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Of Counsel:
Richard Lowerre

October 28, 2020

Gary Westbrook
P.O Box 92
Milano, Texas 76556

via e-mail gwestbrook@posgcd.org

Re: Environmental Stewardship Comments on GMA-12 Proposed Desired Future Conditions

Dear Mr. Westbrook:

Attached, please find comments submitted on behalf of Environmental Stewardship regarding the development of desired future conditions for the aquifers within Groundwater Management Area 12.

Environmental Stewardship appreciates the opportunity to work with GMA-12 to move towards desired future conditions that fully consider environmental impacts, including interactions between surface water and groundwater, as the GMA is charged to consider under Texas Water Code § 36.108(d)(4).

For the reasons expressed in these comments, Environmental Stewardship asks that GMA-12:

- Monitor impacts of groundwater pumping on the mainstem of the Colorado River and its tributaries;
- Perform certain hydrograph separation studies to evaluate groundwater flow contributions to the Colorado River and its tributaries under drought conditions;
- Seek to establish criteria to qualitatively and quantitatively evaluate the impacts of reduced contributions of groundwater to baseflows into rivers and streams;
- Seek to establish factors to be considered in evaluating whether impacts on surface water resulting from reduced contributions of groundwater have become unreasonable, requiring remedial action;
- Adopt DFCs which include the current DFC parameters, while adding DFC parameters specifically focused on surface water dynamics. Environmental Stewardship proposes the following parameters for this purpose:

1) Maintain subsistence flow in the Colorado River at the Bastrop Gage 100% of the time; and,
2) Maintain base-dry and base-average flow in the Colorado River at the Bastrop Gage during the spring (March - June).

- Develop a DFC for the Colorado Alluvium Aquifer which includes a surface water component.

Environmental Stewardship requests that it be placed on the agenda for the next GMA-12 meeting, so that it may present a summary of these comments and respond to any questions about them.

Environmental Stewardship is providing a copy of this letter and comments to the general manager for each groundwater district in GMA-12. By this letter, we hereby request that the general manager circulate this letter and attached comments to the board of directors for each of their respective groundwater districts.

Thank you for your consideration of these comments. We look forward to hearing from you.

Respectfully submitted,

/s/ Eric Allmon
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Proposed Desired Future Condition(s) for Aquifer(s) in GMA 12

Environmental Stewardship

Considerations 1 & 4

Submitted October 28, 2020

Contact Information

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Representing: Environmental Stewardship

Executive Summary

Environmental Stewardship has appreciated the opportunity to work with GMA 12 in the development of DFCs in the past and feels that the GMA has been responsive to Environmental Stewardship's concerns. Based on the best available science, the current DFCs will still result in unreasonable impacts on surface waters, including the flow of groundwater into the Colorado River and its tributaries. In light of these anticipated impacts under the current DFCs, Environmental Stewardship asks that GMA 12:

- Monitor impacts of groundwater pumping on the mainstem of the Colorado River and its tributaries.
- Perform certain hydrograph separation studies to evaluate groundwater flow contributions to the Colorado River under drought conditions and to inform development of a surface water DFC component.
- Establish a DFC component that is protective of surface water, including subsistence, base-dry and base-average flows, that will trigger corrective actions should the predictions of surface water impacts be validated and/or realized in fact.
- Initiate the development of DFCs for the Colorado River Alluvium in anticipation of adopting such DFCs during the next planning cycle. Give consideration to the guiding principles provided in Section VII.
- Seek to establish criteria to qualitative and quantitative evaluate the impacts of reduced contributions of groundwater to baseflows into rivers and streams.
- Seek to establish criteria to determining when such impacts become unreasonable and thereby require remedial actions.

These steps will help move the Districts and the community towards a more sustainable management of groundwater that also protects the region's important surface water resources.

Proposed Desired Future Condition(s): Environmental Stewardship's primary interest in this GMA-12 DFC review process is to protect the integrity and functioning of the ecological systems that form the basis of the Colorado and Brazos river basins and the Carrizo-Wilcox and associated aquifers for current and future generations. In conformance with the Conservation Amendment of the Texas Constitution, it is the duty of Groundwater Conservation Districts to conserve and preserve the natural resources of the state -- our groundwater, our rivers, our springs, and our bays ... our ecosystems -- by passing laws, rules, and for the purposes of this effort, adopting desired future conditions, that achieve a balance between conservation and development of those resources *in perpetuity*. To protect our aquifers as we found them while respecting the ownership rights of landowners.

Though the ability to preserve an aquifer for future generations is not totally in our control -- its rate of replenishment, and its hydrologic characteristics, are largely a function of Mother Nature and must be accepted and respected -- development of an aquifer, and ultimate depletion of an aquifer and/or the surface water and ecosystems which depend on groundwater, *is the voluntary human action in which we are currently engaged.*

The essence of conservation and preservation of an aquifer resource is that the rate at which we deplete our aquifers must be in balance with the protection of the aquifer. That the depletion not be driven only by the desire for development, against which we simply wait for damage to the aquifer's sustainability before attempting to bring it back "in balance". Only when a definite "conservation standard" describing a sustainable aquifer is established -- an aquifer that is preserved in perpetuity -- can we then determine how much of that aquifer we can develop in balance with the conservation standard. Conservation and protection of an existing aquifer for the *common good of future generations* must be the priority, not the *development* of an aquifer to satisfy every current and speculated human demand on it. Civilizations that have disappeared have failed to realize this distinction when they exploited natural resources.

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Proposed AQUIFER DFCs and Measuring/Calculating Method

Please be as detailed as possible in describing your proposed DFC. Include the quantifiable value and a description of the method for measuring or calculating the value. Attach additional pages as needed.

Aquifer	Proposed DFC and Measuring/Calculating Method
Carrizo Aquifer	ES requests that the Districts re-adopt the current DFCs based on DFC Run 3 (New GAM) and include the following as a surface water component in the DFCs for this aquifer: 1) subsistence flow in the Colorado River at the Bastrop Gage will be met 100% of the time. 2) base-dry and base-average flow will be met during the spring (March - June) in order to protect the state-threatened Blue Sucker, and 3) non-exempt pumping will be curtailed if subsistence flow drops below the month's standard expressed in cubic feet per second (cfs) for seven (7) cumulative days in any month.
Calvert Bluff Aquifer	ES requests that the Districts re-adopt the current DFCs based on DFC Run 3 (New GAM) and include the following as a surface water component in the DFCs for this aquifer: 1) subsistence flow in the Colorado River at the Bastrop Gage will be met 100% of the time. 2) base-dry and base-average flow will be met during the spring (March - June) in order to protect the state-threatened Blue Sucker, and 3) non-exempt pumping will be curtailed if subsistence flow drops below the month's standard expressed in cubic feet per second (cfs) for seven (7) cumulative days in any month.
Simsboro Aquifer	ES requests that the Districts re-adopt the current DFCs based on DFC Run 3 (New GAM) and include the following as a surface water component in the DFCs for this aquifer: 1) subsistence flow in the Colorado River at the Bastrop Gage will be met 100% of the time. 2) base-dry and base-average flow will be met during the spring (March - June) in order to protect the state-threatened Blue Sucker, and 3) non-exempt pumping will be curtailed if subsistence flow drops below the month's standard expressed in cubic feet per second (cfs) for seven (7) cumulative days in any month.
Hooper Aquifer	ES requests that the Districts re-adopt the current DFCs based on DFC Run 3 (New GAM) and include the following as a surface water component in the DFCs for this aquifer: 1) subsistence flow in the Colorado River at the Bastrop Gage will be met 100% of the time. 2) base-dry and base-average flow will be met during the spring (March - June) in order to protect the state-threatened Blue Sucker, and 3) non-exempt pumping will be curtailed if subsistence flow drops below the month's standard expressed in cubic feet per second (cfs) for seven (7) cumulative days in any month.

Aquifer	Proposed DFC and Measuring/Calculating Method
Queen City Aquifer	
Sparta Aquifer	
Yegua-Jackson Aquifer	
Brazos Alluvium Aquifer	
Colorado Alluvium Aquifer	ES requests that the Districts initiate the development of DFCs for this aquifer in anticipation of adopting such DFCs during the next planning cycle. Give consideration to the guiding principles provided in Section VII,

Consideration of Proposed Desired Future Condition(s)

The Texas Water Code requires that the GMA develop DFCs that "provide a balance between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater and control of subsidence in the management area." In the space below, or on additional attached pages, please provide your considerations with regard to the nine items that must be considered, per the Texas Water Code, for the proposed DFC(s).

CONSIDERATION 1 – "Aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another:"

Environmental Stewardship requests clarification on the following table from GMA-12 Consultants' presentation on July 24, 2020. For LPGCD Steam-Electric Power is 0% on slide 29 which contradicts slide 7 which indicates groundwater use for Steam-Electric Power at 75%. LCRA's permit is strictly for use of Simsboro water as cooling water at the Lost Pines Power Park. As such, it seems that the LCRA water use should be listed as Steam-Electric Power.

Approximate Carrizo-Wilcox 2018 Groundwater Use (Percent)

	LPGCD	POSGCD	BVGCD	METGCD	FCGCD
Irrigation	10%	34%	25%	10%	95+%
Livestock	<5%	7%	<5%	5%	0%
Manufacturing	<5%	5%	<5%	10%	0%
Mining	<1%	0%	5%	10%	0%
Municipal	80-85%	59%	55+%	65%	0%*
Steam-Electric Power	0%	0%	10%	0%	0%

CONSIDERATION 4 – "Other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water:"

Environmental Stewardship (ES) provides the following comments for consideration by the GMA-12 Districts before adopting desired future conditions (DFCs) for the Carrizo-Wilcox Aquifer Group (Carrizo, Calvert Bluff, Simsboro and Hooper formations).

I. BACKGROUND

ES has participated in the proceedings of GMA-12 since its inception by providing comments and recommendations to the first, second, and now the third round of desired future conditions review and adoption.

First Round - Adoption of initial DFCs. In the first round of review (2008-13) ES raised the issue of impacts of groundwater pumping on surface waters; Colorado, Brazos Rivers and their tributaries. ES also noted that the DFCs initially adopted during this round were based on the demands in the Regional Water Plans and did not consider the capacity of the aquifers to sustainably produce the amount of groundwater demand without causing unreasonable damage to surface waters and the communities (human and ecological) that depend on both surface and groundwater. ES appealed the initial DFCs based on these issues. The details of our appeal can be found on our website at Groundwater Management Area 12 Appeal.[1]

Second Round - Readoption of initial DFCs. During the second round of review (2012-17) ES continued to call attention to surface water-groundwater issues. GMA-12 consultants presented convincing evidence that the then current GMA-12 groundwater availability model (Old GAM) was deficient in its ability to reliably predict surface water-groundwater interactions and needed to be updated in order to have the predictive capacity necessary. There were other issues related to faults that also needed to be corrected. GMA-12 and TWDB agreed to update the GAM before the third round of reviews. As such, ES supported GMA-12's decision to re-adopt the initial DFCs with adjustments necessary to extend the DFCs through 2070. The details of our concerns can be found on our website at GMA-12 DFC Review (2013-2016).[2]

Subsequently, TWDB provided funding for revision of the faults, Brazos Valley and Post Oak Savannah GCDs provided funding to update the surface water-groundwater interaction portion of the GAM to provide a *regional* capacity. ES, working with the Colorado-Lavaca Basin and Bay Area Stakeholder Committee (CL-BBASC) provided Senate Bill 3 funding through the TWDB to upgrade the capacity for the GAM to be used for *local* predictions in the Colorado River basin. INTERA was contracted to update the GMA-12 GAM.

The New GAM has been adopted by GMA-12 for use in developing and adopting desired future conditions in the third round of DFC review and adoption.

Third Round (current) - Review of DFCs using updated GMA-12 GAM. The initial task for the committee has been to compare the results from the Old GAM and the New GAM and develop a strategy for developing and adopting new DFCs. Presentations on considerations 1-5 have been made by the GMA-12 Consultants. The following are ES' comments and concerns related to Consideration #4.

