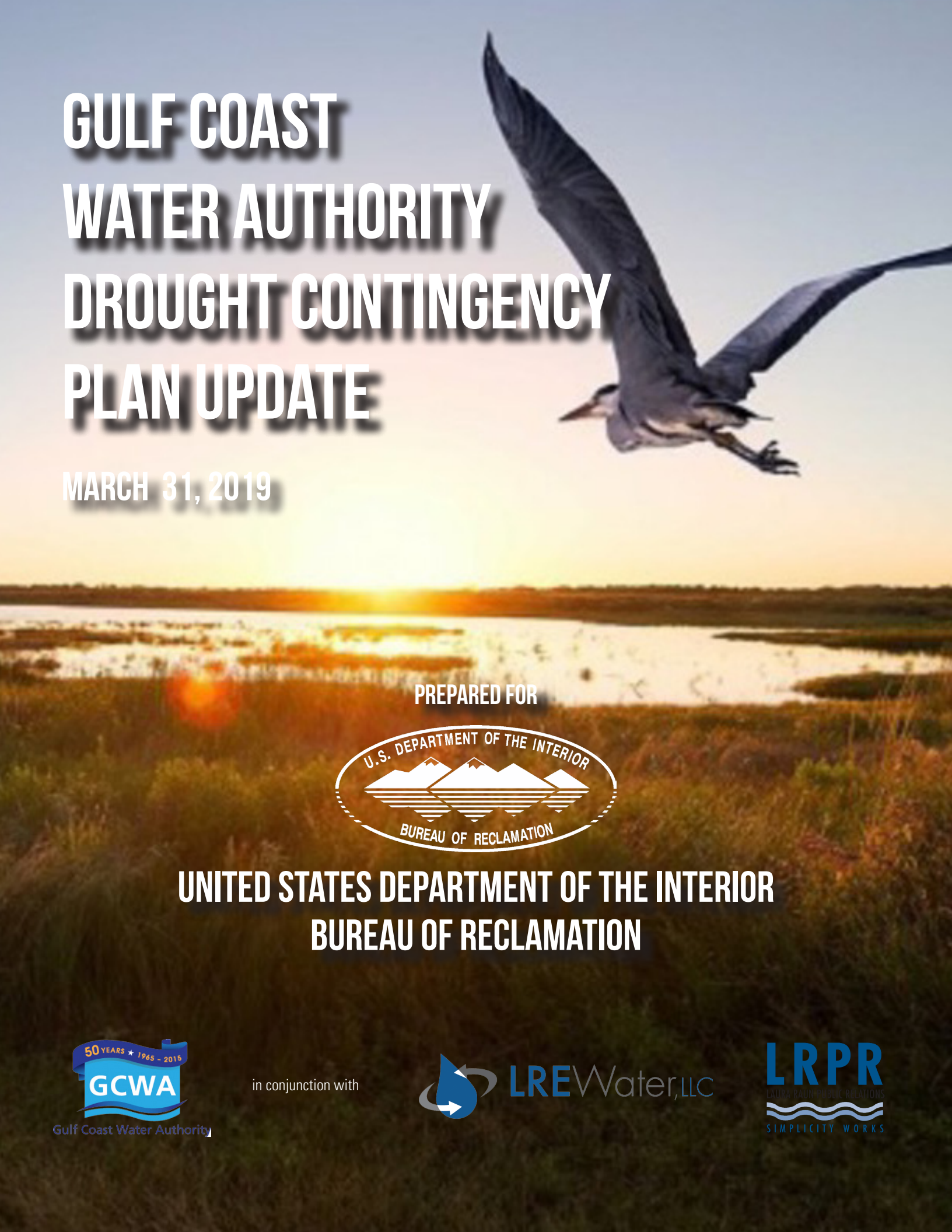

# GULF COAST WATER AUTHORITY DROUGHT CONTINGENCY PLAN UPDATE

MARCH 31, 2019

PREPARED FOR

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

## UNITED STATES DEPARTMENT OF THE INTERIOR
## BUREAU OF RECLAMATION

50 YEARS ★ 1965 - 2015
GCWA
Gulf Coast Water Authority

in conjunction with

LREWater, LLC

LRPR
LAURA RAUN PUBLIC RELATIONS
SIMPLICITY WORKS

# Gulf Coast Water Authority
# Drought Contingency Plan Update

Prepared for:

## UNITED STATE DEPARTMENT OF THE INTERIOR
## BUREAU OF RECLAMATION

March 2019

Under Agreement Number:

R16AC00114

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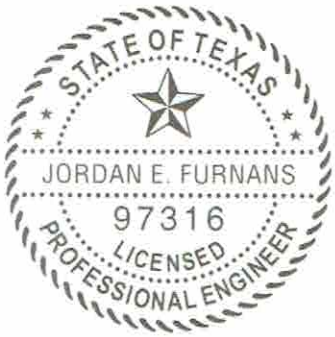
# Geoscientist and Engineer Seals

To complete this Drought Contingency Plan Update, the Gulf Coast Water Authority contracted with LRE Water, LLC, a licensed professional geoscientist firm (Texas License No. 50516) and licensed professional engineering firm (Texas License No. 14368). This report documents the work of the following licensed professional geoscientists and licensed professional engineers in the State of Texas:

Jordan Furnans, Ph.D., P.E., P.G.

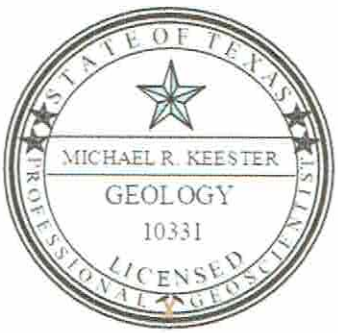
Dr. Furnans was the Project Manager for this work and was responsible for the entirety of the project, including data analysis, plan development, holding public/stakeholder meeting, and numerical water availability modeling. His work also involved final report review and acceptance.




Signature 3/29/19 Date

Michael Keester, P.G.

Mr. Keester was responsible for assessing the viability of local groundwater usage to supplement surface water flows during drought periods.




Signature 3/29/2019 Date

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# Gulf Coast Water Authority
# Drought Contingency Plan Update

## Introduction

### Scope and Purpose of Drought Contingency Plan Update

The Gulf Coast Water Authority ("GCWA") provides water on a wholesale basis to customers in Galveston, Fort Bend, and Brazoria Counties (TX), including municipalities (e.g. Galveston, Sugarland, Missouri City) as well as petro-chemical industries (e.g. Dow-UCC, Valero, INEOS, Marathon, Ascend). The majority of GCWA's water is diverted from the Brazos River, and the location of its diversions in the Lower Brazos basin cause GCWA's water availability to be dictated both by natural streamflow variations and the water usage behavior of upstream entities. Texas regulations require that GCWA develop and routinely update basic drought contingency plans to aid in mitigating the effects of drought on customers. The existing GCWA plan, however satisfying state criteria, does not include all standard drought contingency practices as endorsed by the US Bureau of Reclamation ("Reclamation"). Through this project, GCWA has updated its plan to better satisfy its customer's needs and expectations, and meets or exceeds standard practices required by the Bureau of Reclamation. The plan integrates four critical components:

1. Drought severity assessment though data gathering and analysis,
2. Planning to conjunctively utilize available groundwater during periods of drought,
3. Developing/implementing infrastructure monitoring and mitigation activities to reduce water loss, and
4. Incorporating standard drought contingency planning elements into GCWA's existing plan.

GCWA's Response and Mitigation Actions include a detailed evaluation of the availability of locally-sourced groundwater suitable for supplementing surface water sources during periods of drought. Additionally, GCWA has refined water loss monitoring procedures, geared to minimize demands for additional Brazos River water, thereby making such water available for other users within the Brazos Basin.

This updated DCP was developed by GCWA over the course two years (November 2016-December 2018) and describes how GCWA will operate to ensure water availability to customers through future droughts. The project was managed by LRE Water, LLC in close coordination with GCWA management and engineering staff. GCWA solicited and received plan input from its municipal, agricultural, and industrial clients, and many such clients readily served as members of the project Drought Task Force ("DTF") that continually guided plan development during the project.

Through this plan update process with the Reclamation, GCWA also revised and updated its DCP for submission and approval by the Texas Commission on Environmental Quality (TCEQ). This updated DCP (Appendix A) utilized the research and components of the Reclamation DCP, yet is contains formatting and content consistent with Texas standards.

## Planning Area

As water availability to GCWA is dictated by hydrologic conditions throughout the Brazos Basin, the planning area for this project must include the majority of the Brazos River Basin. However, with the creation of the Brazos Basin Watermaster program in 2015, the TCEQ effectively separated the Brazos Basin into upper and lower portions, with the lower portion under the jurisdiction of the Watermaster. As such, the overall planning area for this project includes the Brazos Basin watershed downstream of and including Possum Kingdom Lake (Figure 1**)**. This region encompasses 21,903 square miles, and provides water to 1,227 water right holders authorized to divert by the TCEQ. Within the region there exist 47 active USGS streamflow gauges, as well as 21 reservoirs capable of storing at least 5,000 acre-ft of water. All drought monitoring activities, as well as some vulnerability assessment efforts and mitigation activities derived under this project cover the entire project planning area as shown in Figure 1.

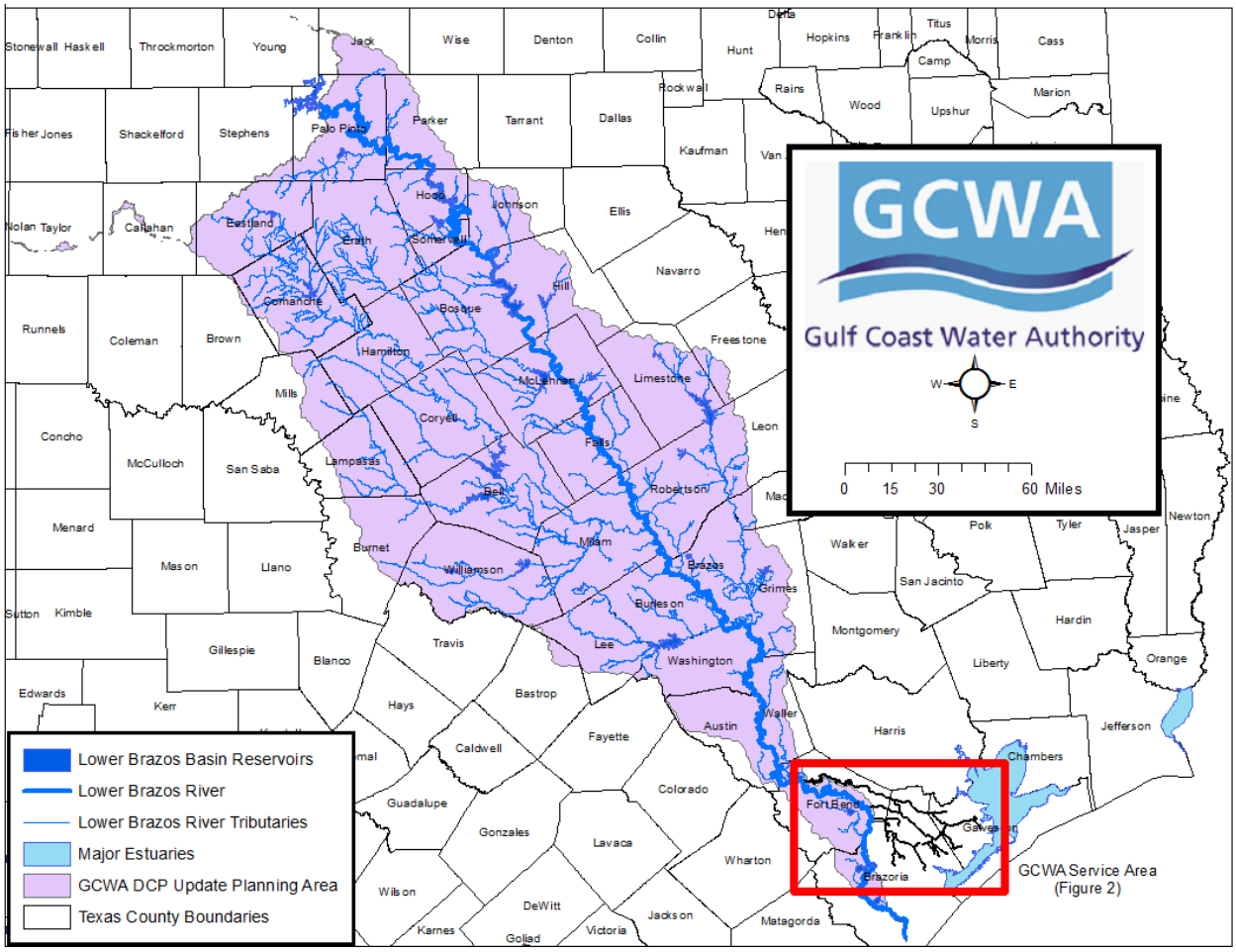



*Figure 1 - Brazos Basin Map showing the full extent of the GCWA DCP Update Planning Area, as well as the GCWA Service Area at the downstream end of the Brazos.*

Figure 2 provides details of GCWA's service area within Fort Bend, Brazoria, and Galveston Counties, and is visible in the lower-right hand corner of Figure 1. GCWA's response actions developed during this project are limited in geographic scope to the areas shown in Figure 2. Some vulnerability assessment

efforts and mitigation actions are also limited in scope to the areas shown in Figure 2. The majority of mitigation and response actions included within this DCP are limited to areas adjacent to GCWA and GCWA's customers, including water conveyance infrastructure utilized by GCWA and its customers. Through this project, however, GCWA also investigated mitigation actions potentially to be undertaken by GCWA outside of GCWA's immediate service area (Figure 2).

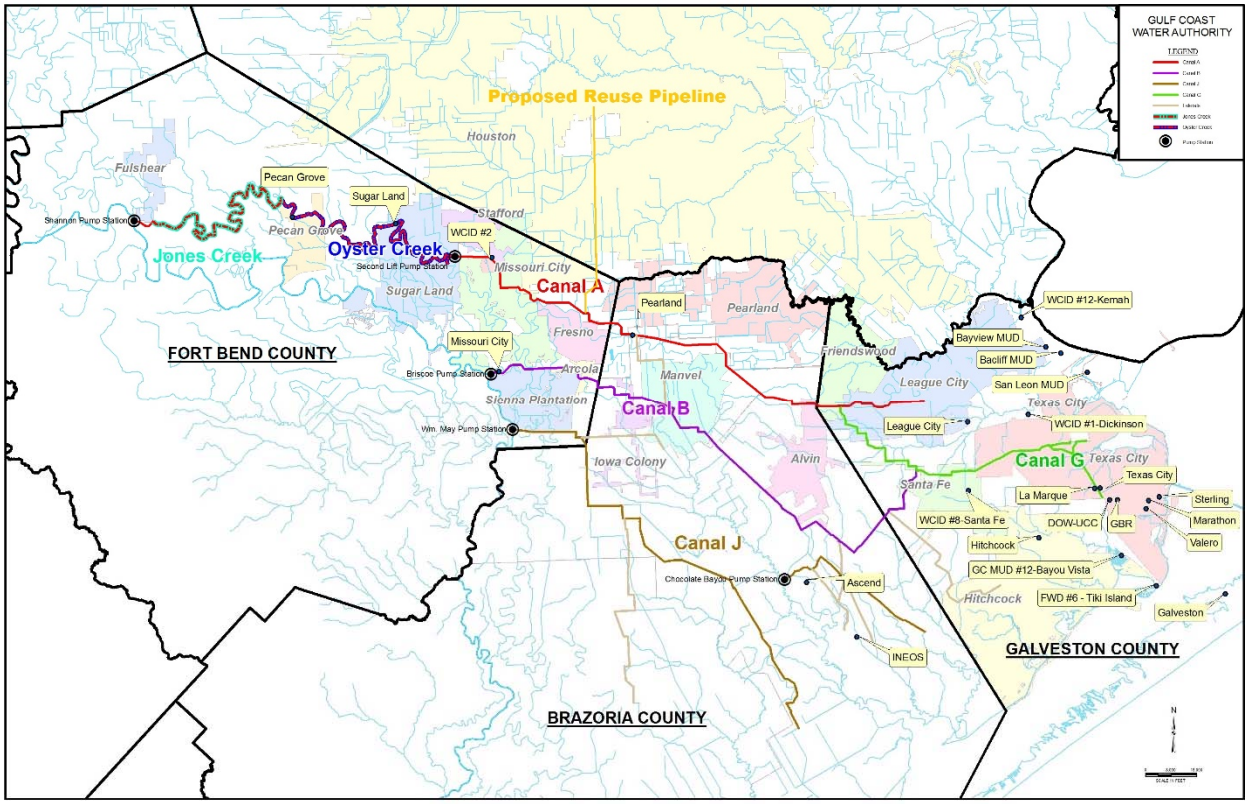



*Figure 2 – GCWA's Service Area showing canals and customer locations*

## Background

As required by TCEQ, GCWA's drought contingency plan must provide TCEQ, GCWA customers, and the general public with basic information regarding actions to be undertaken in the case of Brazos Basin drought and/or a reduction in water availability to GCWA. GCWA has maintained a drought contingency plan throughout its years of operation, and the last plan update (prior to this project) occurred in 2012. This "Previous Plan" satisfies all plan requirements stipulated by the Texas Administrative Code (§288.20-§288.22). Under the Previous Plan, the general manager of GCWA was given the authority to impose voluntary and mandatory water usage reductions on its customers, based upon unspecified drought forecasts/triggers and specified water usage rate values. The Previous Plan defined only four stages of drought response, with increases in curtailment required with increases in drought severity. The Previous Plan also addressed public/stakeholder involvement in the planning process, obtaining variances from plan requirements, penalties for non-compliance, and how the plan was to be periodically updated and reviewed. The Previous Plan was sufficiently general in that GCWA retained great flexibility in deciding how to implement drought responses, and exactly what actions were to be undertaken at each plan stage.

Through this project, GCWA developed two separate planning documents: 1) a Drought Contingency Plan Update ("Reclamation Plan") meeting Reclamation requirements, and 2) a Drought Contingency Plan update meeting only TCEQ requirements ("TCEQ Plan") yet based entirely on the elements of the Reclamation Plan. The TCEQ Plan (Appendix A) was approved for use by the GCWA Board of Directors on December 6, 2018. This document is the Reclamation Plan, and will serve as the research basis from which all GCWA drought contingency planning efforts will be undertaken. GCWA will update both plans continuously based on observations of plan implementation, analysis results, and continued development of water resources infrastructure and monitoring systems, implemented by GCWA and other entities within the Brazos Basin. GCWA will formally update the TCEQ Plan every 5-years, with the next formal update due to the TCEQ in 2024.

## GCWA– Reclamation Planning Approach

Through the development of the TCEQ Plan and the Reclamation Plan, GCWA was guided by the plan requirements stipulated by Reclamation. These plan requirements, including the six essential elements ("Drought Monitoring," "Vulnerability Assessment,", "Mitigation Actions," "Response Actions," "Operational & Administrative Framework," and "Plan Update Process") are addressed in detail below in the following Plan sections. The next section describes the Drought Task Force ("DTF") formed to guide the Plan update process, and details the DTF-GCWA interactions throughout the project duration.

### Drought Task Force & Guiding the DCP Update Process

To ensure that the updated DCP would be accepted by GCWA customers, GCWA formed a Drought Task Force (DTF) that would meet periodically throughout the project and provide feedback on the project progress and plan development. The DTF consisted of interested stakeholders committed to aiding GCWA in the drought contingency planning update. DTF membership was open to the public, yet GCWA direct customers as well as local regulators and officials were specifically invited to participate. Membership in the DTF was not fixed, and meeting attendance (while recorded) was not required. DTF members were kept informed of the plan progress via a website developed for the project, linked to the main GCWA website. DTF members were able to provide feedback directly to GCWA or LRE Water via email or via a comment section on the DCP Update website. When comments were provided, the comments were discussed at the subsequent DTF meeting.

Table 1 lists the dates of the DTF meetings conducted during this project effort, as well as provides a brief summary of the main topics of discussion of each meeting. All meetings were held at GCWA facilities, with the exception of the first and last meetings which were held at a large venue to accommodate the expected number of participants. Entities were also always able to participate online and via conference call, as each meeting was broadcasted via a GoToMeeting Invitation to interested participants. Presentations made at each meeting were posted to the DCP website immediately after the meeting, to aide in participant review and comments. Participant surveys were also conducted via "SurveyMonkey.com" to determine levels of "acceptable" curtailment DTF member organizations could accept, as well as to gauge interest in a proposed curtailment-trading scheme designed to minimize the potential impacts of curtailments on certain GCWA customers.

*Table 1 – Drought Task Force Meetings – Dates and Topics*

| Meeting # | Date | Topic |
|---|---|---|
| 1 - Kickoff | 1/12/2017 | Project Description, Solicit ideas/interest |
| 2 | 4/17/2017 | Detailed Work Plan Development, Review Existing DCP from GCWA, Customers, and BRA |
| 3 | 7/17/2017 | Project Website, Planning Dashboard, Water Loss Monitoring |
| 4 | 10/17/2017 | Climate Change Analysis, Flow Prediction Tool, Curtailment Rules |
| 5 | 2/26/2018 | Basin Hydrology, US Drought Monitor Review, Curtailment Survey Results, Curtailment Modeling, Canal Losses, Groundwater Usage |
| 6 | 5/7/2018 | Basin WAM Modeling, Groundwater Availability, Existing DCP Contents, Draft DCP Preparation & Review |
| 7 -– TCEQ Plan Discussion | 8/14/2018 | Presentation of TCEQ Plan – V. 9, Hydrology Discussion, Request for Review & Comment |

All communications between GCWA, LRE Water, and the project stakeholders (DTF members and other interested parties) were initiated based on terms of the Reclamation-approved Communications & Outreach Plan ("C&O Plan") developed for this DCP update project. The C&O plan was designed to optimize stakeholder and public engagement in preparation of the GCWA DCP update. The C&O plan directed how information regarding the update will be made available to stakeholders and the public (via the DCP project website), how meetings will be announced (via the DCP project website and email reminders to DTF members and past meeting attendees), and how parties may provide information or comments during the project (via email to GCWA, LRE Water, or via the DCP project website).

The DCP project website was available during the duration of the project at the following URL:

http://gcwa.lrewater.com/

It was updated periodically though the project, and served as a central repository for all information regarding the project. The DCP project website will be active and accessible at the above address until 12/31/2019, at which time the website contents will be archived and possibly transferred to another GCWA website for GCWA continued maintenance. LRE Water, LLC will retain all archived website contents, including all correspondence, for a minimum of 3-years and will make all project information available upon receipt of written request. Material generated during this DCP update process will prove invaluable during the upcoming 2024 DCP update.

Upon adoption of the Reclamation and TCEQ Plans by GCWA, both plans will be available from the GCWA website at the following URL:

http://gulfcoastwaterauthority.com/reports-studies-data/conservation/

This URL will also contain updated drought stage triggers and response actions (compared to the 2012 TCEQ Plan currently posted), thus serving as the resource for GCWA customers working under the GCWA DCP.

Table 2 provides a list of the DTF members not employed by GCWA and who actively provided input during the DCP update process. DTF members guided the update process through answering surveys

regarding potential DCP components and offering insights into the benefits and difficulties to arise from the proposed actions. Survey results and DTF insights were always discussed at the next DTF meeting and were used to dictate meeting contents and ultimately the DCP components.

*Table 2 – DTF Members & Affiliations*

| First Name | Last Name | Email | Affiliation |
|---|---|---|---|
| Bill | Alcorn | mud12@comcast.net | MUD 12 |
| Robert | Gadbois | robert.gadbois@missouricitytx.gov | City of Missouri City |
| Shashi | Kumar | shashi.kumar@missouricitytx.gov | City of Missouri City |
| Chris | Cruz | ccruz@marathonpetroleum.com | Marathon Petroleum |
| David | Anton | dwanto@ascendmaterials.com | Ascend Materials |
| David | Davalos | ddavalos@dow.com | Dow Chemical Co. |
| Jerry | Dobbs | jerry.dobbs@valero.com | Valero |
| Kevin | Moore | kevinmoore@eastman.com | Eastman |
| Dennis | Stark | starkden@cityofgalveston.org | City of Galveston |
| Doug | Kneupper | dkneupper@texas-city-tx.org | City of Texas City |
| Jody | Hooks | jody.hooks@leaguecity.com | City of League City |
| San Leon MUD | | slmud1@slmud.org | San Leon MUD |
| Scott | Elmer | elmer@missouricitytx.gov | City of Missouri City |
| Kyle | Jung | kjung@cityofmanvel.com | City of Manvel |
| Bobby | Gervais | BGervais@cityofmanvel.com | City of Manvel |
| Delores | Martin | dmartin@cityofmanvel.com | City of Manvel |
| Kirby | Brown | kbrown2@ducks.org | Ducks Unlimited |
| Glen | Lord | mglord@dow.com | Dow Chemical Co. |
| Dennis | Stark | dstark@galvestontx.gov | City of Galveston |
| Ross | Blackketter | rblackketter@galvestontx.gov | City of Galveston |
| Tim | Samford | tsamford@texas-city-tx.org | City of Texas City |
| Keith | Morgan | kmorgan@wcid1.com | Fort Bend WCID #1 |
| John | Mitchiner | jmitchiner@wcid1.com | Fort Bend WCID #1 |
| Terri | Gale | tlsgale@gmail.com | GCWCID #12 |
| Nancy | McDonald | nancytmcd@aol.com | WCID #12 |
| Roselle | Bleile | calongrf@dow.com | Dow Chemical Co. |
| Angelo | Grasso | agrasso@galvestontx.gov | City of Galveston |
| James | McWhorter | jmcwhorter47@yahoo.com | City of Texas City |
| Nancy | Ragland | nancy.ragland@tceq.texas.gov | TCEQ |
| Katie | Clayton | kclayton@sugarlandtx.gov | City of Sugar Land |
| Debra | Davison | ddavison@cityofmanvel.com | City of Manvel |
| Daniel | McGraw | Daniel.McGraw@missouricitytx.gov | City of Missouri City |
| Les | Rumburg | l.rumburg@cityoflamarque.org | City of La Marque |
| Christopher | Dorow | christopher.dorow@basf.com | BASF |
| Andrew | Miller | amiller@slmud.org | SL MUD |
| Venkat | Venkatasubbiah | vvenkatasubb@marathonpetroleum.com | Marathon Petroleum |
| Richard | Matthews | rmatthews6490@gmail.com | Galveston County MUD12 |

## Public Participation Opportunities within the DCP Update

GCWA always strives to conduct its operations in an open and transparent manner. All DTF meetings were open to anyone who wished to attend, and meetings were announced a minimum of two weeks prior to the meeting date. In preparation for the project kickoff meeting (1/12/2017), GCWA invited (via email) all individuals and entities with previous interactions regarding GCWA operations. During each meeting, participants selected the date of the next meeting, and this information was included in the meeting minutes which became immediately available upon the DCP project website. At each meeting, participants were encouraged to contact either GCWA or LRE Water directly with comments or information regarding the project. Comments were generally provided only by a select few of the DTF members (Table 2), and these comments were addressed privately via email prior to the next DTF meeting and then publically at the next DTF meeting. The majority of comments were received after the last DTF meeting, at which a draft DCP was presented. The provided comments highlighted many concerns the DTF members had with the draft DCP, and these concerns led to draft DCP revisions and ultimately the final DCP version as presented herein and in Appendix A. Each entity that submitted a comment after the last DCP meeting received a detailed email discussing the comment and how the comment led to any modifications between the draft and final DCPs. Copies of these emails will be included in the project archive.

