ArkDSS Memorandum
Final

To: Bill Tyner and Kelley Thompson, Colorado Division of Water Resources

From: Wilson Water Group

Subject: Task 2.1 – Interview Water Users and Providers
Ground Water Demands and Major Augmentation Plans below Pueblo Reservoir

Date: April 2019

INTRODUCTION

One of the Task 2 objectives is to:

> *Develop and document an understanding of the operations of key water use facilities in the basin in order to facilitate modeling and to support selected data needs for the ArkDSS effort. This understanding will be developed through interviews with DWR personnel, major water users, including operators of large canal and reservoir systems and representatives of federal facilities.*

This memorandum provides notes from the December 11, 2017 meeting with Division 2 staff regarding ground water demands and major augmentation plans below Pueblo Reservoir. The objective of the meeting was to gain the understanding necessary to develop the augmentation plan operating rules required for StateMod and collect any user-data that does not exist in HydroBase specific to well pumping and replacement. Information in this memorandum is believed to be accurate for water planning and modeling purposes; however this information should not be relied upon in any legal proceeding.

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Several aspects of ground water administration and augmentation were discussed during the meeting. The discussion, however, focused on ground water depletions for irrigation purposes within the H-I Model area and replacement supplies (i.e. augmentation) provided through Rule 14 plans for the three major well associations in the basin: Arkansas Groundwater Users Association (AGUA), Colorado Water Protective & Development Association (CWPDA) and the Lower Arkansas Water Management Association (LAWMA). As such, this memorandum outlines the process used by Division 2 staff to administer wells and replacement supplies for these well associations.

For more information:

- Additional information on augmentation demands and supplies upstream of Pueblo Reservoir is presented in the ArkDSS Upper Arkansas Water Conservancy District memo.
- Additional information on augmentation demands and supplies within the Lower Arkansas Valley Water Conservancy District service area is presented in the ArkDSS Lower Arkansas Valley Water Conservancy District memo.

Meeting Attendance

The meeting was held at the Division of Water Resources Office in Pueblo. The following people attended the meeting:

- Charles DiDomenico, Augmentation Plan Coordinator
- Bethany Arnold, Division 2 Water Resources Engineer
- Kelley Thompson, DWR, Lead Modeler
- Bill Tyner, Division 2 Division Engineer
- Rachel Zancanella, Division 2 Assistant Division Engineer
- Scott Cuthbertson, Deputy State Engineer
- Kara Sobieski, Wilson Water Group
- Lisa (Wade) Brown, Wilson Water Group

ADMINISTRATION OF WELLS

Administration of well pumping along the Arkansas River between Pueblo Reservoir and the Stateline (H-I Model area) follows the rules outlined in the Amended Rules and Regulations Governing the Diversion and Use of Tributary Ground in the Arkansas River Basin (Use Rules). The Use Rules apply to diversions of tributary ground water within the H-I Model area, excluding wells that produce water (e.g. coal bed methane wells) or wells that pump from Designated Basins, the Denver Basin aquifers, or along tributaries hydrologically disconnected from the Arkansas River. The Use Rules outline several rules and regulations that guide administration of wells in the basin:

- **Rule 3** addresses ground water depletions affecting the Usable Stateline Flow including considerations for depletions from pre- and post- Compact ground water rights, determination of depletions using the H-I Model, and requirements of plans to provide replacement supplies for out-of-priority depletions.

- **Rule 4** addresses ground water depletions in both the Arkansas River and Fountain Creek alluvium that affect senior surface water rights. This rule outlines the presumptive stream depletions based on the use and irrigation type:
    - 30 percent for ground water used as a 50 percent or less supplemental supply for flood/furrow irrigation. The presumptive stream depletion factor increases by 3 percent for every 10 percent decrease in the amount of surface water supply used (e.g. surface water use of 40 to 49 percent results in a 33 percent presumptive stream depletion factor, 30 to 39 percent results in a 36 percent factor).
    - 50 percent for ground water used as a sole supply for flood/furrow irrigation.
    - 75 percent for ground water used as sole supply for sprinkler[1] irrigation.

  Rule 4 also allows for annual review of the depletion factors by the Division Engineer and revision, if necessary, to prevent injury to senior water users or the Usable Stateline Flow.

  It should be noted that following the 2002 and 2003 drought years, when it appeared Colorado might fall short in replacing stateline depletions for the first ten year compliance period (1997-2006), the supplemental flood depletion factor was increased for all supplemental wells to 39 percent. This factor has been evaluated annually from that point forward pursuant to the procedure in Amended Appendix A.4 of the decree in Kansas v. Colorado, potentially resulting in annual changes to the supplemental flood depletion factor.
- **Rule 14** addresses information required for and condition of approval of plans to divert tributary ground water, referred to as "Rule 14 plans". Information required in a Rule 14 plan is outlined in Rule 13 and Rule 14 of the Use Rules and includes:
    - Well user contact information
    - Well permit/registration information
    - Ground water right information
    - Well use information, and if used for irrigation, inclusion of supply type and irrigation method
    - Estimates of well pumping and amount, timing, and location of associated depletions, based on the Rule 4 criteria
    - Source of water used as an augmentation supply
    - Description of how out-of-priority depletions to senior water rights in Colorado and depletions to Usable Stateline flows will be replaced under the plan.

[1] Although not outlined directly in the Use Rules, drip irrigation is assumed to be 100 percent depletive by Division 2 staff.

The Use Rules also address responsibilities of the Division 2 staff, including criteria for determining the adequacy of augmentation supplies and curtailment of well pumping if out-of-priority diversions are not fully augmented.

The following sections summarize the process used by Division 2 staff to administer well pumping in the H-I Model area, and how that process and information will be represented in the ArkDSS modeling effort. For purposes of the modeling effort, Rule 3 depletions and Rule 14 replacement plans will be referred to herein and represented in the model as augmentation plan demands and supplies.

AUGMENTATION DEMANDS

Augmentation demands can be defined as out-of-priority stream depletions caused by tributary well pumping. Developing and accounting for augmentation demands is a multi-step process and requires the following information:

- **Well Pumping**: Pumping volumes, recorded on a monthly time-step, for each well reported by the well user or by a well association or as determined from power company records for wells that are measured with a power coefficient.
- **Presumptive Depletion Factors**: Defines the amount of pumping consumptively used and the amount that will return back to the river.
- **Unit Response Functions**: Defines the location and timing of the well depletions on the river.
- **Ground Water Rights:** Determines if the stream depletion is in or out-of-priority.

In general, Division 2 staff determines a presumptive depletion factor based on well use information and applies that factor to the recorded pumping for each well. This resulting volume of water reflects the amount of pumped water that will deplete the stream; the remainder is assumed to return to the river. A unit response function is then applied to the depletive amount to determine the timing and location (i.e. “lagged affect”) of the depletion on the stream. If the depletion impacts the stream when there is a senior call on the river or depletes Usable Stateline Flows, it becomes an augmentation demand and well users must replace or augment that depletive amount.

