Response to Technical Questions Regarding Supplemental Environmental Assessment

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This document contains responses to technical questions submitted via email by Nabil Shafike, New Mexico Interstate Stream Commission, to Filiberto Cortez, US Bureau of Reclamation, on May 14, 2013, regarding data and methods used in Reclamation's analysis of the Rio Grande Project Operating Agreement in support of the Draft Supplemental Environmental Assessment (EA) for Implementation of the Rio Grande Project Operating Procedures, New Mexico and Texas. Accompanying this response are a number of digital files containing data and calculations used in this analysis. A brief description of the accompanying files is provided at the end of this document.

The details provided here will be addressed in a technical appendix to the final Supplemental EA. The technical appendix is currently being developed and is not yet available.

It should be noted that a number of data values, calculations, and assumptions have been revised since the release of the Draft Supplemental EA. Revisions were made in response to further review by

Reclamation staff and comments received from Cooperating Agencies. Where discrepancies occur, the data, methods, assumptions, and calculations detailed in this response and the accompanying files supersede those in the Draft Supplemental EA.

1. Back-up data to in support of Tables 4.1a,b,c and 4.2 for the estimates of the prior operations scenario

Tables 4.1(a-c) detail the Annual Allocated Water, Accrued Carryover Water, and Total Diversion Allocation to EBID, EPCIWD, and Mexico, respectively, for each year during the period 2008-2012 under the OA (Proposed Action) and under Prior Operating Practices (No Action). Tables 4.1(a-c) also include differences in Annual Allocated Water, Accrued Carryover Water, and Total Diversion Allocation between the OA and Prior Operating Practices for each year, along with average values and average differences over the period 2008-2012. Values shown in Tables 4.1(a-c) for the OA are actual historical values obtained from the final Project allocation spreadsheets for 2008-2012; Values shown for Prior Operating Practices are estimated as detailed below.

It should be noted that the method used to parse district allocation's into their various components has been revised since the release of the Draft Supplemental EA in response to comments received from Cooperating Agencies. Tables 4.1(a-b) have been updated to specify four components: Annual Allocated Water, Accrued Carryover Balance, Transfer of Excess Carryover Balance, and Total Diversion Allocation. In addition, the annual allocation to Mexico is no longer broken down into components, as the allocation to Mexico consists of a single annual allocation under both the OA and Prior Operating Practices. Revised allocation components are described below in response to Question 3. Updated allocation tables are provided in worksheet "Tables_EA" of Microsoft Excel workbook RGP_AllocationAnalysis_2008-2012_FinalClean.xlsm, included as a digital supplement to this response.

During the period 2008-2012, historical (actual) Project operations followed the procedures detailed in the OA; Project operations consistent with Prior Operating Practices were therefore estimated for this period, so that a comparison could be made between operations under the OA and those that would have occurred under Prior Operating Practices. An annual allocation model was developed to estimate Project operations under Prior Operating Practices based on Project storage and inflows, estimated Project diversion ratio, and estimated Project diversions by EBID, EPCWID, and Mexico during a given year. The annual allocation model was initialized based on total Project storage at the start of the 2008 irrigation season (taken as March 1, 2008). Project operations as they would have occurred under Prior Operating Practices were then estimated through the 2008-2012 irrigation seasons based on actual Project inflows during this period.

For the period 2008-2012, the annual allocation model of Prior Operating Practices was implemented as a simple Microsoft Excel worksheet. See worksheet "AllocationCalculation" in the file RGP_AllocationAnalysis_2008-2012_FinalClean.xlsm, included with this response. The equations, data, and assumptions used in the annual allocation model of Prior Operating Practices are summarized below.

Overview of Annual Allocation Procedure under Prior Operating Practices

Procedures for allocation of Project water under Prior Operating Practices are documented in annual correspondences from Reclamation to the districts and to IBWC on behalf of Mexico during the period 1980-2007. For the purposes of this study, the general procedure used by Reclamation to determine annual allocations to EBID, EPCWID, and Mexico was obtained from the El Paso Field Division, who operated the Project and determined annual Project allocations during this period.