II. COMPARISON OF IMPACT OF PUMPING ON OUTFLOWS TO MAIN STEM COLORADO RIVER

Adopted 2017 DFCs (Old GAM) - Environmental Stewardship presented information to GMA-12 and Lost Pines GCD demonstrating the predicted impacts of groundwater pumping on the Colorado River in March and July 2016. The data presented was based on GAM runs done by George Rice[3] using the Old GAM.

Figure 1 represents the predicted discharge of groundwater into the main stem of the Colorado River for baseline pumping (which later became the adopted 2017 DFCs) and baseline plus potential pumping (now permitted pumping) using the Old GAM.

In the old GAM (2010 - 2060) baseline pumping from the Simsboro Aquifer in Bastrop and Lee Counties ranged from 20,300 acre-feet per year to 40,300 acre-feet per year. The average was 29,400 acre-feet per year. When pumping for additional projects was added to the old GAM[4], pumping from the Simsboro Aquifer ranged from 20,300 acre-feet per year to 121,000 acre-feet per year. The average was 86,600 acre-feet per year. For purposes of comparing trends between GAM runs the average pumping amount is used.

- Average Pumping Amount (Old GAM):
  - Baseline = 29,400 acre-feet per year average for the Simsboro formantion only.
  - Baseline + potential = 86,600 acre-ft per year average for the Simsboro formation only.
- The Old GAM predicted that baseline pumping will:
  - Reduce discharge to the main stem of the Colorado River by about 13,000 ac-ft per year from 2010 to 2060.
  - Reverse its historical relationship to the aquifers by changing from a stream that *gains* water from the aquifers (a gaining stream) to a stream that *loses* water to the aquifers (a losing stream) in about 2040.
- The Old GAM predicted that potential pumping by Vista Ridge, End Op (now Recharge Water) Forestar and LCRA power plant will:
  - Reduce discharge to the main stem of the Colorado River by about 22,000 ac-ft per year from 2010 to 2060.
  - Reverse its historical relationship to the aquifers by changing from a stream that *gains* water from the aquifers (a gaining stream) to a stream that *loses* water to the aquifers (a losing stream) about 20 years earlier (2020) than baseline pumping.

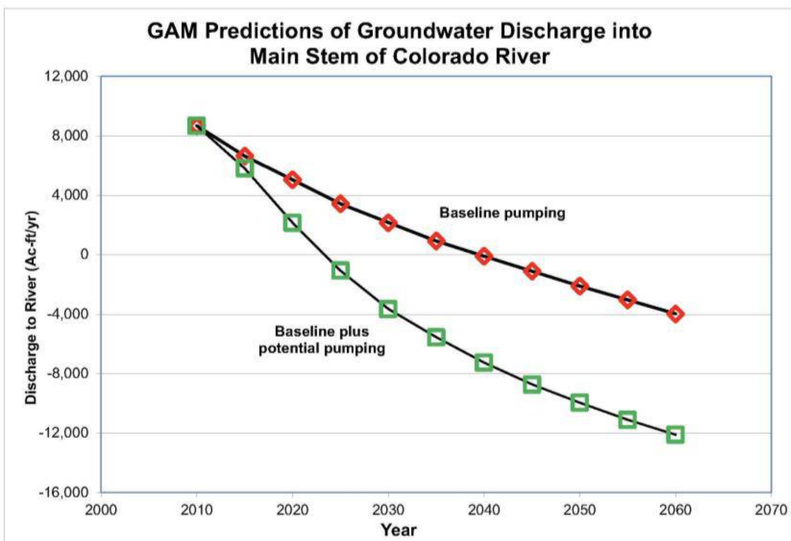


Figure 1. Predicted reduction of discharge of groundwater into the mainstream Colorado River due to combined pumping (Old GAM).

Adopted 2017 DFCs (New GAM) - A logical starting point is to compare the results of the pumping file used in the Old GAM that was the basis of the 2017 (Second) Adopted DFCs with the same pumping file but using the New GAM. Unfortunately, because the New GAM has two additional layers, such a direct comparison is not possible. The GMA-12 Consultant Team looked at several scenarios using the New GAM to simulate the same pumping conditions as the Old GAM. Of those considered, DFC Run 3 was the scenario selected as the one that best represents the Old GAM. The results of this comparison can be found in the Consultant Team's January 29, 2019 presentation.[5]

Figure 2 represents the predicted discharge of groundwater into the main stem of the Colorado River for DFC Run 3 pumping (blue line) and a more recent Scenario S-7 pumping file using the New GAM.[6]

It should be noted that the New GAM has a much longer calibration period (1930 - 2010) thereby providing an historical perspective regarding outflow to the river and its tributaries. Furthermore, the predictions from the model align well with the field data[7] from Saunders's studies.

As seen in Figure 2, the New GAM reflected a reduction in outflows to the main stem of the rivers started with the development period in 1990. During the early development period from 1990 to 2010, outflows to the river declined by about 30,000 acre-feet per year.

ES first compared the DFC Run 3 pumping using the New GAM to the Adopted 2017 DFC pumping using the Old GAM.

In the new GAM (2010 - 2070) baseline pumping from all aquifers in Bastrop and Lee Counties was simulated with two pumping files; first DFC Run 3, and then S-7[8]. DFC Run 3 pumping ranged from 21,000 acre-feet per year to 59,200 acre-feet per year. The average was 50,900 acre-feet per year. S-7 pumping ranged from 25,500 acre-feet per year to 162,000 acre-feet per year. The average was 116,000 acre-feet per year. For purposes of simplicity the average is used to show the trend.

- Average Pumping Amount:
    - Baseline = 29,400 acre-feet per year average for the Simsboro formation only (Old GAM).
    - DFC Run 3 = 50,900 acre-feet per year average pumping all aquifers (New GAM).
- The Old GAM predicts that discharge to the main stem of the Colorado River will:
    - Reduce by about 13,000 ac-ft per year.
    - Reverse of its historical relationship to the aquifers by about 2040.
- The New GAM predicts that discharge to the main stem of the Colorado River will:
    - Reduce by about 14,000 ac-ft per year.
    - Not reverse its historical relationship to the aquifers in the current planning period.
- By comparison:
    - The New GAM predicts about the same magnitude of reduced outflow from the aquifer to the Colorado River as the Old GAM.
    - The New GAM predicts that the river will NOT reverse its historical relationship to the aquifers during the current planning period.

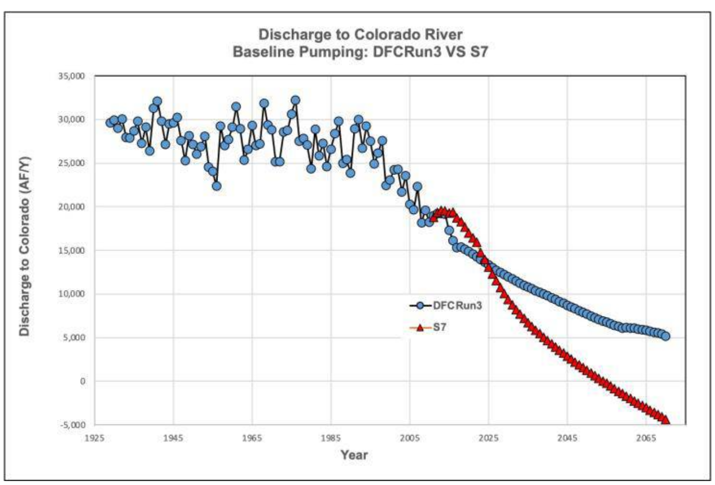


Figure 2. Predicted reduction of discharge of groundwater into the mainstream Colorado River due to DFC Run 3 and Scenario S-7 (New GAM).

<u>Comparison of DFC Run 3 and Scenario S-7.</u> Scenario S-7 is the current run being considered as the pumping basis for adoption of new DFCs. The major differences between the updated file (S-7) and the previous one is 1) the updated file contains historic pumping data through 2018, and 2) the updated file contains pumping for all permitted pumping, including pumping for large projects such as Vista Ridge, End Op, and Forestar.

Figure 2 represents the predicted discharge of groundwater into the main stem of the Colorado River for DFC Run 3 pumping (blue line) and Scenario S-7 pumping (red line) using the New GAM.

- Average Pumping Amount:
  - DFC Run 3 = 50,900 acre-feet per year average pumping all aquifers
  - Scenario S-7 = 116,000 acre-feet per year average pumping all aquifers
- The New GAM (DFC Run 3) predicts that pumping will:
  - Reduce discharge to the main stem of the Colorado River by about 14,000 ac-ft per year from 2010 to 2070.
  - not reverse its historical relationship to the aquifers by changing from a stream that *gains* water from the aquifers (a gaining stream) to a stream that *loses* water to the aquifers (a losing stream) in the current planning period.
- The New GAM (S-7)predicts that pumping will:
  - Reduce discharge to the main stem of the Colorado River by about 24,000 ac-ft per year from 2010 to 2070.
  - Reverse its historical relationship to the aquifers by changing from a stream that *gains* water from the aquifers (a gaining stream) to a stream that *loses* water to the aquifers (a losing stream) by about 2050.
- By comparison:
  - The new GAM predicts that Scenario S-7 will reduce outflows by about 10,000 ac-ft per year more than DFC Run 3.
  - The new GAM predicts that Scenario S-7 will cause a reversal in the surface water-groundwater relationship to occur about 2050 whereas DFC Run 3 does not predict a reversal within the planning period.
  - Scenario S-7 (New GAM) is comparable to Baseline + potential pumping in the Old GAM.
    - Both predict the same magnitude of reduced outflow from the aquifer to the Colorado River; about 22,000 to 24,000 acre-feet per year.

In summary:

Groundwater pumping impacts outflow of groundwater to surface waters, including the main-stem of the Colorado River. Comparison of GAM runs show that the greater the quantity of groundwater pumped, the greater the decrease in outflows to the river.

The quantity of pumping in the 2017 adopted DFCs is predicted by GAM run DFC Run 3 to cause a significant decrease in outflows to the river; an impact that may be unreasonable. GAM Run S-7 is predicted to decrease outflow by an even greater magnitude; and impact that is even more likely to be unreasonable.

III. COMPARISON OF IMPACT OF PUMPING ON OUTFLOWS TO COLORADO RIVER TRIBUTARIES

Groundwater pumping directly impacts both the main stem of the Colorado River and its tributaries. Most of the major tributaries to the Colorado River that are likely impacted by pumping by GMA-12 Districts are located in Bastrop County within the jurisdiction of Lost Pines GCD.

In general, the reliability of GAM predictions regarding outflows to the tributaries are less reliable than predictions for the main-stem of the Colorado River. The GAM does not account for periods when the tributaries are dry and does not account for unsaturated flow between the bottom of the stream and the aquifers. For these reasons, ES' analyses of tributaries are limited to qualitative analysis of trends. The detailed analyses can be found in Appendix 4.

Mr. Rice evaluated the impact of adopted and proposed DFCs on Big Sandy, Wilbarger, Piney and Cypress Creeks. In doing so, Mr. Rice separated the outflows to the tributaries from the outflows to the main stem of the Colorado River. Total outflows to the Colorado River watershed include both outflows.

The Districts have agreed that DFC Run 3 best represents the currently adopted DFCs, that Scenario S-7 represents current permitted pumping and is being considered as the basis for developing desired future conditions for adoption in 2021. As such, ES developed data to compare the impact of DFC Run 3 and Scenario S-7 on the combined flows of four tributaries to the Colorado River (Figure 3).

The new GAM predicts (Figure 3) that combined flows of the four tributaries:

- Have had historic outflows that were significantly higher than are predicted during development,
    - outflows declined during the early development period; and
    - outflows are predicted to continue to decline as pumping increases in the current development period.
- Will reverse their relationship with the aquifers by contributing surface waters to the aquifers (losing streams) during the planning period.
    - S-7 pumping will accelerate the reversal by several decades.

