big Thompson Project unit as recognized by resolution of the Loveland utilities commission, divided by the yield (in acre-feet) of one (1) Colorado-Big Thompson Unit as set forth in Section 19.04.018.B, with the resulting quotient multiplied by 1.05. Said fee shall be calculated in accordance with the resolution in effect at the time such payment is due.

__**Section 4**__. That Section 19.04.045 of the Loveland Municipal Code is hereby amended to read as follows:

19.04.045 Native raw water storage fee.

A. When credit in the city's water bank received in exchange for the transfer of ditch water rights to the city is applied to satisfy the city's water rights requirements, it shall be subject to the native raw water storage fee unless exempted under subsection B. or C. below. Said fee shall be calculated and due at the time such water bank credit is applied to satisfy the city's water rights requirements as provided in Sections 13.04.245.C and 19.04.020. The current native raw water storage fee applicable to each ditch or ditch company shall be as follows:

Ditch / Ditch Company	Native Raw Water Storage Fee Per Acre-Foot
Barnes Ditch	$5,750
Big Thompson Ditch & Manufacturing Company	$3,530
Buckingham Irrigation Company (George Rist Ditch)	$7,400
Chubbuck Ditch	$7,400
Louden Irrigating Canal and Reservoir Company	$6,850
South Side Ditch Company	$6,770

The native raw water storage fees set forth in the table above are taken from the city's 2012 Raw Water Master Plan, adopted by city council by resolution on June 5, 2012. These values are subject to change at any time by ordinance of city council. The native raw water storage fee applicable to water bank credit received in exchange for transferring to the city ditch water rights not set forth in the table above shall be determined by city council by resolution on a case-by-case basis at the time such water bank credit is applied to satisfy the city's water rights requirements. The native raw water storage fee shall not apply to water bank credits received in exchange for the transfer of Colorado-Big Thompson Project units to the city or water bank credits acquired from the city by cash payment or to payments of the cash-in-lieu price.

B. When credit in the city's water bank received in exchange for the transfer of ditch water rights to the city on or before July 20, 1995 is applied to satisfy the city's water rights requirements, it shall not be subject to the native raw water storage fee, notwithstanding the provisions of subsection A. above.

C. When water bank credit is applied to satisfy the city's water rights requirements, the person applying the credit may choose not to pay the native raw water storage fee set forth above, in which case the value of the credit shall be decreased in accordance with the table set forth in subsection B. of Section 19.04.018.

Section 5. That as provided in City Charter Section 4-9(a)(7), this Ordinance shall be published by title only by the City Clerk after adoption on second reading unless the Ordinance has been amended since first reading in which case the Ordinance shall be published in full or the amendments shall be published in full. This Ordinance shall be in full force and effect ten days after its final publication, as provided in City Charter Section 4-8(b).

ADOPTED this 17th day of July, 2012.

Cecil A. Gutierrez, Mayor

ATTEST:

City Clerk Deputy

CITY OF LOVELAND SEAL COLORADO

APPROVED AS TO FORM:

Assistant City Attorney

I, Teresa G. Andrews, City Clerk of the City of Loveland, Colorado, hereby certify that the above and foregoing Ordinance was introduced at a regular (or special) meeting of the City Council, held on July 3, 2012 and was initially published in the Loveland Daily Reporter-Herald, a newspaper published within the city limits in full on July 7, 2012 and by title except for parts thereof which were amended after such initial publication which parts were published in full in said newspaper on July 21, 2012.

City Clerk

Effective Date: July 31, 2012

Appendix B

SUMMARY OF WATER RIGHTS DEDICATION AND REQUIREMENTS

The following water rights requirements are set forth in Ordinance #5691, which was adopted on July 17, 2012. The provisions of Ordinance #5691 went into effect July 31, 2012. This document summarizes the City's water rights requirements; it is not intended to replace Chapter 19.04 of the Loveland Municipal Code. Any conflicts should be resolved in favor of Chapter 19.04, available at the City's website at: http://www.cityofloveland.org/government/municipal-code or http://online.encodeplus.com/regs/loveland-co/doc-viewer.aspx#secid-3743

Satisfying the Water Rights Requirement

- The City requires that at least 50% of every raw water payment be made with Colorado-Big Thompson units (CBT), existing Cash Credits in the Water Bank, or Cash-In-Lieu (CIL). See "50% Rule" set forth in Municipal Code Section 19.04.040 for more details.
- Current CBT value: 1 CBT unit = 1.00 acre-foot (may be subject to change)

Native Water:

- No native ditch water rights shall be accepted by the City without approval by the Loveland Utility Commission (LUC).
- These values may be subject to change at any time at the City's sole discretion.

Native Ditch Right	Value WITH Payment of Native Raw Water Storage Fee(1)	Native Raw Water Storage Fee per Acre-foot	Value WITHOUT Payment of Native Raw Water Storage Fee(2)
Barnes Ditch(3)	3.32 acre-feet per inch	$5,750	0.86 acre-feet per inch
Big Thompson Ditch & Manufacturing Company	186.57 acre-feet per share	$3,530	70.90 acre-feet per share
Buckingham Irrigation Company (George Rist Ditch)	6.36 acre-feet per share	$7,400	0.38 acre-feet per share
Chubbuck Ditch(3)	2.94 acre-feet per inch	$7,400	0.41 acre-feet per inch
Louden Irrigating Canal and Reservoir Company	12.17 acre-feet per share	$6,850	2.43 acre-feet per share
South Side Ditch Company	4.55 acre-feet per share	$6,770	1.46 acre-feet per share

(1)(2) Average yield(1) and firm yield(2) for ditch credits as determined by the 2011 Spronk Report
(3) The City no longer accepts deposits of Barnes and Chubbuck Ditch. Those values only apply to ditch rights already dedicated to the City's water bank.

- The Native Raw Water Storage Fee is applicable to all native water deposited in the Water Bank on or after July 21, 1995.
- The above table (column 3) indicates the storage fees associated with each ditch. Those fees are due when the water bank credit is applied to development, not when the shares are put into the Water Bank.

Cash-in-Lieu (CIL) Price:

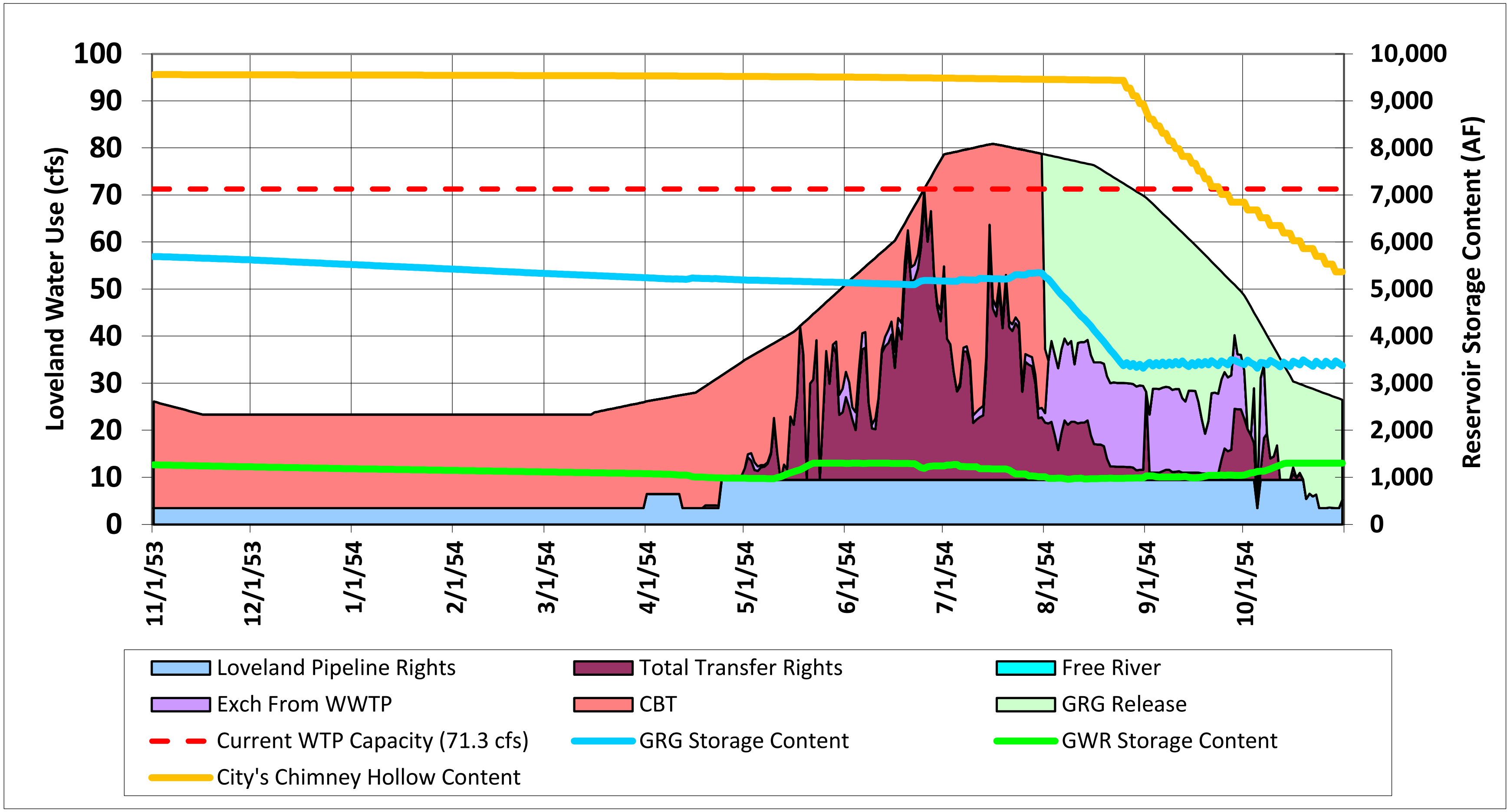
- CIL Price = Market Price of one CBT unit, as set by the LUC, divided by the yield of one CBT unit as set forth in Section 19.04.018.C (see "Current CBT Value," above).
- Credit in the City's water bank may not be acquired from the City by cash purchase on or after January 1, 2006.
- Call Nathan Alburn at (970) 962-3718 for the current CIL Price. This Price may be subject to change at any time.