Over the course of the project, two separate surveys were sent to DTF members and past meeting attendees. The first survey contained questions which were designed to gauge GCWA customer abilities to reduce their current demands during a drought period. Customers were asked if they could maintain basic operations with a 5%, 10%, 15%, 20% or greater reduction in available water. Customers were also asked about their notification preferences, specifically how long prior to implementing the reduction would they like to receive notice of the reduction. This information directly led to the development of the water use reduction goals included in the DCP (See discussion on Essential Element #4 – Response Actions) as well as in setting the 2-week flow prediction window incorporated into GCWA's Flow Prediction Tool (FTP – See Essential Element #2 – Vulnerability Assessment). The second survey was designed to determine GCWA customer interest in the development and administration (by GCWA) of a "Cap-and-Trade" type system in which certain GCWA customers might be avoid (or lessen ) reducing their water usage during a drought, while other customers would reduce usage to a greater extent to make the overall water usage meet the reduction goals. Under this scheme, the entities who reduced less than the desired goal would compensate those entities who reduced more than the desired goal. This scheme was favorably discussed during the 5/7/2018 DTF meeting, yet was found to be un-tenable based on the survey results. As such, the scheme was abandoned and not included as part of the final DCP presented herein.

The final DCP presented herein was ultimately crafted by LRE Water based on direct input from GCWA and the DTF. The DCP evolved over the course of the project, and the evolution was largely directed by input received during and as a result of the DTF meetings. Receiving stakeholder input (and acceptance) was crucial to the DCP development process. Future revisions to GCWA's DCP will also include stakeholder and public input processes, as GCWA recognizes the importance of customer and public acceptance of proposed GCWA drought management actions.

## Essential Element #1 – Drought Monitoring

The purpose of the Drought Monitoring actions described herein is to provide information to GCWA to allow for informed assessment of available water supplies and demands within the GCWA service area. Such provided information will be used by the GCWA General Manager (or designee) in assessing hydrologic conditions and in consideration of the need to increase drought stages (and stage responses). As described in the Response Actions and Operational and Administrative Framework sections, information gathered through drought monitoring activities is to be used only to suggest drought responses. The GCWA General Manager (or designee) will CONSIDER such information when deciding whether or not to implement a higher or lower drought stage response; such decisions will not be made automatically based only on the drought monitoring information.

As described within the Detailed Work Plan for this DCP, efforts undertaken under the drought monitoring task were to include the development of an online data repository for Brazos Basin streamflow that would aide GCWA in analyzing and predicting drought conditions. The dashboard was created and made accessible at the URL:

http://www.gcwa-dashboard.com

The dashboard provided a map-based interface to Brazos Basin streamflow and reservoir water level gauges, and would update daily through the executing of a Matlab program which obtained data from USGS websites, processed data into usable formats, stored the data in GCWA databases, and displayed the data through the dashboard (Figure 3). Aside from displaying streamflow data, the dashboard also displays reservoir water level time-histories and time-histories of reservoir storage (total storage and storage as a percentage of conservation storage).

Along with real-time and historical data, the GCWA dashboard also displays predicted stream flow at certain locations within the study area. These predicted streamflows were created utilizing the "Flow Prediction Tool (FPT)" (Appendix B), designed to assess streamflows up to 2-weeks (14 days) into the future and compare those flows against the expected water needs of all permitted water diverters in the Lower Brazos Basin (including GCWA, Dow Chemical Company, and NRG Energy). Figure 4 shows sample results from the FPT for the period from *9/15/18 to 10/6/18.* Specifically, the FPT routes downstream known releases from water supply reservoirs within the Brazos Basin, and then determines streamflows to be expected at select locations, including at the USGS gauge locations (Hempstead, Richmond, and Rosharon) as well as at the locations of GCWA pump stations. The FPT tool relies upon travel time and conveyance loss data provided by the Brazos River Authority, and is most accurate under dry (low flow, low rainfall) conditions. As shown in Figure 4, the FPT results contain 3-weeks of data. The first week of displayed results corresponds to the week prior to the date of execution of the FPT program. During this time, it is possible to compare real-time streamflow gauge data (shown in GREEN) against the predicted streamflow (shown in RED), thus providing an assessment of the potential validity of the FPT's predictions. The 2$^{nd}$ and 3$^{rd}$ weeks of data provided by the FPT are predicted streamflows. Figure 4 also shows the monthly streamflow target(s) representing the minimum streamflow needed to satisfy the needs of all Lower Basin water right holders (black lines). The monthly streamflow targets are discussed in the "Vulnerability Assessment" Section. FPT graphical output, like Figure AC, can be utilized by GCWA

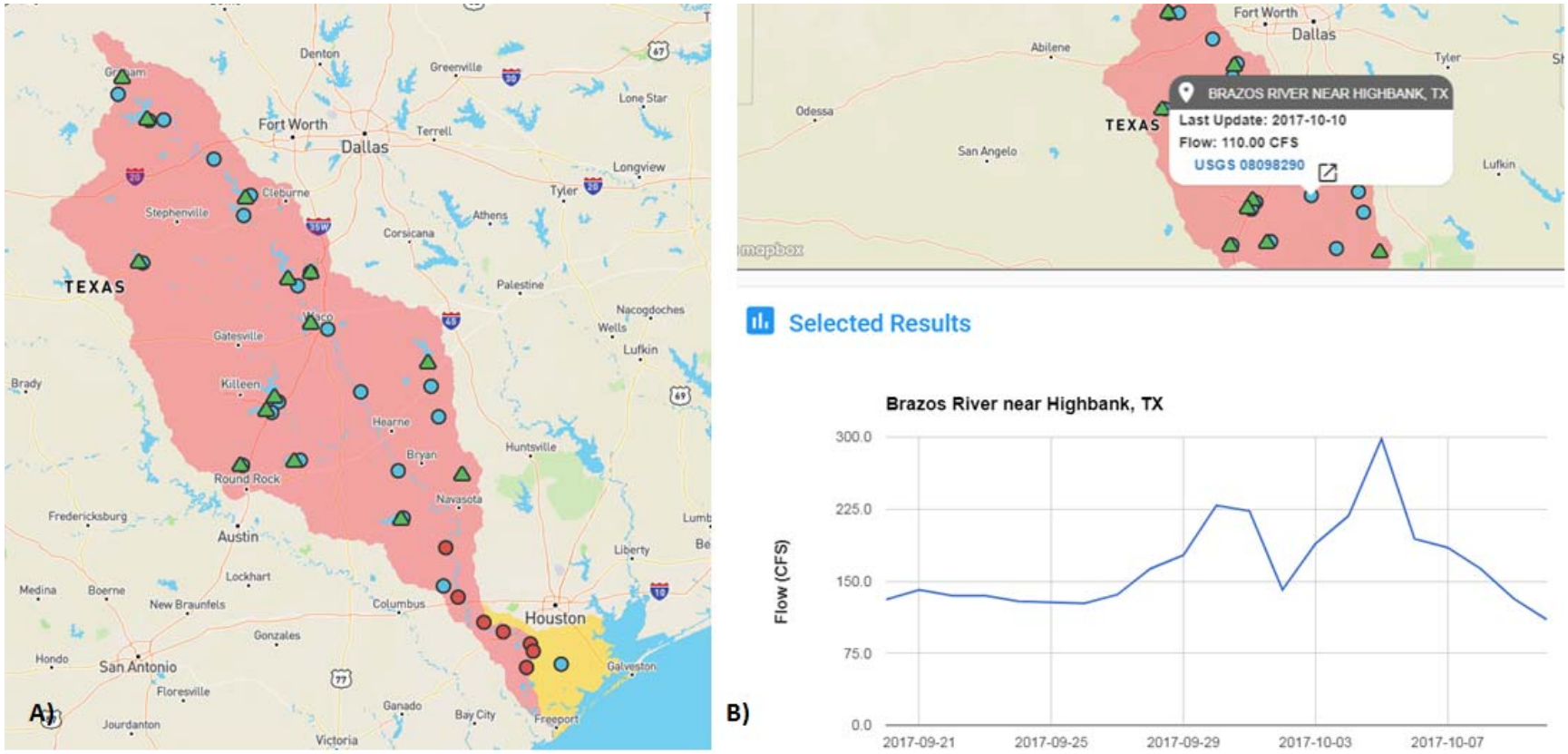



*Figure 3– GCWA Dashboard for Storing & Displaying Brazos Basin Watershed conditions (streamflow and reservoir information). A) Map view showing the entire contributing area for GCWA, as well as stream gauges, reservoir gauges, the GCWA canal system, and location*

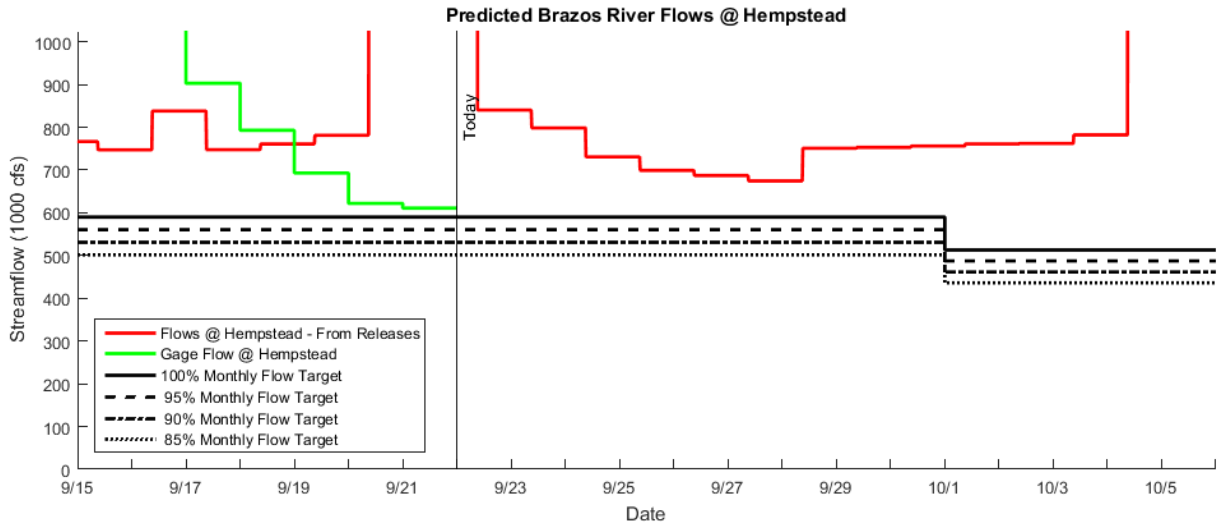



*Figure 4– Flow Prediction Tool (FPT) results for the Brazos River at Hempstead, showing observed (green) and predicted (red) flows for the period 9/15/18-10/6/18. Also shown are the computed GCWA Monthly Flow Targets (Discussed in the Vulnerability Assessment Section). FPT results provide a visual assessment of the likelihood that near-term future stream flows will be lower than those needed to satisfy the needs of GCWA customers and other water users in the Lower Brazos Basin.*

staff to quickly assess whether it is necessary to implement any of the drought response measures discussed in the "Response Actions" section.

Additional drought monitoring activities developed during this DCP update include monitoring methods utilizing data from the US Drought Monitor (Appendix C). The US Drought Monitor data for Texas is obtainable at:

http://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?TX

Drought Monitor data is maintained by National Drought Mitigation Center (University of Nebraska at Lincoln), the US Department of Agriculture, and the National Oceanic and Atmospheric Administration. Data is produced nationwide and updated every Thursday. Drought data is produced graphically and in ArcGIS format, allowing visual and quantifiable assessment of drought conditions in specific regions of interest. GCWA decided to utilize US Drought Monitor data in its assessment of the onset of Stage 1 drought conditions under its revised DCP. Routinely reviewing US Drought Monitor data has become common amongst GCWA staff and customers in charge of water usage and operational decisions, which led to inclusion of the drought monitor data with the GCWA DCP. Figure 5 shows how GCWA utilizes the US Drought monitor data to assess drought conditions within its "contributing watershed." Specifically if GCWA determines that over 50% of its contributing watershed is classified as a "D1-Moderate Drought" or higher by the US Drought Monitor, then GCWA will consider entering Stage 1 of its DCP.

Along with the dashboard, FPT results, and data from the US Drought Monitor, GCWA requested additional information regarding basin streamflow in order to make operational decisions regarding water diversions, contract water releases, and possible demand curtailment. Specifically GCWA staff requested the creation of a drought monitoring system which automatically obtains data, processes data, and formats the data into an easily understandable customized summary. Staff desired such data to be automatically emailed to select GCWA email addresses, and that the data/email be easily readable from mobile devices as well as desktop or laptop computers. This utility was developed in conjunction with the Matlab program used to update and populate the GCWA dashboard with data for points of interest in the Brazos River basin. Figure 6 shows the tabular data emailed to GCWA accounts, and Figure 7 presents a graphical representation of Brazos Basin reservoir storage contents; this graphic accompanies the tabular emailed data as an emailed attachment. Figure 8 is another graphic attached to the email detailing expected releases from Brazos Basin reservoirs based on the reservoir operating rules; this graphic is only created and emailed if at least one of the reservoirs is above conservation pool elevation.

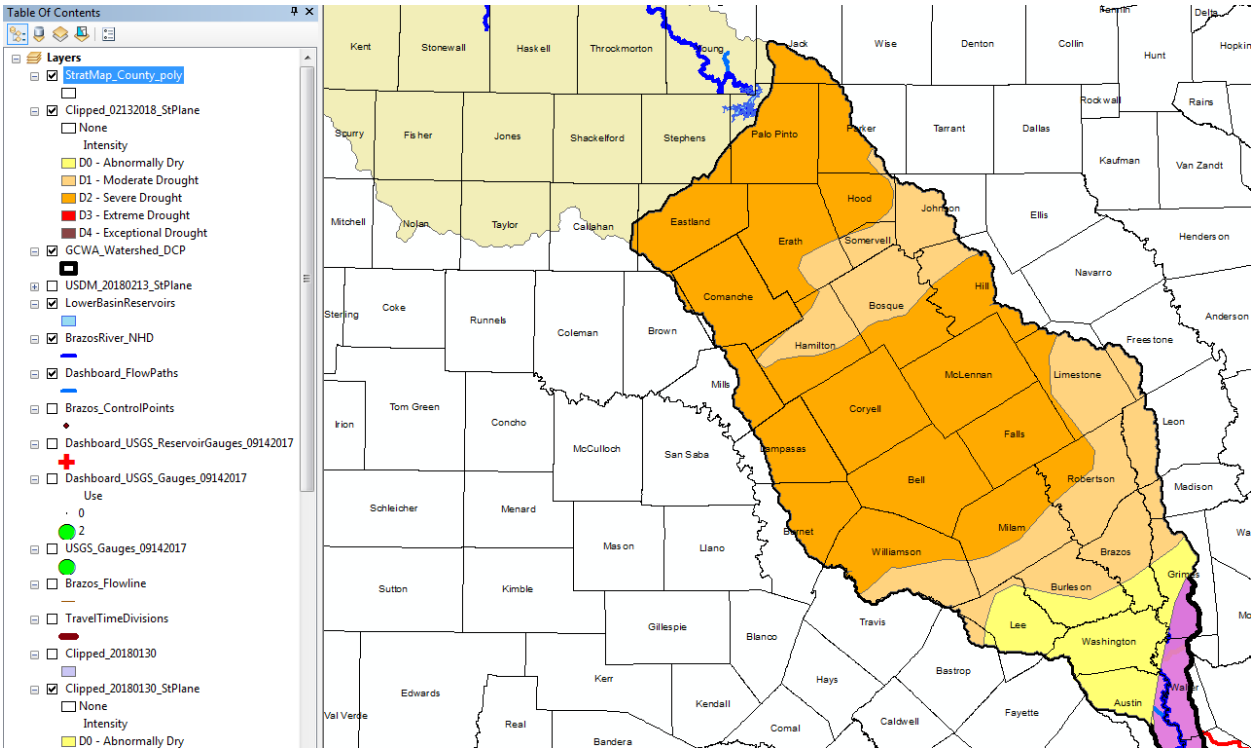



*Figure 5 – Usage of US Drought Monitor Data to assess conditions within the GCWA "Contributing Watershed" – within ArcGIS, GCWA clips the nation-wide drought monitor data to the watershed upstream from GCWA, and determines what percentage of the watershed is experiencing what levels of drought. If over 50% of the GCWA contributing watershed is experiencing D1-Moderate Drought or greater, then GCWA will consider entering Stage 1 Drought Conditions.*

```
  RESERVOIR              STORAGE            %          STATUS    CHANGE FROM PREVIOUS DAY
-------------------------------------------------------------------------------------------
  Possum Kingdom     = 527,803 acre-ft   (100.75%)   INCREASING     1,803 acre-ft
  Granbury           = 125,433 acre-ft   (100.18%)   INCREASING       378 acre-ft
  Whitney            = 553,521 acre-ft   ( 99.88%)   INCREASING     5,664 acre-ft
  Aquilla            =  46,826 acre-ft   (105.07%)   INCREASING     1,552 acre-ft
  Stillhouse Hollow  = 284,716 acre-ft   (124.97%)   INCREASING     4,750 acre-ft
  Belton             = 463,310 acre-ft   (106.45%)   INCREASING    10,412 acre-ft
  Proctor            =  55,834 acre-ft   (100.68%)   INCREASING       189 acre-ft
  Granger            =  62,364 acre-ft   (122.82%)   INCREASING     8,296 acre-ft
  Georgetown         =  40,415 acre-ft   (109.51%)   INCREASING     1,807 acre-ft
  Somerville         = 166,437 acre-ft   (113.14%)   INCREASING    17,267 acre-ft
  Limestone          = 211,924 acre-ft   (101.88%)   INCREASING     3,768 acre-ft
-------------------------------------------------------------------------------------------
  System-Wide:
  Current            = 2,538,583 acre-ft  (105.37%)
  Yesterday          = 2,482,699 acre-ft  (103.05%)   Change =    55,884 acre-ft
  One Week Ago       = 2,532,527 acre-ft  (105.12%)   Change =     6,056 acre-ft
  Three Months Ago   = 1,965,454 acre-ft  ( 81.58%)   Change =   573,130 acre-ft
  One Year Ago       = 2,167,261 acre-ft  ( 89.96%)   Change =   371,322 acre-ft
  Recent Low         = 1,447,266 acre-ft  ( 60.07%)   Change = 1,447,266 acre-ft (8/10/2011)
-------------------------------------------------------------------------------------------
 Streamflow Records (cfs):
                                 Current Flow        12/7/2018 Average Flow
  Whitney            =          618 cfs              522 dcfs
  Waco               =        4,860 cfs            2,180 dcfs
  HighBank           =       10,900 cfs            4,180 dcfs
  Bryan              =       23,800 cfs           15,800 dcfs
  Hempstead          =       36,100 cfs           13,400 dcfs
  San Felipe         =       26,900 cfs           13,100 dcfs
  Richmond           =       21,300 cfs           13,900 dcfs
  Rosharon           =       25,700 cfs           13,700 dcfs
-------------------------------------------------------------------------------------------
```

*Figure 6 – Sample Daily Text Emailed Automatically to GCWA Staff – detailing basin reservoir storage content, changes from the previous day, recent trends in reservoir storage, current streamflow and streamflow from the previous day. For users familiar with the locations of each reservoir and stream gauge, this information allows for easy assessment of watershed conditions, aiding GCWA staff in system management and drought monitoring.*

As shown in Figure 6, the daily email provided to select GCWA staff contains information regarding status of water resources in the basin. All data is based on data provided by the US Geological Survey. The upper section of the email contains the current quantity of water stored in the basin reservoirs from which GCWA may receive BRA contract water. This information is obtained from USGS published water level data, translated into storage data using the most updated reservoir elevation-area-capacity curves published by the Texas Water Development Board. Along with the current storage, the reader is informed how the storage level changed from the previous day, and by how much. The middle section of the email provides a historical look at the combined water storage in all listed reservoirs, and provides the change in combined storage over time. The third email section contains streamflow at the USGS gauges on the Brazos River within the GCWA watershed. Gauges are listed in geographical order from North to South, and provided as current flow (at the time the program is executed) and as a daily averaged flow from the previous day. Recipients can utilize this information to assess the likely future quantity of water to arrive at GCWA pumping stations (located between the San Felipe, Richmond, and Rosharon gauges).

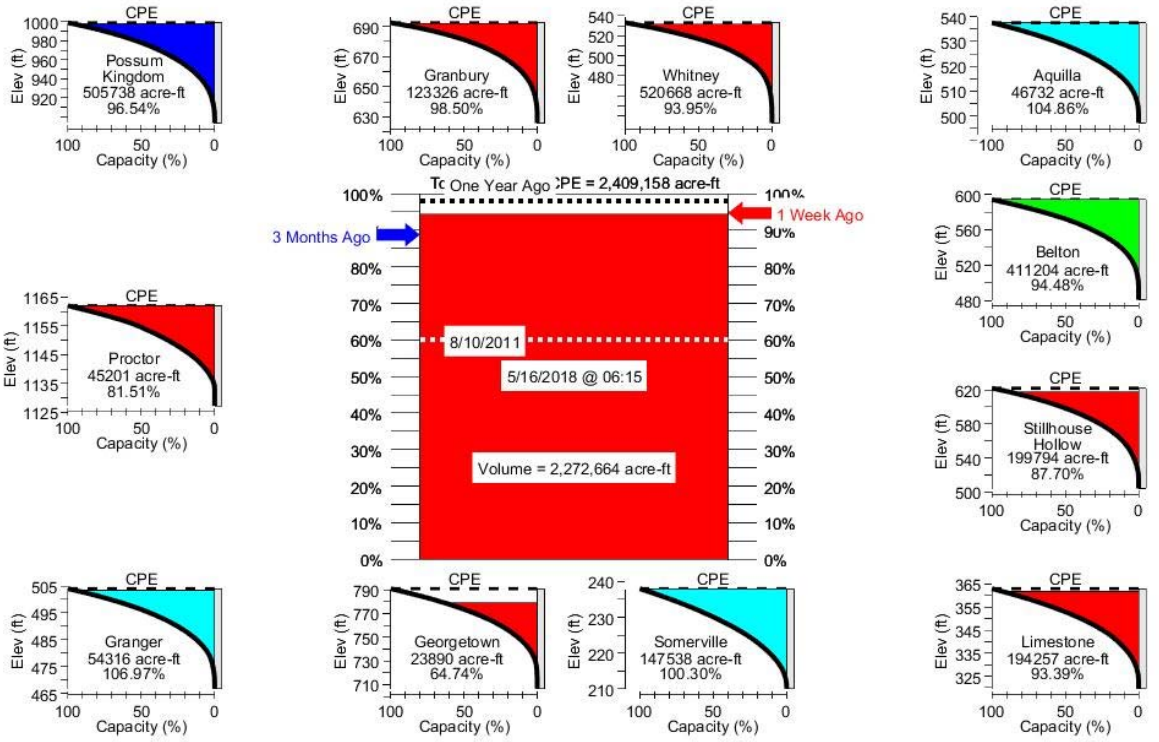



*Figure 7 – Graphic Emailed to GCWA Staff depicting storage contents and trends of BRA reservoirs. Individual reservoirs are shown around the perimeter, with the composite storage shown in the center. Dark blue indicates storage increased from the previous day; red indicates storage decreased from the previous day. Cyan indicates that the reservoir is currently storing more than conservation storage and is releasing water from the flood pool. Green indicates no change from the previous day (usually due to a gauge malfunction).*

Figure 7 displays the graphical representation of reservoir storage content in the Brazos River basin, as emailed to GCWA staff on a daily basis. Recipients can quickly assess the capacity of the basin's reservoirs, as well as the day-to-day storage trends for individual reservoirs. Daily, 1-week, 3-month, and 1-year trends in composite reservoir storage are also provided. Colors within the graphic indicate trends in reservoir storage as follows:

- Dark Blue – Increasing Storage from Previous Period (ex. Possum Kingdom Reservoir in figure)
- Red – Decreasing Storage from Previous Period (ex. Lake Limestone in figure)
- Cyan – Reservoir is releasing water from the flood pool (ex. Granger Lake in Figure)
- Green – Reservoir storage is steady from the Previous Period (ex. Belton Lake in Figure)

As it is rare that reservoir inflows exactly balance evaporative losses and outflows on a given day, the green color in such graphics typically indicates a gauge malfunction or missing data in the USGS files.

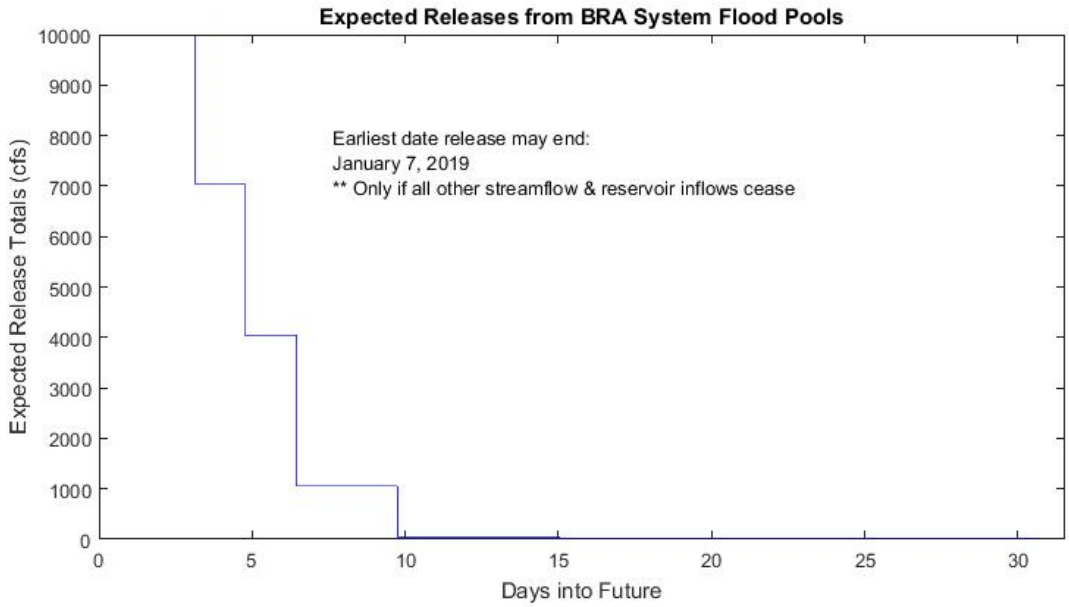



*Figure 8 – Expected Releases from Brazos River Authority (BRA) reservoirs based on reservoir operating rules. Releases are determined for each reservoir with storage currently in the flood pool. Releases are shown cumulatively for all reservoirs in the flood pool, and are predicted into the future based on the current storage in each reservoir, downstream flow conditions in the basin, and the reservoir release rules developed by the BRA and US Army Corps of Engineers.*

Figure 8 depicts a second graphic emailed to GCWA staff, yet this graphic is only created when one or more of the basin reservoirs is releasing water from its flood pool. When a reservoir's storage exceeds its conservation storage capacity and water is within the reservoir flood pool, reservoir releases are dictated by published operating rules. These rules specify the release rates based on downstream conditions and the quantity of water within the reservoir flood pool. Release rates for all applicable reservoirs are computed into the future and combined into the graphic shown above, providing the recipient with a predicted duration of releases. This data provides GCWA staff with knowledge regarding how long streamflows are likely to remain elevated. In Figure 8, releases are to exceed 1000 cfs for the next 5 days, after which they will continue for another 10 days yet at a much lower release rate. The graphic also provides the future date at which releases will end, assuming no further reservoir inflows occur and other basin conditions do not change. Figure 8 is only created and emailed to GCWA staff when one or more reservoirs is in flood stage; during prolonged drought periods this graphic is not likely to be created. However the graphic does provide GCWA with useful knowledge about the watershed conditions and can assist in water resources management by GCWA.