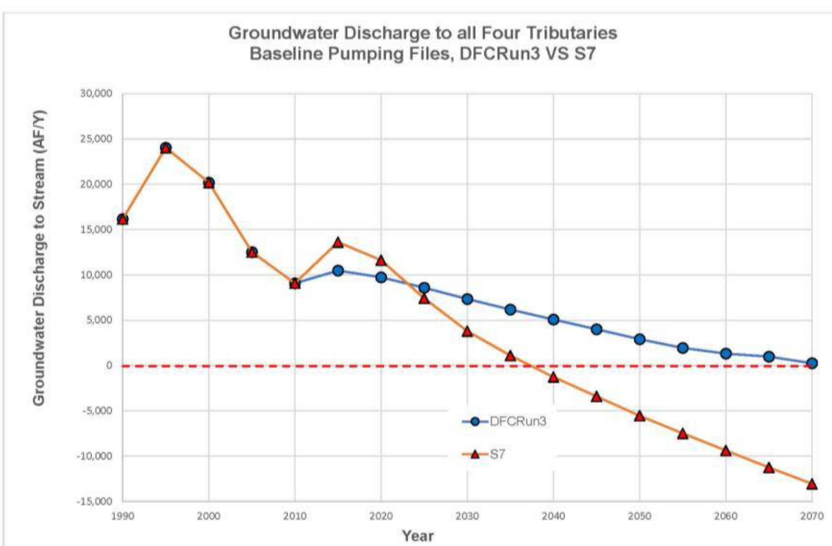


Figure 3: Groundwater Discharge to four tributaries of the Colorado River located primarily in Bastrop County, TX (New GAM).

To get a better understanding of the impact of groundwater pumping on individual tributaries, similar graphs were developed to represent the groundwater discharge predicted for the 2017 adopted DFCs (DFC Run 3) and proposed DFCs (S-7) to four creeks -- Wilbarger Creek, Big Sandy Creek, Walnut/Cedar Creek and Piney Creeks/Lake Bastrop -- all located in Bastrop County, TX (Figure 4). The four creeks have the common feature of communicating with one or more of the formations in the Wilcox group.

The following is a brief summary of the findings for each creek:

Wilbarger Creek: Overall, S-7 pumping caused a greater decline in outflows from the aquifers than DFC Run 3. Likewise, S-7 pumping is predicted to cause a reversal in the surface water-groundwater relationship whereas DFC Run 3 does not predict a reversal. Wilbarger Creek flows across the outcrops of the Hooper, and the Simsboro.

Big Sandy Creek: Overall, S-7 pumping caused a greater decline in outflows from the aquifers than DFC Run 3. Both DFC Run 3 and S-7 pumping predict a reversal in the surface water-groundwater relationship has already occurred. Big Sandy Creek flows across the outcrops of the Hooper, Simsboro, and Calvert Bluff.

Walnut/Cedar Creek: Overall, S-7 pumping caused a greater decline in outflows from the aquifers. Likewise, S-7 pumping is predicted to cause a reversal in the surface water-groundwater relationship whereas DFC Run 3 does not predict a reversal. Walnut/Cedar flows across the outcrops of the Hooper, Simsboro, Calvert Bluff, and Carrizo.

Piney Creek/Lake Bastrop: Overall, S-7 pumping caused a greater decline in outflows from the aquifers. Both S-7 pumping and DFC Run 3 are predicted to cause a reversal in the surface water-groundwater relationship. Piney Creek/Lake Bastrop flows across the outcrops of the Calvert Bluff and Carrizo.

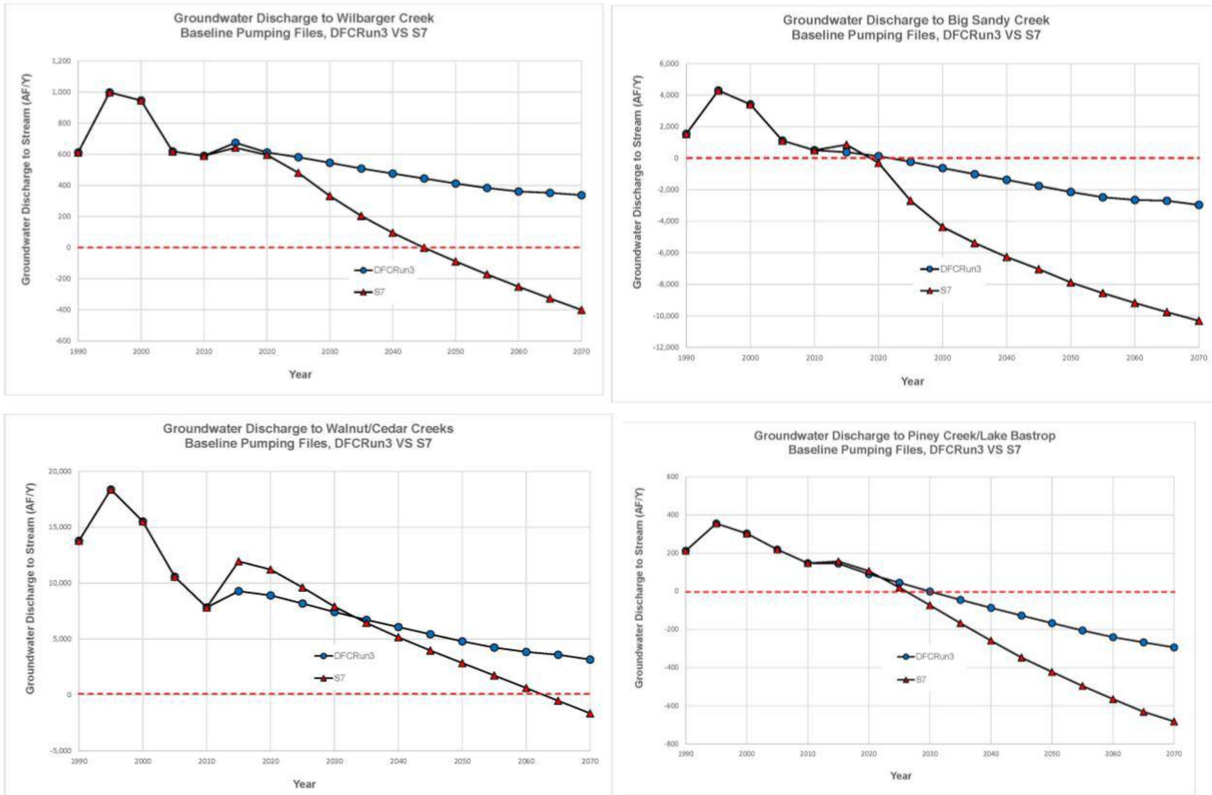


Figure 4. Groundwater Discharge to Wilbarger, Big Sandy, Walnut/Cedar and Piney Creeks/Lake Bastrop, Bastrop County, TX (New GAM).

In order to compare the four creeks and to get a sense of the full history of each of creek, as found in the new GAM , a graphic was prepared using Scenario S-7 covering the period of 1930 to 2070 (Figure 5). Once again, we see that Walnut/Cedar and Big Sandy Creeks show the greatest change in outflows from the pre-development period of 1930-1990 through the Development period of 1990-2070.

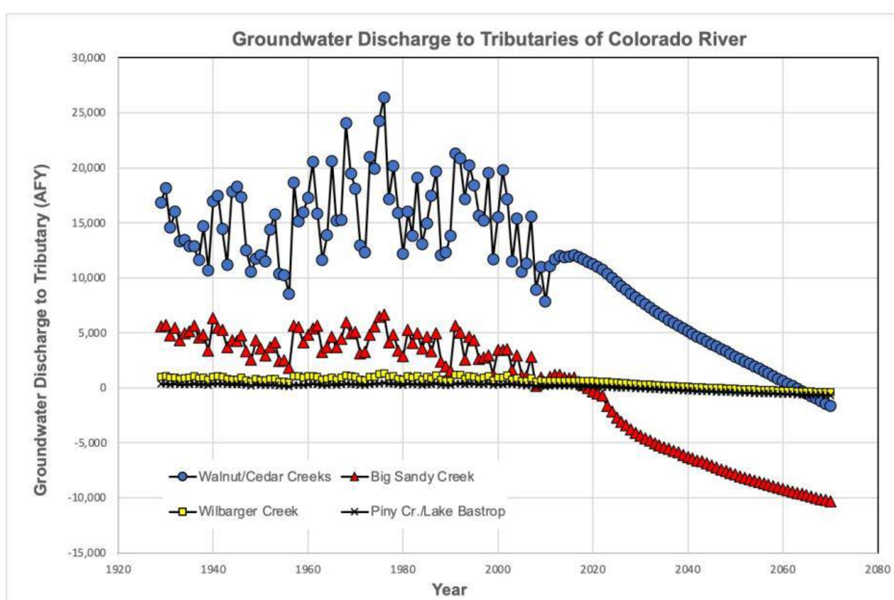


Figure 5. Groundwater Discharge to four tributaries of the Colorado River located primarily in Bastrop County, TX (New GAM).

Since Wilbarger communicates directly with the Simsboro and Hooper formations of the Wilcox Group, ES used this creek to better understand how the new GAM is constructed and functions relative to the river nodes that measure the communication between the stream and the aquifer formations. What ES found was confirmation of two of the short-comings of the new GAM as presented in the GMA-12 Consultant's presentation on other environmental impacts[9]. The consultants listed both strengths and short-comings.

Among the four short-comings were:

- Hydrological properties of stream beds are largely unknown.
- Equations do not account for potentially important processes such as unsaturated flow and bank flow.

Mr. Rice conducted an analysis to better understand GAM predictions of the interaction of Wilbarger Creek and the underlaying aquifers using run S-7. The study was concerned with one type of stream/aquifer interaction – when discharge from the stream reaches its maximum rate. This occurs when the head in the underlying aquifer falls below the bottom of the streambed. Once this occurs the rate of discharge from the stream to the aquifer remains constant, regardless of how far below the streambed the head in the aquifer falls. Note that this is an artifact of the way the GAM calculates the discharge rate. The GAM does not consider unsaturated flow between the streambed and the water table.

Figure 6 represents Wilbarger Creek's interaction with the Colorado River alluvium, and the Hooper and Simsboro formations of the Wilcox Group in the years 1990, 2020, 2050 and 2070.

In the new GAM, Wilbarger Creek is represented by 57 river nodes[10]. Thirty five of these nodes communicate with layer 1 (alluvium) and 22 with layer 2 (water table portions of Carrizo-Wilcox Hooper and Simsboro formations). These nodes correspond to 11 cells in the old GAM.

The maximum discharge rate from Wilbarger Creek to the aquifers[11] occur at 14 nodes. These nodes are listed in Appendix 1. At 13 of the nodes the maximum rate is already occurring by the year 1990. This is because the head in the underlying aquifer is already below the bottom of the streambed. The exception is node 4615 (layer 2 Hooper) which begins discharging at the maximum rate by 2020.

The other finding from this analysis occurs in the last six nodes nearest the confluence of Wilbarger Creek with the Colorado River. There is a strong trend for outflows in this segment of the stream to decline from a high of 150 ac-ft per year in 1990 (a gaining stream) to a low of minus 100 ac-ft per year in 2070 (a losing stream).