Appendix C

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 1954

Firm Annual Yield = 30,150 + 590 = 30,740 AF

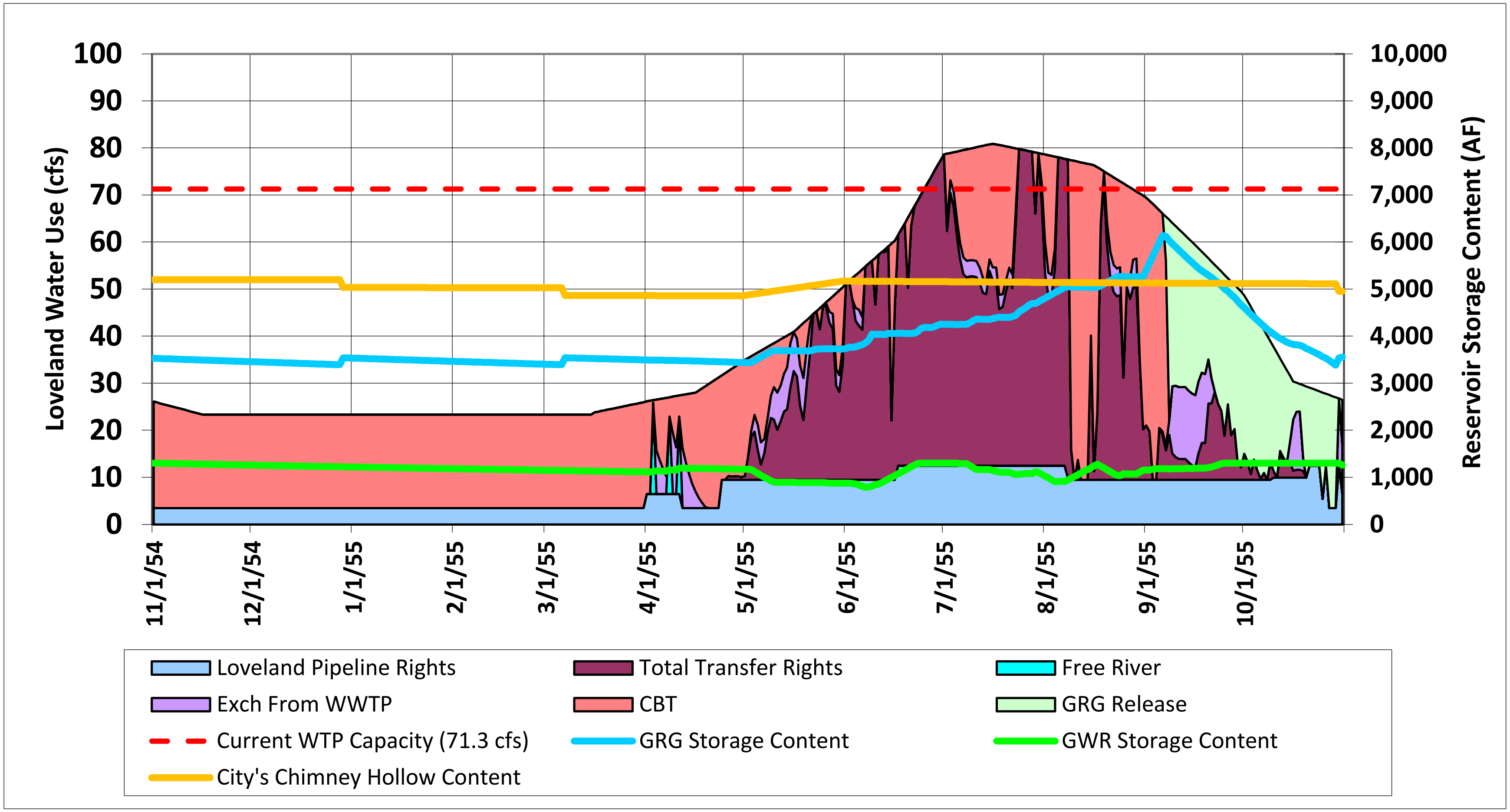


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 1955

Firm Annual Yield = 30,150 + 590 = 30,740 AF

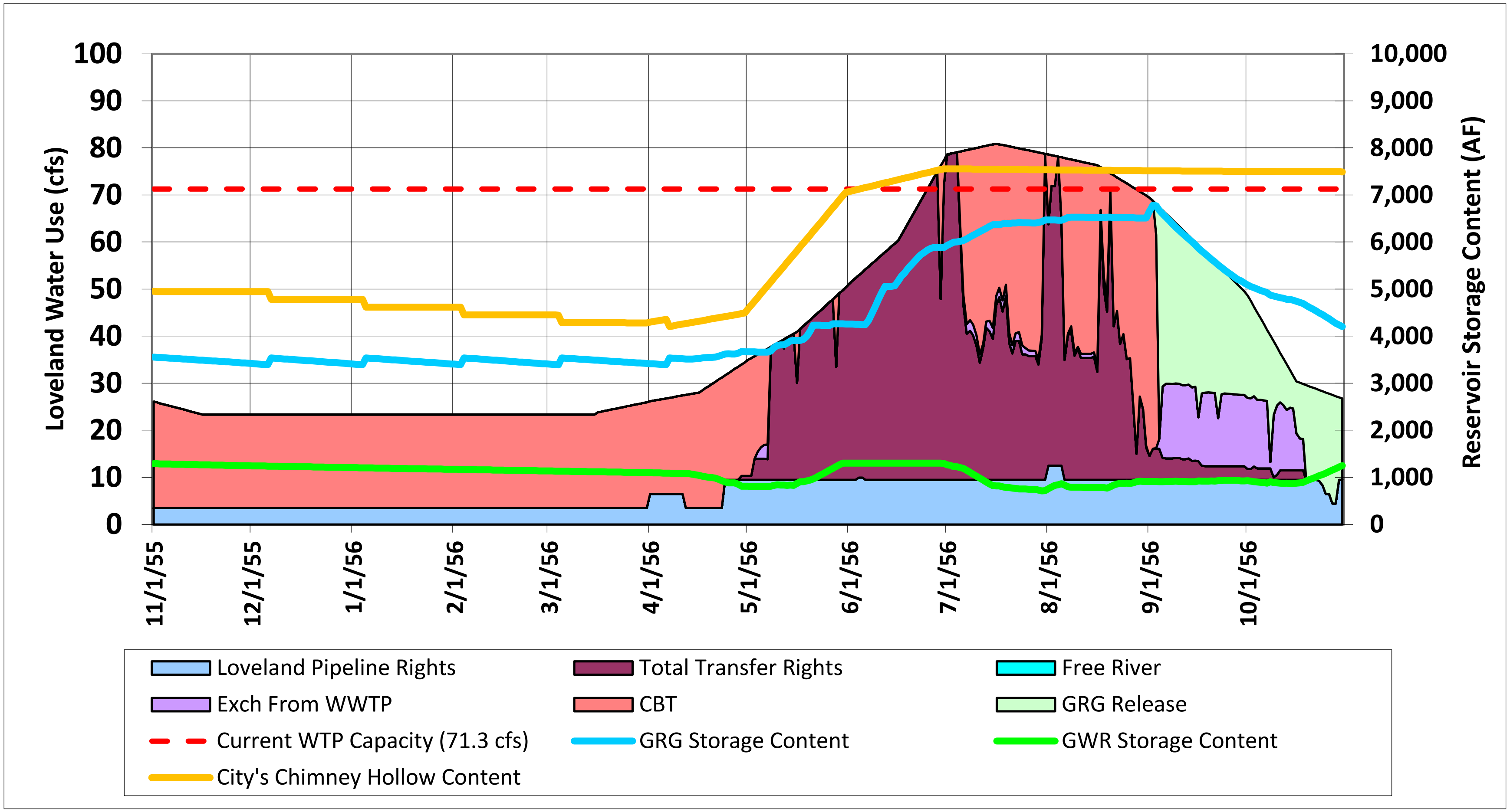