# Essential Element #2 – Vulnerability Assessment

In general, the purpose of the "Vulnerability Assessment" is for GCWA to understand the risks to its water supply under threat of drought. As originally envisioned, work under this heading was to involve statistical assessment the hydrologic data from the dashboard, with a goal to predict likely streamflow condition up to six months in advance. This section will outline the streamflow prediction methods developed for GCWA, as well as the modeling efforts undertaken to help GCWA understand its ability to reliably provide water to its customers.

As of January 2019, GCWA has committed to delivering to customers firm customers 274,319.52 acre-ft/yr (244.88 MGD). To determine the actual water volume diverted by GCWA, it becomes necessary to increase delivered quantities by canal loss factors, which vary depending upon the location of the GCWA customer diversion along the canal system. For modeling purposes, GCWA assumes canal losses amount to 24% at the end of its canal system, and lower percentages for diversions located upstream from the end of the canal system (See "Mitigation Actions" Section). By including canal losses, GCWA calculated that their needed diversions (from the Brazos River and other water sources) must total approximately 342,424 acre-ft/yr (305.68 MGD) to meet the demands of firm customers. Additional water demands for interruptible customers (mostly for rice irrigation) may also be satisfied by GCWA, yet interruptible supplies are determined annually and are reduced based on firm customer demands.

Historically, GCWA customers have not used all of the water they have under contract with GCWA. Figure 9 presents the usage of GCWA firm customers in 2017 as a percentage of their contracted water quantities. As shown, only Ashland utilized over 70% of its firm contract quantity in 2017, and some customers (Pearland, Galveston, and Texas City) did not use any of their contract quantities. Most GCWA firm contract holders have simply reserved more water than currently needed in order to ensure sufficient future water supplies to meet their anticipated future needs. In total, GCWA's 2017 usage by firm customers amounted to 154,600 acre-ft (138 MGD).

GCWA requested that efforts to assess the vulnerability of its water supplies be tailored to determine its ability to obtain sufficient water to meet both historical usage quantities (as in Figure 9) and its contractually obligated supplies to firm customers.

## Vulnerability Assessments via Water Balance Modeling

To assess vulnerability of its water supplies, GCWA utilizes water availability models which are essentially mass-balance accounting models that divide available water among eligible water users according to State of Texas water allocation rules. For this purpose, the State of Texas has developed a monthly-timestep Water Availability Model (WAM). GCWA has also developed a daily-timestep model ("GCWA Daily-Hydro") which applies water allocation rules to water users in the Lower Brazos Basin downstream of Hempstead. GCWA favors utilizing this daily-timestep model because it factors into the allocation process items such as GCWA pumping limitations, daily fluctuations in Brazos River water levels, and greater customization (allowing GCWA to experiment with different water management scenarios and options). For this project, GCWA utilized Version 7 of the GCWA Daily Hydro model ("V7") to assess water reliability and various curtailment strategies. The V7 model is also preferable over the available WAM model because it runs on non-naturalized streamflow data, which is readily available for the period 1939-Present. As such the model is capable of simulating water availability for GCWA during the most severe dry years, including 1956 and 2011.

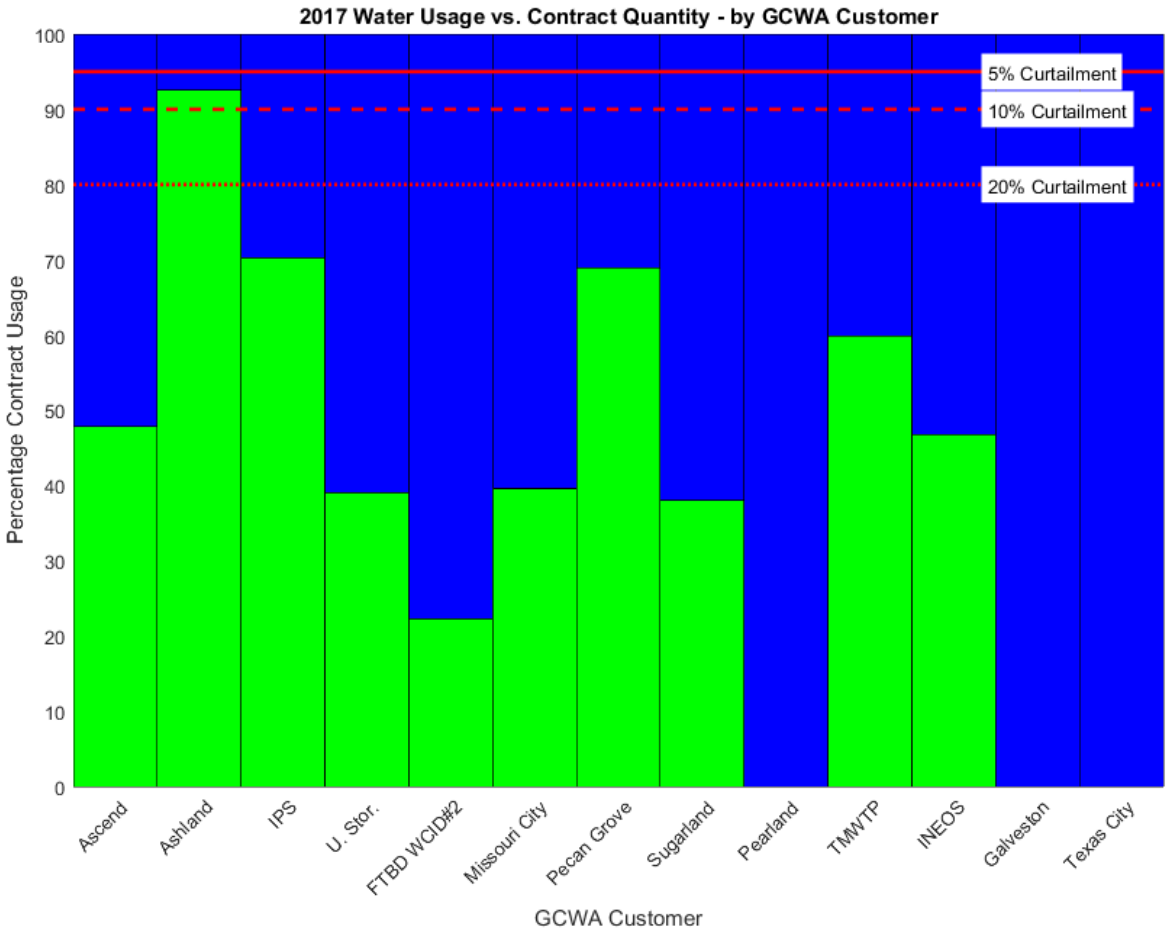



*Figure 9 – 2017 Water usage by GCWA firm customers, showing that nearly all customers used less than 70% of their contractual allotment.*

Another benefit of the V7 model over the WAM model is that within V7, any shortages incurred by GCWA may be satisfied through the usage of water supplied under contract with the Brazos River Authority (BRA). This "contract water" essentially serves as insurance for GCWA as it is used when GCWA is unable to obtain water under its own water rights. GCWA maintains numerous long-term contracts with BRA, each with differing rules regarding water usage, contract quantities, Brazos River delivery losses, etc. The V7 model considers all these rules when utilizing the contract to satisfy shortages in diversions made under GCWA's own water rights. The V7 model can also simulate the impact of any short-term contract water GCWA may obtain from BRA or other entities. However for assessing vulnerability in this effort, the V7 model only utilized the long term contracts GCWA has with BRA, totaling 44,569 acre-ft/yr as delivered to the GCWA pump stations along the Brazos River. The BRA, through WAM modeling performed on its behalf (not presented here) has determined that GCWA's contract water is 100% reliable and will always be available for GCWA usage.

To assess the vulnerability of its water supply, including the sufficiency of GCWA's contract water with BRA, the V7 model was set to simulate two years of severe drought – specifically with river flows from 2011 followed by stream flows from 1956. This approach is fairly conservative, as historical hydrology in the Brazos Basin has rarely included two consecutive extremely low-flow years.

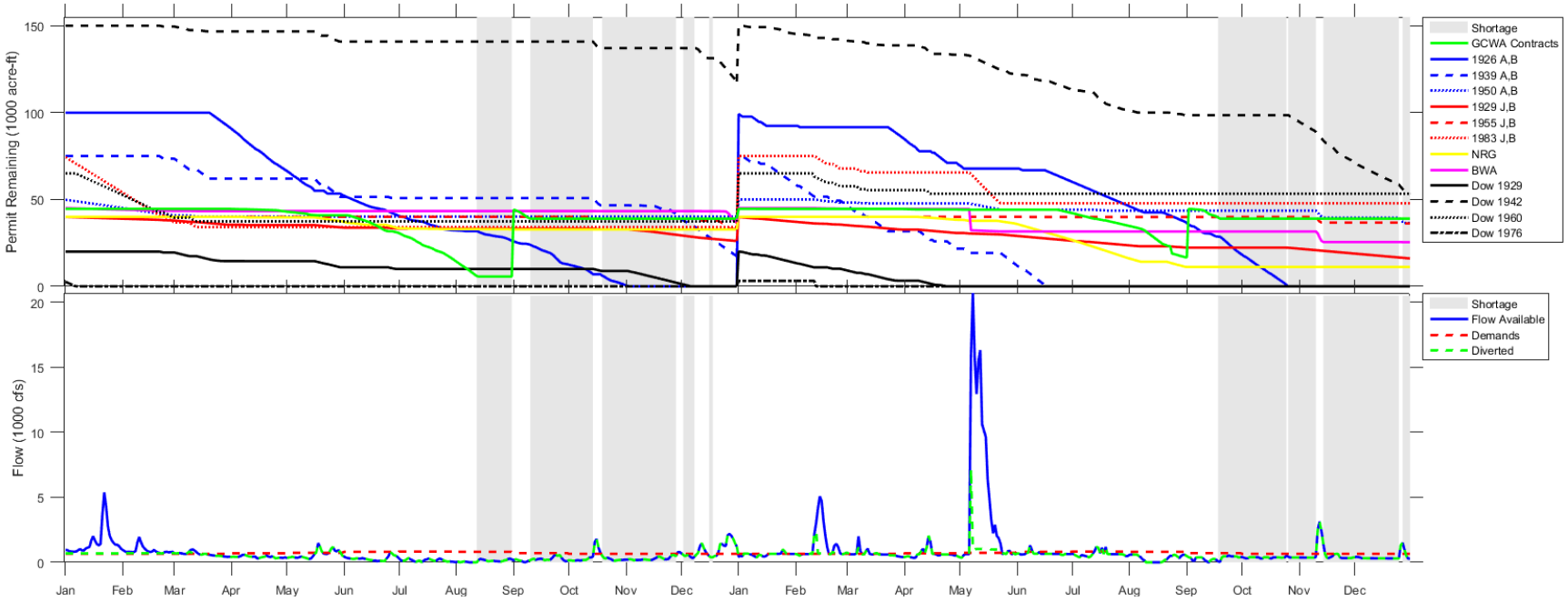



*Figure 10 – GCWA Daily Hydro (V7) modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses.*

Results from the V7 modeling (Figure 10) indicate that GCWA will experience shortages when attempting to meet all firm customer demands. The shortages occur at the end of the calendar year (August-December), and result from the fact that streamflow is extremely low during these periods. Shortages are eliminated when streamflow temporarily increased, as evident in mid-October 2011 and mid-November 1956. Based on the modeling presented in Figure 10, GCWA would have experienced shortage of 39,440 acre-ft in simulated 2011, followed by 42,255 acre-ft in simulated 1956. These shortages amounted up to 350 cfs per day.

Figure 11 presents V7 results for an identical simulation, yet with GCWA having the freedom to utilize its BRA contract water whenever needed. In the V7 simulations generating Figure 10, GCWA was prohibited from using some of its BRA contracts from September-December, in an effort to conserve those contracts for use in the summer of the following year. This conservation is necessary as the majority of the GCWA contracts with BRA renew on a fiscal-year basis, defined by the BRA as September-August. As such, if GCWA were to use up contract water in October, the

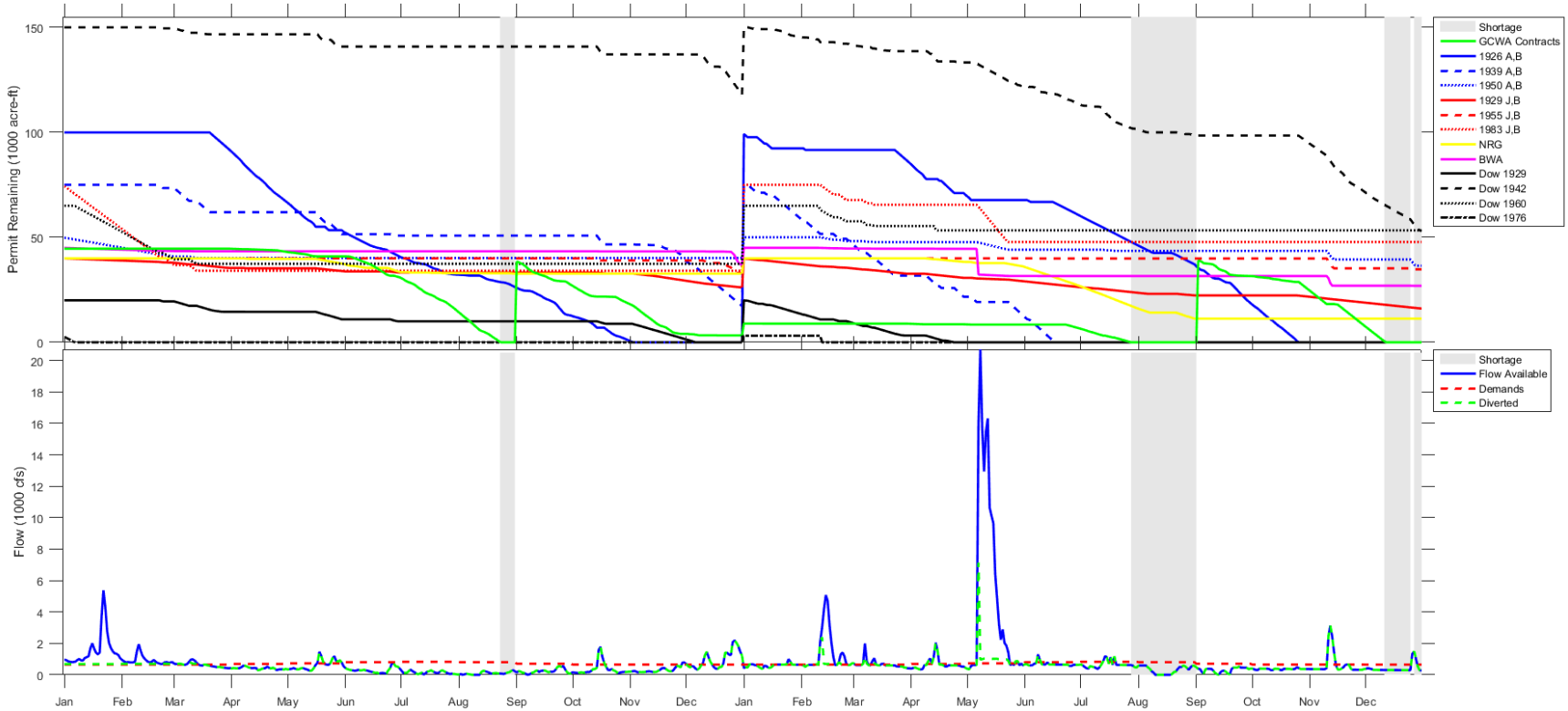



*Figure 11 – GCWA Daily Hydro (V7) modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA could utilize available BRA contract water whenever needed, resulting in reduced shortages.*

water would not be available until the contracts had renewed the following September, thus putting GCWA potentially at risk if the June-August months were low streamflow periods.

As shown in Figure 11, freedom to utilize BRA contracts when needed greatly reduces the times at which modeled shortages occurred. Total shortages amounted to only 3,776 acre-ft in 2011 and 25,355 acre-ft in 1956. The maximum daily shortage, however, increased to 400 cfs. More troubling, however, is the observation that by the end of 1956 (the second modeled year), GCWA's available contract water from BRA was depleted. Thus if the modeled drought extended into a third year, GCWA's shortages would have likely increased, possibly significantly.

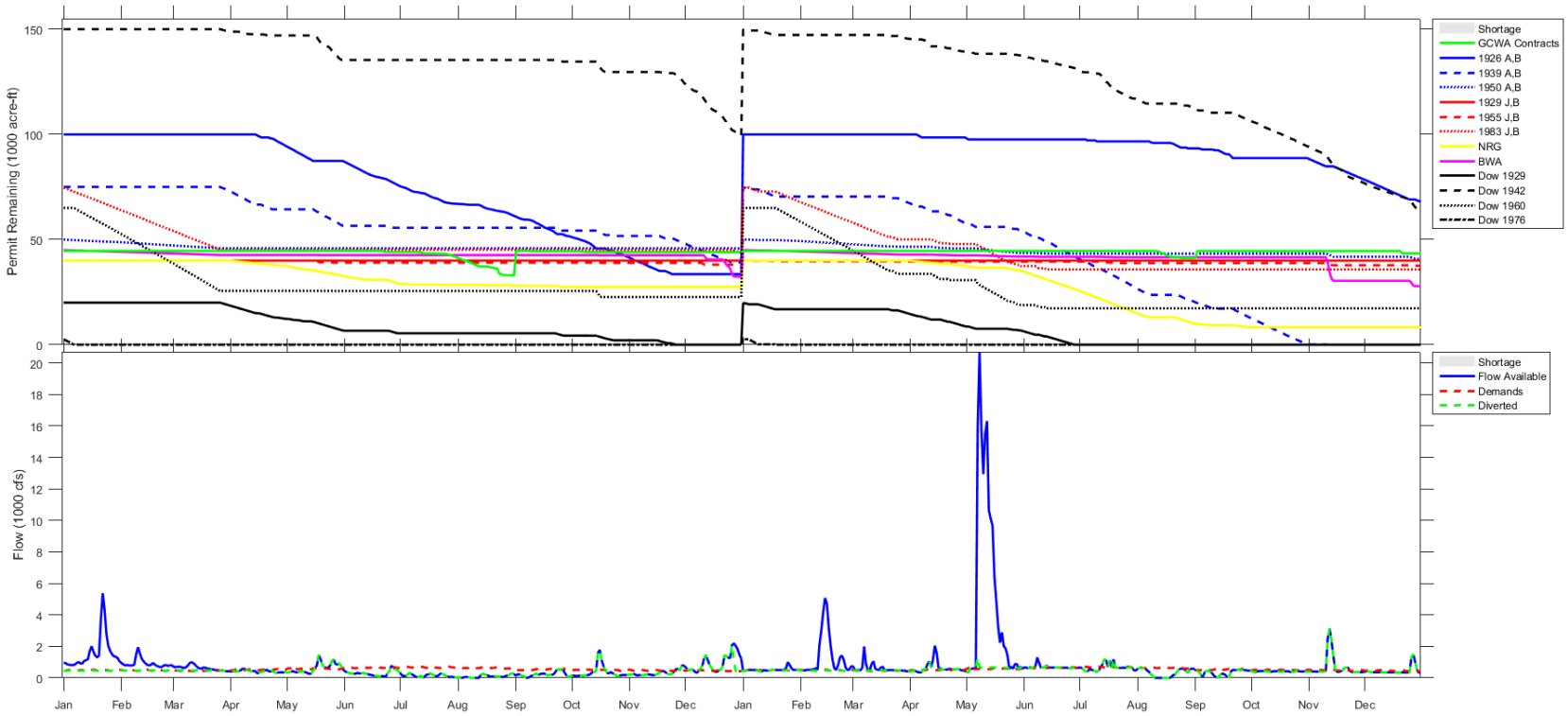



*Figure 12 – GCWA Daily Hydro (V7) modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to 2017 firm customer demands and associated canal-system losses. In this simulation, GCWA did not experience shortages, and only minimally utilized contracts with BRA.*

As shown in Figure 12, GCWA will not experience shortages if attempting only to meet 2017 firm customer demands, and it does so without using very much of its contract water with BRA. This indicates that until GCWA firm customer usage approaches full contractual obligations, shortages can generally be avoided and BRA contract water is generally sufficient to make up any differences between demand and run-of-river supplies available to GCWA.

In assessing the modeling results shown in Figure 10-Figure 12, it is necessary to consider that assumptions inherent in the V7 algorithms will not necessarily reflect the management actions of GCWA, the BRA, or the Brazos Basin Watermaster (who has ultimate responsibility for making

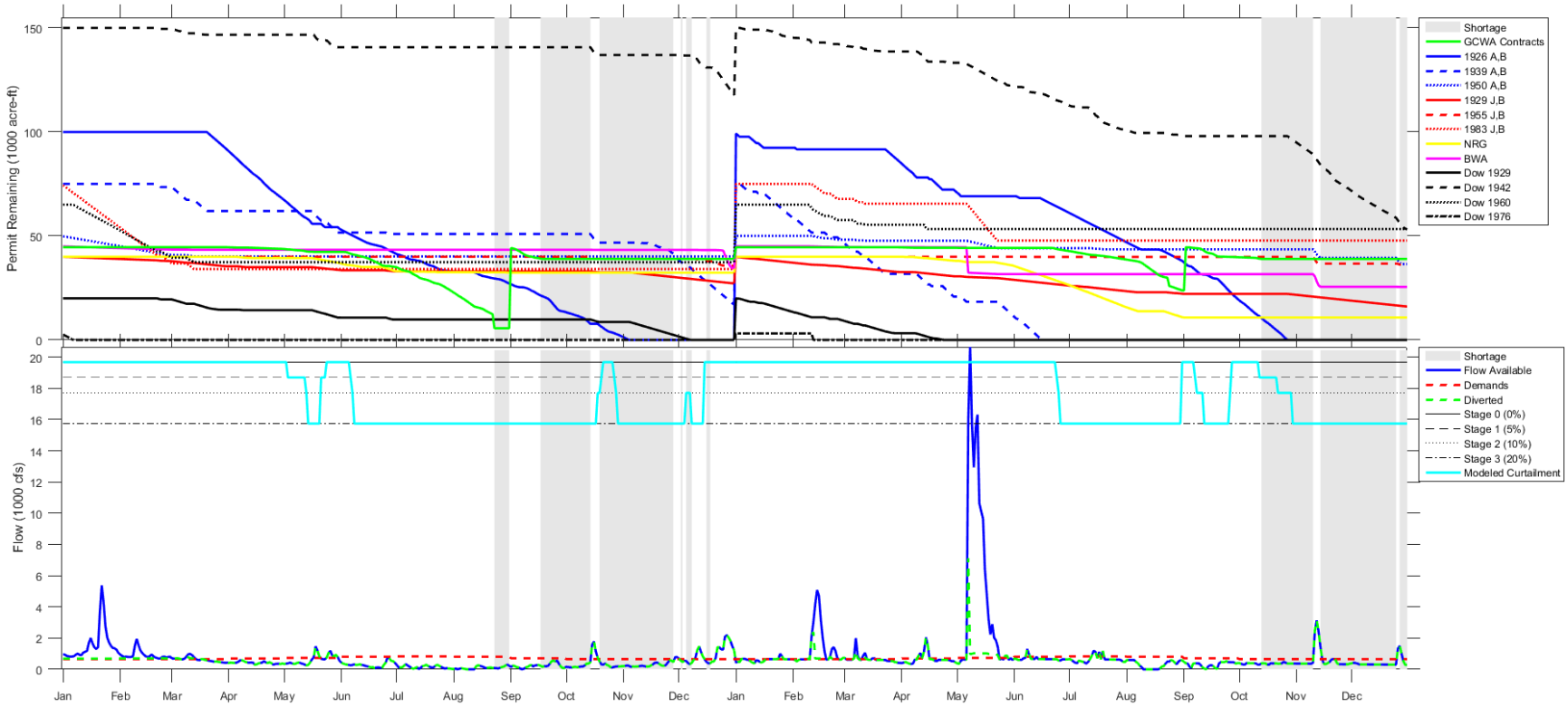



*Figure 13 – GCWA Daily Hydro (V7) Modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA implements the demand curtailment rules in place per its existing 2012 Drought Contingency Plan. Shortages are diminished but not eliminated.*

water allocations during drought periods). For instance, the V7 model assumes allocation decisions will always be made based on the priority system, yet the Watermaster may implement alternate allocation methods that could reduce water to GCWA during drought periods.

In Figure 13, the V7 model results are presented assuming GCWA must limit BRA contract usage in September-December, and assuming firm contract demands can be curtailed according to the existing 2012 GCWA Drought Contingency Plan. Under the 2012 plan, Stage 3 droughts

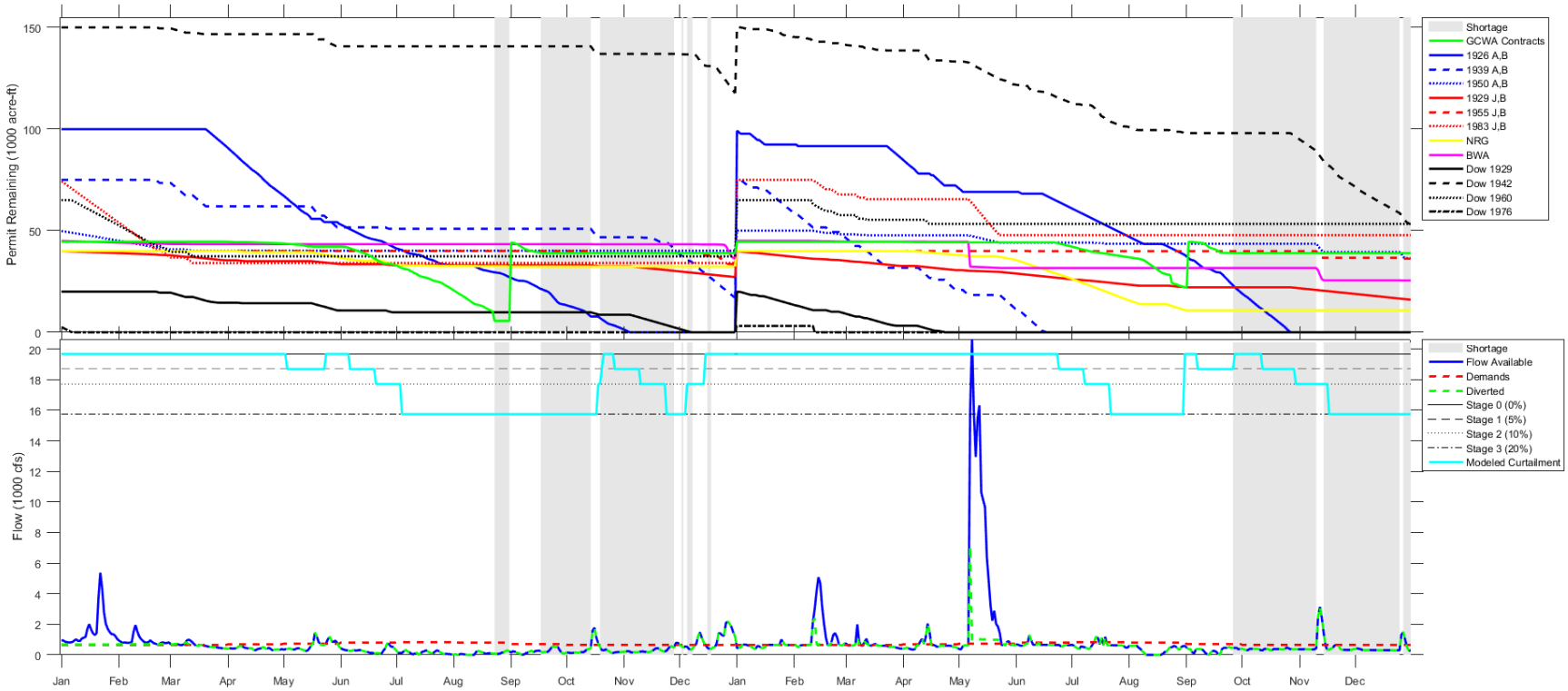



*Figure 14 – GCWA Daily Hydro (V7) Modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA implements the demand curtailment rules in place per its existing 2012 Drought Contingency Plan, yet with the requirement that 2-weeks must pass before a higher drought stage can be implemented. This requirement, while beneficial to GCWA customers, leads to an increase in annual shortages compared to results shown in Figure 13.*

request a 20% reduction in firm demand, with lower reductions requested at lower drought stages. As shown in Figure 13, through the 2-year simulation, it was often necessary to enter Stage 3 drought status, with generally rapid transitions from Stage 0 (Normal operations) to Stage 3. Such rapid transitions would likely be difficult to implement for GCWA firm customers. Through the demand curtailment, shortages are reduced to 21,554 acre-ft in 2011 (from 39,440 acre-ft, See Figure 10) and to 31,794 in 1956 (from 42,255 acre-ft, See Figure 10). These reductions are beneficial, yet it is evident that the existing DCP does not provide full drought protection under these modeled circumstances.