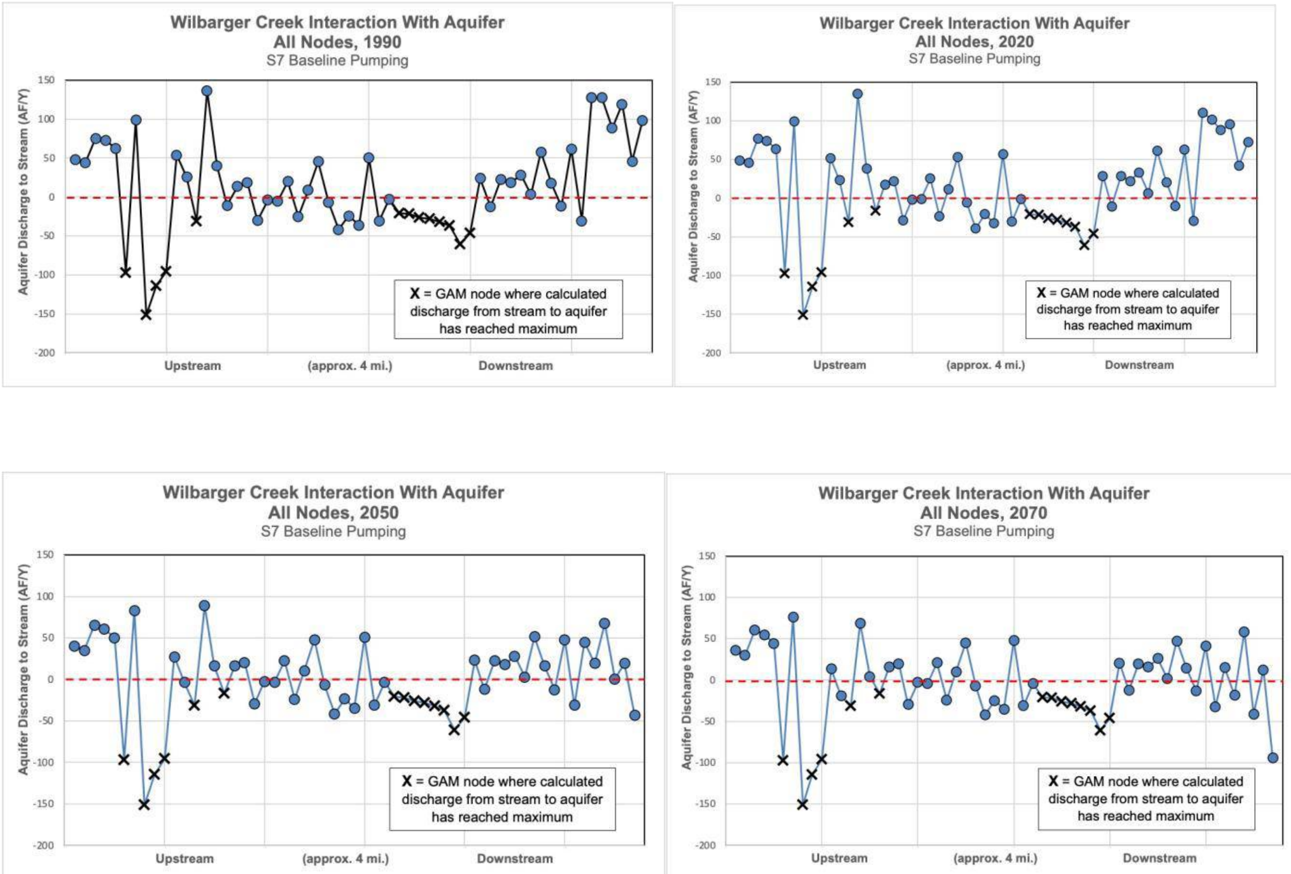


Figure 6. Wilbarger creek Interaction with Aquifer, All Nodes 1990, 2020, 2050 and 2070 (New GAM).

In summary:

From this analysis, one of the places where the GAM short-comings have an impact becomes evident; in this case on tributary streams. With the understanding that this is a calculation of limited maximum discharge, it is reasonable to conclude that there is a level of uncertainty related to the GAM predictions that should be noted. Field studies would be the only means of confirming the situation and provide empirical data to update the GAM.

Because environmental flow standards have not been adopted for tributaries in this river segment, such standards are not available for use in protecting stream flow in the same manner requested for the main-stem of the river. The tributaries also cannot be protected from the impacts of groundwater pumping by increased releases of surface water from the Highland Lakes.

The best method for monitoring and protecting the tributaries is to develop DFCs for the Colorado Alluvium Aquifer. Hydrological separation of stream gage records, where such exist for tributaries, will help inform the need for instream monitoring and surface water-groundwater monitoring. Further study and analysis will be needed to find methodologies for monitoring groundwater outflows, instream flows, biological impacts, and managing remedial actions for tributaries.

Initiation of the process to establish DFCs for the Colorado Alluvium Aquifer is requested as an initial basis for protecting tributary flows for the four tributaries mentioned above. Other tributary streams associated with other aquifers will also benefit from development of DFCs for the alluvium. As such a DFC component for tributaries per se is not being requested during this round of review.

IV. SURFACE WATER MODELING PREDICTS UNREASONABLE IMPACTS OF GROUNDWATER PUMPING ON SURFACE WATERS OF THE COLORADO RIVER

Evaluation of the impacts of reduced flows on established environmental flow standards is the appropriate means of determining whether or not the impact of groundwater pumping on surface waters can be accepted without causing unreasonable harm to the biological soundness of the state's rivers, lakes, bays and estuaries.

The Texas State Legislature recognized the value of Texas surface waters by enacting Senate Bill 3 which was passed by 80th Session of the Texas State Legislature and signed into law June 16, 2007.

Section 1.06 of the Bill acknowledges that *maintaining the biological soundness of the state's rivers, lakes, bays, and estuaries is of great importance to the public's economic health and general well-being*. The legislature encourages voluntary water and land stewardship to benefit the water in the state. The legislature expressly required that the TCEQ (the commission), while balancing all other public interests, to consider and, *to the extent practicable, provide for the freshwater inflows and instream flows necessary to maintain the viability of the state's streams, rivers, and bay and estuary systems* in the commission's regular granting of permits for the use of state waters.

The TCEQ, through expert science teams and area stakeholder committees, has established environmental flow regimes for the basins and bays of the state. "Environmental flow regimes" means a schedule of flow quantities that reflects seasonal and yearly fluctuations that typically would vary geographically, by specific location in a watershed, and that are *shown to be adequate to support a sound ecological environment and to maintain the productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies*.

After an extensive review[12] by the Colorado and Lavaca Rivers Expert Science Team (CL BBEST) and consideration by the Colorado and Lavaca Basins and Matagorda and Lavaca Bays Area Stakeholder Committee (CL BBASC), a set of environmental flow recommendations were delivered to the TCEQ in August 2011[13]. The TCEQ adopted environmental flow standards into the Texas Water Code on August 8, 2012 that became effective August 30, 2012[14] (APPENDIX 3).

<u>Evaluation by surface water expert:</u>

Environmental Stewardship's surface water expert, Joe Trungale, used the current surface water availability model (WAM) to evaluate the impact of reduced inflows to the Colorado River and its tributaries to predict changes in critical environmental flow attainment rates that have been adopted by the State to protect the Colorado River as intended by Senate Bill 3.

Mr. Trungale used inflow reduction quantities resulting from by Mr. Rice's analysis of DFC Run 3 and Scenario S-7 as discussed above.

<u>Based on Mr. Trungale's analysis Environmental Stewardship concludes that:</u>

- Water in the Colorado River at Bastrop and below has, for all intents and purposes, been fully appropriated.; *i.e.* no more water remains available for future appropriation as a water right. A decrease in streamflows, including a decrease as a result of increased pumping of groundwater, would likely come at the expense of existing water rights holders, and these reduced flows would have an adverse effect on flows needed to maintain a sound ecological environment.

  - The fact that the river is already over appropriated means that any reductions in flows will negatively impact existing water rights holders. Specifically, existing water rights holders will be able to divert less of the water that they are legally entitled to than they would be able to divert if there were no reductions in flow due to groundwater pumping. The WAM allows for a quantification of how many water rights holders would be negatively impacted.

  - There are about 1,300 active water rights in the Colorado basin though not all include authorization to divert water. The reliability decreases for almost every water right in the basin. It should be noted that the reduction in reliability was generally relatively small with less than a 3 percent reduction in reliability in almost all cases. However, the *prior appropriation doctrine* is intended to ensure that senior water rights are protected from new (junior) water development projects. New water development projects, generally, cannot be permitted if they would result in reducing the reliability of flows available to satisfy existing water rights, at the full appropriation amount permitted. Groundwater pumping appears to create a gradual reduction of reliable streamflows, over a relatively long period of time (versus an immediate reduction of streamflows from a single development project).

- Environmental flow standards are not being met at recommended frequencies, and additional groundwater pumping would likely result in further reduction in these attainment frequencies. While there were some small changes in the results, the frequencies of meeting the flow standards are still below their recommended levels, and these shortfalls are further exacerbated by the decrease in flow as a result of the groundwater pumping. This reduction continues to be most concerning in the segments below Bastrop during spring when the *base dry and base average flows*, which are important for maintenance of habitat for the state-threatened Blue Sucker, drop further below already undesirable frequencies.
  - The Blue Sucker[15] *Cycleptus elongatus* is listed as a species of greatest conservation need, threatened, presumed extirpated, or endangered by 19 of the 23 states it inhabits. Their status in these 19 states is concerning, and an indication of potential trouble for the species. Blue Sucker are well known for occupying swift moving waters and have even been referred to colloquially as swift water sucker. The status of Blue Sucker in Texas is unclear and attempts to elucidate information at the population level have proven difficult due to their life history, behavior, and cryptic nature. *However, their sensitivity to anthropogenic modifications makes them a good indicator species for overall ecosystem health*. A report by Bio-West (2008) described instream flows necessary to maintain spawning habitat availability in the lower Colorado River that were later used to inform water policy. The resulting 2010 Water Management Plan (WMP) for the lower Colorado River had flow requirements at or above 500 cfs to last for at least six weeks during the months of March, April, and May. These flow requirements were specifically to keep Blue Sucker spawning habitat available. However, a severe drought affected the implementation of environmental releases for Blue Sucker from 2010-2012. The Lower Colorado River Authority (LCRA) frequently requested emergency suspensions or reductions in required releases.

- The reduction in flows impact the ecological health of the Colorado River.
  - A sound ecological environment is defined as "a functioning ecosystem characterized by intact, natural processes, resilience, and a balanced, integrated, and adaptive community of organisms comparable to that of the natural habitat of a region." (Texas Instream Flow Program, Technical Overview, May 2008). Instream flow standards were recommended and adopted that included subsistence, base, high flow pulse, and bankfull flows necessary to maintain a sound environment for the Colorado River. These recommendations, consistent with literature on the science of instream flows recommended that flows be managed to mimic natural patterns. The Instream Flow Program further recommended that subsistence flows should be considered **"hands** off **flows"** with the goal that flows do not fall below the subsistence flow guidelines and thus should be met 100% of the time. For base flows, which provide for variable instream habitat conditions that differ during dry and average times, the recommendation was that base-dry and base-average flow magnitude occur 80 and 60 percent of the time.

  - The above flow recommendations were adopted by the Senate Bill 3 Colorado Bay and Basin Expert Science Team and the Bay and Basin Stakeholder Advisory Group.

  - <u>Impacts of reduced groundwater outflows to the Colorado River due to current and proposed DFCs:</u>

    Appendix 5 to this Report provides detailed information regarding the attainment frequencies of the Senate Bill 3 Flow Standards in the Lower Colorado River. The values in the table show the percentage of months when flows in the river are predicted, based on the WAM model, to meet or exceed the TCEQ adopted flow standards. Results are provided for the three sites on the lower Colorado river where flow standards have been adopted (Bastrop, Columbus, and Wharton). The table presents results based on the naturalized flows, which are an input to the WAM models and three distinct WAM simulations.

    - <u>Surface water flow simulations</u>: The first model simulation, labeled TCEQ3, is the official state water rights permitting model which assumes all water rights are exercised at their fully permitted authorization and assumes that there are no return flows. The other two runs, DFCRun3 and S7, are built on the TCEQ3 run but in these simulation streamflows have been adjusted to account for losses that are predicted by the respective GAM runs described above.
    - The first thing to note in the table is the percent of time that subsistence, base-dry and base-average flow standards are met or exceeded under each of the scenarios. As discussed above subsistence flow should be met 100% of the time, base-dry 80% of the time and base-average 60% of the time based on the results of the instream flow study upon which these standards were developed.
      - Except for some of the subsistence flows, the naturalized flows generally meet the flow frequency targets.
      - The simulations based on the TCEQ3 simulation, in many months at multiple sites, do not meet the target frequencies.
      - Of particular concern is the failure to achieve the desire frequency of 60% of the time for the base average flows in the spring (March and April) in the Columbus reach. Base average

flows were developed in part to provide optimal spawning habitat for the state threatened blue sucker.