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 1956

Firm Annual Yield = 30,150 + 590 = 30,740 AF

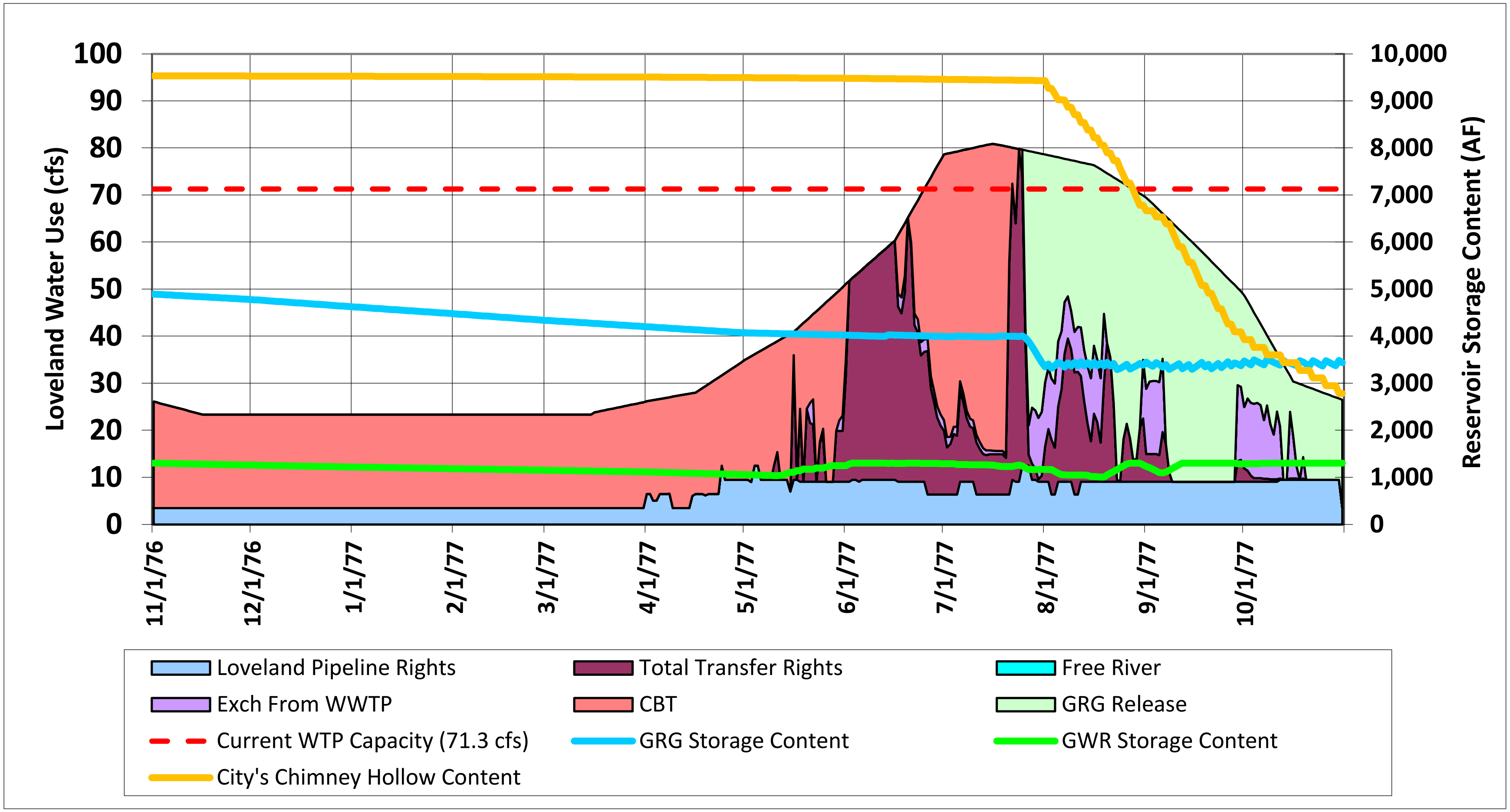


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 1977

Firm Annual Yield = 30,150 + 590 = 30,740 AF

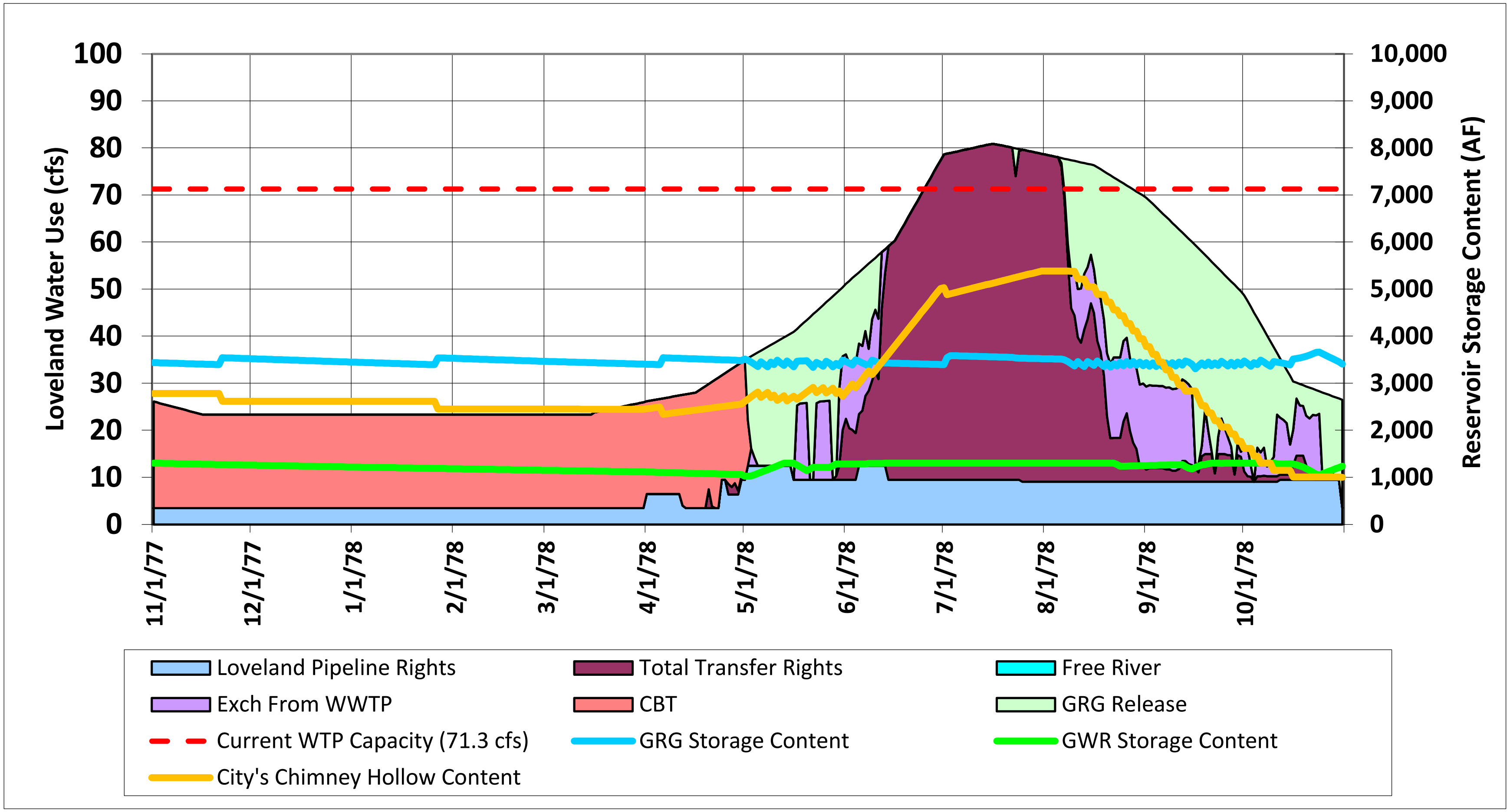