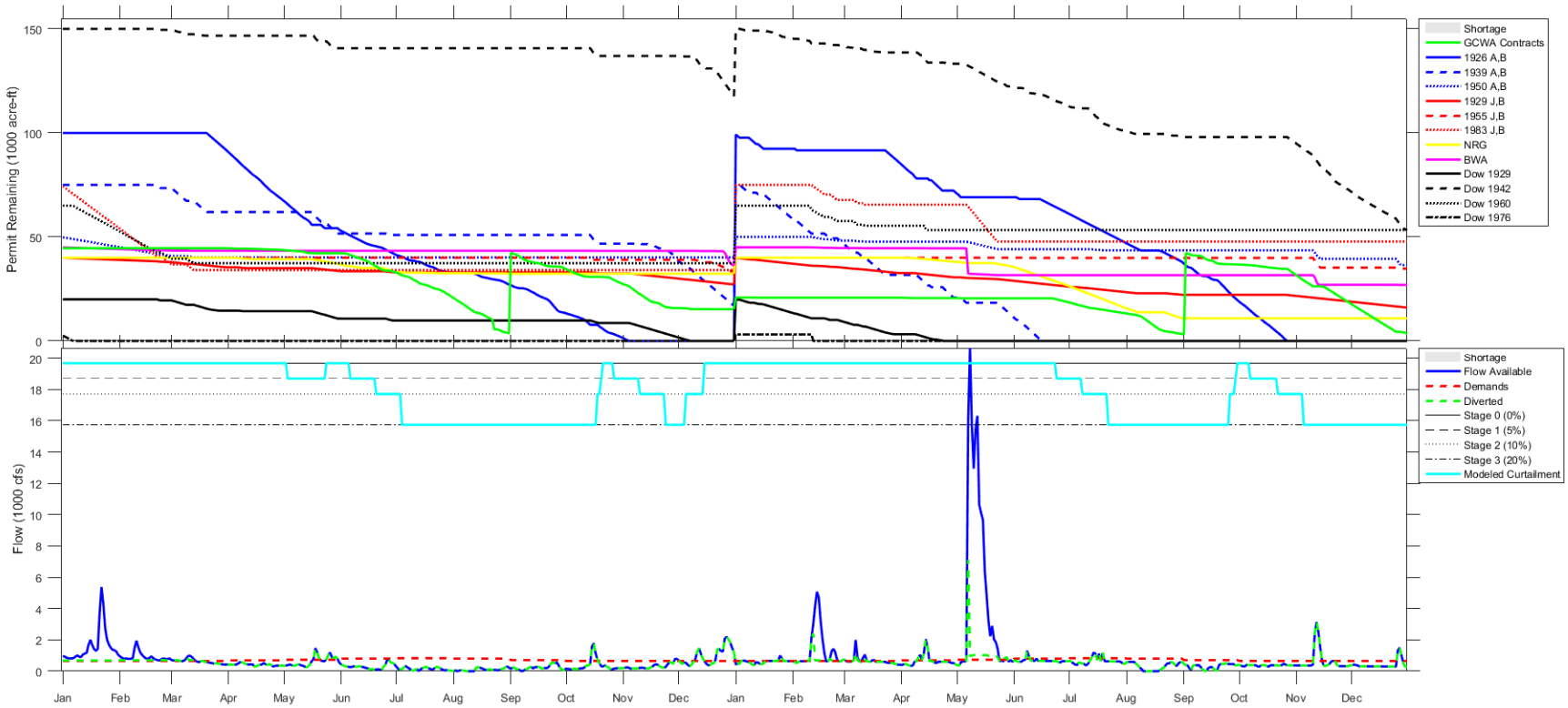



*Figure 15 – GCWA Daily Hydro (V7) Modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA implements the demand curtailment rules in place per its existing 2012 Drought Contingency Plan and has full freedom regarding usage of BRA contract water. Under these modeled circumstances, shortages are eliminated and some contract water is conserved for use in an extended drought.*

In Figure 14, results are shown from the V7 model using 2012 Drought Contingency Plan rules, yet requiring a minimum of 14-days at each drought stage before entering a higher drought stage (with increased curtailment). This scenario would allow GCWA customers to better adjust their processes and operations in order to tolerate less water availability. Modeling results still indicate shortages incurred later in the year, with

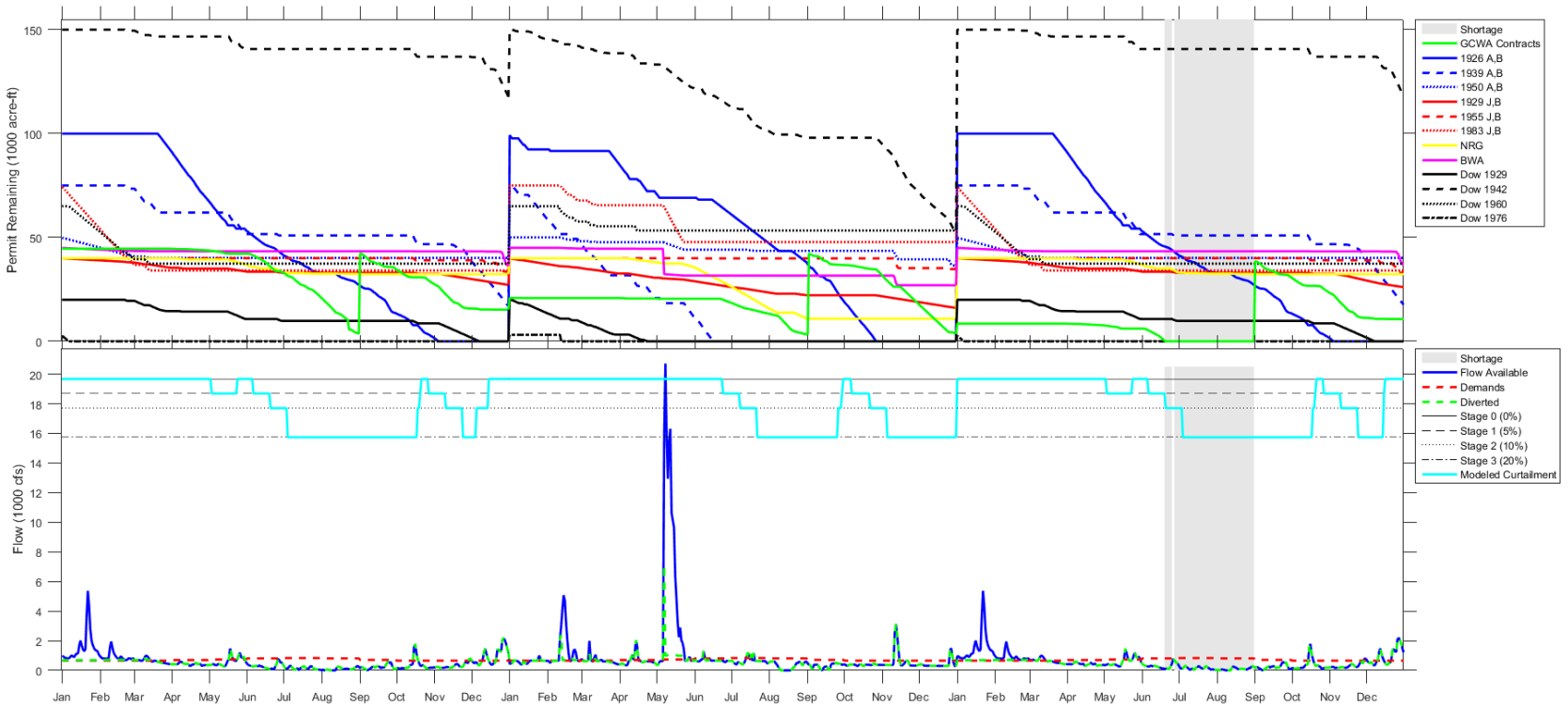



*Figure 16 – GCWA Daily Hydro (V7) Modeling of water availability in the Lower Brazos Basin, simulating three consecutive extremely dry years (2011, 1956, and 2011 again), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA implements the demand curtailment rules in place per its existing 2012 Drought Contingency Plan and has full freedom regarding usage of BRA contract water. Under these modeled circumstances, shortages are eliminated only in the first two modeled years, and shortages occur in the third year once contract water has been fully utilized.*

the total modeled shortages of 23,704 acre-ft/yr in modeled 2011, with a 33,734 acre-ft shortage in modeled year 1956. These shortages are larger than those computed without the 14-day requirement prior to transitioning to higher drought stages (Figure 13).

Figure 15 presents V7 results including the existing curtailment rules (from GCWA's 2012 DCP) and assuming GCWA may freely use BRA contract water whenever needed. As shown, Stage 3 curtailment is still common, yet all modeled shortages have been eliminated. At issue here, however, is the relative lack of remaining contract water GCWA retains at the end of the 2nd modeled year, thus making it likely that shortages would occur if the following year were also dry. This assertion is presented in Figure 16, which shows results from 3 consecutive years of dry conditions (2011, 1956, and 2011 again).

Figure 16 presents results from a 3-year simulation (2011, 1956 and 2011 repeated), with a modeled shortage of 29,000 in the third year. This demonstrates that GCWA's current level of contract water with the Brazos River Authority is insufficient to avoid shortages during an extended drought, even with implementation of the 2012 drought contingency plan. This suggests GCWA would benefit from obtaining additional water sources other than those currently available. It should be noted, however, that for the period 1940-2018, the Lower Brazos Basin has not experienced three consecutive years of severe drought as simulated in Figure 16.

Table 3 presents the model-computed shortages for the scenarios depicted in Figure 10-Figure 16. It is evident that GCWA, based on historical hydrology, should be able to satisfy recent customer demands as well as full contract demands through efficient operation of its canal system and management of available contract water from BRA. Obtaining additional contract water would be beneficial if GCWA were to experience a prolonged severe drought of duration longer that two years. Limiting restrictions on contract water usage is a key component to reducing shortages to be experienced by GCWA.

*Table 3 – GCWA Daily Hydro (V7) Modeled Shortages*

| Figure | Years | Notes | Shortage |
|---|---|---|---|
| 10 | 2011<br>1956 | Full Demands<br>Limited Contract Usage<br>Without 2012 DCP | 39,440 acre-ft<br>42,255 acre-ft |
| 11 | 2011<br>1956 | Full Demands<br>Freed Contract Usage<br>Without 2012 DCP | 3,776 acre-ft<br>25,355 acre-ft |
| 12 | 2011<br>1956 | 2017 Demands<br>Limited Contract Usage<br>Without 2012 DCP | 0 acre-ft<br>0 acre-ft |
| 13 | 2011<br>1956 | Full Demands<br>Limited Contract Usage<br>With 2012 DCP | 21,554 acre-ft<br>31,879 acre-ft |
| 14 | 2011<br>1956 | Full Demands<br>Limited Contract Usage<br>With 2012 DCP & 14-day Stage Minimum | 23,704 acre-ft<br>33,737 acre-ft |
| 15 | 2011<br>1956 | Full Demands<br>Free Contract Usage<br>With 2012 DCP & 14-day Stage Minimum | 0 acre-ft<br>0 acre-ft |
| 16 | 2011<br>1956<br>2011 | Full Demands<br>Free Contract Usage<br>With 2012 DCP & 14-day Stage Minimum | 0 acre-ft<br>0 acre-ft<br>29,000 acre-ft |

Figure 17 presents computed annual shortages for the period 1940-2018 using the GCWA Daily-Hydro model (V7), set so that contract water quantities at the end of one model year are available at the beginning of the next model year. As shown, only in two out of the 79 modeled years did GCWA experience a shortage. Model simulations utilized full customer demands, free contract usage, and the 2012 DCP with the 14-day stage duration minimum. Figure 17 demonstrates that at least for the period of record of the V7 model, severe droughts of durations exceeding 2 years are extremely rare.

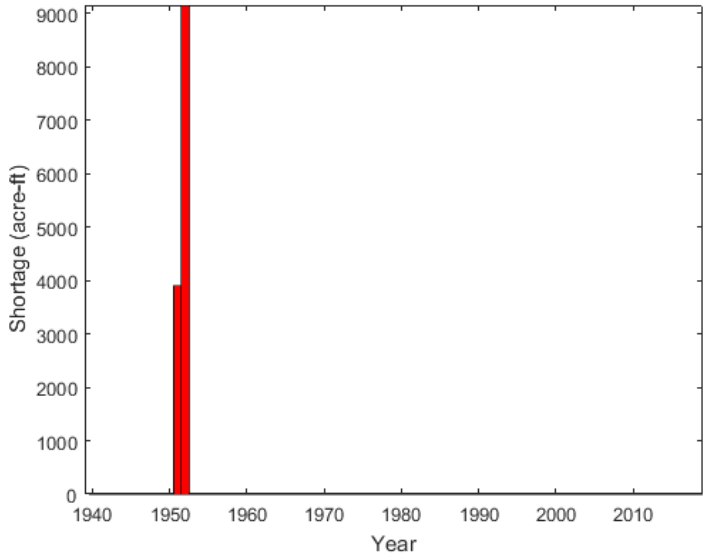



*Figure 17 – Modeled Annual Shortage for 1940-2018 from the GCWA Daily-Hydro Model (V7), assuming full demands, free contract usage, the 2012 drought contingency plan in-place yet modified to include a 14-day required transition period prior to increasing drought stages. Only in 1951-1952 would GCWA not been able to satisfy demands per the 2012 Drought Contingency Plan.*

### Vulnerability Assessment using the Flow Prediction Tool (FPT)

As detailed in the Drought Monitoring Section, GCWA created a "Flow Prediction Tool" (FPT) which was designed to predict Brazos River streamflow at GCWA pump stations for up to 2 weeks into the future. The FPT is detailed in Appendix B of this plan, but is detailed here with respect to how it is used to assess immediate drought vulnerability for GCWA.

Statistical analysis of lower basin hydrology (gauge records, and reservoir water levels) indicated that while some seasonal trends are evident, the trends are not reliable enough to utilize in the prediction of long-term basin streamflow or reservoir contents. However shorter term predictions in streamflow did prove viable, especially under the assumptions used in the FPT. Based on a survey of the drought task force members (DTF), it was found that most GCWA customers would prefer longer advanced notice of curtailment measures to be implemented under the DCP. As such GCWA strived to develop the FPT so that it could provide up to two weeks (14 days) of advanced notice for when stream flows were likely to be insufficient to meet customer needs. DTF members also were not confident that any "sophisticated, statistically based" prediction algorithms would provide meaningful Brazos River streamflow predictions with any greater accuracy than simpler methods or common guesswork. As such, GCWA abandoned all efforts to statistically predict streamflows and reservoir storage contents, in favor of a simple routing model based on travel times and loss rates published by the Brazos River Authority.

Specifically the FPT tool predicts streamflow within the Lower Brazos Basin by routing known releases from upstream reservoirs downstream through the Brazos flow network (i.e. the Brazos River and its tributaries). Travel times between reservoirs and the downstream prediction locations are fixed by BRA, and do not vary based on flow rate. In addition, flow losses are fixed along the flow network, and also do not vary with flow rate. Losses are assumed even though numerous studies and statistical analyses have

proven that the Brazos River is often a "gaining" stream, with flows increasing in the downstream direction due to watershed contributions and groundwater influxes. Hence the FPT is likely to provide the most accurate predictions of future Lower Brazos streamflow only when the entire basin is in drought conditions, with little to zero flow contribution from the watershed or underlying aquifer.

Results of the FPT, shown in Figure 4 and reproduced in Figure 18, include a graphical depiction of the time-series of observed and predicted flows at a given location. From the figure, it is possible to compare 1-week of measured and predicted streamflow data, which allows GCWA to assess how well the assumptions inherent in the FPT reflect actual basin conditions. This assessment may help GCWA in evaluating the "accuracy" of the predicted streamflow for the future 2-week period. However, the key result of the FTP, for the purposes of the vulnerability assessment, is the comparison between the predicted streamflow and the "Monthly Flow Targets" shown in the graphic.

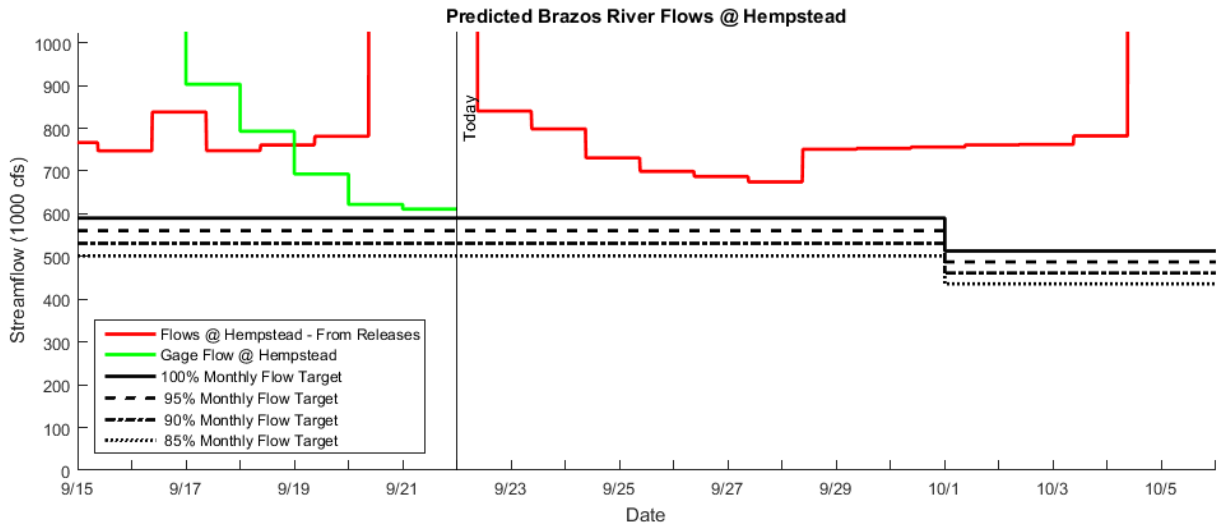



*Figure 18 – Flow Prediction Tool (FPT) results for the Brazos River at Hempstead, showing observed (green) and predicted (red) flows for the period 9/15/18-10/6/18. Monthly Flow Targets reflect the computed needs of Lower Brazos water users, and can be compared against the predicted streamflow assess immediate drought vulnerability. Reproduced from Figure 4.*

In utilizing the FPT predictions to make demand management/curtailment decisions as part of this revised DCP, GCWA needed to compare the predictions to some base level of streamflow. The "Monthly Flow Targets" represent the monthly-averaged streamflow needed to meet the diversion needs of all Lower Brazos water users, including GCWA customers. The targets include the channel losses within the GCWA canal system, as well as an averaged monthly estimate of water needed by each GCWA customer. To compute the average customer water needs, GCWA utilizes its historical diversion records, and takes an average of the monthly diversions for the past three years. For example, if Customer X diverted 10, 20, and 18 acre-ft in July of 2016, 2017, and 2018, respectively, then GCWA would estimate that they will require 16 acre-ft in July of 2019 (i.e. 16 acre-ft is the average of the customer's diversions for the three previous Julys). GCWA would then adjust this estimate upward based on a canal loss factor (relative to the customer's location on the GCWA canal system), and sum the total customer needs (along with needs from Dow Chemical Company and NRG Energy) to compute the Monthly Flow Target. As such, if the FPT predicts that streamflows over the next two weeks are likely to dip below the

monthly flow target, GCWA can consider implementing a higher stage in its drought contingency plan, or it can take other measures to ensure sufficient water supplies are being delivered to customers.

## Vulnerability Assessment Using Climate Change Analysis for GCWA

In Texas, water availability is officially determined, for permitting purposes, using the State of Texas Water Availability Models (WAMs). Water availability for GCWA is determined based on the Brazos & San Jacinto-Brazos WAM model, referred to herein as "bwam3." The bwam3 model simulates water availability according to the Texas prior-appropriation system, and determines the monthly amount of water available for each water right holder in the basin. The simulation "period of record" for the bwam3 model is from 1940-1998. GCWA owns three separate water rights on the Brazos River, with each right having between 1 and 3 separate diversion quantities and priority dates. Therefore GCWA's Brazos River water rights are modeled as 6 different water rights within the bwam3 model. To determine the quantity of water available to GCWA on a monthly basis, it is necessary to add up the diversions made under each of GCWA's 6 modeled water rights.

To assess the impacts of climate change on water availability for GCWA, it is necessary to expand the modeled period of record for the bwam3 model. To expand the period of record to time periods prior to 1940, a statistical correlation analysis was performed using PDSI data from tree ring studies (Cleaveland et al, 2011). To expand the period of record to time periods after 1998, correlations were attempted using precipitation and temperature predictions from downscaled Global Climate Models (GCMs) and measured streamflow from 1940-1998. Neither the tree-ring analysis nor GCM analysis yielded highly-confident correlations, yet the modeling results are still useful in assessing the potential severity of droughts likely to be experienced by GCWA.

### Water Availability Modeling Using Tree-Ring Data – 1500 to 1999

In their 2011 paper "Extended Chronology of Drought in South Central, Southeastern, and West Texas," Cleaveland et. al detailed their utilization of tree rings to re-construct the Palmer Drought Severity Index (PDSI) for the period 1500-2011. Figure 19 presents the extended the PDSI data as annual values and as a 5-year rolling average. As shown, the PDSI values are highly variable, and the period from 1500 to 1940 (pre-WAM model period of record) indicates that there were numerous instances when the climate was both wetter and drier than in the modeled period of record. Also based on the 5-year rolling PDSI averages, there appear to have been numerous moderate drought periods for the Lower Brazos Basin, including many prolonged drought periods that are longer in duration than the 1950's drought period (which is recognized as the drought of record for the Brazos Basin. It is notable that the recent drought period (2005-2016) appears to be the most severe, based on the 5-year rolling average PDSI values.

The PDSI data from Figure 19 was used to develop a correlation between PDSI and naturalized streamflow in the Brazos River near Rosharon. The correlation yielded a reasonable fit ($R^2 = 0.6$) between the naturalized flows in the bwam3 model (1940-1998) and predicted flows based on the PDSI for the same time period. This correlation was then utilized to determine the naturalized streamflow at Rosharon for the period 1500-1940. Naturalized streamflow was then created for the entire Brazos River basin for the period 1500-1940 by applying a separate relation between the Rosharon naturalized flows and all other naturalized flows within the model. Any resulting negative streamflows were set to zero. Figure 20 presents modified bwam3 model results for the period 1500-1998, showing water reliability for GCWA over this period.

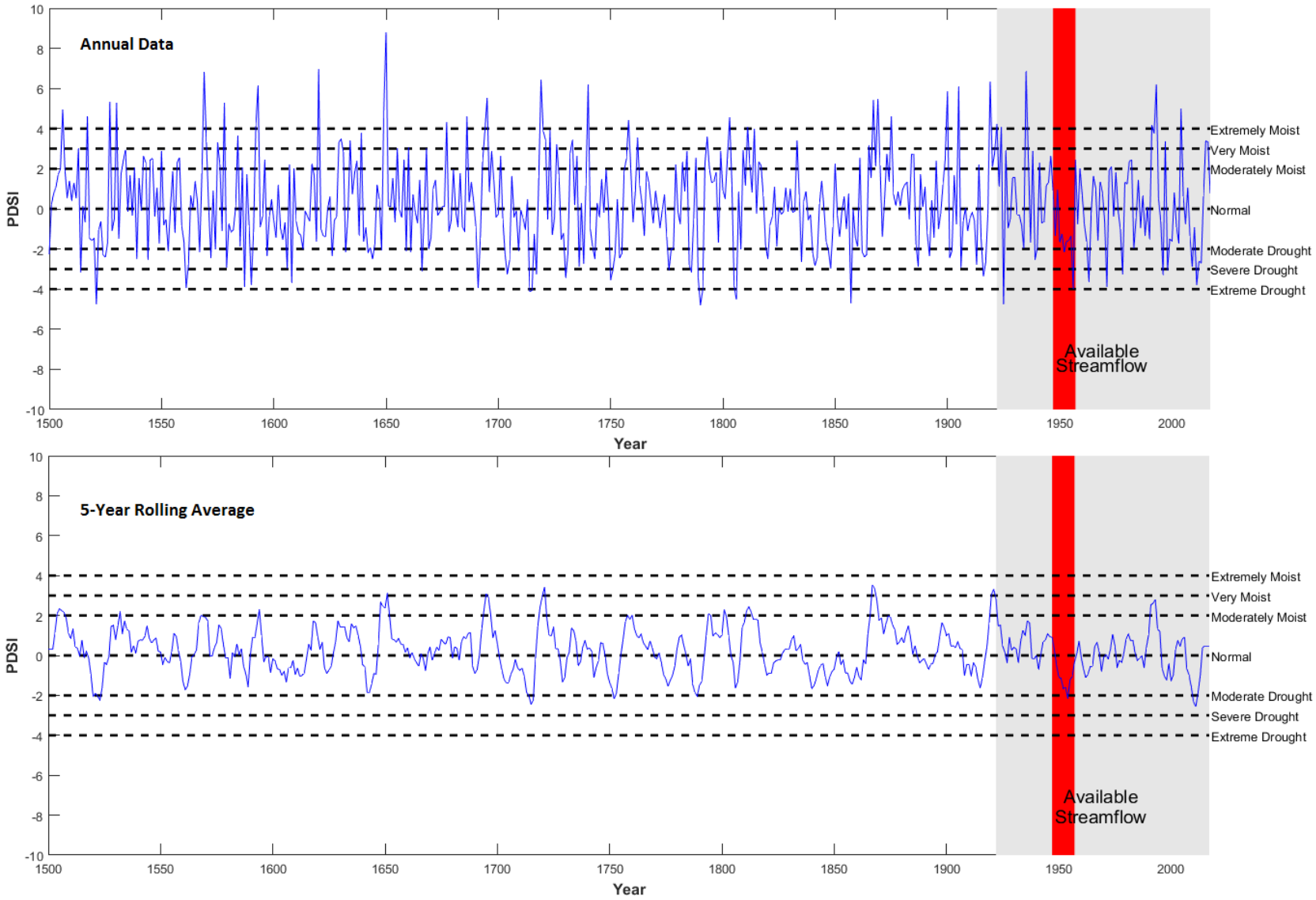



*Figure 19 – PDSI Values for the Lower Brazos Basin – 1500 to 2017*

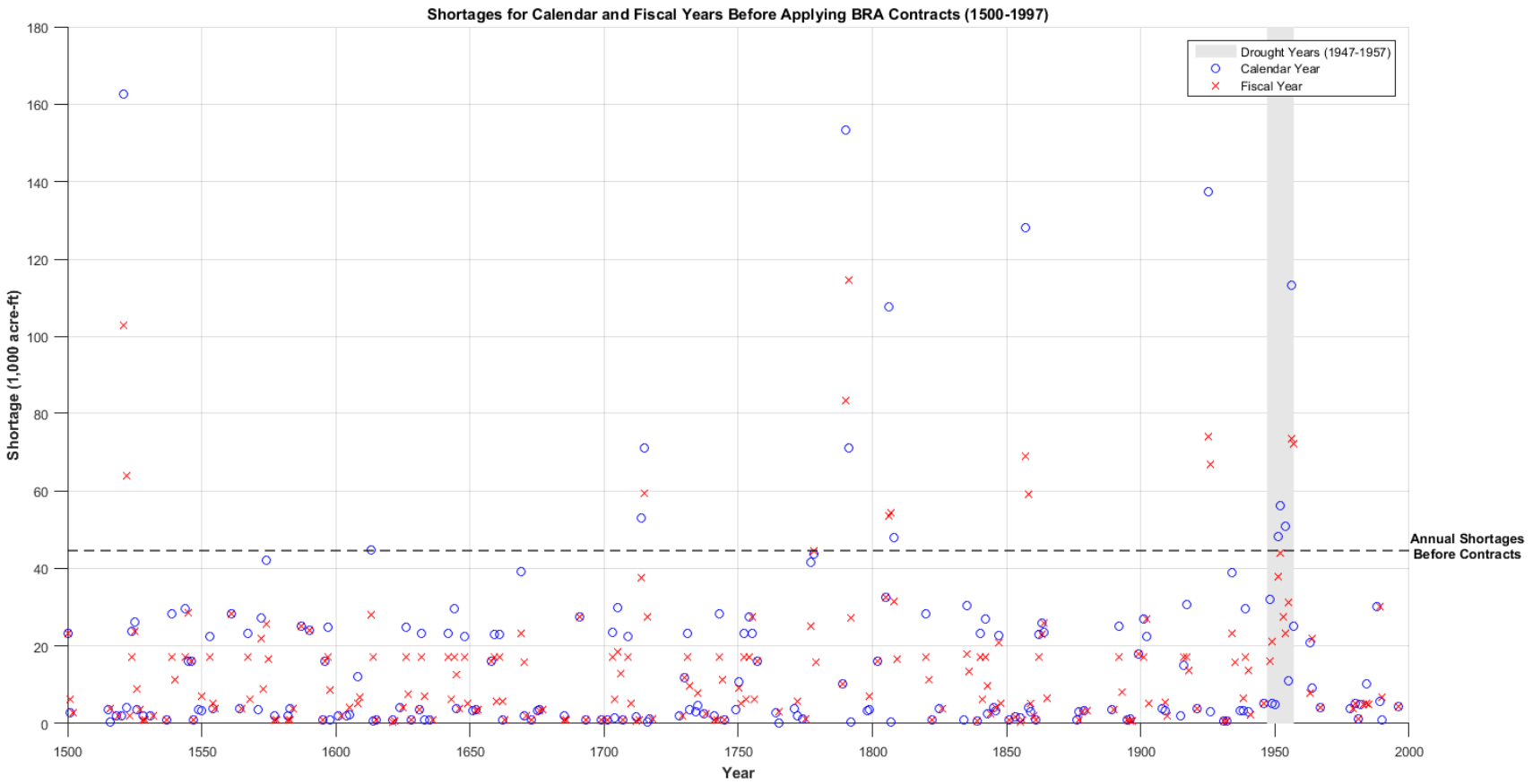



*Figure 20 – Modeled shortages by year for GCWA, based on full contractual demands (337,150 acre-ft/yr). Shortages are determined monthly, and may be reduced or eliminated through the use of GCWA contract water from the BRA. While shortages existed in most modeled years, in only 9 of the 499 modeled calendar years (1.8%) were shortages in excess of GCWA's contract quantities from BRA.*

As shown in Figure 20, GCWA was routinely unable to divert sufficient water quantities under its water rights in order to avoid monthly water shortages. However, in only 9 of the 499 modeled calendar years (1.8%) was GCWA unable to eliminate shortages through the use of contract water from the BRA (based on currently held long-term contracts between GCWA and BRA). Similarly, in only 13 of the 499 fiscal years modeled was GCWA unable to fully meet full contract customer demands through both Brazos River diversions and BRA contract water usage.