Under Prior Operating Practices, Project allocations to EBID, EPCWID, and Mexico were made on an annual basis based on the amount of usable Project water available for allocation each year. Reclamation determined initial Project allocations at the start of each calendar year based on the total usable water available for current-year allocation. If the total usable water available for current-year allocation was not sufficient at the start of the year to provide a full allocation, Reclamation reevaluated allocations on a monthly basis throughout the irrigation season until a final annual allocation was determined. Under Prior operating Practices, the total usable water available for current-year allocation was equal to the total usable water available for release, up to a maximum of 790,000 AF. Usable water available for release was calculated as the total water in Project storage minus non-Project water in storage (i.e., total storage minus San Juan-Chama Water and Rio Grande Compact Credit Water).

Pursuant to the Convention of 1906, the annual Project allocation to Mexico is 60,000 AF/year, except under extraordinary drought conditions in which case the annual allocation to Mexico is equal to 11.3486% of the sum of the quantity of Project water delivered to lands in the United States plus the quantity of Project water delivered to the heading of the Acequia Madre for diversion by Mexico. Under Prior Operating Practices, the total annual Project delivery to Project lands within the United States (i.e., delivery to individual farm gates within EBID and EPCWID) plus total deliveries to the heading of the Acequia Madre was calculated from the estimated annual release of Project water based on Equation 1, which is referred to as the D-1 Curve:

$$D_{D1} = 0.8260932 \cdot R_{Caballo}^{Est} - 102{,}305 \tag{1}$$

In Equation 1, D_{D1} is the calculated total annual Project deliveries to lands in the United States plus deliveries to the heading of the Acequia Madre [AF], and $R_{Caballo}^{Est}$ is the estimated annual release of Project water from Caballo Dam [AF]. The D-1 Curve was developed via linear regression based on Project operations data for the period 1951-1979 (inclusive). Under Prior Operating Practices, the estimated annual release of Project water ($R_{Caballo}^{Est}$) was determined assumed to equal the usable water available for current-year allocation.

The annual allocation to Mexico was subsequently calculated according to Equation 2:

$$A_{Mexico} = \min[60{,}000;\;\; D_{D1} \cdot 0.113486] \tag{2}$$

where A_{Mexico} is the annual diversion allocation to Mexico.

The total amount of water available for diversion at river headings for the year was then calculated based on the D-2 Curve, given by Equation 3:

$$A_{GrossD2} = W \cdot 1.3377994 - 89{,}970 \quad (3)$$

where $A_{GrossD2}$ is the gross D-2 diversion allocation and W is the total usable water available for current-year allocation, which is equal to estimated annual release of Project water ($R^{Est}_{Caballo}$).

It should be noted that when the total usable water available for current-year release is greater than approximately 266,350 AF, the gross D-2 diversion allocation is greater than the usable water available for release. Under these conditions, the diversion ratio (ratio of Project diversions to Project releases) must be greater than 1.0 in order for the total available release to satisfy the total gross diversion allocation. The diversion ratio is a measure of Project performance, which is used by Reclamation, EBID, EPCWID, and IBWC to represent the performance of the Rio Grande in conveying Project water from release to authorized points of diversion. The D-2 Curve relates Project diversions to Project releases, based on the past relationship between these two parameters.

Historically, the annual diversion ratio was less than 1.0 during fifteen years over the period 1951-2012, approximately 24% of years. However, the total usable water available for allocation was above 266,350 AF in all years. The D-2 Curve therefore implicitly overestimates the diversion ratio during these years. In several of these cases, the gross D-2 diversion allocation was therefore greater than the amount of water that could actually be delivered for diversion. In these cases, Reclamation adjusted annual allocations to ensure that Mexico received its full entitlement under the Convention of 1906 and that EBID and EPCWID received 57% and 43%, respectively, of the total delivery to points of diversion. For this analysis, a drought adjustment factor is applied to the gross D-2 diversion allocation as needed to ensure that the gross allocation can be satisfied from the usable water available for release given the current-year diversion ratio.

The total diversion allocation to EBID and EPCWID, referred to as the net D-2 diversion allocation, was then calculated by subtracting the annual allocation to Mexico A_{Mexico} from the gross D-2 allocation:

$$A_{NetD2} = A_{GrossD2} - A_{Mexico} \quad (4)$$

Finally, the annual diversion allocations to EBID and EPCWID (A_{EPCWID} and A_{EBID}, respectively) were calculated based on the percentage of authorized Project acreage within each district according to Equations 5 and 6, respectively:

$$A_{EBID} \quad = A_{NetD2} \cdot \left(\frac{88}{155}\right) \quad (5)$$

$$A_{EPCWID} = A_{NetD2} \cdot \left(\frac{67}{155}\right) \quad (6)$$

See below regarding the breakdown of the Total Diversion Allocations to EBID and EPCWID into Annual Allocated Water, Implicit Accrued Carryover Balance, and Implicit Transfer of Excess Carryover.