TCEQ Adopted Flow standards vs DFCs: These frequencies under the two scenarios which account for streamflow loss due to increased groundwater pumping demonstrate that further diminishment of groundwater inflow into the Colorado River has the potential for additional adverse impacts on wildlife dependent upon the Colorado River.

- The column labeled "TCEQ3-DFC3" shows how much the attainment frequencies would be expected to fall due to the pumping that is projected by the New GAM run that represents the currently adopted DFCs.
- The column labeled "DFC3-G7" show the additional decrease that would be expected if Scenario S7 were to be adopted.
- While the percent changes may appear small. It is important to note that in months were the attainment frequencies are already failing to meet the target frequencies, such as the base-average targets in March and April at Columbus, an unsound environmental condition would be made even worse.
- It is also important also to note that the flow standards were developed to support the full community of species in the lower Colorado and that these negative trends extend the entire length of the river and into Matagorda Bay.

- Texas groundwater law requires that permits for wells shall consider whether the proposed use of water unreasonably affects existing groundwater and surface water resources for existing permit holders.

  - The effect of the proposed groundwater pumping on surface water resources is unreasonable because it increases the shortfalls in meeting environmental flow targets. Since the flows in the river are already often below levels needed to maintain the ecological health of the river, then any additional pumping that causes further instream flow reduction is unreasonable.

- Groundwater and surface water sources are physically connected and considering them as independent and disjointed is contrary to reality. The best available science concludes, logically, that pumping water from aquifers near the Colorado River and its tributaries will reduce the flow in the river and the tributaries.

  - Since this river is already fully appropriated, this reduction will adversely impact the reliability of water for existing senior water rights holders. The reduction in flow will also mean that the flows needed to maintain a sound environment, which in some cases are already not being meet, would be further reduced below levels recommended by the best available science.
  - The uncertainty regarding the precise magnitude of the river flow decline does not change the fundamental dynamics. Groundwater pumping will decrease flows in the river and the tributaries, and for the reasons stated above, the river cannot afford the reduction.

In summary:

The water of the Colorado River at Bastrop has already been fully allocated and simulations of groundwater production using surface water modeling have shown groundwater pumping to negatively impact both water rights holders and the ecological health of the river. The state has adopted environmental flow standards to maintain the biological health of the river and Matagorda Bay and instructed the TCEQ, to the extent practicable, provide for the freshwater inflows and instream flows necessary to maintain the viability of the state's streams, rivers, and bay and estuary systems. The Legislature has further instructed groundwater conservation districts to consider the impacts of groundwater pumping on surface waters and existing permits before granting operating permits or adopting desired future conditions.

Groundwater pumping volumes already authorized and under the currently adopted DFCs have the potential to negatively and unreasonably impact surface water environmental flows and thereby the ecological health of the Colorado River and its tributaries. Additional pumping volumes as proposed by Scenario S-7 further threaten the health of the river. These negative trends extend the entire length of the river and into Matagorda Bay.

It is appropriate that GMA-12 Districts adopt desired future conditions that maintain the flow of the river at levels that protect threatened biological communities at and below Bastrop.

V. THE NEED FOR FIELD STUDIES TO VALIDATE THE NEW GAM AND INFORM WATER MANAGEMENT PLANS

The need for additional data to inform the GMA-12 GAM is recognized by the Districts and Environmental Stewardship. As explained above, the GAMs predict potentially unreasonable impacts to the surface water system as the result of the current adopted DFCs [16] and the additional permitted groundwater pumping.[17] Although such impacts cannot currently be precisely quantified, it is unreasonable for the Districts to summarily dismiss the potential for such impacts and the Districts should take pro-active steps to obtain the field data necessary to inform decisions regarding these predictions.

The following conclusions from this analysis should inform the path forward:

- The New GAM, as opposed to the Old GAM, is the better model to use to predict the effect of pumping, particularly considering that the calibration of the new GAM is better than the old GAM.
- The New GAM has short-comings that make analysis of impacts on tributaries difficult. Field studies are the only means of confirming the impacts of groundwater pumping on tributaries and to provide empirical data to update the GAM.
- Improved monitoring is necessary to evaluate the impact of groundwater pumping on surface water.
- Districts need to address conjunctive water management in their water management plans and in the adoption of the DFCs. Sufficient monitoring of the interaction between surface water and groundwater is needed to perform that function.

- GAM modeling shows the possibility of future unreasonable effects on surface water resources caused by the cumulative effects of GMA-wide pumping. Monitoring is required to have sufficient knowledge to mitigate, and, if possible, prevent such impacts.

The field studies needed have been described in Chapter 7 Field Studies to Investigate Surface Water-Groundwater Interaction of the final report[18] on the New GAM provided to the Colorado and Lavaca Basin and Bay Area Stakeholder Committee (CL-BBASC). Pilot studies are underway with Senate Bill 3 funding requested by the CL-BBASC and administered by the TWDB with supplemental funding from Post Oak Savannah GCD, LCRA and BRA. Progress on this work has been reported[19] to the GMA-12 as recently as the September 18, 2020 meeting.

Funding is needed to investigate, install, calibrate and monitor surface water-groundwater interactions in the GMA-12 Districts where monitoring is appropriate. Sources for such funding need to be identified and secured. There seems to be a growing consensus that the Legislature needs to consider appropriating such funding in the 2021 session. Comments on this topic have been provided to the House Natural Resources Committee in response to Interim Charge 3.

In summary:

Field studies to monitor surface water-groundwater interaction are needed in order to validate the New GMA-12 GAM so that the predictions can be relied upon to inform decisions regarding the management of groundwater pumping and the adoption of desired future conditions. The methodology for conducting such studies have been developed and practiced in other portions of the Colorado River basin and are described in documents available to the Districts. Pilot studies that are currently underway should help refine the methodology and identify suitable monitoring sites within the Utley-Bastrop segment of the basin. Funding is needed to enable such monitoring to proceed in a timely manner.

VI. GMA-12 PRESENTATION: CONSIDERATION FOR ENVIRONMENTAL IMPACTS

GMA-12's Consultant Team gave a presentation on Consideration for Environmental Impacts[20] at the September 18, 2020 virtual meeting. These comments are offered in light of the information contained in that presentation.

Hydrologic separation of gage data to quantify drought conditions

During discussion of slide 5 the GMA 12 Consultants emphasized that average annual flows for the Colorado River is about 2,000 cfs with a range of 200 - 80,000 cfs. But, the GMA 12 Consultants omitted the impact of low flows of groundwater during drought conditions. During the most recent drought, average flow dropped to less than 800 cfs with a range of about 120 - 30,000 cfs (Figure 7). Such conditions, extending over weeks and months, have severe impacts on aquatic and terrestrial flora and fauna. As discussed in Section IV, above, stream flow standards for such severe conditions are set to sustain the biota during such low flow periods -- subsistence flows should be considered **"hands** off **flows"** with the goal that flows do not fall below the subsistence flow guidelines and thus should be met 100% of the time. As such, the "short persistence (less than a few years) of low water levels in alluvium" (slide 10) are biologically lethal and do not meet the subsistence criteria set forth by the environmental flow standards. GMA 12 should move towards a DFC that would protect these subsistence flows.

One of the primary differences between surface water and groundwater planning is the focus on drought. Groundwater planning tends to approach things from a dominantly geologic perspective that emphasizes long-term aquifer characteristics, whereas surface water planning gives due consideration to the impact of hydrological and climatological conditions on the biological communities (both aquatic and terrestrial). We often hear, whether disregarding or understating drought concerns, the arguments that the groundwater contribution to rivers and streams are a low percent of the average flow in the river -- in this presentation about 3.5% of the flow; with gage error of 5-10%.

Reality will refuse to be so easily dismissed. Droughts happen.

Fortunately, surface water considerations are most often driven by the desire to minimize and survive the harmful effects of drought conditions on human and ecological communities. With this in mind, it is important that surface water methodologies be applied to understand and mitigate the impacts of groundwater pumping during drought conditions.

Slide 27 of the GMA Consultant Team's presentation (Appendix 6) discussed hydrograph separation of river gage data to separate a hydrograph into groundwater discharge and runoff Using this methodology, it is possible to get an estimate of the groundwater contribution to stream flow, known in surface water hydrology as "baseflow". Hydrograph separation methodology and applications are discussed in further detail in the recent publication: Surface water-groundwater interaction issues in Texas.[21]

ES comments to the GMA-12 on September 21, 2015[22] presented the following information and requested that a hydrograph separation be done in order to get a better understanding of the magnitude of groundwater inflow (baseflow) at the Bastrop gage during the 2011-2013 period.

The subsistence flow standard at the Austin gage is 50 cfs and is subject to emergency curtailment. Otherwise, the flow in the river during drought conditions is primarily from City of Austin return flows, and perhaps City of Pflugerville (via Wilbarger Creek) return flows. A significant reduction in groundwater outflows due to pumping could shift this segment of the river from a minor losing segment (estimated at -9 cfs) to a major losing segment if Simsboro pumping were to significantly reduce groundwater outflow in this segment of the river.

Figure 7 is a hydrograph of the period from 2008 - 2013 when the Colorado River at the Bastrop gage routinely had peak flows in the range of 2,000 - 4,000 cfs for much of the time; much lower than average annual flow. Though seasonal agricultural flows were occurring during 2009, river flows were significantly below average flows -- in the range of 200 cfs -- for several months. Seasonal agricultural flows were curtailed in 2012 - 2013.

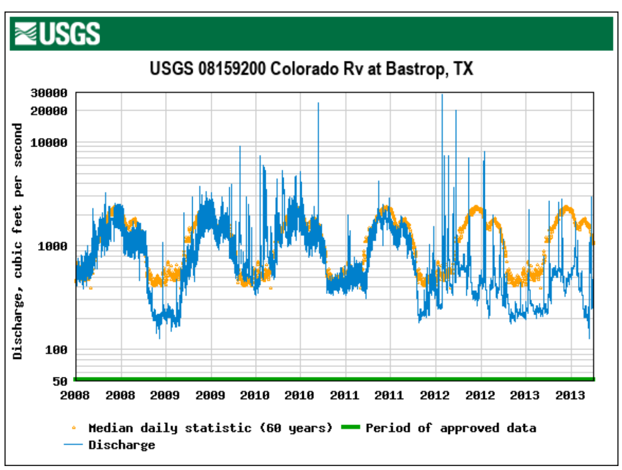


Figure 7. Colorado River at Bastrop gage during drought period Jan. 2009 - Sept. 2013. Total flow was in the 2,000 - 4,000 cfs for most of the period. Seasonal Agricultural releases were curtailed in 2012-2013.

Figure 8 is a hydrograph of the three year drought period from January 2011 through December 2013 when the region experienced some of the most severe drought conditions in decades. The distinguishing feature of this figure is that in-stream flows benefitted from the irrigation releases for down-stream rice farming during the spring, summer and early fall of 2011 and then was curtailed during the 2012 and 2013 irrigation seasons. There was very little flow from rainfall during the 2011 period. Lacking irrigation flows, flow in the river for the summer and fall would likely have dropped below the subsistence environmental flow range during that period. The health of aquatic communities in the Colorado River cannot be dependent on such calls by downstream water rights holders, demonstrating the need to protect and preserve groundwater inflows to the maximum degree possible.