### Water Availability Modeling Using Global Climate Models – 1950 to 2099

To assess how future climate change may affect GCWA's ability to satisfy customer demands, attempts were made to utilize results of Global Climate Models and correlate those results to available naturalized streamflow data. GCM results were obtained for the period 1950-2099 using a variety of available datasets. Results included predicted average temperatures and precipitation depths for the area around the Lower Brazos Basin. This correlation was attempted in a fashion similar to that for the correlation between PDSI and streamflow used in developing the 1500-1940 period of record. Unfortunately, meaningful correlations were unattainable, between either temperature and streamflow or precipitation and streamflow using data from a variety (20+) GCMs. The greatest obtained correlation ($R^2$ = 0.23) was insufficient to justify creating a revised naturalized flow dataset and running the bwam3 model into the future.

Figure 21 presents typical GCM results obtained for the Lower Brazos Basin, showing a definite increasing trend in average July temperatures between 2000 and 2099. GCM results shown in Figure 21 are from the RGRD3 GCM, showing results from three separate emissions scenarios.

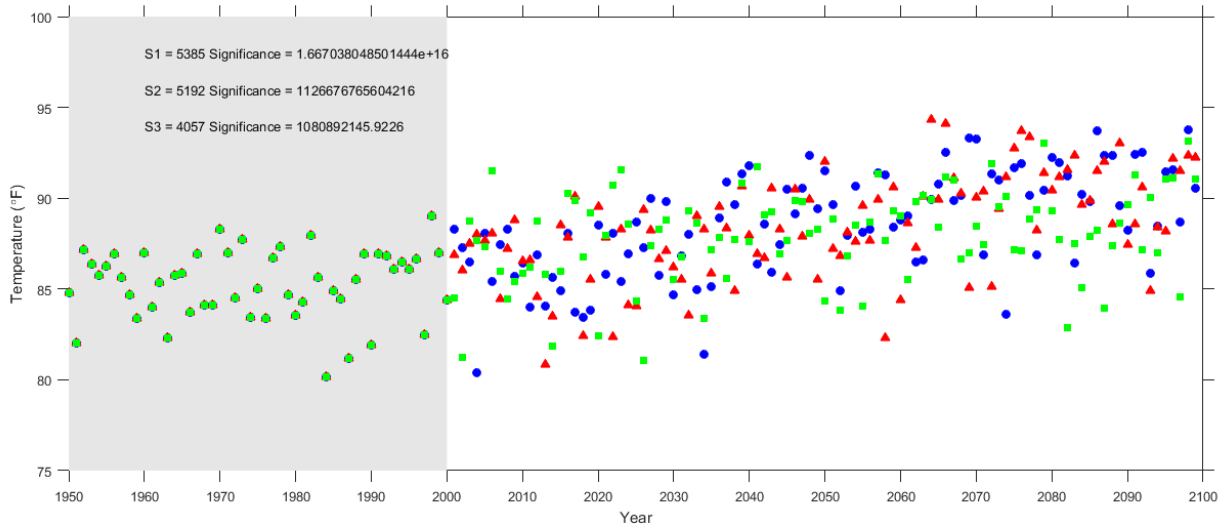



*Figure 21– Average July Temperatures for the Lower Brazos Basin – from GCM RGRD3. Results show a statistically significant increasing temperature trend for each emission scenario, as computed using a standard Mann-Kendall analysis.*

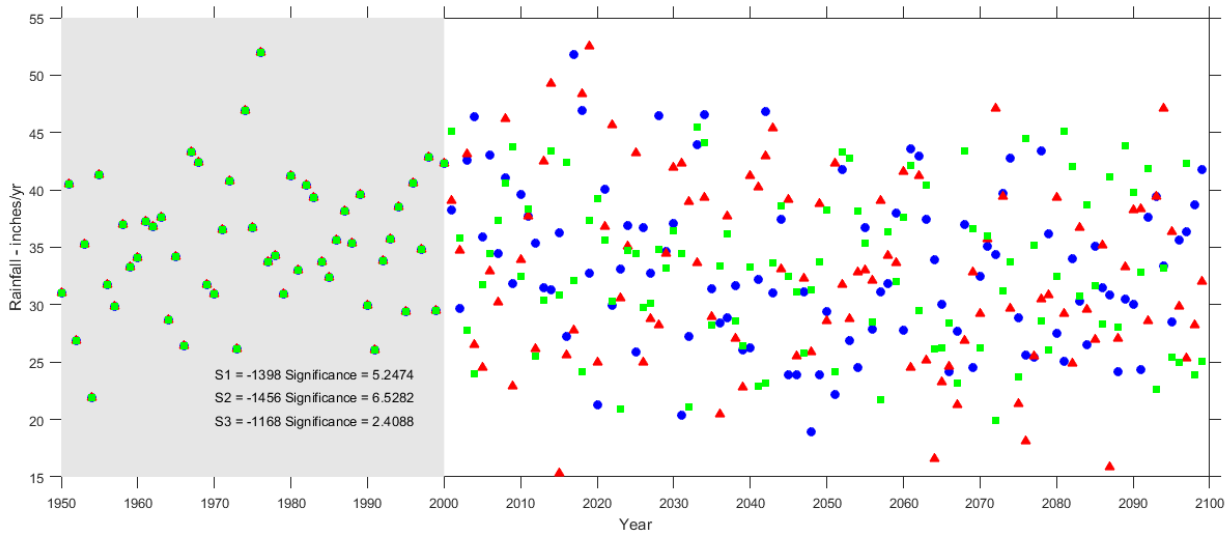



*Figure 22 – Total Annual Precipitation Results for the Lower Brazos Basin – from the GCM BC3 model with standard emission scenarios. Decreasing trends are indicated, yet wide annual variations are evident, and variations are evident by emission scenario for most given years.*

Figure 22 presents annual precipitation results from the BC3 GCM, utilizing the standard 3 emission scenarios. As shown, there is a statistically significant decreasing trend in total annual precipitation, yet the trend is not as strong as for the temperature data (Figure 21). There is also a wide annual variation in total precipitation, and a large variation in total precipitation by emission scenario.

Taken in general, the results of the majority of GCMs reviewed for this effort suggest that the Lower Brazos Basin will experience lower annual precipitation and higher average temperatures by the year 2099. This would suggest that less streamflow would be generally available over this time period, yet it is difficult to quantify any streamflow decreases with any real certainty.

Based on this climate change analysis, it is likely that GCWA will be able to obtain sufficient water to meet customer demands for the vast majority of months and years. Depending upon actual future climate change impacts on local hydrology, however, it remains possible that GCWA would experience an increase in the likelihood of not being able to satisfy customer demands in the future. As such, it is recommended that GCWA continue efforts to obtain additional water supplies to supplement run-of-river water available from the Brazos Basin. Such supplies could take the form of local groundwater usage, increasing contracts with BRA, desalination, or importing water from other surrounding river basins. Reducing GCWA demands (through customer demand reduction, canal loss reduction, or by other means) is also recommended.

### Vulnerability Assessment Summary and Conclusions

Based on the assessments presented in this section, GCWA is well suited to provide sufficient water for its customers through repeats of droughts experienced historically in the Lower Brazos Basin region. GCWA's water rights are generally reliable, and when properly supplemented with water available under contracts with BRA, are largely sufficient to meet historical and contractual water needs. GCWA will need to make operational decisions regarding the usage of BRA contract water, especially in the months of September to December, in order to best ensure that contract water is available when needed by GCWA customers. Obtaining additional contract water, or other reliable sources of water, will certainly increase GCWA's ability to meet customer needs.

Through the Flow Prediction Tool, GCWA has developed a useful tool for assessing immediate drought risk and providing customers with sufficient lead-time to implement water saving and conservation measures to counter such risk. The FPT is simplistic in concept, yet useful in implementation for GCWA. However GCWA wisely did not require usage of the FPT in defining drought triggers in its approved TCEQ DCP (Appendix A). This allows GCWA to consider tool output when making water availability and drought stage response decisions.

The true uncertainty inherent in GCWA's drought vulnerability lies in the future climate change analysis. If temperatures increase in the Lower Brazos basin coupled with decreases in precipitation, then the impact on water availability for GCWA could be significant. Further efforts, outside the scope of the DCP update, would be necessary to better quantify this uncertainty and incorporate it in GCWA's ongoing efforts to increase water reliability and augment its Brazos River water supplies.

## Essential Element #3 – Mitigation Actions

Efforts under this essential element were to include the identification, analysis, and implementation of drought mitigation actions. Mitigation activities addressed in this GCWA DCP update, as detailed within the approved "Detailed Work Plan" were to include: 1) maximizing delivery percentage in the GCWA canals and client distribution systems, and 2) assessing the conjunctive use of groundwater and surface water at times when surface water is scarce. Over the course of the project effort, a third mitigation action was identified and implemented, specifically monitoring and tracking reservoir inflows to ensure that streamflow is properly passed downstream to senior water right holders (such as GCWA) rather than illegally storing the inflows in upper basin reservoirs. This section details GCWA's analysis of each of these mitigation actions and how they have been implemented over the course of this DCP update.

### Mitigation through Canal Delivery Efficiency Enhancement

The goal of this mitigation effort is to increase the delivery efficiency of the GCWA canal system, thereby ensuring that a greater percentage of water entering the canal system is delivered to GCWA customers. For this discussion, the terms "water losses" and "un-accounted water" are used interchangeably, each meaning water entering the GCWA system yet not delivered to GCWA customers. Water losses within the canal system may be due to: 1) evaporation to the atmosphere, 2) transpiration through vegetation along the canal banks, 3) seepage and/or leaks into the canal banks and underlying soils, and 4) illegal or unpermitted diversions from the canal system. Water delivery efficiency is also affected by changes in water storage within the canal system, including water needed to fill-in the canals prior to water being diverted by GCWA customers. Mitigation activities designed to minimize loss through each of these

causes are discussed individually below, after a discussion of the current water loss rates applied to portions of the GCWA canal system.

### Quantification of Current Loss Rates within the GCWA Canal System

GCWA currently does not have a scientifically defensible quantified loss rate that is applicable for its canal system. The losses included within the GCWA Daily-Hydro (V7) model are such that 24% of Brazos River diversions are lost between the river and the Industrial Pump Station at the canal end. Loss rates to intermediate locations within the canal system vary based on the distance between the canal system entrance and the intermediate location. The 24% loss rate is essentially a conservative loss estimate based loosely on a combination of canal flow measurements from 2013 and annual water budget analyses utilizing GCWA reported diversions and water deliveries to customers.

Annual water budgets for 2014-2017 were analyzed by GCWA canal section in order to estimate canal losses. Table 4 presents the water budget results and quantifies the percentage of "un-Accounted" water by section and year. For this analysis, "un-Accounted" water is defined as water introduced into the GCWA canal system yet not delivered to GCWA customers. The data contained in Table 4 do not take into account changes in water storage within the various canal systems, with the exception of calculations related to the Canal A2-Brisco-G-I system. For this canal subsystem, water storage changes in Texas City Reservoir are included in the calculations, but changes in storage within the actual canal system are not included.

*Table 4 – Computed Gains and Losses by GCWA Canal Section via Annual Water Budget*

| | Un-Accounted Water by Calendar Year | | | | |
|---|---|---|---|---|---|
| **Canal Section** | **2014** | **2015** | **2016** | **2017** | **Average** |
| Entire System | -33% | -8% | -13% | -21% | -19% |
| Jones & Oyster Creek (Canal A1) | 11% | 28% | 14% | 23% | 19% |
| Canal A2-Briscoe-G-I | -22% | -6% | -17% | -20% | -16% |
| Juliff Canal System | NA | NA | -34% | -17% | -26% |

As shown in Table 4, results are highly variable by year and canal section. Percentages shown for the "Entire System" are calculated by dividing the total delivery to GCWA customers by the total system inflows, and include inflows and deliveries made from all other listed canal systems. It is also notable that for every year, outflows from the Jones & Oyster Creek (Canal A1) system exceed measured inflows to the system. Outflows for this reach include GCWA pumping at the Second Lift pump station, as well as water diversions by the City of Sugar Land, Pecan Grove, Flour Daniels, First Colony, Southwyck Country Club and Riverbend Country Club as well as leakage through the Amil Gates within the City of Sugar Land. The routinely positive values shown in Table 4 for this section indicate that the watershed of the canal section is clearly contributing inflows to the section. Percentages for the Canal A2-Briscoe-G-I system include the remainder of the GCWA canal system with the exception of the Juliff system and the Monsanto Canal/Chocolate and Mustang Bayou systems. It is probable that some of the Un-Accounted water attributed to the Canal A2-Briscoe-G-I system was transported via the Monsanto Canal into the Chocolate and Mustang Bayou systems. Any such water transported via the Monsanto Canal and subsequently delivered to customers would be captured within the "Entire System" analysis, however.

Un-accounted water for the Juliff system was determined by comparing the water delivered to farmers (based on GCWA Mace Meter data) with water diverted from the Brazos River at the May Pumping Station. Data is unavailable for 2014 and 2015 as GCWA did not commence metering all irrigation diversions until mid-2015.

Conclusions to be drawn from the data presented in Table 3 are:

- Water loss rates (or Un-accounted water rates) are variable between canal sections and over different years
- The modeled 24% loss rate for the GCWA Canal system may be appropriate, but is likely overstating actual rates
- Better quantification of losses or un-accounted water would enhance GCWA's ability to manage available water supplies.

### Recommended Canal System Improvements to Better Control Water Losses

GCWA is considering various options for improving the operational efficiency of its canal system in order to:

1. Increase water delivery efficiency to customers,
2. Increase water storage capacity within the canal system, and
3. Decrease staff time spent manually monitoring canal operations and status

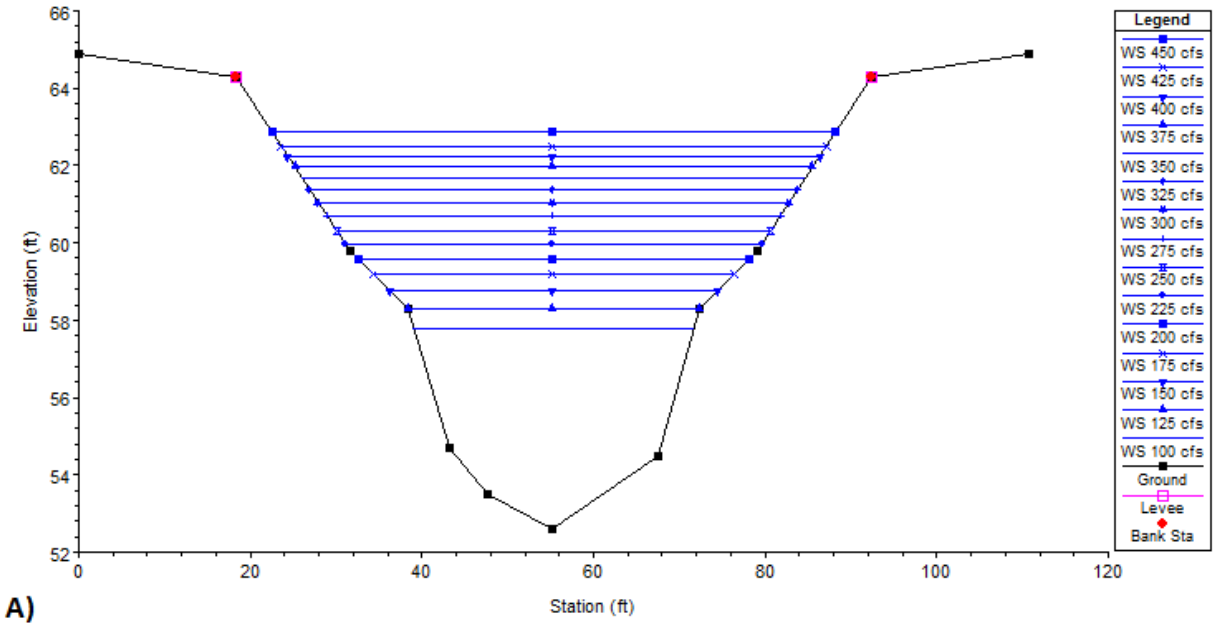
All options for addressing the three objectives listed above will also provide GCWA with data and knowledge about where water is located within their canal systems, and how quickly that water is moving through the canal systems. The following options will each enhance GCWA's ability to monitor canal operations and reduce water loss.

### Recommendation #1 – Canal Storage Monitoring Devices

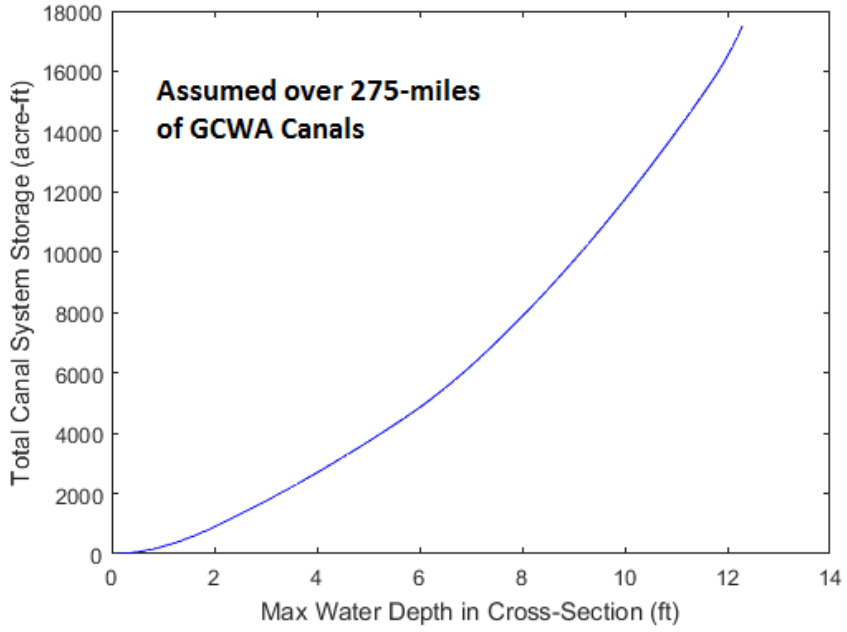
GCWA maintains over 275 miles of canals used to transport water throughout its distribution system. Canal dimensions vary over the entire system, as well as canal slopes and conveyance capacities. Currently GCWA does not actively track and record how much water is within each section of the canal system at any given time. Tracking such information would enhance GCWA's ability to track water movement through the canals over time, and would better allow GCWA to assess the true time-averaged water gains or losses through the canal system.

Figure 23 provides approximate information regarding the potential storage capacity of the GCWA canal system. Figure 23A depicts the cross-sectional dimensions of a portion of the Briscoe canal system, as included in a HEC-RAS model describing water flow through the system. For this analysis, it was assumed that the entire 275 miles of GCWA canals followed this cross-section. Figure 23B shows the computed storage within this approximated GCWA canal system, based on the maximum water depth within the system. As shown, under these gross system simplifications, the GCWA canal system could be capable of storing up to nearly 18,000 acre-ft of water.

The computed canal system capacities shown in Figure 23B are provided not as "truth" but rather to illustrate the fact that the GCWA canal system can potentially store a significant amount of water. Knowledge of where this stored water is located within the canal system would better allow GCWA to manage water deliveries and track water gains and losses throughout the system and over-time.




A)




B)

*Figure 23 – A) Canal cross-section dimensions from a HEC-RAS model of the Briscoe canal system, B) computed total-system storage capacity assuming a constant cross-section over the entire 275 mile canal system, and neglecting the effect of canal slope, obstructions, and other features. The true potential canal system storage capacity may be larger or smaller depending upon cross-sectional area changes over the entire system length.*

The canal storage computations shown in Figure 23B are likely overstated in that canal cross-sections differ at different locations within the system, the canal bottom has a slight slope (allowing for free-flowing water downstream, and the existence of structures within the canal (check structures, gates, siphons, etc.) also impact water storage. Given these limitations, however, it is possible to use available information from existing canal HEC-RAS models to determine the storage capacity of the canal system, assuming the HEC-RAS models are accurate. For example, there are numerous "check" structures, gates, and culverts located throughout the GCWA canal system (Figure 24), and these structures are points at which the canal system could be considered "divided." If GCWA had detailed knowledge of the canal system cross-sections upstream of each division point, then by measuring water levels at the division points would allow for the determination of both canal flow and water storage within the canal section.


*Figure 24 – Structures within the GCWA canal system – A) Gates, B) Culverts, and C) Check stations. Recording water levels at each structure would allow for the computation of flow past the structure as well as water stored in the canal section immediately upstream of the structure.*

GCWA could install water level loggers/recorders at every structure within its canal system, and then continuously record water levels at each location. Using knowledge of the canal system geometry (either from direct measurement or from existing HEC-RAS canal system models), the water level readings could be translated into local flow rates and water storage quantities within the canal section. The loggers can be mounted to SCADA data control and telemetry systems, operated on battery and solar power, and be largely self-sustainable without requiring significant servicing by GCWA staff. Staff

could then collect all data from the SCADA units from their central office, and be able to continuously monitor flow and storage (as well as logger performance) throughout the system. Accuracy of the computed flows would depend upon the accuracy of the HEC-RAS models used to translate the recorded water levels into flow rates. These HEC-RAS models would likely need periodic revision and spot checking – yet the data from the water level loggers could become useful in identifying when and where a HEC-RAS model would need updating. For example, consider three sections of the GCWA canal system, each defined at the downstream end by one of the control structures shown in Figure 24. If the flow through sections 1, 2, and 3, were each 100±1 cfs, then GCWA would conclude that this stretch of the canal system was not gaining or losing water. If, however, water levels at the section 2 division point reported 110 cfs, then GCWA staff would be able to notice the discrepancy and attempt to explain it. Possible explanations could be:

- Local influx of flow to the system within section 2
    - Yet if section 3 still showed only 100 cfs, this would be unlikely
- Accumulation of sediment/debris within section 2 that would increase measured water depth for the same flow rate (possibly requiring sediment removal)
- Changes to the canal cross-section (possibly due to bank failure, illegal dumping, or vegetation over-growth)
- Faulty water level readings.

Each of the above-listed explanations could warrant an inspection of the section 2 area by GCWA staff, who could look for and fix causes for the reading discrepancy. Conversely, if the section 2 water level logger were reading 90 cfs, and if logger #3 downstream were also reading 90 cfs, then this might indicate that the canal section 2 developed a leak, or that known (or unknown) entities are diverting water in the section. GCWA could use the data from all of the SCADA readings to pinpoint their canal inspection and maintenance operations.

Having knowledge of the water storage content within each section of GCWA's canal system would also provide useful data for the over-all water budget calculations used to estimate canal system losses (See Table 3). It would become possible to perform water budget calculations on each section of the canal system, with greater accuracy achieved through better tracking of the stored volume changes over time.

The installation of water level loggers and SCADA equipment at each GCWA in-canal structure would require significant capital investment, as well as staff time in developing and enhancing HEC-RAS models of the canal system. One mechanism of funding available to GCWA would be through an Agricultural Water Conservation Grant from the Texas Water Development Board. GCWA utilized such a grant to partially fund the development of the irrigation diversion metering system currently used to measure and track water usage rates for GCWA irrigation customers.

### Recommendation #2 – Increasing in-canal water levels

Storing more water in the canal system segments (defined as the portion of the canal between in-canal structures such as checks, gates, and culverts) would have three main benefits:

- It would reduce the amount of canal "charging" needed to efficiently divert water, such that less water would be needed to add to a segment so that diversions could be made in the segment or downstream

- Less vegetation growth would occur along the canal banks and bottom, thereby increasing the ease with which water can flow through the segment (reducing roughness) and reducing the amount of water lost to transpiration through the vegetation, and
- The stored water could be made available to downstream customers during periods when water from GCWA sources (the Brazos River, Chocolate, Halls and Mustang Bayou) are low.