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 1978

Firm Annual Yield = 30,150 + 590 = 30,740 AF

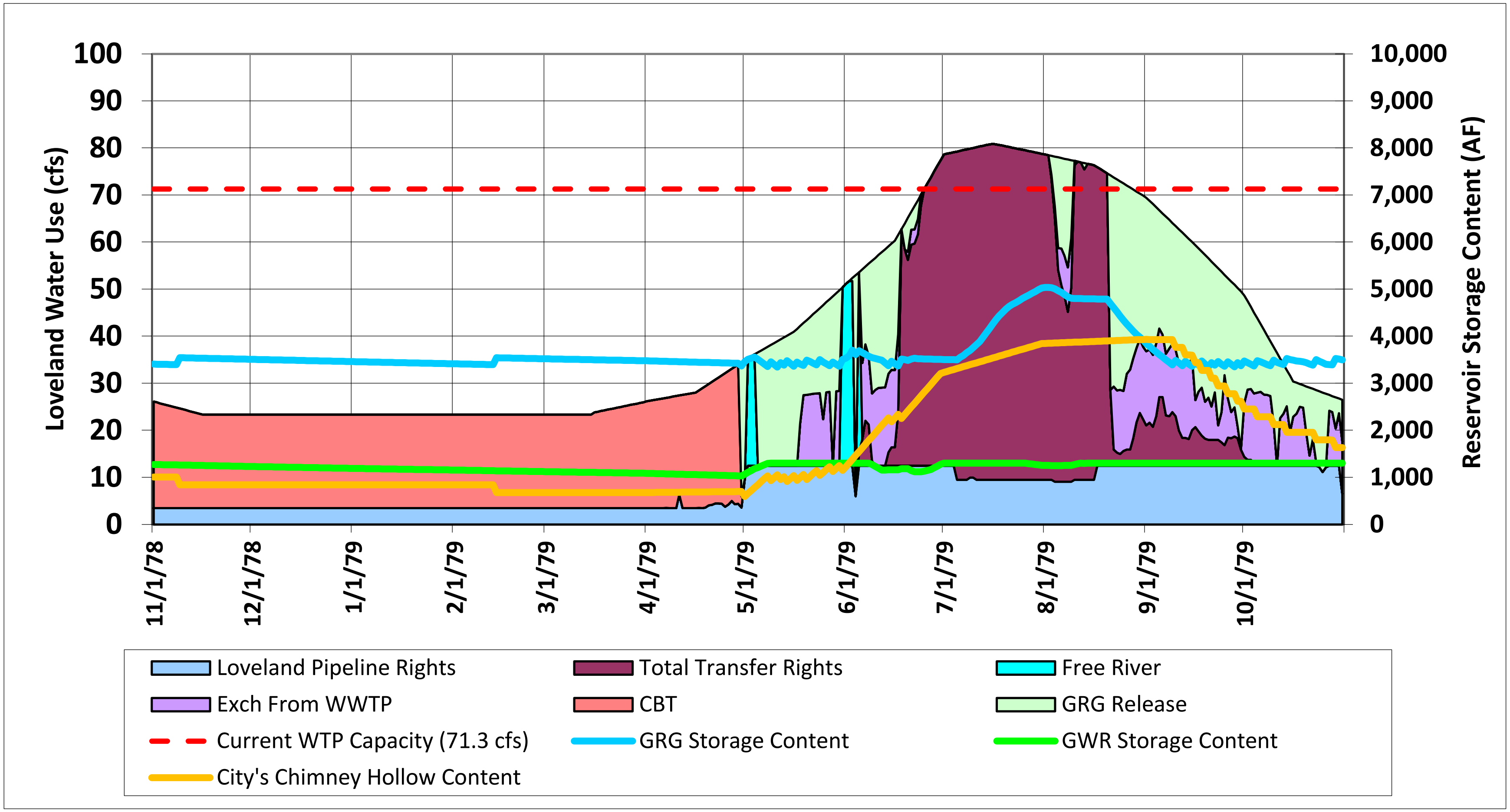


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

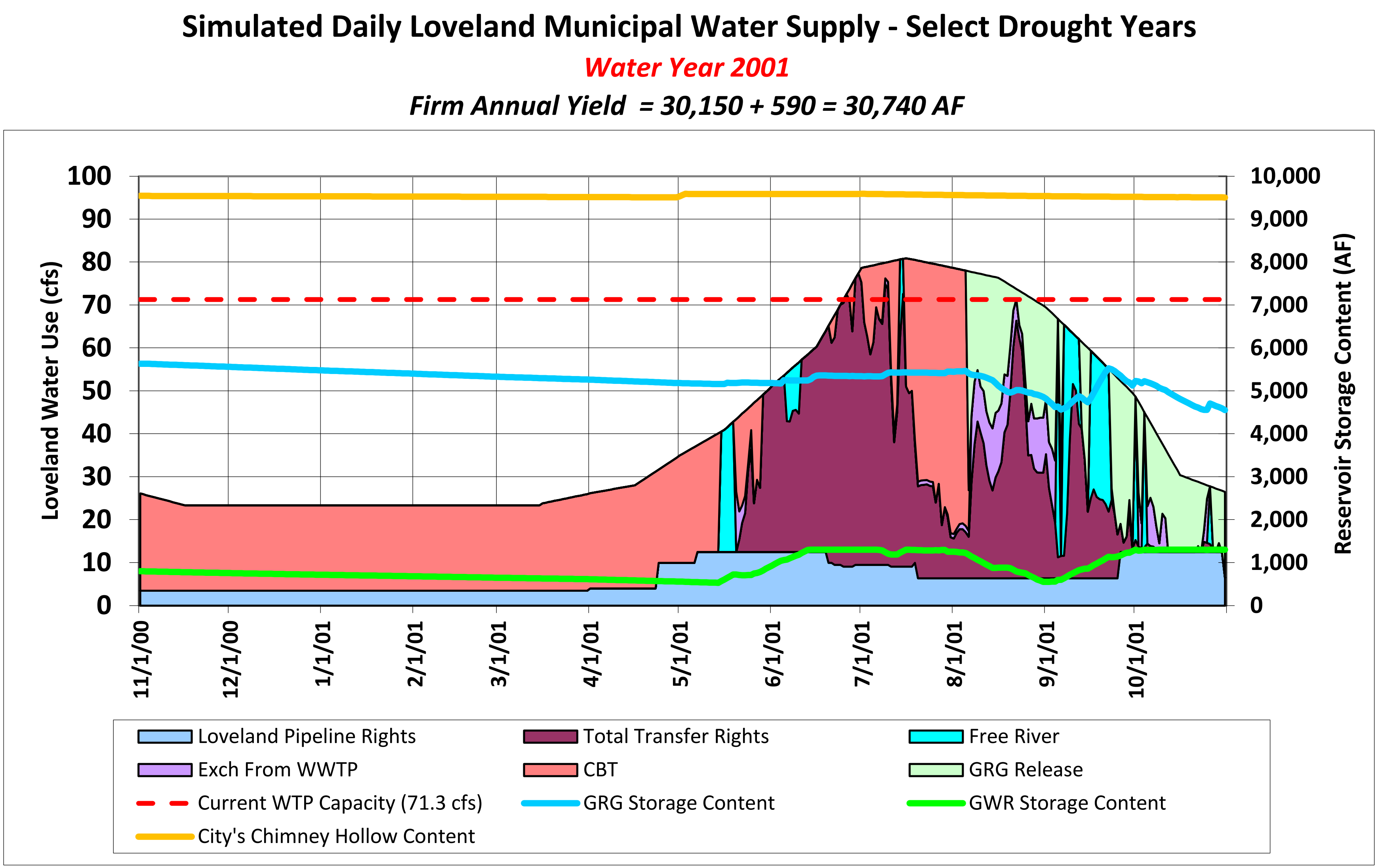
Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 1979