Division 2 staff uses the Ground Water Accounting Model (GWAM) for irrigation wells to apply the URF patterns to the well depletions; aggregate lagged depletions from current and historical pumping by river reach; determine if the depletion is out-of-priority; and determine the augmentation demand by river reach in the H-I Model area. The following sections explain the process Division 2 currently uses to develop the augmentation demand.

Well Pumping

Since 1994, pumping records on a monthly time-step have been required for active wells. In practice, a majority of individual well users join well associations such as AGUA, CWPDA, and LAWMA and the associations then compile the well meter readings for their members and submit them to the Division 2 office. Historically, well records were based on power records and coefficients, however, well associations and well owners have transitioned primarily to totalizing meters because they provide more accurate and up-to-date values than the power records and require less frequent calibration. Currently, less than 10 percent of the well records are based on power consumption coefficients. Division 2 staff quality controls the data by checking for negative numbers, comparing the current pumping to historical pumping for each well, and checking for errant data points. Division 2 staff also collects power records directly from the power company, which they use as an additional check on the well meter readings. However, the power records are based on the power company's billing cycle, which generally does not align with the accounting that the Division Office needs. Division 2 uses an Access Database to account for wells and well pumping.

Figure 1 reflects the total annual well pumping and depletions in the Arkansas River Basin over the 2012 to 2016 period. Depletions generally average approximately 65 percent of well pumping. The decline in well pumping in 2013 is due more to the lack of augmentation supplies immediately following the 2012 dry year, as opposed to a decrease in the number wells in the basin. As discussed above, many well users are enrolled in of one the three large well association plans in the basin. Figure 2 reflects the total pumping in the Arkansas River basin grouped by well association plan.

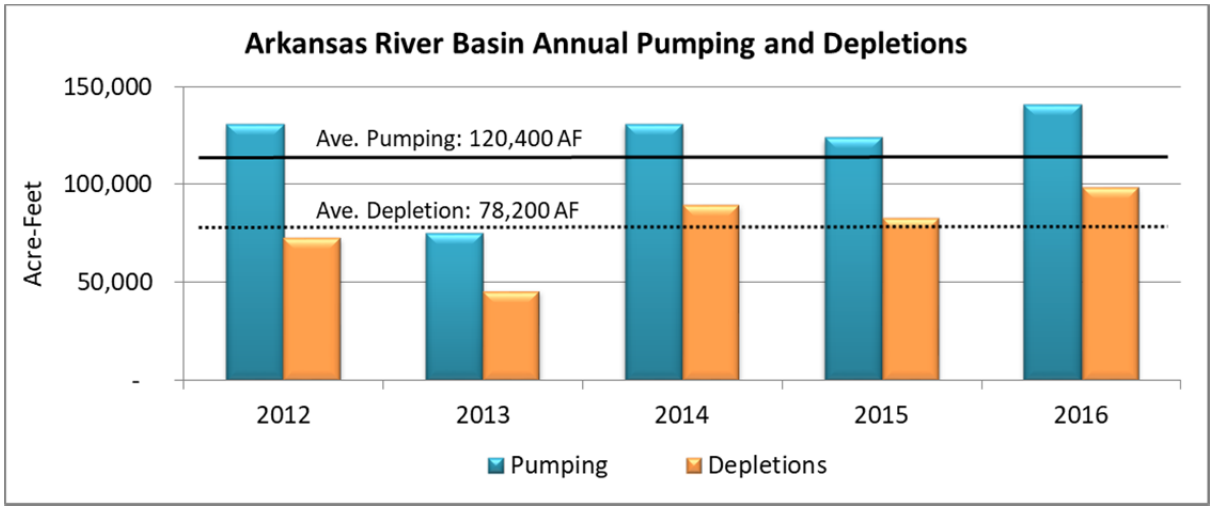

Figure 1: Arkansas River Basin Annual Pumping and Depletions

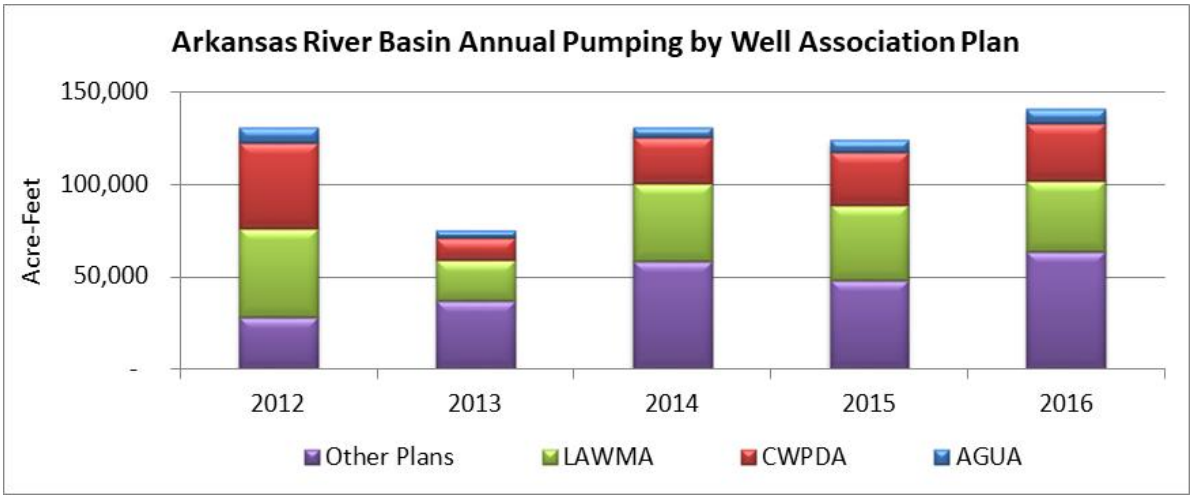

Figure 2: Arkansas River Basin Annual Pumping by Well Association Plan

In general, Division 2 accounts for well pumping by individual well meter, with one record per well. However, some well pumping is used for multiple uses, or all of the pumping does not generate the same augmentation demand (i.e. pumping applied through different irrigation methods with different depletion factors). When this occurs, Division 2 staff accounts for the pumping under separate records using separate "Measuring Points" to associate the individual records to the original well. This occurs for less than 5 percent of the total wells in the basin.

Pumping records are generally available in HydroBase for decreed tributary wells for the 1999 to current period. Pumping records for wells within the H-I Model area over the 1994 to 1998 period are digitized and available from Division 2 in Access database format and will be included in HydroBase as part of the ArkDSS data gathering effort. Additionally, historical pumping estimates within the H-I Model area back to 1950 were developed to support Compact litigation. Initial quality control on these earlier records has been performed and they can be used to support or review modeling efforts; however since they are estimated, there is no plan to incorporate the records into HydroBase.