Summary of Data, Assumptions, and Calculations used to Estimate Project Operations under Prior Operating Practices for the Period 2008-2012

Historical Annual Inflows to Project Storage (I_t)

Actual annual inflows for the period 2008-2012 were used as inputs to the annual allocation model in order to estimate what Project operations would have been under Prior Operating Practices during this period. Due to the dynamic nature of the Rio Grande channel at the San Marcial gaging station upstream of Elephant Butte Reservoir, gaged inflows to the reservoir exhibit substantial uncertainty. In addition, the annual allocation model does not explicitly account for evaporation and seepage losses from Elephant Butte and Caballo reservoirs. For the purposes of this analysis, historical annual net inflow (inflows minus evaporation) was used as input to the annual allocation model.

Historical annual net inflows were calculated according to Equation 7 as the change in Project storage during a given year plus the total release from Caballo Dam during that year:

$$I_t = S_t^{EoY} - S_{t-1}^{EoY} + R_{Caballo,t} \qquad (7)$$

where I_t is the net inflow during year *t*, S_t^{EoY} is the historical total Project storage at the end of the irrigation season for year *t*, S_t^{EoY} is the historical total Project storage at the end of the prior irrigation season (i.e., year *t*-1), and $R_{Caballo,t}$ is the historical total release from Caballo Dam during year *t*, including releases to meet Project deliveries as well as releases for flood control, reservoir spill, and other purposes. Historical Project storage data were obtained from Reclamation's El Paso Field Office; historical annual release data were calculated from daily flow records for the stream gage below Caballo Reservoir (USGS gage 08362500; operated by Reclamation). For the purposes of this study, annual Project inflows were calculated for the period November 1 through October 31 in order to coincide with the end of the irrigation season (i.e., annual inflow for year 2008 is calculated over the period November 1, 2007 through October 31, 2008).

Annual net inflows calculated according to Equation 7 are shown in Figure 1 for the period 1951-2012 (red squares); measured inflows at San Marcial are also shown for comparison (blue diamonds). Annual inflow values for the period 2008-2012 are provided in Table 1. Measured inflows at San Marcial are the sum of measured flows in the Rio Grande conveyance channel (the Low Flow Conveyance Channel, or LFCC, gage 08358300) and measured flows in the Rio Grande floodway (gage 08358400).

Figure 1 clearly shows that measured inflows are generally greater than calculated net inflows. On average, inflows calculated according to Equation 1 are approximately 13% less than measured inflows. This difference reflects reservoir losses that reduce the amount of inflow that is ultimately available to the Project, including reservoir evaporation, reservoir seepage losses, seepage losses between Elephant Butte and Caballo reservoirs, and seepage losses between Caballo Dam and stream gage 08362500. Equation 1 thus returns the historical amount of inflow to Project storage during each year that was actually available for release.