Firm Annual Yield = 30,150 + 590 = 30,740 AF



Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

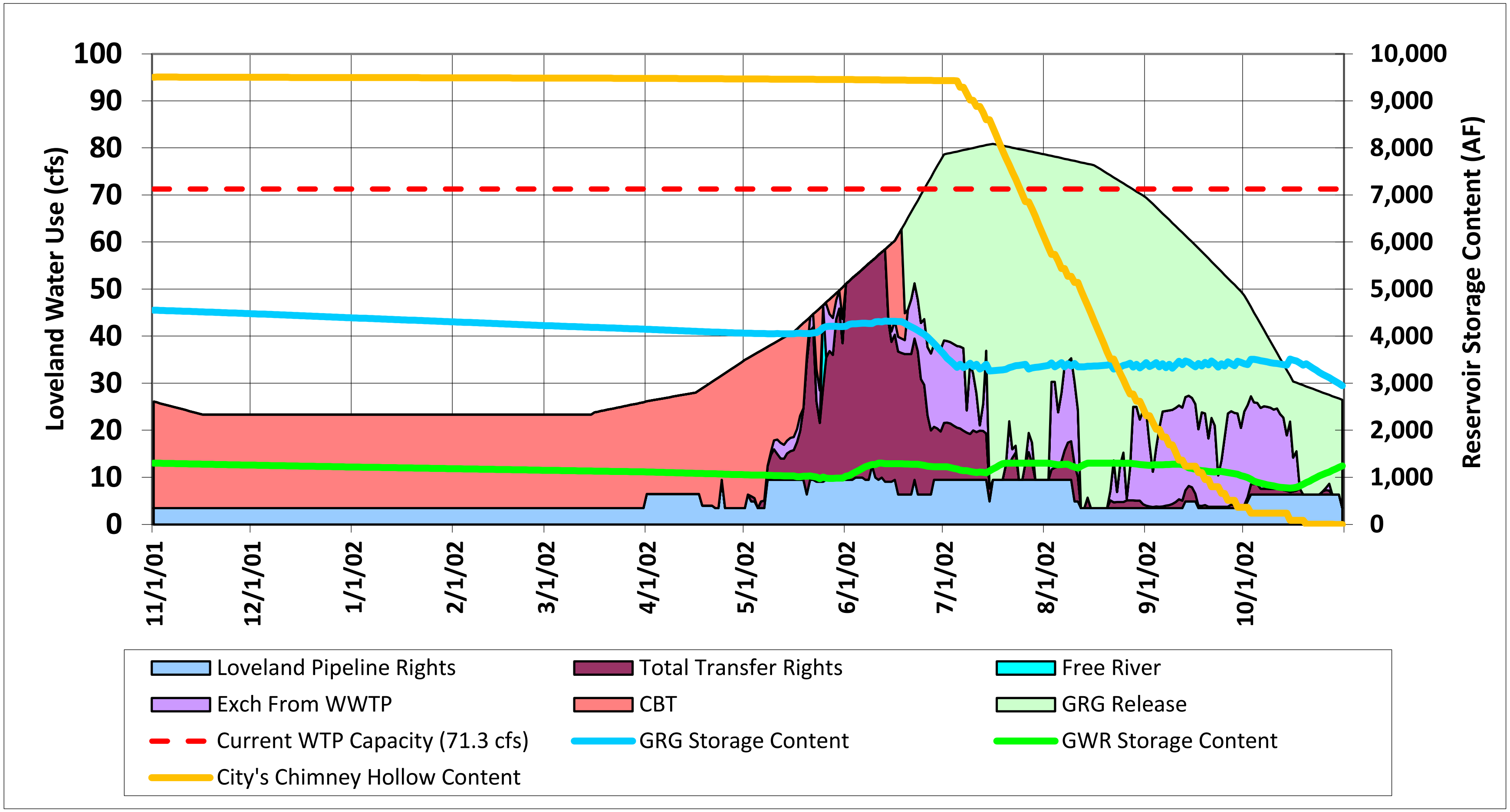


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 2002

Firm Annual Yield = 30,150 + 590 = 30,740 AF

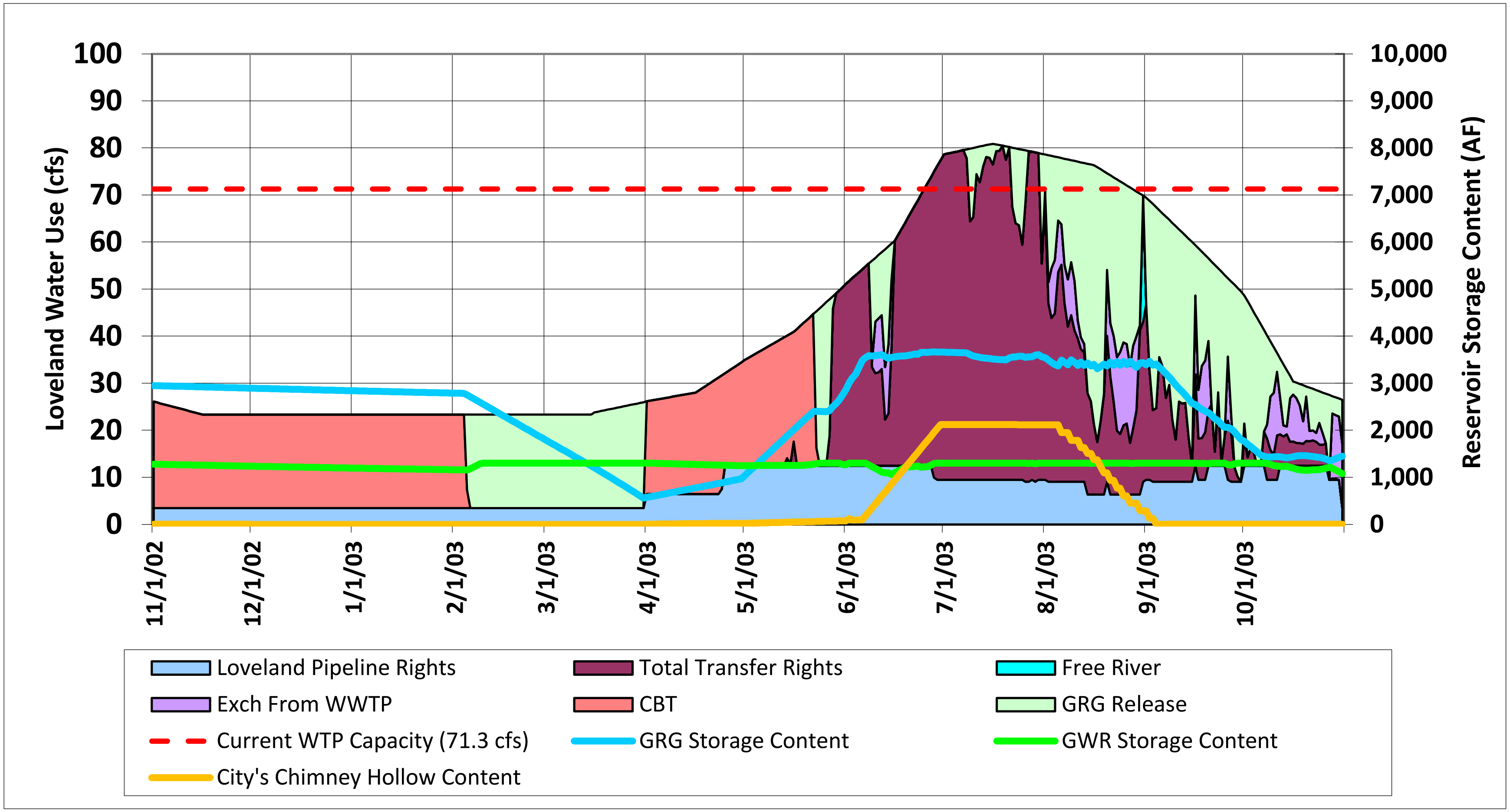