Presumptive Stream Depletions

As discussed above, Rule 4 outlines the Presumptive Stream Depletion factor used to calculate the amount of depletions generated from pumping in any given well. The depletion volume each well is assessed is based on the recorded well pumping and the presumptive depletion factor for the use of the well water. The basic use types for presumptive stream depletion factors are domestic, irrigation, and industrial. As discussed in the Well Pumping section, wells with multiple uses are currently tracked by use type and the appropriate depletion factor is applied to the pumping amount for each use type. Historically, however, multiple uses were not tracked separately and the primary water use of the well was used when applying a depletion factor.

The presumptive depletion factor for irrigation depends on the irrigation method (e.g. flood, sprinkler, drip) and whether the well is the sole water source or provides a supplemental supply. Depending on the irrigation method, the presumptive depletion factor can vary by month. The presumptive depletion factor for each well is assigned and tracked in the Division 2 Access database.

Table 1 summarizes the presumptive stream depletion factors used for the 2016 accounting of well pumping and depletions by the Division 2 staff, organized by use type.

Table 1: Presumptive Stream Depletion Factors

Use Type	Presumptive Stream Depletion Factor
Irrigation	
Flood/Furrow Irrigation GW <= 50% supply[2]	35.5%
Flood/Furrow Irrigation GW is Sole Supply	50%
Sprinkler Irrigation GW is Sole Supply	75%
Drip Irrigation GW is Sole Supply	100%
Municipal	Varies%
Industrial	100%

Depletions for municipal wells in the lower Arkansas Basin east of Pueblo are determined typically by lagging the full well pumping to the river using Glover parameters for individual wells (sometimes batched in an Excel model). A deduction or "credit" is given for reverse osmosis pre-treatment reject water that is measured back to the river. A base winter use rate is determined using November through February pumping. Outside lawn irrigation uses are estimated as total city supply (net after pre-treatment) less the winter base flow. Lawn return flows are estimated at 18 percent of supply and are lagged to the river using appropriate Glover parameters for the city and deducted from stream depletions caused by well pumping. Measured wastewater treatment plant discharges are also credited against pumping stream depletions.

[2] The presumptive stream depletion factor increases by 3 percent for every 10 percent decrease in the amount of surface water supply used. For example, if surface water supplies 40-49 percent, then the presumptive stream depletion factor of ground water is 33 percent.

For some smaller municipal entities a depletion factor from 39 to 50 percent is applied in lieu of the above calculation and modeling process.

Unit Response Functions

There is typically a delay between when alluvial ground water is pumped and when the depletion impacts the river. Additionally, depletions from ground water pumping can be isolated to a single reach of the river or impact a larger stretch of the river. The timing and location of stream depletions from pumping can be estimated using unit response functions (URF). Unit response functions are generally developed using aquifer parameters and ground water models that estimate how quickly and where depletions impact the river from a unit "stress" on the aquifer. Note that as URFs are based on aquifer parameters, URFs can also be used to estimate the timing and location of accretions to the river resulting from irrigation return flows that accrue sub-surface to the river.

Rule 8 of the Use Rules required that URFs be developed for the alluvial aquifers located within the H-I Model area. As such, the Lower Arkansas River was divided into 21 reaches and URFs were developed for each ditch ("user") in the H-I Model area with respect to the river reaches. Figure provides a graphical representation of the URF zones in the H-I model, Table 2 provides the reach descriptions and Table 3 lists the ditches represented on the illustration.

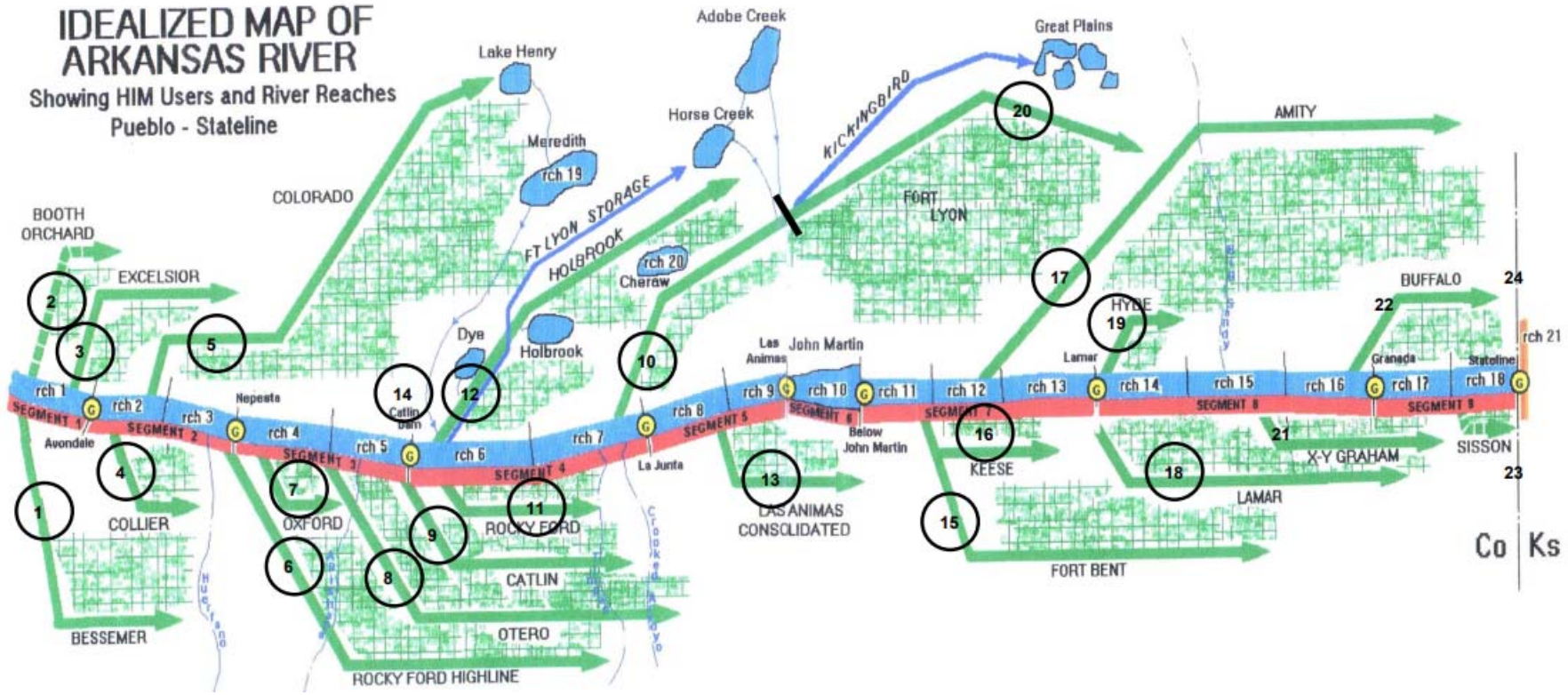

Figure 3: H-I Model Graphical Representation of Users and River Reaches

Table 2: H-I Model River Reaches

Reach	From	To
1	Fountain Crk	Avondale Gage
2	Avondale Gage	Below Colorado CN Div.
3	Below Colorado CN Div.	Nepesta Gage
4	Nepesta Gage	Below Otero CN Div.
5	Below Otero CN Div.	Below Catlin CN Div.
6	Below Catlin CN Div.	Below Ft Lyon Storage CN
7	Below Ft Lyon Storage CN	La Junta Gage
8	La Junta Gage	Below Las Animas CN Div.
9	Below Las Animas CN Div.	Las Animas Gage
10	Las Animas Gage	John Martin Res. Gage
11	John Martin Res. Gage	Below Ft Bent CN Div.
12	Below Ft Bent CN Div.	Below Amity CN Div.
13	Below Amity CN Div.	Lamar Gage
14	Lamar Gage	Below Former Manvel HG
15	Below Former Manvel HG	Below XY Graham HG
16	Below XY Graham HG	Granada Gage
17	Granada Gage	Below Former Sisson-Stubbs
18	Below Former Sisson-Stubbs HG	Stateline
19	Lake Meredith Inflow	
20	Lake Cheraw Inflow	
21	Kansas below Stateline	