Storing water within the GCWA canal system could provide water supply benefits, without the need for large infrastructure outlays (at least in comparison to the efforts undertaken to obtain new reservoirs). This could be a significant benefit to GCWA, however a more detailed canal-system study would be needed to fully address these benefits. Potential detractors of increased water storage in the canal system include:

- Increased evaporative losses from the canal system, as the free-surface area is greater
- Potentially increased leakage from the canal system, as the canal walls would be retaining more water and hence subject to more weight/pressure
- Decreased canal freeboard, which could lead to canal over-topping during heavy rainfall events, especially where stormwater is discharged into the canal system. Decreased canal freeboard could also pose a public safety concern, despite the notion that the canals are not supposed to be accessible to the public.
- Increased need for canal systems operation to ensure water is stored while sufficient flow is passed through to meet diversion needs.

To more efficiently manage the canal system while retaining greater on-canal storage, it would be beneficial to install automated gates and check structures within each canal section. The gates could be either battery/solar powered, or could be connected to the local power grid. SCADA control sensors would allow the gates to be operated from GCWA headquarters, eliminating the need for manual gate operation and the expenditure of staff time/effort. The gates could be operated from the same SCADA network used to transmit water level data.

### Recommendation #3 – Increasing Flow Monitoring and Canal Spot-Checks

This recommendation follows largely from the previous recommendations, yet would be beneficial with or without implementation of the previous recommendations. GCWA owns an Acoustic Doppler Current Profiler (ADCP) which is setup to allow easy and accurate flow measuring along the GCWA canal system. The ADCP could be used to spot-check modeled predicted flows (based on measured water level data), and could be used to continuously refine the canal HEC-RAS models. The ADCP could also be used repeatedly over a canal section to identify where water may be leaking from (or entering into) the canal section. In 2013 and 2014, GCWA utilized its ADCP as well as additional ADCP units to perform a gain-loss study of the canal system. That study was largely inconclusive as to the overall water loss rate across the entire GCWA system. The study was, however, beneficial in indicating locations where losses were observed, and where further study was warranted to pinpoint the cause of the loss.

Figure 25 shows the locations along the GCWA Briscoe Canal where ADCP measurements were made in 2013. The measured flow values (RED) indicate that between 121 cfs and 127 cfs were occurring in the canal, yet flows decreased to 112 cfs closer to the confluence with the Lateral-10 canal. Flows entering the Briscoe Canal from Lateral-10 were not measured. Subsequent flow measurements at this location

in later months confirmed there was a decrease in flow along this stretch of canal. Additional measurements, made along a regular schedule and at locations along this stretch could lead to pinpointing the cause of the flow decrease.

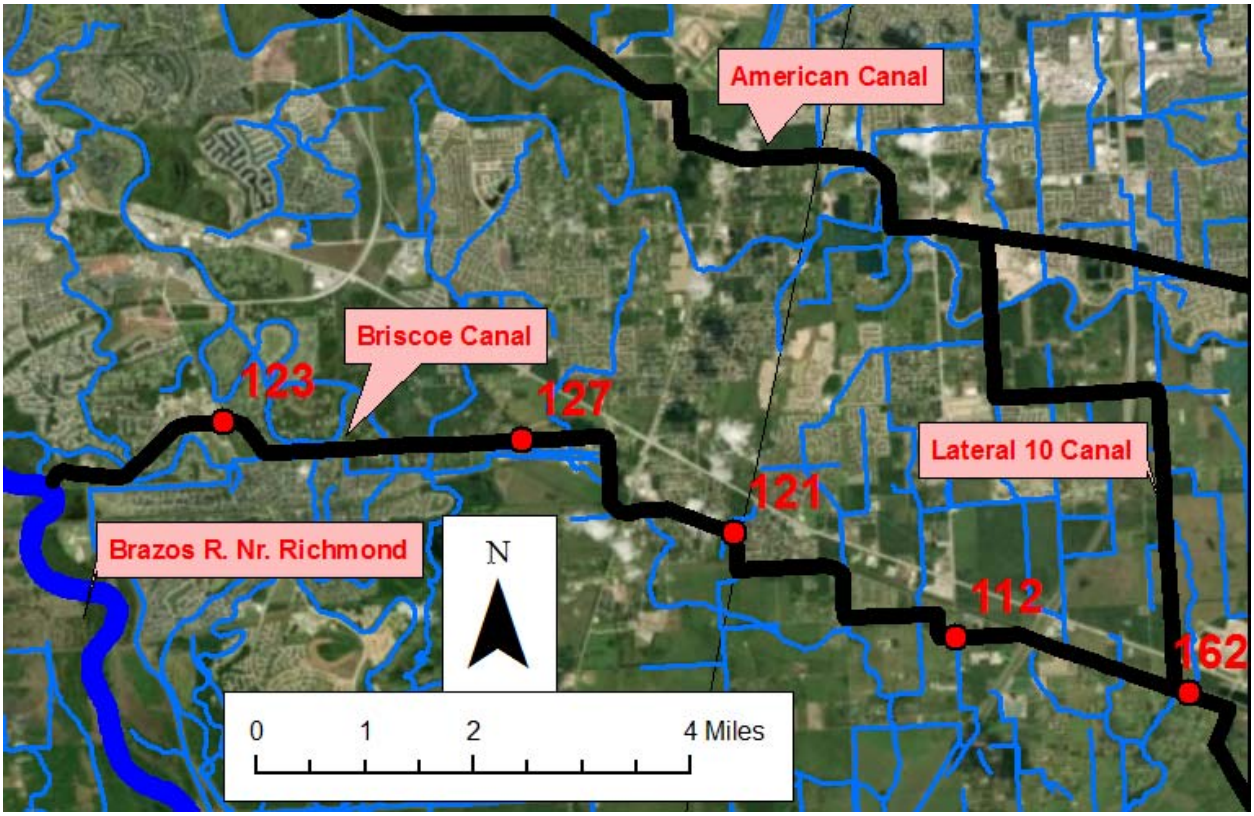



*Figure 25 – GCWA flow measurements from the ADCP on 4/16/2013 along the Briscoe Canal during a period of steady pump operation and river levels. The apparent loss of 9 cfs along the mid-section of the canal segment was observed with repeated measurements*

The ability of GCWA to maintain a regular flow measurement and monitoring program using its ADCP is contingent upon staff availability. The accuracy of spot flow measurements is also dependent upon the skill and experience of the field technician. Efficiently collecting measurements to assess gains and losses within the canal system could require two field crews of 2 people each, each with their own ADCP and associated equipment. This would allow for the simultaneous flow measurement at downstream and upstream portions of a reach, thus providing accurate gains or loss data if the flow is steady along the reach. Given the staff effort and the difficulty with maintaining steady canal flows, it is recommended that GCWA utilize its ADCP to aid in the development and updating of HEC-RAS models and continuously defining the relationship between flow and water depth along GCWA's canal systems. This will ensure that the water level measurement network (Recommendation #1) accurately produces a detailed picture of water movement through the GCWA canal system. Large and small scale flow gains or losses suggested by the water level monitoring network could then be further investigated by GCWA field technicians using the ADCP unit, on a periodic or as-needed basis.

## Mitigation through Supplemental Groundwater Usage

A parallel option for mitigating drought risk is for GCWA to utilize groundwater supplies to supplement available surface water supplies during drought periods. GCWA investigated two potential groundwater sources during this DCP update project, and determined each had significant pros and cons with respect to availability, price, environmental impacts, and political impacts. The following options were reviewed, and each option is discussed separately below:

- **Groundwater Option #1** – Transporting Groundwater to GCWA from the Upper Brazos River Basin via the Brazos River, and
- **Groundwater Option #2** – Using groundwater pumped from new or existing wells in the immediate vicinity of the GCWA canal system

### Groundwater Option #1 – Regional Groundwater Transport and Usage

Under this mitigation action, GCWA would purchase groundwater leases located on land upstream of the GCWA service area and not too distant from the Brazos River. GCWA would then pump groundwater from these leases and deliver the groundwater via pipeline to the Brazos River, where it would travel downstream to GCWA pump stations. GCWA has previously identified possible sites for the leased groundwater and groundwater wells, yet has not actively pursued the projects based on project costs (initial capital outlay and operation and maintenance fees). The following aspects are considered "Pros" for GCWA in exercising this groundwater option:

Pro #1. Groundwater is readily available, and could be available either continuously or on an as-needed basis during drought periods

Pro #2. Infrastructure and accounting mechanisms are already in place to handle diverting the groundwater from the Brazos River into the GCWA canal system

Pro #3. Groundwater usage from outside of the immediate vicinity of the GCWA service area will not exacerbate land subsidence within the GCWA service area

The following "Cons" are also under consideration with respect to GCWA's decision in exercising this groundwater option:

Con #1. High Initial & Ongoing costs for lease setup, well setup, maintenance & operation, and pipelines between the wellhead(s) and Brazos River (including easements), especially if the groundwater is only used to supplement surface water during drought

Con #2. Many groundwater conservation districts upstream of GCWA have water export fees GCWA would need to pay in order to transport the groundwater outside of the district's service area. Permits for exported water are also not politically popular in many districts.

Con #3. Many of the groundwater conservation districts issue permits on an annual yet renewable basis, limiting the assurance that the groundwater supply will be available continuously into the future.

Con #4. Additional accounting measures would need to be developed between GCWA and the Brazos Watermaster, and GCWA would need to obtain a "Bed and Banks" permit to transport water via the Brazos River. Such a permit would require potentially expensive environmental studies to determine the impact to aquatic fauna and flora of discharging groundwater (at potentially high temperatures) into the Brazos River.

Based on these relative Pros and Cons, GCWA has decided to "table" all further considerations of regional groundwater as a supplemental drought mitigation water source. This option may be re-considered in the future should situations change to make such actions more favorable and less costly.

### Groundwater Option #2 – Local Pumping into the GCWA Canal System

A more favorable option for GCWA is to use locally sourced groundwater supplies to supplement surface water supplies during times of drought. This option is favorable because it does not require interaction with the Watermaster, does not require additional Bed-and-Banks permitting, and does not require a large amount of infrastructure to get the water into the GCWA canal system. This option is also beneficial in that many GCWA customers have existing groundwater wells that they could use to supplement their own diversions from GCWA, and reduce their demands on the GCWA system. Within its TCEQ DCP (Appendix A), GCWA has requested that customers utilize other water sources (including groundwater sources) when GCWA enters Drought Stages 2-5. GCWA has not considered using customer groundwater supply wells to supplement water distributed through the GCWA canal system. This option would require compensation agreements between GCWA and the individual customer(s), and may be feasible yet was not explored explicitly as part of this DCP update project. A review of well records held by TCEQ indicates that GCWA firm customers own 74 public water supply wells that have a combined total production capacity of 88,185 GPM (approximately 196 cfs). It is unknown how often these wells are used by GCWA customers, and whether the wells are well maintained and capable of currently producing water at these production rates.

Figure 26 depicts the known groundwater wells in the immediate vicinity of the GCWA canal system, and provides reported indications of the well productivity. As shown, many wells exist near the GCWA system that are capable of producing in excess of 1,000 GCP. The largest portion of these wells exist within Fort Bend County around the upstream end of the GCWA canal system. The well capacities displayed in Figure 26 are likely reflective only of the well characteristics and design; many of the wells shown with lower production capabilities would likely produce more if they were refurbished or re-developed. Each of these wells is located within the Gulf Coast Aquifer (or perhaps the Brazos River Alluvial Aquifer), which is generally known to be a high production aquifer across Texas.

One significant obstacle for local use of groundwater from the Gulf Coast Aquifer is that the aquifer is recognized as a high-risk aquifer for land subsidence due to groundwater pumping (LRE, 2017). GCWA's canal system travels through portions of the Fort Bend Subsidence District and Harris-Galveston Subsidence District, and both districts have the authority to regulate groundwater production to minimize subsidence risk. Therefore any groundwater pumping within those district's jurisdictions would require a permit from the district, as well as strict monitoring of the diverted quantities in comparison to overall used quantities. For example, the Harris-Galveston subsidence district requires that groundwater

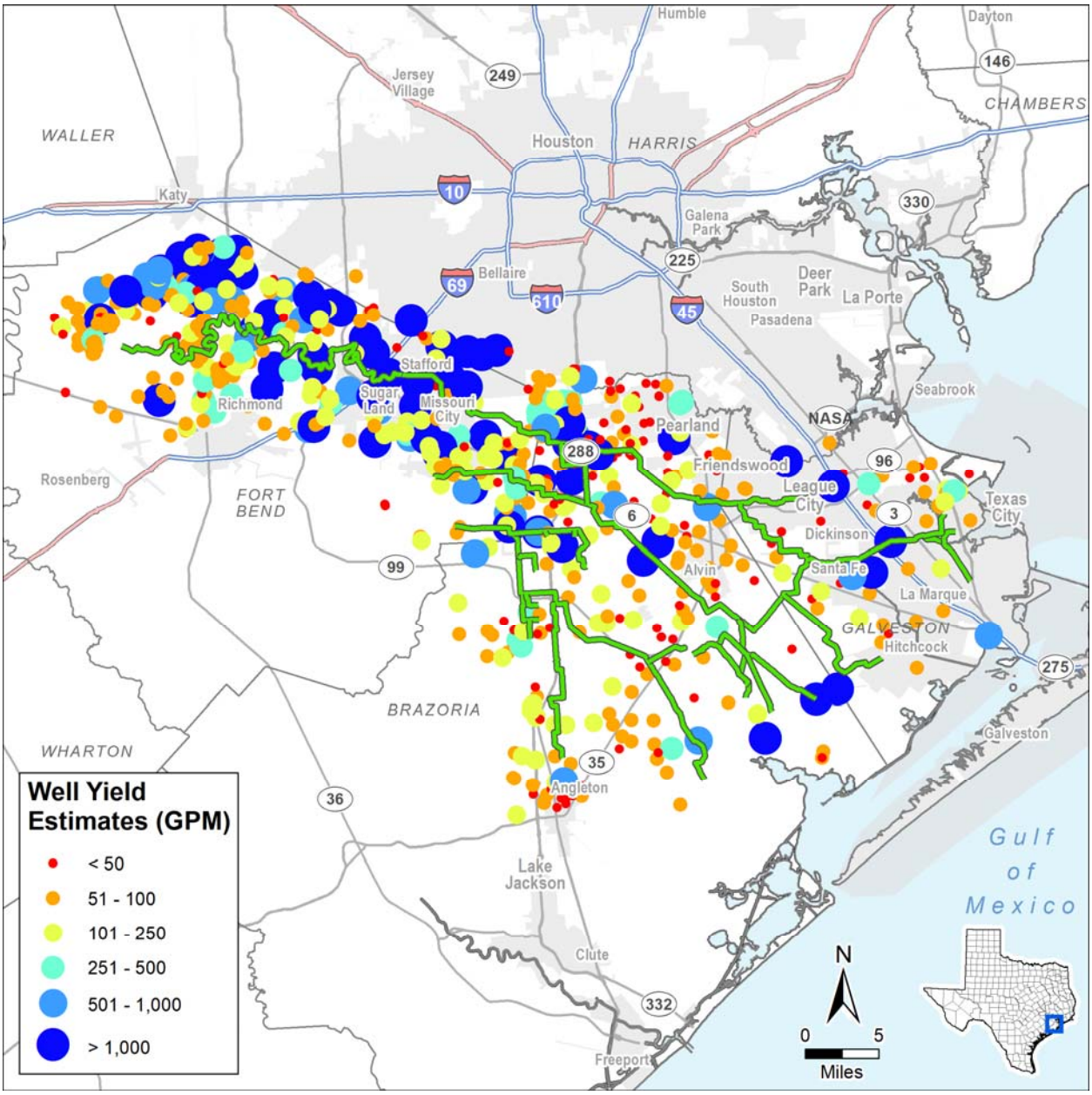



*Figure 26 – Known well productivities (Gallons-per-minute "GPM") in the immediate vicinity of the GCWA canal system, based on TWDB databases.*

usage make up no more than 10% or 20% of a customer's annual water usage, depending on the groundwater location within the district boundaries. Most entities within subsidence district boundaries rely nearly entirely upon surface water sources in order to comply with district rules. Thus using groundwater to supplement surface water sources would be numerically feasible, in only for a limited period over the course of a calendar year. Accounting for the groundwater usage would have to be approved by the subsidence district, yet this is not likely to be a significant obstacle to groundwater usage.

As Brazoria County does not have a subsidence district, groundwater withdrawals in that county are not as stringently regulated with respect to subsidence impacts. However the Brazoria County GCD does have numerous rules regarding groundwater pumping, and they charge large fees if pumped groundwater is transported out of Brazoria County. Therefore there would be potentially large financial penalties if GCWA were to pump groundwater from wells in Brazoria County and have that water travel down the canal system into Galveston County for use by other GCWA firm customers. In addition, even though Brazoria County is not part of an official subsidence district, it was recognized as being at high-risk of subsidence in the recent statewide subsidence risk assessment published by the TWDB (LRE, 2017). Therefore it is likely that Brazoria County GCD may become a subsidence district in the future, and that action may alter the benefits of using Brazoria County groundwater to supplement surficial sources during drought.

Figure 27 details a proposed groundwater project designed for this DCP Update, where GCWA would locate up to twelve wells along the GCWA G-Canal system upstream from where the G-Canal and B-Canals converge. These wells would be located within the Harris-Galveston Subsidence District Area-2 and therefore be subject to the 20% customer annual water usage requirement. Well production was simulated within the official Houston Area Groundwater Model (HAGM) in order to assess resulting drawdown and subsidence risk. Simulated production levels included 4 MGD, 8 MGD, and 16 MGD with production assumed constant and continuous in time (due to the limitations of the HAGM model). Resulting drawdown and subsidence risk varied based on model parameters, well location, and subsidence calculation methodologies. It was estimated that subsidence of up to 1 ft would occur by 2070 if these wells were pumped at 16 MGD continuously. Significantly less subsidence would be expected if the wells were only to be used periodically to supplement surface water supplies during drought.

If GCWA were to move forward with the groundwater development project depicted in Figure 27, it would be necessary to determine through negotiations with the Harris-Galveston Subsidence District exactly what type of well permitting and accounting would be required. Based on this investigation, it was unclear whether HGSD would consider the water user to be GCWA or whether the user would be considered GCWA's individual customers. The distinction is potentially important as it relates to the HGSD rule regarding a maximum of 20% of a customer's annual usage be derived from groundwater sources. If, for example, GCWA was considered the customer, then 20% of GCWA's annual water usage would be upwards of 50,000-70,000 acre-ft/yr. Alternatively if the water user were considered the HGSD customer, then groundwater usage by GCWA would have to be added to any other groundwater usage by the individual customer, and then compared against the surface water usage by that customer for the given year. The accounting tasks involved are not insurmountable, yet through discussion with HGSD staff it has become evident that the tasks have not yet been considered and the water accounting methods have yet to be developed.

Total cost estimates for the 12 wells shown in Figure 27 were determined based on the TWDB's Unified Costing Model utilized in the Regional Water Planning process. Based on this model, the initial construction costs for the 12 wells is likely to be approximately $18M, and operation and maintenance costs will be $2.7M per year depending upon how often the wells are pumping.

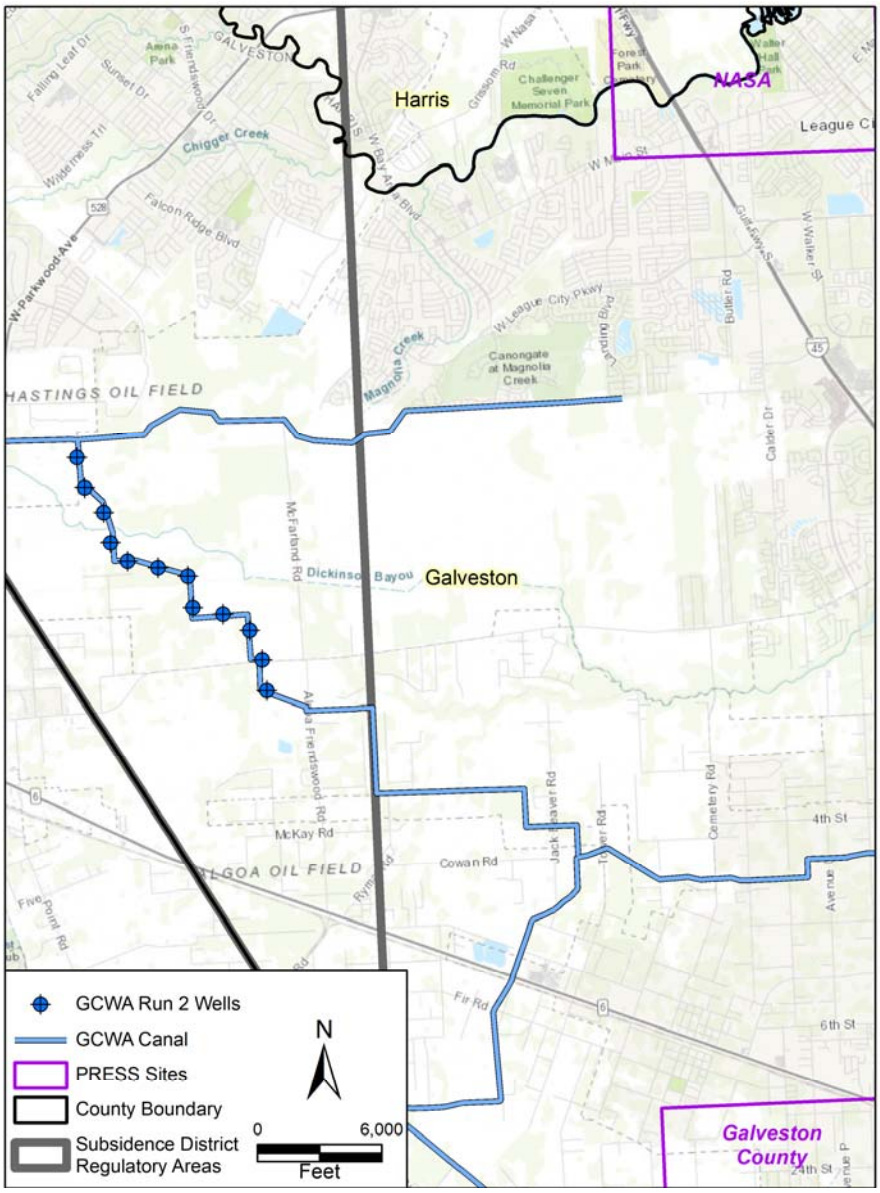



*Figure 27 – Proposed groundwater wells along the GCWA G-canal within the Area-2 of the Harris-Galveston Subsidence District. Pumping from these wells could provide 16 MGD with limited effect on area subsidence.*

Additional groundwater projects under consideration by GCWA include the installation of wells along the Monsanto Canal within Brazoria County. These wells would be used to supply water to GCWA customer INEOS, and could reduce GCWA's Brazos River demands by up to 24 MGD. Using pumped groundwater within the Monsanto Canal system would also eliminate the groundwater export fee imposed by the Brazoria County GCD.

Within its TCEQ DCP, GCWA provides financial compensation to customers who successfully reduce their demand for GCWA water, potentially through the use of their own groundwater supplies. This financial incentive was intended by GCWA to offset the costs of well maintenance and operation by the GCWA

customer. Customers only receive the incentive, however, if they reduce demands for GCWA water by certain percentages prescribed in the DCP.

### Mitigation through Reservoir Inflow Analysis

As a senior water right holder in the lower Brazos Basin, GCWA is entitled to priority-access to water from the Brazos River basin. In theory, only entities holding water rights with priority dates senior to those of GCWA should be able to divert water before GCWA, as long as GCWA has a demonstrated need for the water and sufficient water would not be available to GCWA should the water first be diverted by others. The same is true for water impounded in reservoirs – namely any reservoir owner/operator with a storage right junior to GCWA's active water right(s) should not be allowed to impound inflows to the reservoir if those inflows are needed to satisfy GCWA's demands under its water rights. It is the job of the Brazos Watermaster to monitor all movement of water through the Brazos River basin, and to authorize diversions such that all entities (reservoir owner/operators and water right holders) are behaving fairly according to the Texas prior-appropriation system. The watermaster has been active in the Brazos Basin since June 2015, yet only over the summer of 2018 did the watermaster have to make water allocation decisions to mitigate drought impacts for the Lower Brazos Basin. In general, the Brazos Watermaster has worked cooperatively with GCWA, the BRA, and other basin water right holders to manage available water supplies.

Near the beginning of June, 2018 there was a period when the flows in the lower Brazos River were decreasing to the point where GCWA was considering initiating releases of contract water from BRA reservoirs. During this same period, drought monitoring tools developed during this DCP update (Figure 6, Figure 7) indicated that reservoirs within the BRA system were typically increasing in storage on a day-to-day basis. This, in turn, indicated that the BRA was storing water at a time when GCWA was in need of water downstream under its senior water right. GCWA discussed the observations with BRA and the Brazos Watermaster, and it was determined that BRA would begin releasing more of the inflow, and not charging the releases against GCWA's contract quantities.

As part of its reservoir management operations, the BRA has developed a daily water accounting plan in which it calculates inflows to each of its system reservoirs. The inflows are calculated according to the equation:

$$I = \Delta S + O + E - P + D$$

Where "I" is the inflows, "ΔS" is the change in reservoir storage, "O" is the gauged outflows, "E" is water lost to evaporation, "P" is water gained due to precipitation, and "D" is water lost to diversions made along the lake boundaries. The BRA regularly tracks and records this information at each of their reservoirs, and it updates the official accounting spreadsheet monthly or weekly depending on the drought status. During the summer of 2018, the Brazos Watermaster used inflow calculations made by BRA to aid in its decisions regarding how much (if any) of the inflows needed to be passed downstream to senior water right holders (including GCWA).

GCWA decided to modify its dashboard and Flow Prediction Tool in order to compute and track inflows to BRA's reservoirs. The purpose of the action was not necessarily to challenge BRA's or the Watermaster's management of reservoir inflows, but rather to provide GCWA with a means to independently assess the actions of the BRA and Watermaster with regard to reservoir operation during

drought. As such, the various Matlab scripts that run the dashboard, FPT, and emailing tools created for Drought Monitoring and Vulnerability Assessment were modified to include approximate daily calculations of reservoir inflows, outflows, and water lost to evaporation. GCWA's methods included using the same base equation as BRA, yet assuming lakeside diversions ("D") were negligible. GCWA also made the assumption that evaporative loss rates would be approximately equal to the 5-year averaged historical loss rates for the reservoir area, as reported by the Texas Water Development Board. Both the diversion and evaporation assumptions were needed as actual real-time information is not available to GCWA. GCWA could obtain the real, measured data from BRA yet doing so would necessitate time delays in computing inflows and assessing water management practices by BRA and the Watermaster. As such, GCWA recognizes that its inflow estimates are not exact, yet also assumes that they are "close enough" to demonstrate to the Watermaster that the BRA should or should not be passing inflows at a given time.

```
--------------------------------------------------------------------------------
 Streamflow Records (cfs):
                          Current Flow        12/8/2018 Average Flow
  Whitney           =         382 cfs              660 dcfs
  Waco              =       2,410 cfs            5,190 dcfs
  HighBank          =      13,500 cfs           13,300 dcfs
  Bryan             =      42,400 cfs           39,700 dcfs
  Hempstead         =      47,100 cfs           38,400 dcfs
  San Felipe        =      50,700 cfs           33,500 dcfs
  Richmond          =      41,300 cfs           24,100 dcfs
  Rosharon          =      37,600 cfs           27,000 dcfs
--------------------------------------------------------------------------------
 BRA Reservoir Inflows vs. Outflows & Evaporation: 12/8/2018
                        Inflow             Outflow          Evaporation
  Possum Kingdom    =  1,341 acre-ft       580 acre-ft       106 acre-ft
  Granbury          =    988 acre-ft     1,545 acre-ft        47 acre-ft
  Whitney           =  5,051 acre-ft       870 acre-ft       144 acre-ft
  Aquilla           =  2,411 acre-ft        52 acre-ft        20 acre-ft
  Stillhouse Hollow =  6,282 acre-ft       117 acre-ft        46 acre-ft
  Belton            = 10,262 acre-ft       153 acre-ft        81 acre-ft
  Proctor           =    147 acre-ft        69 acre-ft        31 acre-ft
  Granger           =  5,774 acre-ft        61 acre-ft        29 acre-ft
  Georgetown        =  1,132 acre-ft        14 acre-ft         8 acre-ft
  Somerville        = 29,002 acre-ft       458 acre-ft        76 acre-ft
  Limestone         = 14,631 acre-ft    14,124 acre-ft        88 acre-ft
  Total             = 77,020 acre-ft    18,043 acre-ft       676 acre-ft
--------------------------------------------------------------------------------
```

*Figure 28 – Portion of Sample Daily Text Emailed Automatically to GCWA Staff – detailing current Brazos River streamflow and computed BRA reservoir inflows, outflows, and evaporative losses from the previous day. This text is amended onto the text presented in Figure 6.*

Figure 28 shows the results of the inflow calculations for 12/9/2018 as included in the daily email sent from the Dashboard to select GCWA staff. As shown, the text contains inflows and outflows computed

for each reservoir, and also provides the total inflows and outflows. For 12/9/2018, computed inflows (77,020 acre-ft) greatly exceeded outflows (18,043 acre-ft). GCWA would not complain that BRA was improperly storing inflows in this instance, however, because Brazos River streamflows are higher than GCWA's customer demands or the Monthly Flow Target for December. In this instance, GCWA would not protest BRA's storing of water, as this water could be available to GCWA at a later date (as contract water).