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 2003

Firm Annual Yield = 30,150 + 590 = 30,740 AF

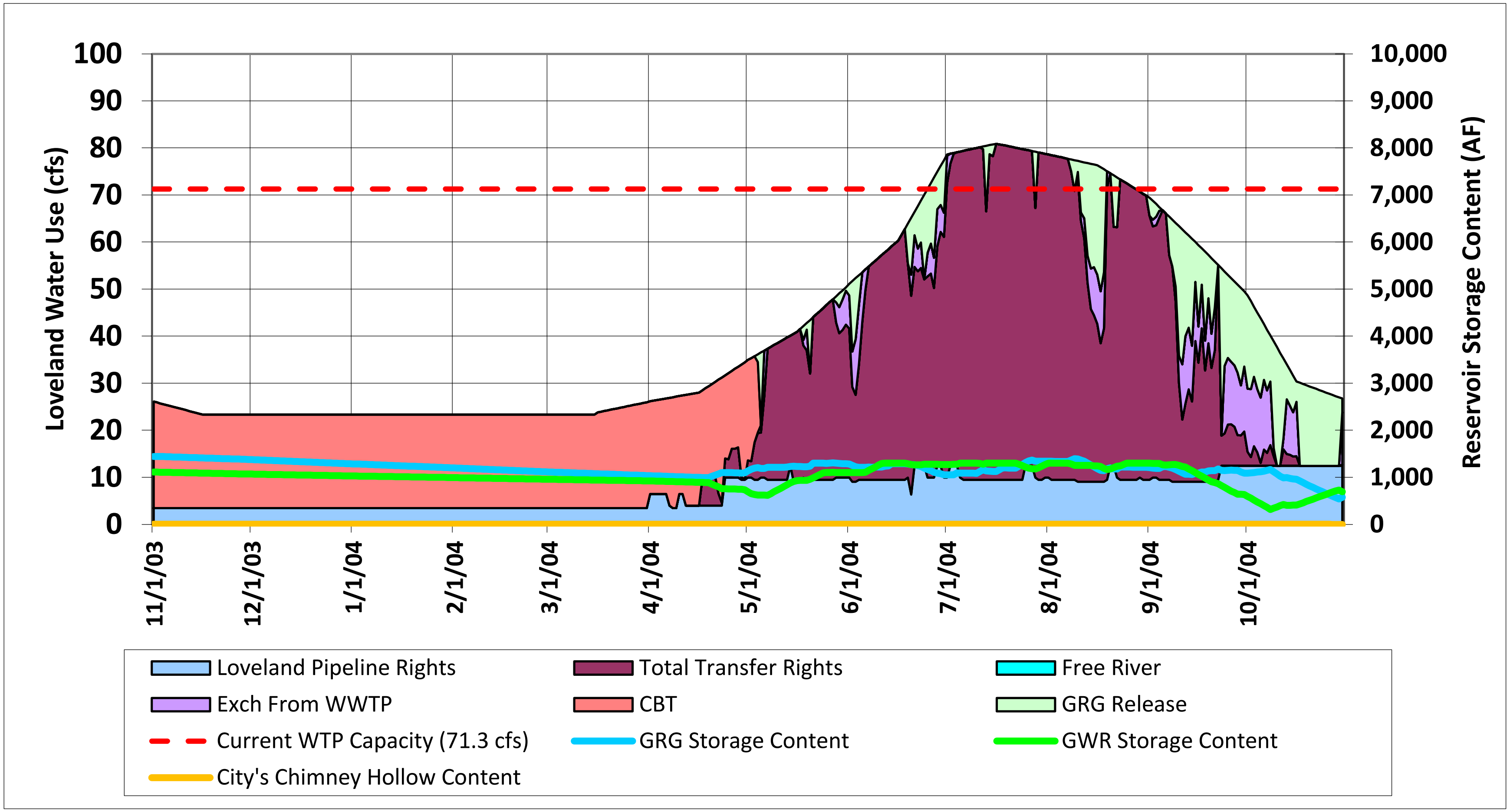


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

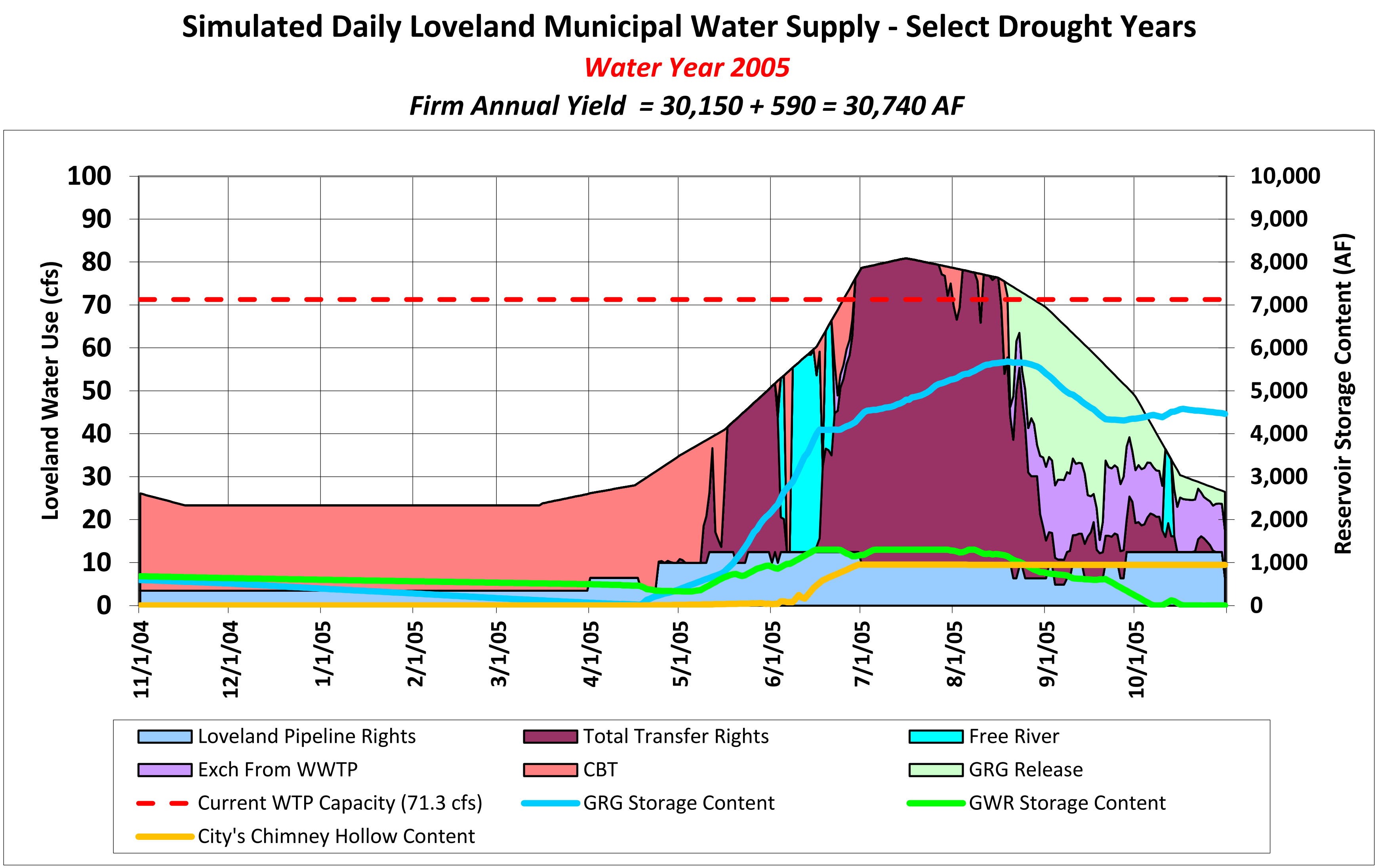
Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 2004