Table 3: H-I Model Ditches/Users

User ID	User Name	User ID	User Name
1	Bessemer Ditch	**13**	Las Animas Consolidated
2	Booth-Orchard	**14**	Baldwin-Stubbs Ditch
3	Excelsior Ditch	**15**	Fort Bent Canal
4	Collier Ditch	**16**	Keesee Ditch
5	Colorado Canal	**17**	Amity Canal
6	Rocky Ford Highline	**18**	Lamar/Manvel Canal
7	Oxford Canal	**19**	Hyde Ditch
8	Otero Canal	**20**	Fort Lyon Canal (D/S of John Martin Res.)
9	Catlin Canal	**21**	XY-Graham
10	Fort Lyon Canal (U/S of John Martin Res.)	**22**	Buffalo Canal
11	Rocky Ford Ditch	**23**	Sisson-Stubbs Ditch
12	Holbrook Canal	**24**	Stateline Pumpers

Ditch specific URFs vary in impact, extending up to 240 months and depleting up to eight river reaches. As an example, Table 4 reflects the URF pattern for Rocky Ford Canal, including the percent of depletions that impact each reach each month.

Table 4: Rocky Ford Canal URF

River Reach Impacted by Depletion	Reach 8	Reach 9	Reach 10
Total Percent River Reach Depletion	**42.4%**	**25.8%**	**31.8%**
Month 1	3.6%	1.7%	1.2%
Month 2	6.0%	2.9%	2.3%
Month 3	4.3%	2.1%	2.0%
Month 4	*3.5%*	1.5%	1.7%
Month 5	2.9%	1.2%	1.4%
Month 6	2.5%	1.0%	1.2%
Month 7	2.1%	0.8%	1.1%
Month 8	1.8%	0.7%	1.0%
Month 9	1.6%	0.6%	0.9%
Month 10	1.4%	0.6%	0.8%
Month 11	1.2%	0.5%	0.8%
Month 12	1.1%	0.5%	0.7%
Month 13	1.0%	0.5%	0.7%
Month 14	0.9%	0.4%	0.6%
Month 15	0.8%	0.4%	0.6%
Month 16	0.7%	0.4%	0.5%
Month 17	0.6%	0.4%	0.5%
Month 18	0.6%	0.4%	0.5%
Month 19	0.5%	0.3%	0.5%
Month 20	0.5%	0.3%	0.4%
Month 21	0.4%	0.3%	0.4%
Month 22	0.4%	0.3%	0.4%
Month 23	0.3%	0.3%	0.4%
Month 24	0.3%	0.3%	0.4%
Month 25	0.3%	0.3%	0.4%
Month 26	0.2%	0.2%	0.3%
Month 27	0.2%	0.2%	0.3%
Month 28	0.2%	0.2%	0.3%
Month 29	0.2%	0.2%	0.3%
Month 30	0.2%	0.2%	0.3%

URF patterns are applied to the stream depletions (i.e. well pumping multiplied by the presumptive stream depletion factor) in the GWAM model. The model then adds the lagged depletions from the current month to lagged depletions from previous months and aggregates the lagged depletions by river reach.

Ground Water Rights

As outlined in the Use Rules, wells must have a decreed water right or permit in order to pump from the alluvial aquifer within the H-I Model area unless the well was constructed prior to May 1965. For the purposes of determining augmentation demands, wells with decreed ground water rights senior to December 14, 1948 are considered to be "Pre-Compact" and wells with decreed ground water rights junior to this date are considered to be "Post-Compact". Rule 3 indicates that alluvial depletions within the H-I Model area due to Pre-Compact wells are limited in aggregate to 15,000 af annually (November 1 through October 31). During the Kansas v. Colorado litigation, Colorado produced a table identifying each well recognized as sharing a portion of the 15,000 acre-foot pre-Compact allowance. This allocation was based on well pumping capacity and each well was assigned an allowable depletion amount. Although the Pre-Compact well depletions can deplete the Useable Stateline Flows up to 15,000 af, their depletions must be augmented if the call on the Arkansas River is senior to individual well rights. The Use Rules do not indicate a Post-Compact well depletion annual limitation; however depletions from Post-Compact wells need to be augmented both with respect to the Useable Stateline Flows and senior water users.

As noted above, the GWAM model is used to track the ground water rights for each irrigation well and determines if the lagged depletions are in- or out-of-priority based on the calling right. As surface water irrigation rights commonly place a call within the H-I Model area, ground water rights are generally out-of-priority. During higher streamflow conditions when John Martin Reservoir is the calling right, Pre-Compact well depletions are in-priority and do not need to be augmented. Post-Compact well rights are rarely in priority.

AUGMENTATION SUPPLY

Augmentation supplies can be defined as legally available water allocated to offset an augmentation demand in amount, location, and time. There are three primary methods available to well users to secure augmentation supplies:

- Participate in a Well Association plan operating a Rule 14 replacement plan
- Participate in a small augmentation plan operating under a substitute water supply plan (SWSP) or decreed augmentation plan
- Develop an individual SWSP or decreed augmentation plan

A majority of the well users that currently pump within the H-I Model area participate in one of the three major well association plans; AGUA, CWPDA, and LAWMA. Prior to the implementation of Rule 14 plans, well users more commonly participated in one of the several small or individual augmentation plans in the area. Over time, many of the small augmentation

plans were incorporated into larger well association plans to have access to a larger quantity and variety of augmentation supplies and to share in the cost associated with plan administration and acquisition of new supplies. Some well users have transferred from one well association to another over the years; however this practice is fairly limited. Additionally, well users can participate in more than one well association plan and/or augmentation plan; this is also fairly limited in practice.

As discussed above, well association plans compile and report metered well pumping on behalf of participating well users. With respect to supplies, the well associations develop annual Rule 14 replacement plans that estimate pumping and identify sources of water to be used as augmentation supplies. The associations then submit the annual plan to the Division 2 office and work with DWR staff and water providers in the basin to gain approval of the Rule 14 plan. DWR staff work with the well associations to determine monthly pumping and depletions and account for monthly replacement of depletions using the various sources of replacement water approved for the plans. Monthly meetings are held during the April through November months to discuss and adjust operations. Reconciliation of estimated versus actual pumping, and reporting of actual augmentation supplies used to meet the demand, are compiled annually by Division 2 staff. Augmentation demands and supplies within the H-I Model area are reported in an "Annual Report to Kansas" for Compact compliance purposes. Rule 14 Approval notifications and Annual Reports to Kansas are available on the DWR website.