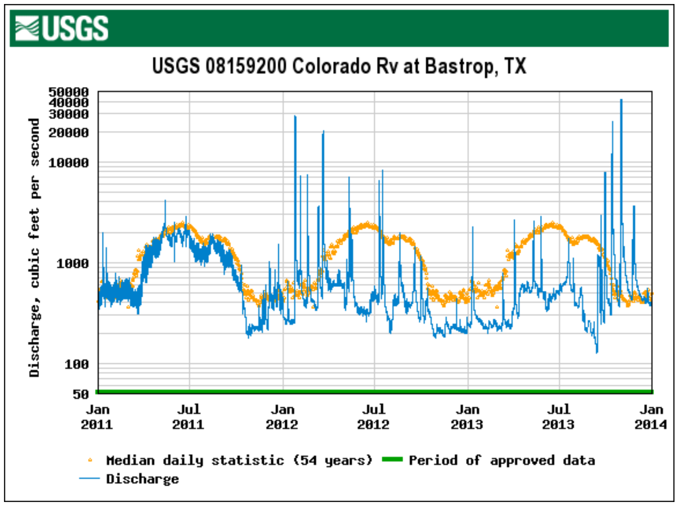


Figure 8. Colorado River at Bastrop gage during drought period Jan. 2011 - Dec. 2013. A hydrograph separation is requested for the period.

Figure 9 is a hydrograph of the month of September 2013 when the flow was trending toward the 123 - 180 cfs subsistence in-stream flow range. Fortunately, the region received significant rainfall starting in mid-September and river flow rebounded.

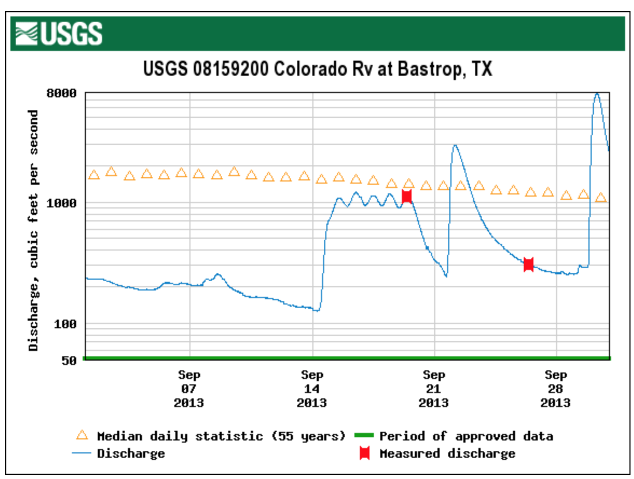


Figure 9. Hydrograph of the month of September 2013 when the flow was trending toward the subsistence in-stream flow minimum. Fortunately, the region received significant rainfall starting in mid-September and river flow rebounded.

A hydrograph separation on the three year period represented in Figure 8, with irrigation releases and return-flows accounted for, would likely reveal a very good estimate of actual groundwater outflows to the river from the Carrizo-Wilcox Aquifer group. During this period the bank storage for the river had likely been exhausted and the river was relying on the minimum flows passing through the Austin gage at Longhorn Dam, City of Austin, Pflugerville and Elgin return flows, and groundwater baseflows.

In summary:

Environmental Stewardship again requests that GMA-12 direct the consultants to prepare hydrographic separations as described above for the period January 2011 through December 2013 for the Bastrop, Wilbarger and Big Sandy gages of the Colorado River to gain insights on the quantity of groundwater that was being contributed to river flow for this extraordinary drought period.

VII. SELECTION OF DFCs THAT BALANCE IMPACTS ON SURFACE WATERS WITH DEVELOPMENT OF GROUNDWATER RESOURCES

The above analysis demonstrates that there is a direct relationship between the amount of pumping authorized under the desired future conditions and predicted reductions in the quantity of groundwater outflows to surface waters in the Colorado River and its tributaries.

Since it is accepted that the impact of diminished environmental flows is most critical during times of drought, as indicated in the environmental flow standards adopted by the Texas Commission on Environmental Quality (TCEQ) for both the Colorado and Brazos River basins, it is reasonable to expect that the greater the amount of authorized pumping, the greater the risk that such pumping will unreasonably damage surface water resources during drought conditions.

Environmental Stewardship and the GMA-12 consultants have demonstrated that the Old and New GAMs are reliable in qualitatively predicting trends and have predicted that increased pumping causes a greater risk to surface water resources. With this knowledge, the GMA-12 Districts should take a conservative and cautionary approach to determining desired future conditions until the impacts of groundwater and surface water interactions can be better quantified. The GMA-12 Districts should take pro-active steps to obtain the scientific data necessary for more definitive actions on permitting and desired future conditions in the fourth (4th) round of DFC review.

It is unreasonable to adopt desired future conditions that increasingly put surface water resources at risk. Recognizing that a subsistence flows analysis demonstrates that pumping increasingly causes a decline in environmental flows of surface waters, it is incumbent upon the GMA-12 Districts to plan for the protection of surface waters, and continuously improve available tools and information to enable further progress prior to the fourth (4th) round of DFC review.

Environmental Stewardship has followed a sensible analytical approach for estimating the impact of groundwater pumping on surface waters (GAM Runs) and then evaluating the ecological impact of the reduced environmental flows on surface water resources (WAM Runs). Certainly, both of these analytical methodologies can benefit from improved field data, however they represent the best scientific methodologies currently available and the results of these analyses should be recognized and used to guide policy and management decisions.

Proposed DFC Component for Bastrop Gage

Environmental Stewardship proposes that the protection of subsistence, base-dry and base-average flows at the Bastrop Gage be adopted as a DFC component. As discussed earlier, environmental flow regimes have been adopted by statute for the lower Colorado River basin at several USGS stream gages and for Matagorda Bay.

Bastrop gage is the point adopted to represent the Austin to Bastrop segment of the river. This segment of the Colorado River is hydrologically connected to the Carrizo and Wilcox aquifer formations that will be impacted by groundwater pumping within GMA-12. As such, it is appropriate that the standards set for this gage be used as the benchmark for managing negative impacts of groundwater pumping on the Colorado River and its tributaries.

ES comments[23] to the GMA-12 on June 27, 2014 demonstrated the importance of Carrizo-Wilcox groundwater outflow in the Utley to Bastrop segment of the river as measured at the Bastrop Gage.

Environmental flow standards adopted for the Bastrop Gage (APPENDIX 3) are:

- Subsistence (Severe Condition) flows vary by month from a low of 123 cfs to 275 cfs.
- Base-dry (Dry Conditions) flows vary during the spring months from a low of 274 cfs to a high of 579 cfs. Spring flows were specifically set to protect the breeding season of the state-threatened Blue Sucker.
- Base-Average (Average Conditions) flows vary during the spring months from a low of 297 cfs to a high of 824 cfs.

DFC component for Bastrop Gage is proposed as follows:

- Subsistence flow in the Colorado River at the Bastrop Gage will be met 100% of the time throughout each year.
- Base-dry and base-average flow will be met during the spring (March - June) in order to protect the state-threatened Blue Sucker.
- Non-exempt pumping within the Colorado River basin will be proportionately curtailed if subsistence, base-dry or base-average flow drops below the month's standard, expressed in cubic feet per second (cfs), for seven (7) cumulative days during any month.

Proposed DFC component for Colorado River Alluvium

The New GAM includes modeling of the Colorado River Alluvium in adequate detail to be used at both a regional and local scale. Though the alluvium is not used extensively as a groundwater supply resource, it is an important component of the Colorado River system and serves as the primary connection between the river and the underlaying aquifers. It is appropriate to develop a DFC component that will serve to protect the Colorado River and its tributaries from negative impacts due to groundwater pumping thereby maintaining the biological soundness of the river and its tributaries.

The Colorado River Alluvium is recognized as an aquifer within the jurisdiction of GMA-12 and Lost Pines District. However, this alluvial aquifer is the only aquifer that does not have adopted desired future conditions that establish planning goals in order to promote better long-term management of this resources. As surface water-groundwater modeling is taking place to better understand the relationship between the river, its tributaries, and the aquifers, it is time for the GMA start the process of establishing desired future conditions for the Colorado River Alluvium.

Recognizing that adequate studies are not available at this time to fully quantify a DFC component for the alluvium , Environmental Stewardship is proposing the following for consideration.

DFC components for Colorado River Alluvium should follow these guiding principles:

- DFC components should be developed for Bastrop and Fayette counties.
- DFC components should maintain the overall gaining status of the river; that is, the river continues to gain groundwater from the alluvium and the hydrologically connected underlaying aquifers.
- DFC components should contribute to maintaining the biological soundness of the river and its tributaries by reflecting the environmental flow standards that have been adopted for the Bastrop gage.
- DFC component should consider the major tributaries associated with the alluvium and the aquifers communicating with those tributaries; Carrizo, Wilcox Group, Sparta, Queen City and Yegua-Jackson.
- DFC components should be measured and monitored at appropriate surface water-groundwater sites associated with the Utley, Bastrop, Smithville and La Grange river gages.

In Summary, ES asks that GMA-12 consider the following factors:

- The current adopted 2017 DFCs are the most protective of surface waters in the Colorado River basin of the DFCs under consideration; as predicted by both the Old and New GAM.
- The GAMs predict that the significant quantity of newly permitted pumping since the 2017 DFCs were adopted have the potential of causing increased and potentially greater impacts on the Colorado River and its tributaries.
- Available surface-water impact methodologies indicate that the impacts of increased groundwater pumping are potentially unreasonable.
- Field data are needed to validate the New GAM and to verify what conditions exit.

Based on a consideration of these factors, ES requests that the Districts, as a part of Consideration 4, take the following actions:

- Monitor impacts of groundwater pumping on the mainstem of the Colorado River and its tributaries.
- Perform certain hydrograph separation studies to evaluate groundwater flow contributions to the Colorado River under drought conditions and to inform development of a surface water DFC component.
- Establish a DFC component that is protective of surface water, including subsistence, base-dry and base-average flows, that will trigger corrective actions should the predictions of surface water impacts be validated and/or realized in fact.
- Initiate the development of DFCs for the Colorado River Alluvium in anticipation of adopting such DFCs during the next planning cycle. Give consideration to the guiding principles provided in Section VII,
- Seek to establish criteria to qualitative and quantitative evaluate the impacts of reduced contributions of groundwater to baseflows into rivers and streams.
- Seek to establish criteria to determining when such impacts become unreasonable and thereby require remedial actions.

ES suggests, with respect to the last two requests, that GMA-12 and its Districts formally request that the Colorado-Lavaca Basin and Bay Area Stakeholder Committee (CL-BBASC) provide recommendations on how these can be accomplished . The CL-BBASC was the state appointed committee that developed the environmental flow recommendations for the Colorado River. As such it is likely the best and correct source for such guidance.

The CL-BBASC reflects the concerns of 17 stakeholder groups and has the Texas Water Development Board, Texas Commission on Environmental Quality, and the Texas Parks and Wildlife Department as resource agencies. In addition, the CL-BBASC has an expert science team (CL-BBEST) that can be tasked to review the existing literature and make recommendations based on the best science available.

ES further suggests that GMA-12 and its Districts seek funding from the State Legislature to fund the CL-BBEST and conduct such studies as are appropriate. Such funding should be channeled through the Texas Water Development Board.