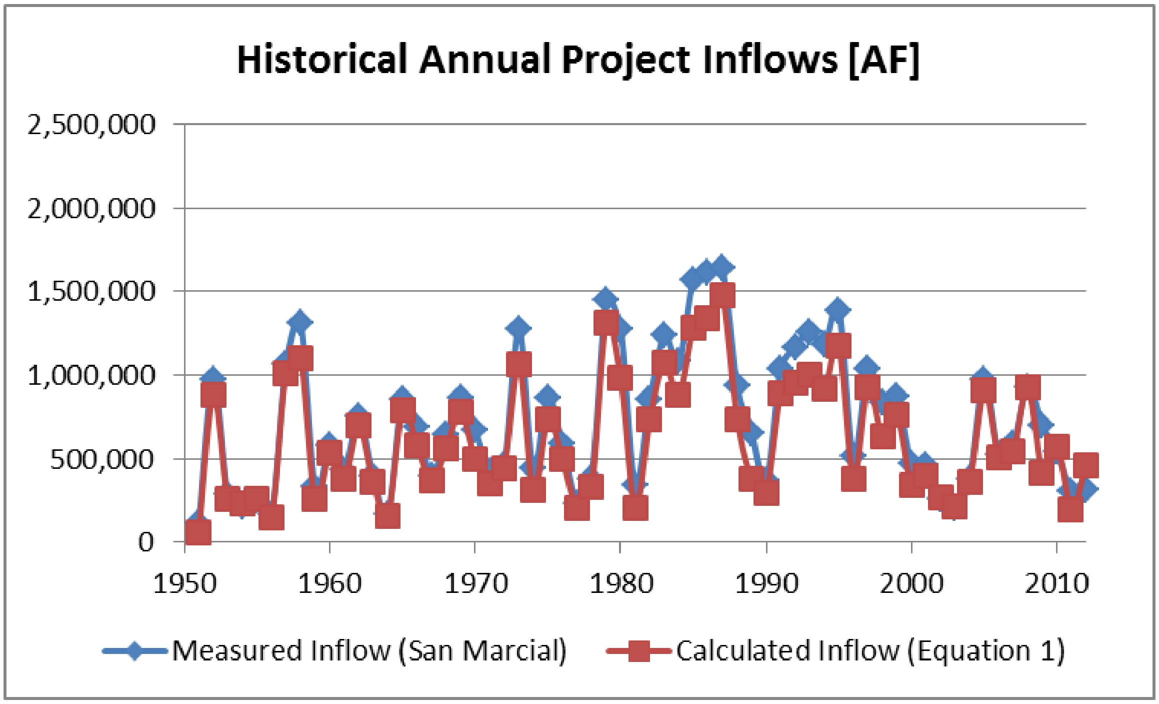

Figure 1: Historical annual Project inflows for the period 1951-2012 measured at San Marcial (blue diamonds) and calculated from historical Project operations data (red squares).

Table 1: Historical Annual Project Inflows (2008-2012)

Year	Annual Project Inflow (Equation 7)	Annual Project Inflow (Measured at San Marcial)
2008	929,174	929,848
2009	410,757	695,535
2010	572,312	541,105
2011	198,509	300,196
2012	462,223	309,349

Total Usable Water Available for Release (U_t)

The total usable water available for release is calculated from the total Project storage at end of the prior irrigation season (S_{t-1}^{EoY}), annual net inflow to Project storage during the current year (I_t), and non-Project water in storage at the start of the current year (i.e., the sum of San Juan-Chama Water S_t^{SJC} and Rio Grande Compact Credit Water $S_t^{Compact}$) according to Equation 8:

$$U_t \quad = S_{t-1}^{EoY} + I_t \ - S_t^{SJC} - S_t^{Compact} \tag{8}$$

Calculated historical annual net inflows are used throughout this analysis (see above). For the period 2008-2012, actual historical non-Project storage (S_t^{SJC}, $S_t^{Compact}$) is provided as model inputs.

It should be noted that Equation 8 assumes that the total annual net inflow to Project storage during the current year (I_t) is known at the start of the year. This assumption is required in order to calculate a single annual allocation, and is a common assumption among allocation models used in water resources planning and operations. In reality, allocation calculations are updated throughout the year as inflows occur. The assumption that annual inflow calculations are made once each year based on inflows that occur throughout the year is commonly referred to as the assumption of perfect foresight and is widely accepted in water resources planning and analysis.

It should also be noted that the total usable water available for release during the current year does not necessarily correspond to reservoir storage at any particular time. Use of total usable water available for release, rather than total Project storage, in calculating annual Project allocations accounts for the fact that allocations may be updated throughout the year according to Project inflows, as well as the fact that inflows and releases occur continuously and simultaneously throughout the year. Total usable water represents the amount of water available for use throughout a given Water Year, not the amount of water in storage at any particular point in time.

Lastly, it should be noted that total usable water available for release may exceed Project storage capacity. This occurs in years when reservoir storage at the end of the prior irrigation season is high and inflows during the current Water Year are also high. In these cases, the total amount of water that could be released during the year may exceed the actual Project storage capacity.

Total Usable Water Available for Current Year Release (V_t)

The total usable water available for release during the current year is equal to the minimum of the total usable water available for release and the normal annual release of 790,000 AF:

$$V_t \quad = \min[U_t,\ 790{,}000] \tag{9}$$

Total Usable Water Available for Current Year Allocation (W_t)

Under Prior Operating Practices, the total usable water available for current-year allocation is equal to the total usable water available for current year release:

$$W_t \quad = V_t \tag{9}$$

Estimated Annual Release of Project Water for Allocation ($R_{Caballo}^{Est}$)

The annual D-1 delivery is calculated from the annual release of Project water using Equation 1. Because the actual annual release of Project water ($R_{Caballo}$) during a given irrigation season is not known at the start of season, the estimated annual release of Project water ($R_{Caballo}^{Est}$) is used to calculate the annual D-1 delivery. The estimated annual release of Project water during the current year under Prior Operating Practices is assumed to equal the total usable water available for current-year allocation:

$$R_{Caballo,t}^{Est} = W_t \tag{10}$$

It should be noted that the estimated annual release of Project water is used only to calculate the annual D-1 delivery. The annual allocation model calculates actual annual releases based on annual total Project diversions and the annual gross diversion ratio as detailed below.