Sources of augmentation supplies generally include return flows from fully consumable water, releases from reservoirs, consumptive use credits from changed ditch shares, and intentionally recharged supplies. The following sections focus on augmentation supplies for the three largest well associations. In general, these associations and individual augmentation plans meet their augmentation demands using supplies in the following order:

1. Excess supplies (i.e. accretions) from the previous month. Excess supplies from the previous month, if available, are carried forward and applied to the current month's demands.
2. Excess supplies from upstream reaches. If an upstream impact reach has more accretions than depletions, the excess accretions will be charged a transit loss and made available to the next downstream reach.
3. Return flows to the river from fully consumable irrigation return flows. These are generally available from Fryingpan-Arkansas Project water or other transmountain imports.
4. Intentionally created recharge from ponds, gravel pits, or accretions from canal seepage.

5. Ditch shares changed for augmentation purposes. Changed shares are limited to their historical use and therefore are only available during the irrigation season.
6. Fully consumable returns flows or stored water leased from municipalities. These supplies are generally available as effluent and/or lawn irrigation return flows, but can also be available as stored supplies.
7. Reservoir water released for augmentation.

Arkansas Groundwater Users Association (ID 7150)

AGUA provides augmentation supplies for wells primarily in Pueblo County, and also for wells located in Otero, El Paso, and Fremont counties. AGUA is the smallest of the three major well association plans, currently providing annual augmentation supplies to approximately 300 wells. Pumping for the well association averages 6,600 acre-feet in recent years; ranging from approximately 8,600 acre-feet in a drier year with available augmentation supplies (for example 2012) to 4,000 acre-feet in a drier year with limited availability of augmentation supplies (for example 2013). Stream depletions average approximately 55 percent of pumping. Note that the amount of pumping and associated depletions requested annually by AGUA well users (i.e. "ordered") consistently exceeds available augmentation supplies; AGUA is generally able to allocate only about 65 percent of the ordered pumping to the well users annually and the allocation can be as low as 30 percent in water short years.

Due to the locations of the wells covered by AGUA, augmentation demands occur both to the Arkansas River within the H-I Model area and to Fountain Creek. Augmentation supplies on Fountain Creek, accounting for generally less than 20 percent of the total supplies, consist primarily of reusable effluent generated from Denver Basin supplies by Donala Water and Sanitation District and Tri-View Metro District. Augmentation supplies on Fountain Creek also include:

- Lease of approximately 250 af annually of changed Fountain Mutual Irrigation Company (FMIC) shares from Tri-View Metro District; turned back to the river at the FMIC augmentation station.
- Lease of changed Laughlin Ditch shares from Donala Water and Sanitation District; also turned back to the river at the FMIC augmentation station.

Historically, AGUA has also leased effluent from Colorado Springs Utilities; however this lease has not occurred in recent years and is not anticipated as a supply in the near future. Augmentation supplies from these sources are assigned a transit loss based on the Fountain Creek transit loss model and shepherded to the Arkansas River.

The remainder of AGUA's augmentation demand is on the Arkansas River; generally depleting Reaches 1 through 7 (refer to Figure). For these reaches, AGUA relies first on fully consumable irrigation return flows from Project supplies and second on changed ditch shares in Excelsior Ditch (1400539) and Mexican Ditch (1500585). AGUA generally receives on average 15 percent of available Project irrigation return flows for use as an augmentation supply annually. Project return flows can be used in the river reach they accrue to or shepherded to downstream reaches, but cannot be exchanged to other reaches or stored for future use by the well associations. The annual allocation of Project return flows are based, in part, on the overall allocation of Project supplies to irrigators.

AGUA owns approximately 54 percent of Excelsior Ditch, with the remaining 46 percent owned by Stonewall Springs Quarry, who is also an AGUA member. Shares owned by the quarry are pooled by AGUA to serve all AGUA members, including the quarry who receives a reduced annual augmentation cost. Excelsior Ditch (1400539) diverts from the Arkansas River east of the Town of Pueblo under two direct water rights; 20 cfs with an 1887 priority and 40 cfs with an 1890 priority. The ditch historically irrigated 1,762 acres north of the river. Case No. 04CW62 changed the use of the total Excelsior Ditch direct flow water rights to include augmentation, including a right to recharge. The decree allows AGUA to use their changed shares, as well as Stonewall shares, as a supply under a Rule 14 plan through diversion at the Excelsior Ditch Augmentation Station, storage in Excelsior Recharge Ponds, or storage in AGUA's Excess Capacity Account in Pueblo Reservoir. In practice, AGUA generally exchanges the consumptive use portion of the changed shares for storage in Pueblo Reservoir and uses the recharge ponds to meet winter return flow obligations and stream depletions. Per the terms of the decree, acreage served by surface water diversions has been dried up and re-vegetated or is re-irrigated by well water from wells in various court decreed augmentation plans, and diversions recorded through the Excelsior Ditch reflect diversions to augmentation and/or recharge.

AGUA can also divert leased excess augmentation supplies from Pueblo Water, delivered from Pueblo Reservoir, at the Excelsior Ditch and account for them directly at the augmentation station or re-time them in the recharge ponds.

AGUA does not have direct ownership in Mexican Ditch; however 25 percent of the water rights changed for augmentation purposes in Case No. 99CW147 are owned by EWSD, who is an AGUA member. The changed shares yield 39.9 af of consumptive use credits annually on average and are considered a "private" augmentation supply; that is the credits are used for the direct benefit of EWSD wells. The Mexican Ditch consumptive use credits are turned out directly to the stream at the augmentation station.

Note that both the Stonewall Springs Quarry and EWSD are currently in the process of obtaining their own augmentation plans using their changed shares in the Excelsior Ditch and the Mexican Ditch, because the changed shares are no longer eligible to be a Rule 14 supply for AGUA.

Remaining augmentation supplies are more variable and rely on "spot-market" supplies within the basin. The following list summarizes additional augmentation supplies that AGUA has obtained and/or used in recent years.

- Continued Farmers Group of Applicants augmentation plan under Rocky Ford Ditch (07CW116). Under this plan, AGUA provides augmentation supplies for these well users and Aurora Water allocates ½ af per acre of augmentation supplies in the form of storage in Pueblo Reservoir. AGUA then integrates this stored amount (440 af on average annually) with the other augmentation supplies it has available.
- Excess reusable credits from Aurora Water generated from irrigation or re-vegetation under the Rocky Ford Ditch; generally 150 af annually.
- Excess Bessemer Ditch credits turned out at the river from St. Charles Mesa Water District (SCMWD); generally 350 af annually.
- Union Ditch (1200835) shares changed for augmentation by two AGUA members; Fremont Schools and Rocky Mountain Materials. Consumptive use credits are turned back to the river at the augmentation station and generate approximately 110 af annually on average.
- Releases from AGUA's Excess Capacity Account in Pueblo Reservoir
- Releases of up to 100 af of Poncha Springs Excess Capacity Account in Pueblo Reservoir

Historically AGUA also relied on excess augmentation credits from the Catlin Canal Augmentation Association; however this augmentation supply is more likely to be used by CWPDA in the future.