Figure 29 depicts the results of the Flow Prediction Tool (FPT) for June 9, 2018, showing predictions based on both releases from the reservoirs (gauged observations) AND from reservoir inflows computed by GCWA. As shown during this period predicted flows at Hempstead due to reservoir inflows (blue line) occasionally exceeded predicted inflows due to the actual gauged releases (red line). However for the majority of the second week of the prediction, flows from releases exceeded flows predicted from inflows. GCWA could have used this information in deciding whether to request that the Watermaster direct BRA to release rather than store more of its inflows. Figure 26 is also notable as it often shows disagreement between the observed and predicted flows at Hempstead. There were two dates, however, when observed and predicted flows due to releases were nearly identical (6/6 and 6/9).

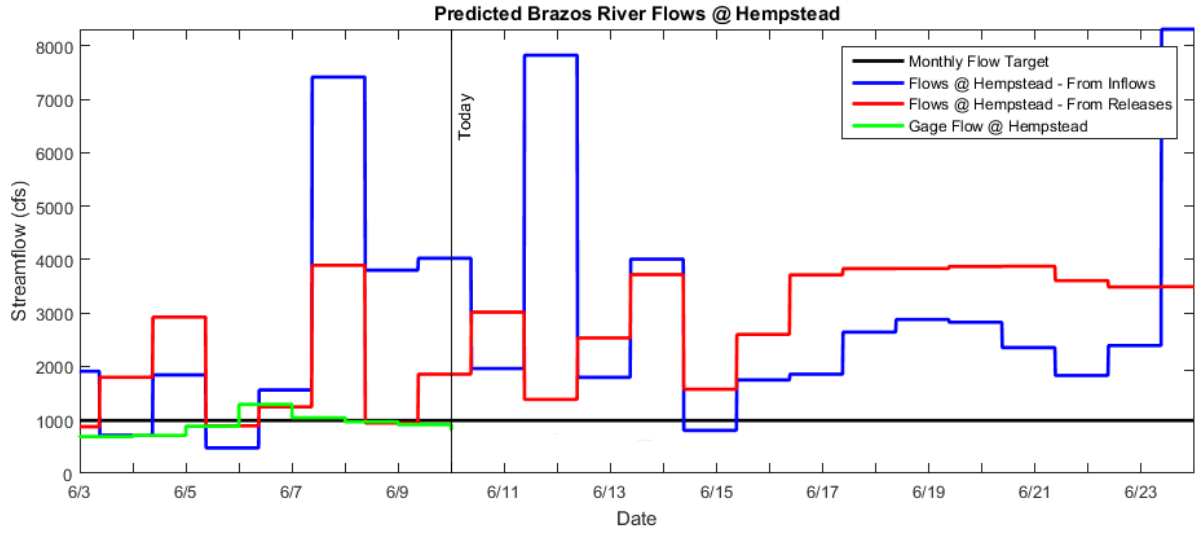



*Figure 29 – Flow Prediction Tool Results for 6/9/2018 – Showing output for actual reservoir releases (Red) and passage of inflows to BRA reservoirs (Blue).*

Results of the FPT (similar to that shown in Figure 28and Figure 29) are emailed to select GCWA staff on a daily basis, and can therefore help inform operational decisions with regard to drought planning. No formal mention of the FPT or the reservoir inflows calculation is made in the GCWA DCP developed for submission to the TCEQ. However both tools form part of the mitigation and analysis framework used by GCWA to ensure its customers obtain their desired water quantities.

## Prioritization of Mitigation Actions

Drought resiliency projects discussed in this section (Essential Element #3 – Mitigation Actions) were prioritized based on their ease of implementation and expected effectiveness. Table 5 presents each resiliency project in priority order. With the exception of the "Regional Groundwater Transport and

Usage" project, GCWA intends to implement each mitigation action as soon as possible, depending upon funding and staff abilities.

*Table 5 – Prioritization of Drought Resiliency Projects (Mitigation Actions)*

| Priority | Mitigation Action |
|---|---|
| 1 | Reservoir Inflow Analysis |
| 2 | Canal Flow Monitoring & Spot Checks |
| 3 | Local Groundwater Usage |
| 4 | Increasing In-Canal Water Levels |
| 5 | Canal Storage Monitoring Devices |
| 6 | Regional Groundwater Transport and Usage |

The "Reservoir Inflow Analysis" mitigation action was assigned the priority rank #1 as this action was implemented during the development of this DCP Update, and has already provided benefits to GCWA and its customers. GCWA used the automated analyses during the summer of 2018 in discussions between the Brazos Watermaster and the Lower Basin User's Group (See Concept #4 in the Response Actions section). This mitigation action required little cost and staff time to develop and implement, and requires minimal effort to maintain.

The "Canal Flow Monitoring & Spot Checks" mitigation action was assigned the 2nd priority rank as this action can be implemented with existing GCWA-owned equipment and by allotting staff time to the effort. The action is likely to identify water loss locations within the GCWA canal system, which will lead to canal repairs and delivery efficiency improvements.

The "Local Groundwater Usage" mitigation action was assigned the 3rd priority rank as this action is already being implemented, with GCWA discussing with customers the availability of groundwater from customer wells. GCWA is also developing detailed plans for the design and construction of GCWA-owned wells adjacent to portions of its canal system. GCWA is discussing with customers potential compensation measures for customer usage of groundwater sources during drought periods.

The "Increasing In-Canal Water Levels" mitigation action was given the 4th priority ranking as the method will increase supplies through on-canal storage of water. GCWA is investigating the availability of numerous grants which will allow for the upgrading of in-canal gates and structures, allowing for improved water delivery efficiency.

The "Canal Storage Monitoring Devices" mitigation action was given the 5th priority ranking, although the strategy is under GCWA development and closely tied to the "Increasing In-Canal Water Levels" strategy. GCWA is investigating the availability of numerous grants which will allow for the purchase and installation of water level monitors and SCADA networks, to work in conjunction with the upgraded in-canal gates, thus allowing GCWA to better manage and operate its canal system.

The "Regional Groundwater Transport and Usage" mitigation action was given the lowest priority ranking due to the numerous (and onerous) permitting requirements associated with such a strategy. GCWA is not actively pursuing this strategy at this time, yet some GCWA customers have expressed interest in developing this strategy in collaboration with GCWA.

# Essential Element #4 – Response Actions

The Response Actions to be undertaken by GCWA during a future drought are encoded within the DCP prepared for submission and approval by the TCEQ. This DCP, included as Appendix A herein, was created during the larger Reclamation DCP update process, and incorporates knowledge and concerns presented by the DTF. The GCWA board of directors formally adopted the DCP for TCEQ on December 6, 2018 as GCWA board resolution #2018-013.

The GCWA DCP contains 5 drought stages, with stages 1-4 depending upon severity of the lack of water within the Brazos River (and other GCWA sources). Stage 5 is an emergency water stage, and is reflective of situations where GCWA infrastructure is not capable of conveying sufficient water to its customers; Stage 5 conditions do not require a lack of water available to GCWA. Stage 5 conditions are likely to occur if GCWA pump stations fail, if canal systems sustain large leaks, or if the source water were to become contaminated (for example). In November of 2018, GCWA's pipeline transferring water to the City of Galveston sustained a significant rupture, causing the City of Galveston to receive reduced water supplies. Under this situation, had GCWA's DCP been adopted, it would have declared a Stage 5 condition for the City of Galveston, yet would not have declared such a stage response for other customers. The City of Galveston did implement its emergency drought response at the suggestion of GCWA, and both entities were able to sustain operations until the pipeline leak was repaired.

Per the approved Detailed Work Plan (DWP), the "Response Actions" portion of the DCP was to include discussions of existing drought contingency plans, rules for use of supplemental groundwater, rules for implementation of other mitigation strategies, and "Last-Resort" Curtailment Rules implementation. During the DCP update process, however, each of these topics intermingled such that they are not easily distinguishable in the final GCWA DCP to be submitted to TCEQ. The following 4 sections detail investigations into each of the topics required in the DWP. Subsequent sections detail GCWA's staged drought responses as included in the DCP for TCEQ.

## Review and Summary of Existing Drought Contingency Plans

This task involved the collecting and analyzing of the drought contingency plans of entities serviced by GCWA, as well as the drought contingency plan developed by the Brazos River Authority. These plans were analyzed to determine if any proposed changes to GCWA's DCP would necessitate significant changes to the DCPs of GCWA customers and supplier (the Brazos River Authority) during drought periods. The DCPs were also reviewed to assess whether any components of those implemented DCPs would provide viable benefit to GCWA and its customers if included in the GCWA DCP.

Table 6 lists the entities who's DCPs were reviewed during this process.

### DCP for the Brazos River Authority – A GCWA Supplier

As the owner of three upstream reservoirs and holder of numerous Brazos River water rights, the Brazos River Authority (BRA) is able to provide its customers with a reliable water supply during all times (drought, normal conditions, or wet conditions). GCWA is a customer of the BRA, and holds long-term contracts requiring BRA to provide water to GCWA when insufficient water is available under GCWA's various water rights. GCWA had initially wished to use BRA's adopted drought triggers, stages, and responses when developing its DCP. However upon review of the BRA DCP, it was concluded that GCWA

could not rely on the concepts included in the BRA DCP in order to protect GCWA customers during drought periods.

*Table 6 – Entities with DCPs Reviewed During this Project*

| Entity | Type | DCP Plan Adoption Date |
|---|---|---|
| Brazos River Authority | Supplier to GCWA | 10/29/2012 |
| City of Galveston | Customer of GCWA | 3/2003 |
| Bacliff MUD | Customer of GCWA | Unknown |
| Bayview MUD | Customer of GCWA | 4/16/2009 |
| City of Hitchcock | Customer of GCWA | Unknown |
| City of La Marque | Customer of GCWA | April, 2009 |
| City of League City | Customer of GCWA | May 2012 |
| City of Texas City | Customer of GCWA | August 2009 |
| Galveston County Fresh Water Supply District No. 6 | Customer of GCWA | May 10, 2005 |
| Galveston County MUD No. 12 | Customer of GCWA | December 17, 2012 |
| Galveston County Water Control and Improvement District No. 1 | Customer of GCWA | January 20, 2010 |
| Galveston County Water Control and Improvement District No. 8 | Customer of GCWA | September 16, 2010 |
| Galveston County Water District No. 12 | Customer of GCWA | April, 2009 |
| San Leon MUD | Customer of GCWA | September 1999 |

The BRA DCP defines “drought severity triggers” based entirely upon stored water contents of its 11 system reservoirs. It can define different drought stages for customers served by each reservoir, and for GCWA (which is downstream and can thus receive BRA water from each of the 11 BRA source reservoirs) drought stages are based upon the total water storage within all BRA system reservoirs. Figure 30 shows the time-history of storage within BRA reservoirs, relative to the various stage triggers included in the BRA DCP.

As shown in Figure 30, since 1980 when the last of the 11 system reservoirs was completed, system storage has periodically approach the “Stage 1- Watch” level, and was below the watch-level during the 2011 and 2013-2014 drought periods. System storage has never been sufficiently low to cause BRA to implement its “Warning,” “Emergency,” or “Pro-Rata Curtailment” clauses within its DCP. Note: the storage time history shown in Figure 30 is approximate, as it assumes Lake Whitney always contained the 50,000 acre-ft of water that BRA has access to per agreement with the US Army Corps of Engineers (USACE); the actual amount of water within Lake Whitney to which BRA has access at any given time is not readily published by the BRA, USACE, or US Geological Survey (USGS).

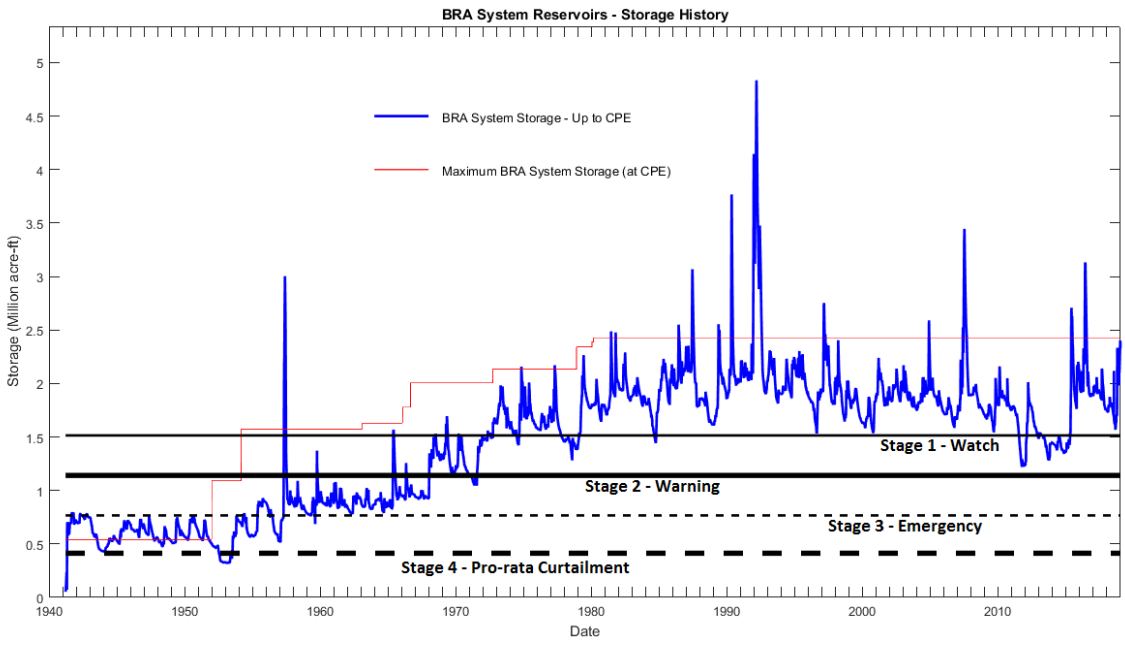



*Figure 30 – Time-history of BRA reservoir storage relative to the defined drought stages within the BRA DCP.*

The significant difference between the BRA and GCWA in terms of water supply is that GCWA owns "run-of-river" rights to water, and does not maintain its own reservoirs to provide water during drought conditions. As such, directly linking GCWA's DCP stages to those of BRA may not necessarily accurately reflect streamflow conditions, as BRA will not alter its drought stages based on streamflow. For this reason, it was decided that while GCWA may use information provided by BRA (including BRA's potential declaration of drought stages) in its assessment of river conditions, GCWA's DCP will not directly "link back" to any decisions made by BRA.

### DCP for the City of Galveston – A GCWA Customer

The City of Galveston receives 100% of its water as treated water via pipeline from the GCWA Thomas S. Mackey Treatment Plant. The City has contracted with GCWA for 21.0 MGD, and recently uses an average of 14 MGD, with higher usage during summer tourist seasons. The City also maintains a groundwater wellfield capable of producing up to 10.3 MGD, yet this wellfield has not been utilized since the City switch to GCWA for its main water supply. The City of Galveston's DCP was approved in March of 2003, and staff have begun updating the DCP to reflect more recent conditions and better coincide with GCWA's revised DCP. The main object of the City of Galveston's DCP is to codify how the city will work to conserve water during drought stages. Conservation measures, such as prohibition of outdoor car washing, mid-day lawn irrigation, etc. are explicitly expressed within the DCP, and violations for non-compliance are also included. As the City passed the DCP rules into law as a city ordinance, the City then had the legal authority to enforce water reduction requirements based on prescribed drought stages.

### Insights based on Existing DCP Review

While some insights were obtained through analysis of BRA's and GCWA Customer DCPs, the greatest insight was that GCWA's DCP must be materially different in that its water source is not a reservoir (or system of reservoirs), and that it is not a retail water provider with direct control over the water demands of end-users. For these reasons, it was determined that GCWA's DCP would be similar in form to that of BRA and its customers, yet would rely upon different analyses and triggers when assessing drought stages. GCWA would consider the drought stages declared by BRA and its customers when making its own drought declarations, but the various drought declarations do not have to be identical. For example, GCWA could declare a stage-3 drought based on streamflow, yet BRA may not declare even a stage 1 drought if their system reservoirs were still sufficiently full. GCWA recommends to each of its customers that the customer's DCP utilize GCWA drought stage determination as one criteria for implementing their own stage declarations. This notion has been incorporated into the revised (and yet-to-be-adopted) City of Galveston DCP.

### GCWA's Adopted TCEQ DCP – Drought Stage Triggers & Response Actions

The purposes of the GCWA DCP are as follows:

- To conserve the available water supply in times of drought and emergency;
- To maintain supplies for domestic water use, industrial use, sanitation, and fire protection;
- To protect and preserve public health, welfare, and safety;
- To minimize the adverse impacts of water supply shortages;
- To minimize the adverse impacts of emergency water supply conditions; and
- To satisfy the requirements set forth by the Texas Commission on Environmental Quality (TCEQ) and other agencies, including the US Bureau of Reclamation.

For GCWA's DCP, a drought is generally defined as an extended period of time when an area receives insufficient amounts of rainfall to maintain or replenish the water supply, thereby causing temporary water supply shortages. In the absence of drought response measures, water demands tend to increase during a drought due to the need for additional outdoor irrigation and cooling water. The severity of a drought depends on the degree of depletion of supplies and on the relationship of demand to available supplies. The GCWA DCP defines four drought stages, with an increase in drought severity with an increasing drought stage number. The Stage 5 drought condition defined by GCWA is reserved for when emergency conditions occur that are related to GCWA's ability to deliver usable water supplies, not based on the quantity of supply available for delivery.

This GCWA DCP addresses periods of time when: (i) the quantity of water in the Brazos River available to GCWA under its water rights, and its alternative sources of water (including contracts for stored water from the Brazos River Authority [BRA]) is insufficient to meet the demands of GCWA's water supply customers; or (ii) the capacity of GCWA's pump stations, canals or water treatment plants is insufficient to meet the demands of any water supply customers dependent on such facilities, or both. The GCWA General Manager (GM), or his/her designee, is to be

responsible for implementing all applicable provisions of this DCP upon determination that such implementation is necessary to protect public health, safety, and welfare. GCWA's general strategy is to monitor hydrologic conditions within the Brazos Basin, and utilize alternative water supplies when insufficient streamflow is available. Only when available streamflow and alternative supplies are insufficient to meet GCWA customer needs will GCWA consider moving up to the next stage within its DCP.

Table 7 provides an outline of GCWA's defined drought stage triggers and responses. GCWA decided to implement water use reduction "goals" under Stage 1-4 responses, and to implement surcharges and credits in order to incentivize water conservation during drought periods. The following sections detail GCWA triggers and response actions for each defined drought stage.

*Table 7- Summary of Drought and Emergency Response Stages*

| | Stage 1 Response | Stage 2 Response | Stage 3 Response | Stage 4 Response | Stage 5 Water Emergency Response |
|---|---|---|---|---|---|
| Minimum percentage of **Contributing Watershed** in "Moderate Drought" or higher per the US Drought Monitor to declare Stage Response | 50% | NA | NA | NA | NA |
| System Demand Exceeds [A]% of **Deliverable Capacity** to declare Stage Response : | 85% | 90% | 95% | 98% | NA |
| **Run-of-River Supplies** plus **GCWA Alternate Water Supplies** are less than [A]% of the **Monthly Flow Target** through August 31 to declare Stage Response | NA | 95% | 90% | 85% | NA |
| **Lower Basin User's Group recommendations**** | NA | YES | YES | YES | NA |
| Water Use Reduction Goal | 95% | 90% | 85% | 80% | GM discretion |
| Potential Surcharge | NA | 2.5x | 2.5x | 5.0x | 10.0x |
| Potential Credit | NA | 1.0x | 1.0x | 1.0x | 1.0x |

*"NA" signifies "Not Applicable". [A] references percentage values listed in Table rows.*
***The Lower Basin User's Group may recommend entering a Stage 2, 3, or 4 drought based on their review of hydrologic conditions.*

## General Concepts Included in the GCWA Response Actions

While specific details are provided below pertinent to each GCWA defined drought stage, there are several key concepts inherent to each stage that must first be explained. These concepts form the backbone of the GCWA DCP, and are rather unique among DCPs developed for Texas entities.

**Concept #1** – GCWA does not wish to impose curtailment rules, and will strive to meet customer demands through usage of all available water sources. Through each drought stage, GCWA will encourage customers to use alternate water sources available to them, possibly including local groundwater sources, before requesting that the customer reduce their demands. GCWA will also carefully utilize its own alternate water sources to supplement available supplies from the Brazos River.

**Concept #2 –** GCWA will not automatically enter (or leave) a given drought stage when any stage entrance/exit criteria are satisfied. The GCWA General Manager will CONSIDER changing from one stage to another based on the criteria stated in this DCP. This provides GCWA with desired flexibility in its actions. GCWA intends to follow the guidelines listed in this DCP, yet reserves the right to deviate from them under unforeseen circumstances not anticipated during the development of this DCP.

**Concept #3** - GCWA's water use reduction goals are targets, and are not mandatory requirements. Customers will be given monetary credit for achieving the goals, and will be penalized/assessed a water surcharge on their monthly bills if water usage exceeds their monthly target amount.

**Concept #4 -** Monthly target water usage is based on an individual customer's actual usage during the same month during the three previous calendar years, excluding any reductions in usage as a result of implementing a Stage Response. In this way, GCWA is basing water usage reductions on historically used quantities, rather than on the quantity GCWA is contractually obligated to provide for the customer (a quantity that is often higher than the actual customer usage).

**Concept #5** – Water management during drought cannot be heavily prescribed, and must be sufficiently flexible to allow GCWA staff to optimally allocate available water resources. GCWA, at the discretion of the GM, will consult the advice of a "Lower Basin User's Group" made up of experienced professionals who will jointly assess the hydrologic conditions and make recommended actions with respect to drought stages. The GM is not required to implement drought stages because one of the particular stage triggers is achieved; Discretion is to be utilized, and rapid consensus amongst participating entities is to be expected. The Lower Basin User's Group may recommend entering (or leaving) Stage 2, 3, and 4 based on their review of hydrologic conditions within the region.

**Concept #6 -** The GCWA DCP pertains to only water obtained by GCWA and delivered to customers. It does not pertain to water procured by customers and delivered (by prior agreement) through GCWA infrastructure. This allows customers to obtain additional supplies for their sole use, subject to GCWA's ability to deliver the water under drought conditions.

The six drought management response concepts listed above were each heavily debated by GCWA staff and members of the Drought Task Force through the duration of this project. The resulting benefits from their inclusion are expected to be that they provide sufficient notice for customers to deal with impending drought conditions, yet also provide flexibility for all to maintain operations using alternate water supplies and proper, flexible water management. Each of these concepts in intertwined in the individual drought response stages discussed below.

### Stage #1 – Mild Water Shortage ("TCEQ Watch Level")

Under Stage 1 drought conditions, GCWA's main goal is to make customers aware of the developing dry conditions, and to have them internally prepare for potential periods in the future where water supplies are diminished. Stage 1 conditions are achieved when the US Drought Monitor classifies over 50% of the GCWA contributing watershed to be in or exceed "Moderate Drought" conditions. This assessment is made by GCWA staff skilled/trained in the use of GIS and geospatial analysis. Training material for this assessment is provided in Appendix C. Stage 1 conditions can also be achieved if GCWA's customer demands exceed 85% of the deliverable capacity of GCWA. This could mean that GCWA can only divert streamflow to meet 85% of customer demands, or GCWA is only able to convey (through its canal system) enough water to meet 85% of demands. Under Stage 1 conditions, customers are encouraged to begin water conservation efforts, and to reduce their usage to only 95% of their monthly targets.

Water usage under Stage 1 conditions is not eligible for customer credits or surcharges. Stage 1 conditions are expected to occur rather frequently, and as such GCWA customers are expected to operate often while considering the constant benefits of water conservation. Figure 31 depicts when Stage 1 conditions would occur based on the US Drought Monitor, from January 2000 to August 2018. As shown, Stage 1 conditions were common, with both 2006 and 2011 experiencing the condition for most of the calendar year. In contrast, there are years (2001 and 2016) when Stage 1 conditions were never experienced. Stage 1 conditions are also likely to yield Stage 2 conditions (or higher). As such, the GCWA GM is likely to recommend entering Stage 1 conditions often, even if hydrologic conditions are ambiguous. By entering Stage 1 conditions, it is hoped that transitions to Stage 2 conditions will be more easily achieved by GCWA customers, should stage 2 conditions become necessary.

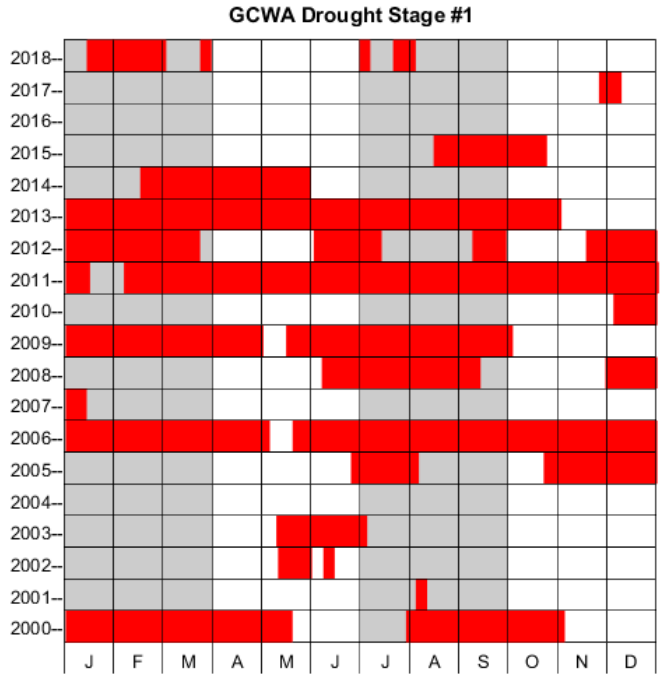



*Figure 31 – Time history of when GCWA Stage 1 conditions would have occurred, based on the US Drought Monitor data criterion.*

### Stage #2– Moderate Water Shortage ("TCEQ Concern Level")

Under Stage 2 drought conditions, GCWA requests greater voluntary reductions in water usage, and offers credits for entities who meet the usage reduction targets. They also impose surcharges if the customer fails to reduce usage to less than their monthly target. GCWA determined, through consultation with the DTF members, that surcharges would only be imposed on entities with monthly usages greater than their individual monthly targets (referred to as "Base Water Usages" in the GCWA DCP for TCEQ – see Appendix A), and that the surcharge would only apply to the quantity of water used in excess of their target. Implementing this policy required the development of a daily accounting method for assessing usage in a month, recognizing that in all likelihood GCWA would enter or exit various drought stages in the middle of a month rather than only at the beginning or end of a month. Monthly assessments of water usage were desired in order to conform to GCWA's customer billing process.