Firm Annual Yield = 30,150 + 590 = 30,740 AF



Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

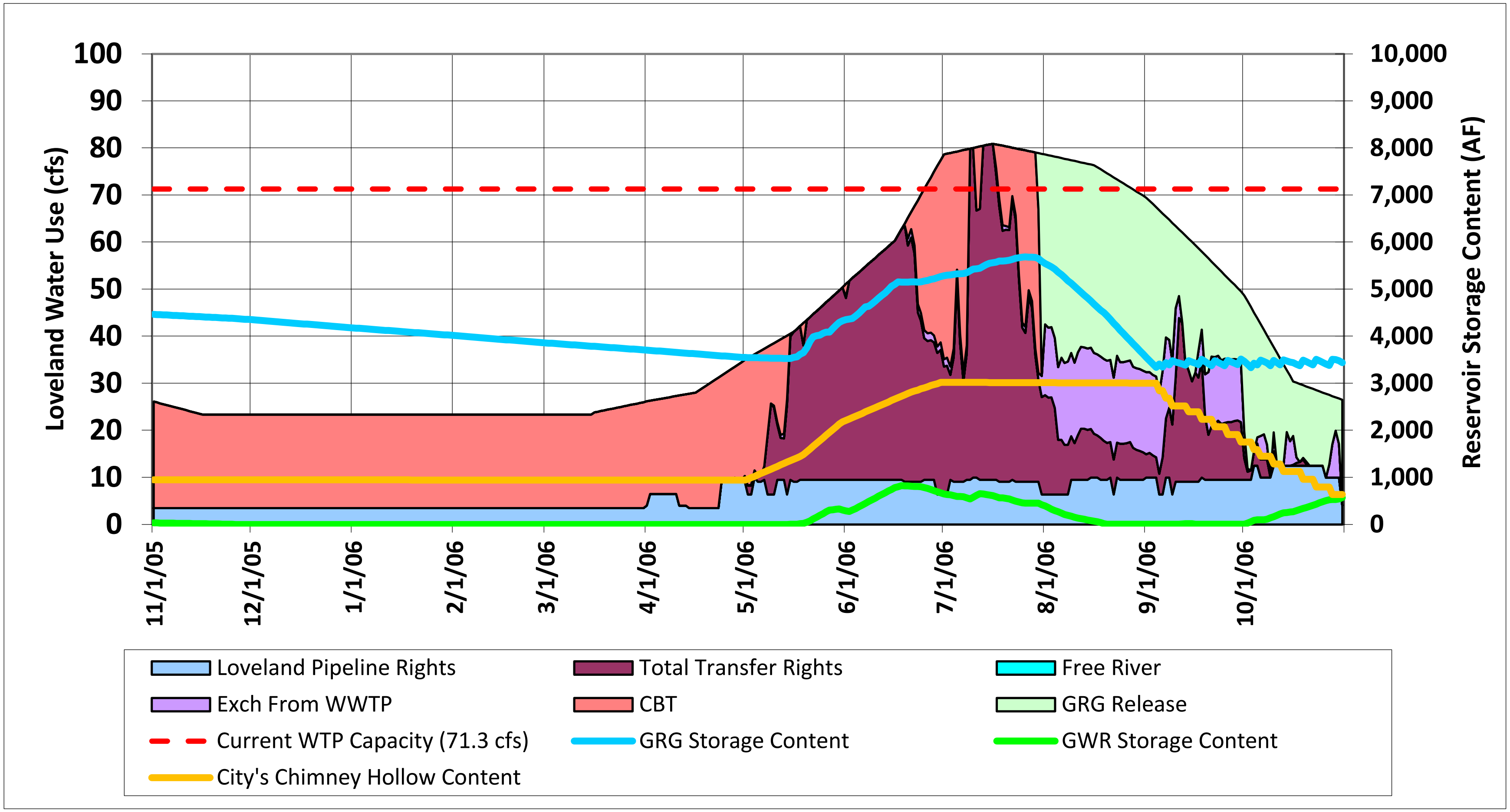


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 2006

Firm Annual Yield = 30,150 + 590 = 30,740 AF

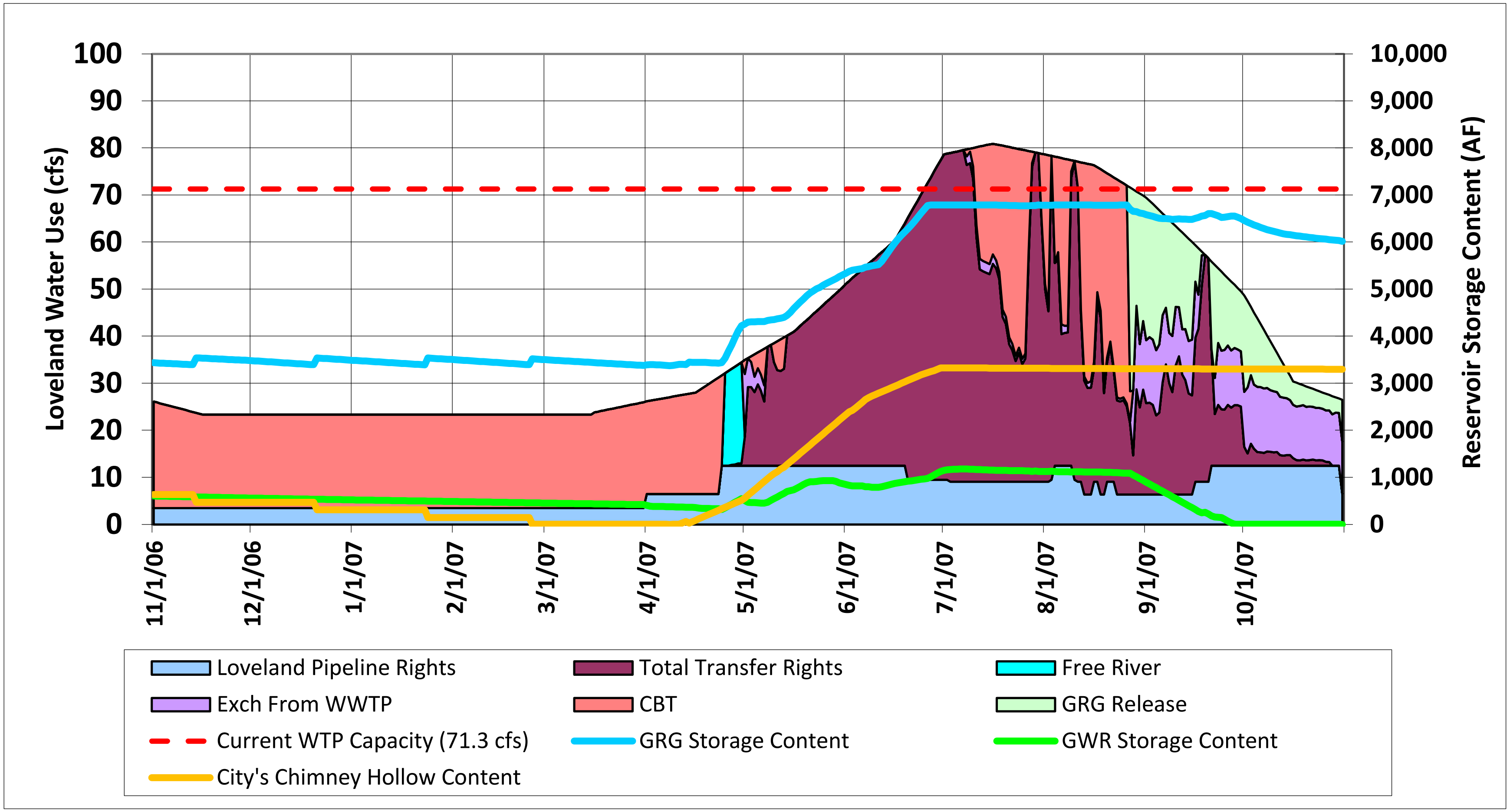


Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met

Simulated Daily Loveland Municipal Water Supply - Select Drought Years

Water Year 2007

Firm Annual Yield = 30,150 + 590 = 30,740 AF



Current Run = 2019 BASE RUN, All Municipal and Augmentation Demands Met