Colorado Water Protective & Development Association (ID 7151)

CWPDA provides augmentation supplies for wells located across El Paso, Pueblo, Otero, and Bent counties. CWPDA members' irrigation wells provide sole source and supplemental irrigation water to over 71,000 acres, and CWPDA's municipal members serve the agricultural communities between Fowler and Las Animas and provide water to about 38,000 people[3]. CWPDA currently provides augmentation supplies for over 950 wells. Pumping for the well association varies significantly depending on year type and availability of augmentation supplies; ranging from approximately 13,000 acre-feet in a drier year (2013) to 31,000 acre-feet

[3] Source: CWPDA.org

in an average year (2016). CWPDA pumping averaged 28,600 acre-feet over the 2012 to 2016 period, with average depletions of 17,000 acre-feet.

Approximately 20 percent of CWPDA's augmentation demand depletes Fountain Creek; the remaining demand generally depletes Reaches 1 through 10 (refer to Figure) on the Arkansas River. **Table 5** reflects the general sources and typical annual volume of augmentation supplies secured by CWPDA and their members for use in their Rule 14 plan operations[4]. Note that CWPDA also operates the *Post-85 Well Augmentation Plan* (07CW128) that currently augments approximately 45 af of annual depletions for 13 wells located from Canon City to La Junta. Augmentation supplies from this plan are comprised primarily of annual leases of Pueblo Water source stored in CWPDA's Excess Capacity Account in Pueblo Reservoir and changed ditch shares[5] (approximately 0.4 percent) in the Bessemer Ditch turned out directly to the river at the Avondale Augmentation Station.

Table 5: CWPDA Augmentation Supplies

Replacement Sources Secured by CWPDA		
Source	Location	Typical Annual Supply (af)
Annual Leases from entities such as Board of Water Works of Pueblo (BWWP), Colorado Springs Utilities (CSU), Aurora, Salida, Poncha Springs, St. Charles Mesa, and Woodmoor.	Arkansas River (Supplies typically stored in a CWPDA's Excess Capacity Account in Pueblo Reservoir, or in Lake Meredith / Lake Henry) & Fountain Creek	6,000
Lease with Fountain, Security, & Widefield - Fully consumable replacement supplies originating on Fountain Creek from water rights owned by the municipalities.	Fountain Creek	1,700
Leased Cody Land & Water supplies available for Augmentation Use	Fountain Creek	1,200
Leased FMIC Shares available for Augmentation Use	Fountain Creek	100
Frying Pan-Arkansas Project Return Flows Attributable to Project Water Irrigation by CWPDA's Members on acres within the South Eastern Colorado Water Conservancy District (aka: District Acres)	Arkansas River from Pueblo Reservoir downstream to John Martin Reservoir	5,000
Former Agricultural Water Rights Changed to Include Augmentation Use Under the Bessemer Ditch and Colorado Canal	Arkansas River	70
Total		14,070

[4] Source: Summary of supplies provided by W.W. Wheeler, engineer for CWPDA.
[5] CWPDA owns 87.354 shares (out of 20,000 total shares) in Bessemer Ditch, which were changed to include augmentation use under 07CW127.

Replacement Sources Secured by CWPDA		
Source	Location	Typical Annual Supply (af)
Replacement Sources Secured by CWPDA Members		
Source	Location	Typical Annual Supply (af)
Project Water & Reusable Waste Water Return Flows for Fowler, Manzanola, Sugar City, Swink, La Junta, and Las Animas	Pueblo Reservoir/Arkansas River	4,500
Upper Arkansas Water Conservancy District Leases for Fully Consumable Replacement Supplies	Arkansas River above Pueblo Reservoir	20
Leases from BWWP	Arkansas River (Supplies typically stored in a CWPDA's Excess Capacity Account in Pueblo Reservoir, or in Lake Meredith / Lake Henry	600
Lower Arkansas Water Conservancy District & Olney Springs Leases for Fully Consumable Colorado Canal Replacement Supplies	Arkansas River	100
Agricultural Water Rights Changed to Include Augmentation Use Under the Catlin Canal	Arkansas River	2,000
Total		7,220

Recharge Supplies and Facilities	
Recharge Supplies	Recharge Facilities
• Leased supplies from Fountain Creek sources • Fully consumable leased supplied from BWWP, CSU, and Aurora • Catlin Augmentation Association (CAA) CU Credits obtained under Case No. 12CW0094 • CWPDA's Bessemer Ditch CU credits under Case No. 07CW127	• Rocky Ford Highline Canal (during the non-irrigation season) • Recharge pit supplied under the Rocky Ford Highline Canal • Recharge pits under the Catlin Canal developed by the CAA (Knapp Pond, Diamond A Pond, Gardner Pond) • Catlin Canal (during the non-irrigation season)

Lower Arkansas Water Management Association (ID 7152)

LAWMA is the other large well association in the Arkansas River basin and provides augmentation supplies for wells generally located on the Lower Arkansas River between John Martin Reservoir and the Stateline. LAWMA augmentation supplies are primarily for irrigation use plus some supplies for small municipalities and industrial uses. LAWMA currently provides augmentation supplies for approximately 500 well structures. Each of the three large well associations manage allocations using a "bank well" concept. An assigned pumping and presumptive depletion amount (generally 100 percent) is included in each association's plan application to simulate unassigned pumping and resulting stream depletions. No pumping actually occurs from the "bank wells" and usually the WDID assigned to a bank well is associated with an inactive well in the plan that is not intended to be pumped. This allows each

association to provide for members who over-pump their allocation using timely transfer of approved pumping from the "bank well" to the member well(s). Within each association, pumping allocations can also be traded between members via a transfer process reviewed by DWR staff.

Pumping for the well association varies significantly depending on year type; ranging from 22,000 acre-feet in the 2013 drier year to nearly 40,000 acre-feet in 2016. Average pumping over the 2012 to 2016 period is approximately 36,000 acre-feet with 21,500 acre-feet of depletions. Pumping predominantly depletes Reaches 11 through 18 and the Stateline (refer to Figure) on the Arkansas River. LAWMA determines an annual pumping allocation for each member based on the number of shares owned, the depletion factor assigned to each well use, and availability of augmentation supplies. Leases between members are allowed, and often exercised, to provide additional pumping allocation to members that may need it.