APPENDIX 1

Nodes with Maximum Discharge Rate from Wilbarger Creek to Aquifers

S7 Baseline Pumping

Year 2010

Node	Layer, aquifer	Stage in Wilbarger Creek	Bottom of streambed	Head in layer 1	Head in layer 2
275	1, alluv	371.0	370.0	369.0	
276	1, alluv	371.0	370.0	368.6	
3943	2, Hoop	452.9	450.9		411.5
4570	2, Hoop	419.1	417.1		409.7
4571	2, Hoop	428.4	426.4		411.1
4572	2, Hoop	432.4	430.4		411.4
4605	2, Hoop	407.7	405.7		399.0
4615	2, Hoop	397.2	395.2		395.9
5330	2, Sim	400.7	398.7		395.6
5331	2, Sim	416.4	414.4		396.3
5335	2, Sim	436.3	434.3		395.8
5336	2, Sim	449.4	447.4		396.9
5349	2, Sim	470.4	468.4		398.5
5350	2, Sim	489.2	487.2		399.6

APPENDIX 2

Approximate Year Tributary Changes from Gaining to Losing Stream

Tributary	DFCRun3 Year	S-7 Year
Wilbarger Creek	Does not change by 2070	2045
Big Sandy Creek	2022	2018
Walnut/Cedar Creeks	Does not change by 2070	2063
Piney Creek/Lake Bastrop	2030	2026

APPENDIX 3

Texas Commission on Environmental Quality Page 281-282.
Chapter 298 - Environmental Flow Standards for Surface Water Rule
Project No. 2011-059-298-OW

(12) Colorado River at Bastrop, Texas, generally described as USGS gage 08159200, and more specifically described as Latitude 30 degrees, 06 minutes, 16 seconds; Longitude 97 degrees, 19 minutes, 09 seconds. (A) United States Geological Survey Gage 08159200, Colorado River at Bastrop.

Figure: 30 TAC §298.330(e)(12)(A)
United States Geological Survey Gage 08159200, Colorado River at Bastrop

Season	Month	Hydrologic Condition	Subsistence	Base	Seasonal Pulse (2 per season)
Winter	December	Severe	186 cfs	311 cfs	Magnitude: 3,000 cfs Duration: 4 days
	December	Dry	N/A	311 cfs	
	December	Average	N/A	450 cfs	
	January	Severe	208 cfs	313 cfs	
	January	Dry	N/A	313 cfs	
	January	Average	N/A	433 cfs	
	February	Severe	274	317 cfs	
	February	Dry	N/A	317 cfs	
	February	Average	N/A	497 cfs	
Spring	March	Severe	274 cfs	274 cfs	Magnitude: 3,000 cfs Duration: 4 days
	March	Dry	N/A	274 cfs	
	March	Average	N/A	497 cfs	
	April	Severe	184 cfs	287 cfs	
	April	Dry	N/A	287 cfs	
	April	Average	N/A	635 cfs	
	May	Severe	275 cfs	579 cfs	
	May	Dry	N/A	579 cfs	
	May	Average	N/A	824 cfs	
	June	Severe	202 cfs	418 cfs	
	June	Dry	N/A	418 cfs	
	June	Average	N/A	733 cfs	
Summer	July	Severe	137 cfs	347 cfs	Magnitude: 3,000 cfs Duration: 4 days
	July	Dry	N/A	347 cfs	
	July	Average	N/A	610 cfs	
	August	Severe	123 cfs	194 cfs	
	August	Dry	N/A	194 cfs	
	August	Average	N/A	381 cfs	
Fall	September	Severe	123 cfs	236 cfs	Magnitude: 3,000 cfs Duration: 4 days
	September	Dry	N/A	236 cfs	
	September	Average	N/A	423 cfs	
	October	Severe	127 cfs	245 cfs	
	October	Dry	N/A	245 cfs	
	October	Average	N/A	433 cfs	
	November	Severe	180 cfs	283 cfs	
	November	Dry	N/A	283 cfs	
	November	Average	N/A	424 cfs	

cfs = cubic feet per second
N/A = not applicable

APPENDIX 4

DFC Impact on Surface Waters from Old and New GAM Runs												
			ALL VALUES INTERPOLATED FROM GRAPHS									
				Total Pumping	Predicted Outflow to Main Stem Colordo River							
				File	InterpOlated from Graphs				Net Change			
	GAM	DATE		ac-ft/yr	1990	2010	2060	2070	1990-2010	2010-2070	1990-2070	Yr = 0
LPGCD 2017 Approved DFCs	**Old**	**2017**										
			Baseline (Initial Adopted DFC)	**29,400**	**N/A**	**9,000**	**-4,000**			**-13,000**		**2040**
			Baseline - potential	**86600**	**N/A**	**9,000**	**-13,000**			**-22,000**		**2020**
Preliminary Results - DFC Run 3 Slide" All Runs"	**New**	**1/29/19**										
			DFC Run 3 (Initial Adopted DFC)	**50900**	**27,500**	**19,000**		**5,000**	**-8,500**	**-14,000**	**-22,500**	-
			Scenario S-7	**116000**	**27,500**	**19,000**		**-5,000**	**-8,500**	**-24,000**	**-32,500**	**2050**
									0	**-10,000**	**-10,000**	
Difference between Baseline and DFC Run 3		Calculated		**21,500**						**-1,000**		**> 30 yrs**
Difference between Baseline + potential and Scenario S-7		Calculated		**29,400**						**-2,000**		**~ 30 yrs**
Colorado River Tributareis: DFC Run 3 vs S-7					Predicted Outflows to Tributaries of Colorado River							
					InterpOlated from Graphs				Net Change			
			ac-ft/yr		1990	2010	2060	2070	1990-2010	2010-2070	1990-2070	Yr = 0
ALL Tributaries			**DFC Run 3**		16,000	9,000	1,000	0	**-7,000**	**-9,000**	**-16,000**	**2070**
			Scenario S-7		16,000	9,000	-10,000	-14,000	**-7,000**	**-23,000**	**-30,000**	**2037**
Difference between S-7 and DFC Run 3		Calculated							**0**	**-14,000**	**-14,000**	
Wilbarger Creek			**DFC Run 3**		600	600	375	350	**0**	**-250**	**-250**	-
			Scenario S-7		600	600	-250	-400	**0**	**-1,000**	**-1,000**	**2045**
Difference between S-7 and DFC Run 3		Calculated							**0**	**-750**	**-750**	
Big Sandy Creek			**DFC Run 3**		1,800	2,000	-2,500	-3,000	**200**	**-5,000**	**-4,800**	**2020**
			Scenario S-7		1,800	2,000	-9,500	-10,500	**200**	**-12,500**	**-12,300**	**2019**
Difference between S-7 and DFC Run 3		Calculated							**0**	**-7,500**	**-7,500**	
Walnut/Cedar Creek			**DFC Run 3**		14,000	8,500	4,000	3,000	**-5,500**	**-5,500**	**-11,000**	-
			Scenario S-7		14,000	8,500	1,000	-2,000	**-5,500**	**-10,500**	**-16,000**	**2063**
Difference between S-7 and DFC Run 3		Calculated							**0**	**-5,000**	**-5,000**	
Piney Creek/Lake Bastrop			**DFC Run 3**		200	150	-250	-300	**-50**	**-450**	**-500**	**2030**
			Scenario S-7		200	150	-550	-700	**-50**	**-850**	**-900**	**2026**
Difference between S-7 and DFC Run 3		Calculated							**0**	**-400**	**-400**	
Sum of four streams communicating with Wilcox Group Aquifers		Calculated	**DFC Run 3**							**-11,200**	**-16,550**	
			Scenario S-7							**-24,850**	**-30,200**	
										-13,650	**-13,650**	

APPENDIX 5

Attainment Frequencies of Senate Bill 3 Flow Standards in the Lower Colorado River

		TARGET ATTAINMENT FREQUENCY 100%							TARGET ATTAINMENT FREQUENCY 80%							TARGET ATTAINMENT FREQUENCY 60%						
		SUBSISTENCE FLOWS							BASE FLOWS - DRY CONDITIONS							BASE FLOWS - AVERAGE CONDITIONS						
CP J30000	MONTH	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7
		(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%
Bastrop	Jan	12,789	100.0%	94.6%	94.6%	0.0%	94.6%	0.0%	19,245	97.3%	85.1%	86.5%	1.4%	85.1%	-1.4%	26,624	93.2%	56.8%	56.8%	0.0%	56.8%	0.0%
	Feb	15,217	98.6%	91.9%	93.2%	1.4%	91.9%	-1.4%	17,605	98.6%	83.8%	85.1%	1.4%	85.1%	0.0%	27,601	94.6%	52.7%	52.7%	0.0%	52.7%	0.0%
	Mar	16,847	97.3%	98.6%	98.6%	0.0%	98.6%	0.0%	16,847	97.3%	98.6%	98.6%	0.0%	98.6%	0.0%	30,559	87.8%	74.3%	68.9%	-5.4%	67.6%	-1.4%
	Apr	10,948	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	17,077	100.0%	98.6%	98.6%	0.0%	98.6%	0.0%	37,785	95.9%	77.0%	75.7%	-1.4%	75.7%	0.0%
	May	16,909	100.0%	97.3%	97.3%	0.0%	97.3%	0.0%	35,601	98.6%	95.9%	95.9%	0.0%	95.9%	0.0%	50,665	93.2%	89.2%	89.2%	0.0%	89.2%	0.0%
	Jun	12,019	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	24,872	100.0%	98.6%	98.6%	0.0%	98.6%	0.0%	43,616	87.8%	93.2%	93.2%	0.0%	93.2%	0.0%
	Jul	8,423	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	21,336	98.6%	98.6%	100.0%	1.4%	100.0%	0.0%	37,507	87.8%	93.2%	93.2%	0.0%	93.2%	0.0%
	Aug	7,562	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	11,928	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	23,426	91.9%	97.3%	97.3%	0.0%	97.3%	0.0%
	Sep	7,319	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	14,042	98.6%	98.6%	98.6%	0.0%	98.6%	0.0%	25,170	94.6%	91.9%	89.2%	-2.7%	87.8%	-1.4%
	Oct	7,808	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	15,064	98.6%	95.9%	95.9%	0.0%	94.6%	-1.4%	26,624	93.2%	74.3%	68.9%	-5.4%	66.2%	-2.7%
	Nov	10,710	100.0%	98.6%	97.3%	-1.4%	97.3%	0.0%	16,839	97.3%	70.3%	63.5%	-6.8%	62.2%	-1.4%	25,229	87.8%	47.3%	47.3%	0.0%	47.3%	0.0%
	Dec	11,436	100.0%	95.9%	95.9%	0.0%	94.6%	-1.4%	19,122	98.6%	73.0%	71.6%	-1.4%	71.6%	0.0%	27,669	86.5%	54.1%	52.7%	-1.4%	52.7%	0.0%
	Non-Attainment		2	6	6		6			0	2	2		2			0	4	4		4	