Prior to entering Stage 2 drought conditions, GCWA has the option of utilizing both alternative and available streamflow to meet customer needs. GCWA has the flexibility to determine which alternative sources to utilize, yet will likely first utilize water available from the BRA prior to other sources, such as local groundwater sources. The decision to enter a Stage 2 drought condition is made by the GM, and per the DCP the GM must CONSIDER making such a stage declaration when at least one of the following triggers is met:

1) System Demand exceeds 90% of Deliverable Capacity within GCWA's conveyance system for three consecutive days (applicable to any portion thereof).
2) The Lower Basin User's Group recommends further water conservation based on its collective experience managing river operations.
3) Water available from Run-of-River Supplies and GCWA Alternate Water Supplies is determined to be insufficient to satisfy 95% of GCWA's Monthly Flow Target through August 31 of the current year (if date is on or after January 1) or through August 31 of the next year (if date is on or after September 1 of the current year).

Within the three criteria listed above, GCWA has intertwined water availability, conveyance capacity, and user recommendations/experience into the decision-making process. The Lower Basin User's Group, as further described in the "Operational and Administrative Framework" section, consists of water management professionals from GCWA, BRA, TCEQ, Dow Chemical, and NRG Energy who each of water provision responsibilities in the lower Brazos basin. These professionals, in 2018, decided that the best way to manage diminished resources during drought periods was to collectively discuss and decide courses of action that would be of the greatest benefit to the group. During the dry summer of 2018, this group met up to 3x weekly via conference call or in person to discuss the water supply and each entity's needs, with each discussion leading to a decision regarding water allocation over the coming few days (until the next informal meeting/discussion). This process, while not originally part of the GCWA DCP, was so successful in 2018 that GCWA decided to include the Lower Basin User's group formally within its DCP. It should be noted, however, that this user's group is not a formal group, can have fluid membership, and relies upon the good-faith efforts of the members to effectively allocate available water. During periods of extreme drought, it is possible that this group may behave differently and make different water allocation decisions. This is largely driven by the fact that GCWA maintains the senior water right in the lower Brazos Basin, and therefore has priority access to available water should it wish to assert this priority

under the lowest of flow conditions. DTF members expressed this desire during DCP development and negotiations.

The third criterion listed above also intertwines the notion of run-of-river supplies and alternate water supplies available to GCWA. Ideally GCWA will be able to meet 100% of its customer demands by diverting only run-of-river supplies, defined as streamflow available for diversion under the State of Texas prior-appropriation system. During times of drought, however, it is possible that streamflows decrease to levels less than that required to meet the cumulative monthly flow targets of GCWA customers. In such instances, GCWA will utilize alternative water supply sources to supplement run-of-river flows and fully satisfy customer needs. However if GCWA determines that its available alternative water supply sources, when combined with expected run-of-river supplies, are insufficient to meet needs through August 31, then the they may consider entering a Stage 2 drought. As shown in criterion #3 above, to enter a Stage 2 drought, the combined run-of-river and alternate water supplies must be less than 95% of the expected GCWA customer water demand. The 95% quantity is based on the implementation of the 5% reduction goal included in the Stage 1 response actions.

To assess criterion #3, GCWA had to develop an accounting mechanism to predict run-of-river supplies and the availability of alternate water supplies up until the August 31 calendar date. This prediction was incorporated into the Flow Prediction Tool (Figure 29), as well as within an Excel spreadsheet used by GCWA staff for tracking flow and water usage. The August 31 date was selected as a target date because it represents the end of the Texas summer, and is also when most of GCWA's available alternate water supplies from the BRA renew. For example, if GCWA was utilizing backup water from BRA and on August 30 they had fully depleted their annual allotment, BRA would have to cease releasing water for GCWA. However, as GCWA's annual allotment renews on September 1, GCWA would only have to wait until September 1 before requesting and receiving more released water from GCWA. As such, GCWA's standard policy is to not utilize BRA releases for as long possible within the calendar year, thus keeping water available to supplement run-of-river supplies in the summer months. Similar supply limitations will be implemented if GCWA utilizes local groundwater supplies to supplement run-of-river flows during drought conditions. Such limitations are not yet included in the Flow Prediction Tool or GCWA Excel spreadsheet, as wells are not yet available and their limitations (specified by the Harris Galveston Subsidence District, Fort Bend Subsidence District, or Brazoria County Groundwater Conservation District) are not yet known.

Within the Flow Prediction Tool and Excel spreadsheet, it is necessary to essentially forecast run-of-river flows into the future. This is achieved using the release rates and travel times for BRA reservoirs, and then assuming that run-of-river conditions remain constant through the remaining period between the calculation date and August 31. GCWA utilizes the aggregate monthly flow target for all its customers as the desired demand to be met, and then subtracts the estimated run-of-river flows from the aggregate monthly flow target. Resulting positive values represent the quantity of GCWA alternate water supplies needed to satisfy GCWA customers. If sufficient alternate supplies are available to satisfy needs through August 31, then GCWA either continues or initiates usage of the alternate supplies, and does not likely enter into a Stage 2 drought condition. However if sufficient alternate supplies are not available, the GCWA GM will consider entering into a Stage 2 drought condition. Figure 32 presents an approximate time-history of when GCWA would possibly enter Stage 2 drought conditions, assuming current monthly target usage rates by GCWA customers, and assuming GCWA's current alternate supply quantities from

BRA. Figure 32 does not include any planned or possible additional alternate water supplies such as local groundwater usage.

As shown in Figure 32, there are many recent years in which GCWA would not have entered into Stage 2 drought conditions (when considering only criterion #3). Recently dry years included 2009, 2011, 2013 and 2014, and correspondingly those years indicated greater frequencies of entering in or remaining in Stage 2 drought conditions. It is also notable that Stage 2 drought conditions do not only occur in the summer months, when streamflow is lower and demand is generally higher. This is because of how GCWA rations the use of its alternate water supplies over the course of the year. For example, if streamflow happened to be low in September, the calculation method would attempt to divide the alternate water supply over a large number of days, making it last until August 31 of the following year. Thus low streamflows in September are more likely to trigger Stage 2 drought declarations that identical streamflows in July, assuming alternate supplies had not already been used-up in the time preceding July. It must be noted that the results shown in Figure 32 only consider criterion #3 for entering a Stage 2 drought, and GCWA may not have made such a decision identically as predicted mathematically using historical streamflow data. The Lower Basin User's Group (criterion #2) could have used some other hydrologic criterion or other means to decide that entering Stage 2 drought was not warranted.

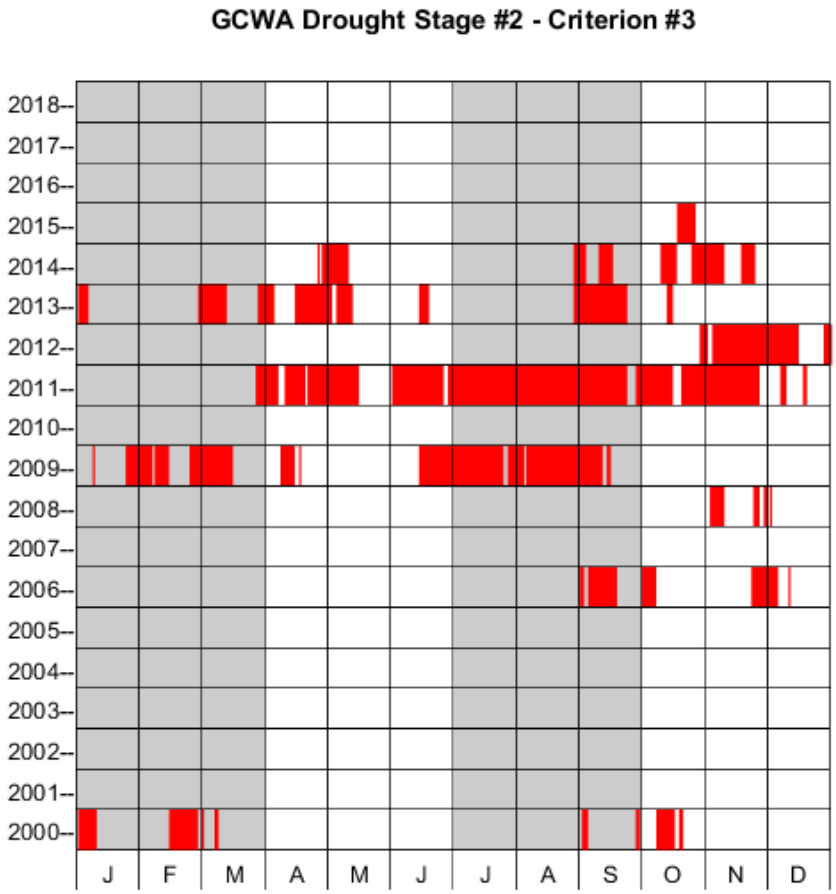



*Figure 32 – Modeled time-history of when GCWA would possibly enter a Stage 2 drought based only on criterion #3 (run-of-river flows and alternate water supplies).*

Figure 33 presents the time-history of GCWA's alternate water supplies from the BRA as calculated when assessing the Stage 2 drought condition criterion #3 (Figure 32). Shown are the remaining volumes of supply from both fiscal-year (September-August) and calendar-year (January-December) contracts GCWA maintains with BRA. As shown, in both 2009 and 2011, GCWA would have fully utilized its alternate water supplies from BRA along with available run-of-river water to meet customer demands. Figure 33 also demonstrates that in most years, GCWA maintains an abundant alternative water supply.

Figure 34 demonstrates the time history of when Stage 2 demand reductions (modeled as 10% reductions) combined with available run-of-river flows and GCWA alternate water supplies would not have been sufficient to meet customer demands. Such instances occurred only in late summer, and would have likely necessitated GCWA's entering a Stage 3 drought condition. Using supplemental groundwater during 2009 and 2011 may have resulted in GCWA having avoided entering a Stage 3 drought condition. Obtaining additional alternate water supplies from BRA would have also provided sufficient relief; GCWA did purchase additional alternate water supplies in 2011.

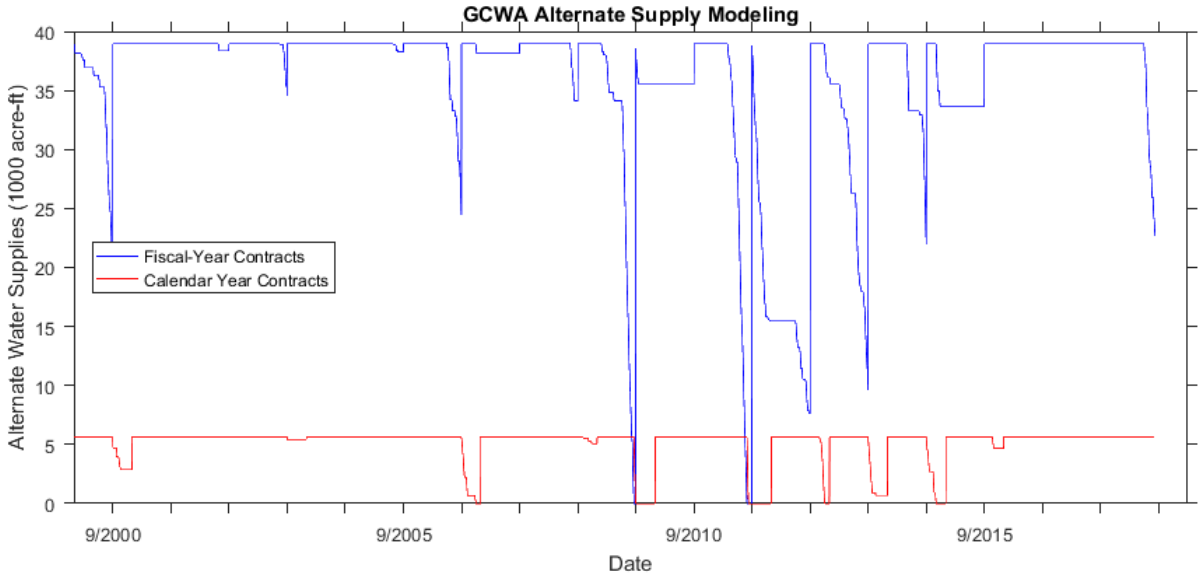



*Figure 33 – Time series of GCWA available alternate supplies from the BRA, as modeled in assessing Stage 2 conditions (Figure 32).*

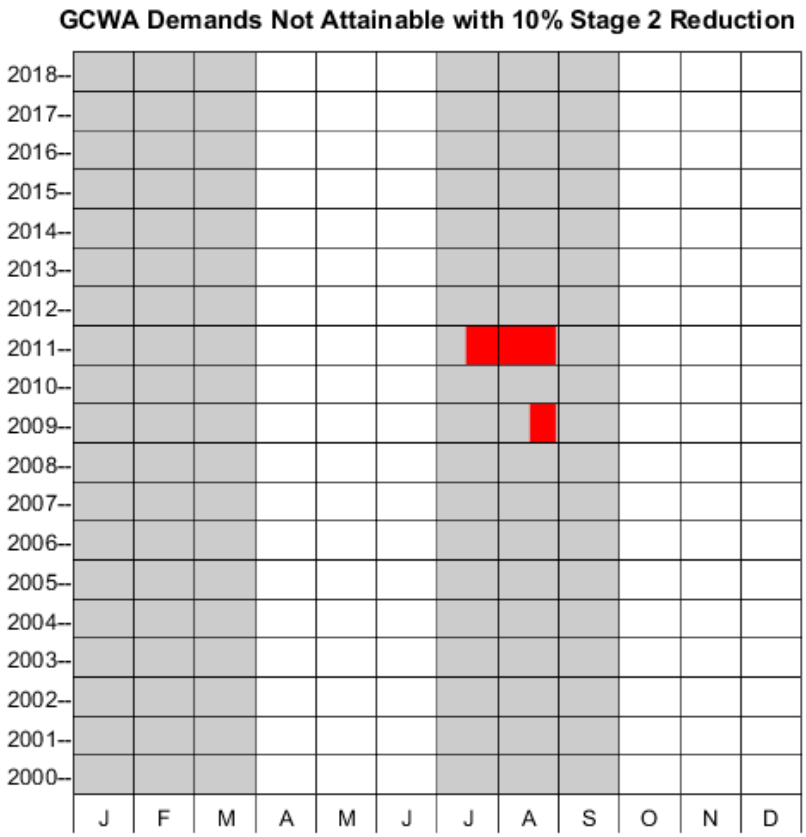



*Figure 34 – Time-history of when GCWA customer demands would have been un-satisfied with available run-of-river flows and alternate water supplies after implementing a Stage 2 demand reduction of 10%.*

Upon declaring a Stage 2 drought condition, GCWA may take the following actions to reduce demands to levels that are achievable given available supplies:

- Continue or initiate any actions available under Stage 1;
- Notify all Affected Customers that a Stage 2 Response condition exists;
- Initiate or continue usage of GCWA Alternate Water Supplies to augment Run-of-River Supplies;
- Request all Affected Customers to initiate Stage 2 or other appropriate stage in their drought contingency plans;
- Request voluntary reductions in water use by Affected Customers;
- Meet with Affected Customers to determine water use on a as needed basis, identify Affected Customers exceeding 95% of their Base Water Use or Interruptible Water Use and encourage them to reduce their usage;
- Cease issuance of new short-term or Interruptible Customer contracts with the exception of contracts needed under emergency conditions;
- Terminate water deliveries to existing Interruptible Customers without Backup;
- Increase public awareness of drought condition and measures to reduce demand; and
- Notify the Brazos Watermaster, NRG, and Dow that a Stage 2 Response Condition exists
- Implement water rate surcharges and credits based on individual customer water usage

All of the measures listed above are designed to convey to water users the severity of the water shortage and to encourage water conservation. The most impactful measure is the termination of water deliveries to interruptible customers. These customers have only short-term contracts for water delivery from GCWA, and are typically used for agricultural crop irrigation. Ceasing deliveries for interruptible customers can significantly reduce GCWA's overall water demand, especially during the summer months when irrigators use the most water. By terminating interruptible customer deliveries under Stage 2, GCWA is vastly decreasing the likelihood of necessitating a Stage 3 drought declaration. However removing interruptible demands during 2011 would not have eliminated the water shortages shown in Figure 34. This is because the run-of-river streamflow during the late summer of 2011 was virtually non-existent, and GCWA would use up its alternate supplies prior to the September 1 renewal date. Shortages for 2009, however, would have been eliminated through the termination of the interruptible customer water deliveries. By eliminating interruptible customer demands under Stage 2 drought conditions, GCWA is making it more likely that all "firm" customer demands will be met.

### Stage #3 & Stage 4– Severe & Extreme Water Shortage ("TCEQ Priority & Emergency Levels")

Stage 3 and Stage 4 droughts, as defined in the GCWA DCP, are really just more severe versions of a Stage 2 drought. The have similar triggers as defined under the Stage #2 description, yet with different percentages used. For example, per criterion #3 for a Stage 2 drought, GCWA cannot meet 95% of demands with available supplies. For a stage 3 drought, the target is lowered to 90% of demands being met. The lower trigger corresponds to the targeted demand reduction from the next lower drought stage.

Water use reduction goals for Stage 3 and Stage 4, respectively, are set to 85% and 80% of the customer's monthly target. These amounts generally exceed "acceptable" reduction quantities identified by GCWA customers and DTF members over the course of this project. GCWA intends to work with individual customers to devise means of reducing water usage through further best management practices, where possible. This includes aiding customers in obtaining alternate water supplies, possibly including assisting to maintain customer groundwater wells which are only to be used during severe or worse drought conditions. Under Stage 4 conditions, GCWA commits to requesting relief from the Brazos Watermaster, asserting GCWA's generally senior priority water rights for preferential use of water during drought conditions. It is only under Stage 4 conditions that GCWA will specifically ask for relief from the Brazos Watermaster.

### Stage #5 – Water Emergency Response ("TCEQ Emergency Level")

A Stage 5 drought condition is only to be declared when GCWA is not physically able to convey sufficient water to customers, or if the water is of poor quality due to a contamination event. It is not foreseen that a Stage #5 condition will be in anyway related to the quantity of water available from GCWA sources. Examples of potential causes of Stage #5 conditions include:

- Canal system failure/leakage/damage
- Damage to GCWA pump stations and other infrastructure
- Chemical contamination making available water unsuitable for desired purpose of use.

Depending upon the location of the cause of the Stage #5 declaration, it is possible that certain GCWA customers would be able to continue operations as normal when other customers would be forced to severely diminish water usage. For example, a failure of the GCWA industrial pump station would result in a Stage 5 drought emergency for only those customers receiving water from the pump station; Customers upstream of the failed pump station would not be affected and would be allowed to continue operations as hydrologic conditions dictate.

GCWA strives to avoid Stage #5 conditions by continuously monitoring the operation of all canal conveyance infrastructure, and immediately solving small infrastructure issues before they become cataclysmic.

Under Stage #5 conditions, GCWA customers do not have defined water use reduction goals, but rather are allotted a pro-rata share of any available water. The pro-rata share is based on the individual customer's monthly target usage rate. Customers who unfairly utilize more water than their allotted quantity during a Stage #5 declaration will be assessed a 10x surcharge on the excess water. GCWA determined that such a financial penalty would provide customers with sufficient incentive to comply with GCWA's water allocation decisions during water supply emergencies.

# Essential Element #5 – Operational and Administrative Framework

GCWA's objective in developing and implementing this DCP is to effectively and fairly manage available water during periods of drought so that customers have the water they need and are provided sufficient time to adjust water usage practices to avoid short-term water shortages due to drought conditions. It is GCWA's intention to administer the DCP in an open manner, and as such GCWA welcomes input and participation from interested parties.

Through discussions between GCWA staff, members of the GCWA Board of Directors, and Drought Task Force members, the operational and administrative framework for the GCWA DCP was established. Responsibility for implementing the DCP lies with the GCWA General Manager (GM), currently Ivan Langford. The GM may delegate responsibilities to GCWA staff members, who will report back to the GM with both data and recommendations for action regarding the drought status. Water accounting tasks, including tracking customer monthly usage and running the Flow Prediction Tool, will be accomplished by GCWA staff otherwise tasked with performing water accounting functions. Analysis of the US Drought Monitor data (for assessing Stage 1 drought conditions) will be performed by GCWA staff trained in geospatial analysis using ArcGIS or similar software.

GCWA staff will coordinate the informal meetings of the Lower Basin User's group as needed. During 2018, this group (organized and lead by GCWA's Assistant General Manager Mr. David Sauer) met as needed either in person, by phone, or via online video conferencing to discuss hydrologic conditions and local water needs. The group then jointly made decisions regarding water allocation, with each participating entity occasionally modifying their diversion requests in order to fairly make water available to other members of the group. During 2018, the Lower Basin User's group consisted of representatives from GCWA, the Dow Chemical Company of Freeport, TX, and NRG Energy, Inc. Other participating members included the Brazos Watermaster, representatives of the TCEQ (including watermaster staff), and representatives of the Brazos River Authority. Their participation was especially important during the summer months when streamflow was low and allocation decisions became especially important. GCWA will consistently organize the informal meetings of the Lower Basin User's group, and decisions will be made based on the desires of the entities participating in each meeting. The Lower Basin User's group membership is designed to be fluid as needed to incorporate the views of all entities interested in contributing to the water allocation decision making process. Expected primary members will be representatives of the three large diverters in the Lower Brazos Basin (GCWA, NRG Energy, Inc. and the Dow Chemical Company of Freeport, TX), with GCWA representing the interests of its customers. Secondary members will be representatives of the TCEQ (including the Brazos Watermaster) as well as representatives of the Brazos River Authority. Tertiary members will be other lower basin water right holders or GCWA customers who wish for more active participation. Such customers are likely to be those who obtain "Alternate Water Supplies" to be managed by GCWA. All members will contribute to group decisions, yet formal operating rules will not be implemented.

Upon deciding to implement a certain drought stage, the GCWA GM will notify customers following their accepted notification procedures, developed through the contracting process between GCWA and each customer. Notice will also be provided on the GCWA website, and will be made via standard GCWA

communication protocols to the media and general public. GCWA did not wish to include these protocols and standard methods of communication here in this DCP document, as the methods are subject to change by agreement of the GCWA Board of Directors and customer representatives.

Imposition of monthly surcharges and credits, according to the DCP, will be incorporated into the GCWA normal customer billing process. Customers will have the ability to review and contest water accounting practices developed by GCWA and used to implement the DCP. Per State of Texas general practices, GCWA's water accounting spreadsheets and methods will be available for review at the GCWA office during normal business hours, or at other times/locations by special permission granted by the GCWA GM.

As part of the DCP implementation process, GCWA will initiate and maintain an ad-hoc Drought Contingency Advisory Committee. The Committee will be administered by GCWA. The Committee will be comprised of representatives from each of the industrial customers, major municipal treated water customers and agricultural customers of GCWA. The Brazos River Watermaster will be an ad-hoc member. The Committee will meet with GCWA twice each year to:

- Review information on river flow and BRA reservoir levels, and drought conditions in the Brazos River Basin.
- Monitor the running computation of water use for each customer.
- Receive information on water use, conservation and drought contingency planning by GCWA, NRG, and Dow.
- Provide feedback to GCWA on the implementation of the Plan.
- Receive information from GCWA on its acquisition of Alternate Water Supplies.

The ad-hoc Drought Contingency Advisory Committee will not be a formal committee established by GCWA, and will not be subject to the legal requirements for formal committees performing business for the State of Texas. Members of the public are eligible to participate in the informal committee meetings, and may learn of meeting dates and times by contacting the GCWA administration office.

Per Section XI of the GCWA DCP (TCEQ version – Appendix A), GCWA customers may request variances to aspects of the DCP. Variances may relate to the surcharges or credits to be obtained, to the water use target to be achieved by each customer, or to some other aspect of the plan. Variances are to be submitted in writing to the GCWA GM, who has the authority to grant or deny each variance request. Any denied variance request may be appealed to the GCWA Board of Directors, who have the final decision regarding any appealed request. The GCWA Board of Directors may uphold or overrule the variance decision made by the GM.

## Essential Element #6 – DCP Update Process

The GCWA DCP will be formally updated every 5 years. The update process will culminate with a GCWA Board of Directors resolution adopting the revised DCP, and the submission of the DCP to the Texas Commission on Environmental Quality (TCEQ) and Texas Water Development Board (TWDB). Current DCP was formally adopted by the GCWA Board of Directors on December 6, 2018. It will be submitted to TCEQ and TWDB upon acceptance of this DCP by Reclamation, or by May 1, 2019 (whichever is earlier). The next required update of the GCWA DCP will be completed by May 1, 2024.

During the period leading up to the next GCWA DCP update, GCWA staff, stakeholders, members of the Lower Basin User's Group, and the ad-hoc Drought Contingency Advisory Committee will continuously track, observe, and scrutinize the methods employed to administer the DCP. The GCWA GM will document any observations regarding the effectiveness of the DCP, including any observed benefits and deficiencies of the plan. These observations will be utilized when developing the plan revision.

The DCP presented in this document will be in place for 5 years, between 2019 and 2024. This 5-year "implementation period" period will be GCWA expects to used year 1 and year 2 of the implementation period to observe the efficacy of the DCP and note aspects that should be improved during the next revision process. Potential revisions are to be recorded by GCWA staff (as delegated by the GM), and revision methods are to be developed and discussed by the ad-hoc Drought Contingency Advisory Committee during years 3 and 4 of the implementation period. During year 5 of the implementation period, GCWA will formally revised the DCP based on the recommendations of the ad-hoc Drought Contingency Advisory Committee (and other recommendations received by GCWA, if any). GCWA will then offer the draft revised DCP for review and public comment, holding at least one public meeting at which GCWA may receive public (including stakeholder or customer) input regarding the DCP. After the public meeting, GCWA will address any issues raised from the meeting discussion, and will present a revised DCP for review and potential adoption by GCWA Board of Directors. After formal adoption, GCWA will submit the revised DCP to the TCEQ and TWDB. The revised DCP will contain all content and format requirements (if any) specified by TCEQ and TWDB. These requirements may change over time, and GCWA will coordinate with TCEQ and TWDB to ensure the updated DCP meets all updated requirements.

GCWA, at the discretion of the Board of Directors, may update the DCP at any time within the 5-year implementation period, and the updates will take effect upon formal adoption of the revised DCP by the GCWA Board of Directors. After the DCP is formally updated and adopted, the revised DCP will be submitted to TCEQ and TWDB.

# References

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LRE Water, LLC (2017). "Final Report: Identification of the Vulnerability of the Major and Minor Aquifers of Texas to Subsidence with Regard to Groundwater Pumping." Texas Water Development Board Contract Number 1648302062. Available at (as of 2/12/2019): http://www.twdb.texas.gov/groundwater/models/research/subsidence/subsidence.asp

# Appendix A

Gulf Coast Water Authority
Drought Contingency Plan

For the

Texas Commission on Environmental Quality


U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
50 YEARS ★ 1965 - 2015
GCWA
Gulf Coast Water Authority
in conjunction with
LREWater, LLC
LRPR
SIMPLICITY WORKS