LAWMA has developed a large water rights portfolio, purchasing irrigated acreage in several ditches and changed the water rights associated with shares in those ditches for augmentation purposes. LAWMA relies primarily on the water generated from these changed shares for augmentation supplies. LAWMA also receives a relatively small allocation of Project return flows relative to other well associations, because it serves some augmentation demand that depletes the river downstream of the SECWCD boundary. LAWMA also leases stored water from Pueblo Water and has in the past leased agricultural return flows that accrue when Pueblo Water leases fully consumable water to a ditch for irrigation.

Table 6 summarizes the water rights changed and used by LAWMA for augmentation purposes, primarily decreed in Case No. 02CW181, 05CW52, 10CW85 and 15CW3067. Consumptive use credits from the changed shares for the Highland Canal and Keesee Ditch water rights listed can be stored in the Offset Account in John Martin and Section II water associated with the other ditch water rights can also be transferred to the Offset Account. Note that LAWMA owns approximately 11.5 percent[6] of the Fort Lyon Canal Company shares and uses these shares in their Rule 14 plan, but has not changed them in water court. An application was filed for a change of water rights in June 2019 for these shares.

[6] Calculated as 7,509 plus 3303 ATM shares out of 93,989.4166 shares; sourced from 2019 LAWMA water rights application in Case No. 2019CW3036 and the summary provided by Randy Hendrix, LAWMA water resources consultant

Table 6: Water Rights Changed and Used by LAWMA

Ditch	LAWMA Ownership	Comments
Sisson-Stubbs Ditch[7]	18 cfs 1891 Priority 19 100.9 cfs 1895 Priority 20 100 percent Article II Storage Acct.	Ditch no longer irrigates, diversions used for augmentation. Consumptive use credits calculated as 50 percent of direct diversions and 67.5 percent of Article II storage [see Sisson-Stubbs Settlement Agreement between Colorado and Kansas (September 23, 2005)]
Manvel Ditch	54 cfs 1890 Priority 15 100 percent Article II Storage Acct.	Ditch no longer irrigates, diversions used for augmentation. Consumptive use credits calculated as 58.3 percent of direct diversions and Article II storage. Article II releases delivered via Lamar Canal.
X-Y Canal	67 cfs 1889 Priority 11 100 percent Article II Storage Acct.	Ditch no longer irrigates, diversions used for augmentation. No ownership in Graham Ditch or Well water right historically conveyed via the X-Y Canal; full ownership of X-Y and Graham Canal Article II storage account. Consumptive use credits calculated as 62.9 percent of direct diversions and 60.9 percent of Article II storage.
Lamar Canal	31.57 percent[8] Priorities 3, 6 ½, 7 ½, 13	Consumptive use credits calculated as 58.3 percent of direct diversions and Article II storage.
Fort Bent Canal	10.7 percent[9] Priorities 6, 10, 12, 14, 1918-2, 1918-9 66.2 percent Article II Storage Acct.	Consumptive use credits calculated as 66.2 percent of direct diversions and Article II storage for 02CW181; monthly consumptive use factors decreed in 10CW85.
Highland Canal	93.9 percent[10] Priorities 27, 97, 120	Consumptive use credits calculated based on decreed monthly factors, limited by monthly volumetrics. Highland Canal does not have an Article II account in John Martin Reservoir.
Keesee Ditch	100 percent Priority 1, 4, 1918-4 100 percent Article II Storage Acct.	Consumptive use credits for direct diversions calculated based on decreed monthly factors, limited by monthly volumetrics. Consumptive use credits calculated as 64.3 percent of Article II storage.

Lagged Accretions

Many of the augmentation supplies outlined above can be delivered directly to the stream when needed, either by turn out of consumptive use credits at augmentation stations, releases from storage, or discharge of reusable effluent. Project return flows and other intentionally recharged supplies (e.g. canal seepage, recharge areas); however, accrue to the stream slowly

[7] 11 cfs of the 1891 priority water right was transferred to Sisson-Stubbs Well 17759 (6705809) and Sisson-Stubbs Well 17760 (6705808); 5.50 cfs to each. The 7.2 cfs water right at an 1895 priority was transferred to Trust Well No. 1 (6705610) and Trust Well No. 2 (6705609); 3.9 cfs and 3.3 cfs respectively.

[8] LAWMA changed shares on behalf of City of Lamar, Colorado Department of Wildlife (DOW), and Colorado Beef.

[9] LAWMA changed 1,104 shares in 02CW181 and an additional 144 shares in 10CW85 per Randy Hendrix water rights summary; a portion of the shares were changed on behalf of other entities including the City of Lamar, Colorado DOW, and individual LAWMA members. An additional 162.5 shares out of 11,651.2 shares is pending in Case No. 17CW3068

[10] LAWMA changed 55.95 cfs of the total 62.5 cfs in 02CW181 and an additional 2.75 cfs in 10CW85

over a period of months. Examples of re-timed recharge include CWPDA's use of canal seepage in the Colorado Canal, Rocky Ford, and Catlin Canal during the non-irrigation season; and AGUA's diversions to the Excelsior Recharge Pond system. Intentionally recharged water can consist of municipal effluent, Pueblo Reservoir releases, or John Martin releases. Well associations generally prefer to leave water in storage, however when there might be a spill of stored water, they will call for their water and use it to generate lagged accretions. Diversions to recharge ponds and for canal seepage are recorded and designated using a specific water class in HydroBase. The timing and location of the lagged accretions from these sources are based on unit response functions in the GWAM model or a decreed accretion lagging pattern developed using Glover or other method.

To quantify and use Project return flows, Division 2 staff work with SECWCD to forecast and account for the actual amount of Project water used by each ditch. The Project water diversion at the headgate is entered into the GWAM model, which calculates the accretion values through time and tracks the previously generated accretion values. The GWAM model assumes that 40 percent of the headgate diversion will return to the river. The return flows are lagged based on the unit response function for the ditch.

Where to find more information:

- Additional information on Project water is presented in the ArkDSS Fryingpan-Arkansas Facilities and Related Operations memorandum.

Augmentation Plan Accounting

The Division Office performs the majority of the augmentation plan accounting. Their process is slightly different for areas that are inside the H-I model boundary and areas that are outside the H-I model boundary. For areas inside the H-I model boundary, the Division Office uses the GWAM model to track lagged depletions for irrigation wells over time and apply augmentation supplies. For areas outside the H-I model boundary, the Division Office uses the Stream Depletion Flow (SDF) model or Glover or AWAS models for the same purpose.

All models are run with actual depletions up to the current month and then forecasted depletions for the rest of year. This allows the Division Office to keep the well associations up-to-date on the amount of replacement supplies they will need in the coming months. The well associations can then manage their supplies and release water from their augmentation storage sources as needed during the month, preventing large reservoir releases at the beginning of the

next month. Once the depletions for the current month are calculated, the Division Office applies the replacement supplies identified by the augmentation plan to the impact reaches.

In addition to the augmentation plan accounting, Division 2 is also responsible for developing Rule 14 summary accounting on behalf of Colorado for distribution to Kansas. These reports, available on the Division of Water Resources website, summarize the annual operation of Rule 14 plans.