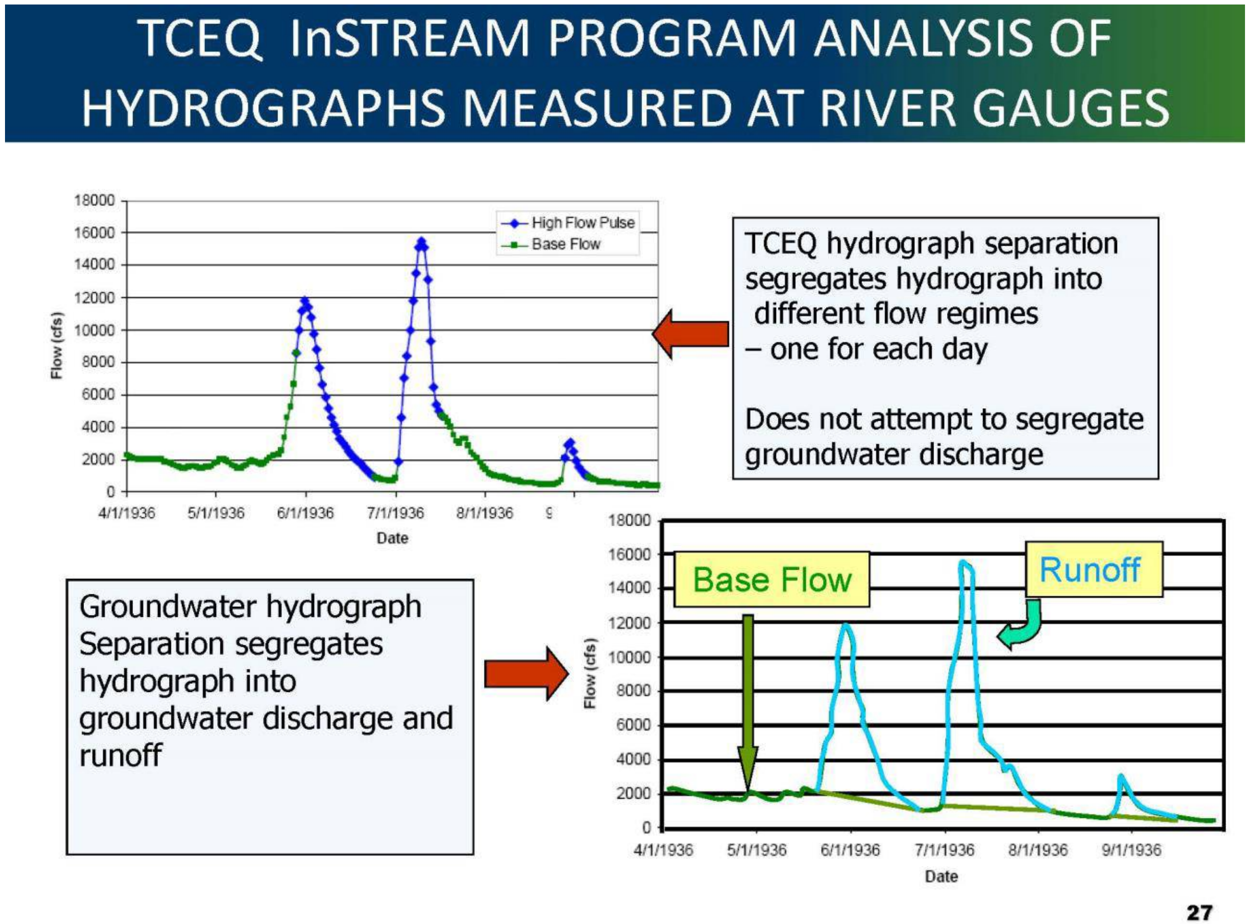
		SUBSISTENCE FLOWS							BASE FLOWS - DRY CONDITIONS							BASE FLOWS - AVERAGE CONDITIONS						
CP J10000	MONTH	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7
		(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%
Columbus	Jan	20,905	97.3%	100.0%	100.0%	0.0%	100.0%	0.0%	29,944	93.2%	68.9%	68.9%	0.0%	68.9%	0.0%	50,911	75.7%	50.0%	50.0%	0.0%	50.0%	0.0%
	Feb	20,826	98.6%	94.6%	94.6%	0.0%	94.6%	0.0%	32,766	93.2%	64.9%	60.8%	-4.1%	60.8%	0.0%	49,705	81.1%	45.9%	47.3%	1.4%	45.9%	-1.4%
	Mar	23,057	91.9%	98.6%	97.3%	-1.4%	97.3%	0.0%	32,280	90.5%	73.0%	73.0%	0.0%	71.6%	-1.4%	62,717	73.0%	50.0%	45.9%	-4.1%	45.9%	0.0%
	Apr	17,791	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	32,965	95.9%	93.2%	93.2%	0.0%	93.2%	0.0%	58,135	82.4%	52.7%	48.6%	-4.1%	48.6%	0.0%
	May	26,132	98.6%	100.0%	100.0%	0.0%	100.0%	0.0%	59,397	91.9%	93.2%	93.2%	0.0%	93.2%	0.0%	80,917	87.8%	86.5%	86.5%	0.0%	85.1%	-1.4%
	Jun	31,775	98.6%	100.0%	100.0%	0.0%	100.0%	0.0%	57,540	89.2%	93.2%	93.2%	0.0%	93.2%	0.0%	85,685	78.4%	86.5%	86.5%	0.0%	86.5%	0.0%
	Jul	21,028	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	35,047	91.9%	98.6%	98.6%	0.0%	98.6%	0.0%	55,031	75.7%	87.8%	85.1%	-2.7%	85.1%	0.0%
	Aug	11,682	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	19,061	98.6%	100.0%	100.0%	0.0%	100.0%	0.0%	31,727	89.2%	90.5%	86.5%	-4.1%	85.1%	-1.4%
	Sep	16,601	98.6%	100.0%	100.0%	0.0%	100.0%	0.0%	24,099	95.9%	100.0%	100.0%	0.0%	98.6%	-1.4%	36,297	93.2%	82.4%	78.4%	-4.1%	79.7%	1.4%
	Oct	11,682	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	21,889	98.6%	91.9%	87.8%	-4.1%	87.8%	0.0%	45,562	86.5%	62.2%	62.2%	0.0%	59.5%	-2.7%
	Nov	12,019	100.0%	97.3%	100.0%	2.7%	100.0%	0.0%	28,561	86.5%	50.0%	50.0%	0.0%	47.3%	-2.7%	44,925	75.7%	43.2%	43.2%	0.0%	43.2%	0.0%
	Dec	18,507	98.6%	94.6%	91.9%	-2.7%	91.9%	0.0%	28,530	91.9%	63.5%	60.8%	-2.7%	60.8%	0.0%	45,316	75.7%	41.9%	36.5%	-5.4%	36.5%	0.0%
	Non-Attainment		7	4	3		3			0	5	5		5			0	6	6		7	

		SUBSISTENCE FLOWS							BASE FLOWS - DRY CONDITIONS							BASE FLOWS - AVERAGE CONDITIONS						
CP K20000	MONTH	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7	FLOW	NAT	TCEQ3	DFC3	TCEQ3-DFC3	S7	DFC3-S7
		(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	% TIME MET	%
Wharton	Jan	19,368	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	30,251	97.3%	73.0%	73.0%	0.0%	73.0%	0.0%	51,526	77.0%	58.1%	56.8%	-1.4%	56.8%	0.0%
	Feb	16,827	98.6%	98.6%	100.0%	1.4%	100.0%	0.0%	33,155	93.2%	71.6%	67.6%	-4.1%	64.9%	-2.7%	50,316	83.8%	48.6%	48.6%	0.0%	48.6%	0.0%
	Mar	12,543	97.3%	98.6%	98.6%	0.0%	98.6%	0.0%	32,649	91.9%	62.2%	62.2%	0.0%	62.2%	0.0%	63,701	74.3%	44.6%	43.2%	-1.4%	43.2%	0.0%
	Apr	16,066	100.0%	98.6%	100.0%	1.4%	100.0%	0.0%	33,381	97.3%	59.5%	59.5%	0.0%	59.5%	0.0%	60,158	85.1%	48.6%	45.9%	-2.7%	45.9%	0.0%
	May	18,692	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	60,565	91.9%	54.1%	56.8%	2.7%	55.4%	-1.4%	85,898	85.1%	44.6%	44.6%	0.0%	44.6%	0.0%
	Jun	22,076	100.0%	97.3%	97.3%	0.0%	97.3%	0.0%	58,552	89.2%	60.8%	59.5%	-1.4%	58.1%	-1.4%	89,970	77.0%	32.4%	33.8%	1.4%	33.8%	0.0%
	Jul	13,035	100.0%	98.6%	98.6%	0.0%	98.6%	0.0%	35,478	93.2%	79.7%	74.3%	-5.4%	73.0%	-1.4%	55,707	78.4%	44.6%	36.5%	-8.1%	37.8%	1.4%
	Aug	6,579	100.0%	100.0%	100.0%	0.0%	100.0%	0.0%	19,307	97.3%	79.7%	77.0%	-2.7%	77.0%	0.0%	32,096	90.5%	73.0%	73.0%	0.0%	70.3%	-2.7%
	Sep	11,186	100.0%	98.6%	98.6%	0.0%	97.3%	-1.4%	24,396	95.9%	73.0%	67.6%	-5.4%	67.6%	0.0%	36,714	94.6%	51.4%	48.6%	-2.7%	48.6%	0.0%
	Oct	9,038	100.0%	98.6%	100.0%	1.4%	100.0%	0.0%	22,135	100.0%	71.6%	71.6%	0.0%	70.3%	-1.4%	46,054	87.8%	48.6%	48.6%	0.0%	47.3%	-1.4%
	Nov	10,294	100.0%	98.6%	100.0%	1.4%	100.0%	0.0%	28,919	91.9%	62.2%	60.8%	-1.4%	59.5%	-1.4%	45,461	79.7%	41.9%	40.5%	-1.4%	40.5%	0.0%
	Dec	12,420	100.0%	97.3%	94.6%	-2.7%	94.6%	0.0%	28,899	93.2%	68.9%	68.9%	0.0%	67.6%	-1.4%	45,869	78.4%	54.1%	52.7%	-1.4%	52.7%	0.0%
	Non-Attainment		2	9	5		5			0	12	12		12			0	11	11		11	

LEGEND:

- NAT – Naturalized Flows – frequency at which flow targets would be met or exceeded when considering the naturalized flows, which are the flows that would have been in the river had there been no human activities including reservoirs, diversions and return flows.
- TCEQ3 – frequency at which flow targets would be met or exceeded when considering TCEQ Run3 which represents the Full Authorization data set in which all currently permitted perpetual water rights holders withdraw their full authorized amount of water.
- DFCRun3 – frequency at which flow targets would be met or exceeded when considering groundwater pumping included in the DFC Run 3 GAM.
- TCEQ3-DFC3 – Difference between the frequency at which flows are achieved under TCEQ3 versus DFC Run3 GAM.
- S7 – frequency at which flow targets would be met or exceeded when considering groundwater pumping included in the Scenario S-7 GAM.
- DFC3-S7 – Difference between the frequency at which flows are achieved under DFC Run3 GAM versus the S7 Scenario GAM.

Slide 27 of the GMA Consultant Team's presentation discussed hydrograph separation of river gage data to separate a hydrograph into groundwater discharge and runoff components.



REFERENCES

[1] Groundwater Management Area 12 Appeal link: https://www.environmental-stewardship.org/groundwater-management-area-12-environmental-stewardships-petition-appealing-desired-future-conditions/#more-506.

[2] GMA-12 DFC Review (2013-16) link: https://www.environmental-stewardship.org/gma-12-dfc-review-2013-16/.

[3] Rice, George. March 22, 2016. GAM Predictions of the Effects of Baseline Pumping Plus Proposed Pumping by Vista Ridge, End OP, Forestar, and LCRA. Figure 5 from Rice Report. Link to report https://www.environmental-stewardship.org/wp-content/uploads/2016/04/EffectsOfPumping_BaselinePlus_VREndOpForestarLCRA-1.pdf.

[4] LCRA (6500 AFY, Forestar (12,000 - 28,500 AFY), and End Op (25,000 - 46,000 AFY).

[5] Consultant Team Presentation January 29, 2019 link: https://posgcd.org/wp-content/uploads/2019/01/GMA-12-Presentation-Summary-of-GAM-Comparison-and-Path-Forward-20190128.pdf.

[6] Rice, George. 2020 unpublished.

[7] ES Presentation to GMA-12. June 27, 2014. GMA-12 DFCs: GW-SW Considerations. LINK: https://posgcd.org/wp-content/uploads/2015/03/06.27.14_Presentation-Environmental-Stewardship.pdf.

[8] The major differences between S7 and DFCRun3 are 1) S7 contains historic pumping data through 2018, and 2) S7 contains pumping for all permitted pumping, including pumping for large projects such as Vista Ridge, End Op, and Forestar.

[9] PRESENTATION TO GMA Consideration for Environmental Impacts By consultants for the: Daniel B. Stephens & Associates Ground Water Consultants, LLC, and INTERA, Incorporated. September 18, 2020, Slide 11. link: https://posgcd.org/wp-content/uploads/2020/09/GMA12_Aug_13_environmental_final1.pdf.

[10] Nodes and GAM output information are shown in an excel file: *S7_WilbargerAndBigSandy_Stream-AquiferInteraction.xlsx* (D:\Jorje\Clients9\NewNewBastrop_GMA-12\2020\WilbargerBigSandy&Brazos\CombinedRun3&S7PumpingResults).

[11] Determined by comparing discharge in 2070 with discharge in 2069.

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