MODELING CONSIDERATIONS

StateMod has the ability to simulate augmentation demands based on a well pumping demand, consumptive use factors, lagged depletion factors (URF), well rights, and the call on the river. Additionally, StateMod has the ability to aggregate the augmentation demands by plan through the association of individual wells to augmentation plans. Augmentation supplies, and the preferred order in which they are used are to meet the augmentation demand, are set in StateMod.

The following summarizes key modeling considerations for representing augmentation demands and supplies in the Arkansas River basin.

- **Representation of Well Structures**: Wells that provide a supplemental irrigation supply will be aggregated under the surface water structure (i.e. representing a Diversion & Well structure). Wells that provide the sole irrigation or municipal supply will be represented individually or in ground water only aggregate structures in the model. Ground water aggregates will be developed spatially based on similar depletion/accretion responses to the stream at key locations such as gages, tributaries, and major diversion structures. Note that ground water only wells do not need to be grouped based on augmentation plans, the association of wells to plans is tied to the well itself and is not dependent on the structure in the model.
    - Within the H-I Model area, ground water aggregates should closely represent the user and stream reaches currently defined in that model.
    - For municipalities, the municipal wells should be aggregated under a municipal structure.
    - Particular consideration should be given to wells that pump non-tributary supplies and/or located in Designated Basins.
    - Exempt wells and other smaller non-irrigation wells should not be represented in the model.

- **Well Pumping**: Metered well pumping will be used for the calibration model when available, and aggregated to the structure level in the model. Note that many of the

historical pumping records are available in only a monthly or annual time series; resulting in their classification as an "infrequent" water class in HydroBase. Historical well pumping records, generally back to the mid-1990s are being digitized and included in HydroBase as part of the ArkDSS effort. Well pumping prior to this period and well demands for the baseline model will be estimated based on crop irrigation water requirement. Estimates will be reviewed and, potentially, adjusted to reflect historical limitations to pumping (i.e. development of wells, deficit irrigation practices).

Where to find more information:

- Additional information on historical pumping records is presented in the ArkDSS Task 2.7 Historical Pumping Record memo.
- Additional information on the development of URF zones and URF patterns is presented in The ArkDSS Task 2.8 Develop Transmissivity and Unit Response Function Estimates memo.

- **Presumed Depletion Factor:** Depletions of ground water pumping in the model will be based on the actual consumption of supplies by the crop based on historical pumping records, as opposed to modeling the presumed depletion factor used by the Division 2 staff for accounting purposes. Pumping prior to available records will be estimated based on IWR versus measured pumping relationships, as documented in the Task 2.7 memorandum. Additionally, discussions with Division 2 staff resulted in the recommendation not to represent secondary evapotranspiration (SEV) or other estimates of incidental loss in the ArkDSS modeling effort.

- **URFs:** The model will use the URF patterns and stream reach assignments developed for the H-I Model boundary for both pumping depletions and sub-surface irrigation return flow accretions that occur within the H-I Model boundary. Note that H-I Model URF patterns reflect the portion of the URF that returns to each stream reach. URF patterns outside of the H-I Model are currently being developed as part of the ArkDSS effort and will be used to model both pumping depletions and sub-surface irrigation return flows.

- **Well Rights:** Well rights will be queried from HydroBase and represented at the structure associated with the well. Note that in coordination with Division 2, the decision was made not to explicitly limit pre-Compact wells to 15,000 af of allowable depletion; however the amount of pumping from pre-Compact wells can be tracked and reported. However, pre-Compact wells will be included in their appropriate augmentation plan for purposes of replacing depletions to senior irrigation rights.

- **Assignment of Wells to Augmentation Plans:** Current well to augmentation plan associations are both stored in HydroBase under the group identifier and are available from the Division 2 staff accounting database. Division 2 staff indicated their desire to include a time series of well associations to augmentation plans in HydroBase to track wells that have moved between plans, but only current associations will be used in the modeling effort. It is recommended that only AGUA, CWPDA, LAWMA, and Upper Arkansas Water Conservancy District augmentation plans be explicitly modeled in the ArkDSS effort. Wells associated with other augmentation plans will be included in an aggregate augmentation plan in each water district that allows the depletions to be tracked; however no augmentation supplies will be explicitly modeled to meet the augmentation plan demand. Wells with no assigned augmentation plan are assumed to be either exempt wells or wells that pump from a designated basin, pre-1996 Dakota/Cheyenne formation or Denver Basin, and will not be assigned to an augmentation plan in the model. Wells covered under multiple augmentation plans will be assigned as such in the model. Additionally, well users that have their own augmentation plans, but are served by or lease supplies from the larger well associations, will be assigned to the larger association plan in the model (e.g. wells that serve Stonewall Springs Quarry, EWSD, Fremont Schools, and Rocky Mountain Materials will be assigned to AGUA).

- **Augmentation Supplies**: The general order in which augmentation supplies are applied to an augmentation plan demand by the well associations and Division 2 staff is outlined in the Augmentation Supply section above. It is recommended this order of operations should be reflected in the model with the following considerations:
    - Division 2 staff allows excess augmentation supplies from the previous month to meet augmentation demands in the following month. StateMod cannot automatically replicate this operation and attempts to meet augmentation demands at the time they impact the river. As such, this operation will be not reflected in the ArkDSS effort.
    - Imported Project supplies will be tracked as a reusable supply in the model; and irrigation return flows generated from the delivery of Project supplies should be made available to the augmentation plans based on Project return flows allocated to each plan.
    - Changed ditch shares for use as augmentation supplies will be modeled explicitly, reflecting the percent of water right changed, consumptive use factors, return flow obligations, volumetrics, and transit losses as decreed.

- Storage and release of augmentation supplies in Pueblo Reservoir and John Martin Reservoir will be explicitly modeled based on the operations, ownership, reservoir accounts, and administration for each augmentation plan.
- Augmentation supplies obtained in the "spot market" are difficult to replicate in the model, and their inclusion will be viewed as a calibration point once the primary augmentation supplies are represented in the model.
- StateMod does not require an augmentation plan demand to be fully satisfied in the model; therefore augmentation operations will be reviewed to determine if sufficient supplies are provided to meet the augmentation demand.

- **Rule 10 Irrigation Improvement Replacement Requirements**: Per the direction of Division 2 staff, replacement requirements needed to offset irrigation improvements will not be explicitly represented in the model. This is a relatively new requirement in the basin (2011), does not have a large impact on the river, and impacts are often mitigated on-farm through recharge ponds.

- **Pilot Programs:** Unless specifically described in the sections above, the model will not represent potential operations contemplated by "pilot programs" within the basin. In many cases, the pilot programs are not yet decreed and, until decreed, can be considered temporary programs.

Where to find more information:

- Additional information on augmentation in Division 2 can be found in the Amended Rules and Regulations Governing the Diversion and Use of Tributary Groundwater in the Arkansas River Basin (Use Rules) available on the DWR website.

- Additional administrative and accounting tools are currently under development as part of Task 6 of the ArkDSS effort, including tools and processes to enable daily or monthly preparation of water diversion classes and streamline the collection of ground water pumping data.