Annual D-1 Delivery (D_{D1})

The annual D-1 delivery (D_{D1}) is the estimated total annual Project delivery to Project lands within the United States (i.e., delivery to individual farm gates within EBID and EPCWID) plus total deliveries to the heading of the Acequia Madre for a given year. The annual D-1 delivery is calculated from the estimated annual release of Project water based on Equation 1 (above), which is referred to as the D-1 Curve.

Annual Allocation to Mexico (A_{Mexico})

Pursuant to the Convention of 1906, the annual allocation to Mexico (A_{Mexico}) is 60,000 AF, except under extreme drought conditions. Under extreme drought conditions, the annual allocation to Mexico is 11.3486% of the current-year Project delivery to Project lands within the United States plus total deliveries to the heading of the Acequia Madre. For the purposes of this study, the annual allocation to Mexico is calcualted as the minimum of 60,000 AF or 11.3486% of the annual D-1 delivery (see Equation 2 above).

Annual Gross D-2 Diversion Allocation ($A_{GrossD2}$)

The annual gross D-2 diversion allocation ($A_{GrossD2}$) is the estimated total amount of water available for current-year diversion based on the total usable water available for current-year allocation. The annual gross D-2 diversion allocation is calculated from the total usable water available for current year allocation (W_t) using Equation 3 and is used to calculate annual Project allocations to EBID, EPCWID, and Mexico.

As noted above, a drought adjustment factor is required in years when the gross D-2 diversion allocation is greater than the amount of water that can actually be delivered for diversion based on the usable water available for release and the current-year diversion ratio. For the purposes of this analysis, a drought adjustment factor is applied to the annual gross D-2 allocation as needed during the period 2008-2012. The magnitude of the drought adjustment factor is determined so such that the gross D-2 allocation equals the total amount of water that can be delivered for diversion based on the total usable water available for release and the current diversion ratio:

$$f_{drought,t} = \frac{U_t \cdot \rho_t}{A_{GrossD2}} \quad (11)$$

Where ρ_t is the current-year diversion ratio, described below.

Annual Net D-2 Diversion Allocation (A_{NetD2})

The annual net D-2 diversion allocation (A_{NetD2}) specifies total water available for current-year allocation to EBID and EPCWID. The annual net D-2 diversion allocation is calculated as the difference between the annual gross D-2 diversion allocation and the annual allocation to Mexico using Equation 4, defined above.

Annual Diversion Allocation to EBID (A_{EBID}^{Final})

Under Prior Operating Practices, the final annual diversion allocation to EBID (A_{EBID}^{Final}) is calculated as 88/155^{ths} (57%) of the annual net D-2 diversion allocation according to Equation 5, defined above.

Annual Diversion Allocation to EPCWID (A_{EPCWID}^{Final})

Under Prior Operating Practices, the final annual diversion allocation to EPCWID (A_{EPCWID}^{Final}) is calculated as 67/155^{ths} (43%) of the annual net D-2 diversion allocation according to Equation 6, defined above.

Annual Diversion to Mexico (D_{Mexico})

For the purposes of this analysis, the annual allocation model of Prior Operating Practices assumes that Mexico diverts its full allocation in all years during the period 2008-2012.

Annual Diversion to EBID (D_{EBID})

The annual diversion to EBID (D_{EBID}) during the period 1951-2007 was generally equal to the district's final annual allocation (A_{EBID}^{Final}). For the purposes of this analysis, the annual allocation model of Prior Operating Practices assumes that EBID diverts its full allocation in all years during the period 2008-2012.

Annual Diversion to EPCWID (D_{EPCWID})

The annual diversion to EPCWID (D_{EPCWID}) for most years during the period 1951-2007 was less than or equal to the district's final annual allocation (A_{EPCWID}^{Final}). In order to estimate EPCWID's annual diversions under Prior Operating Practices during the period 2008-2012, historical project data were evaluated to identify the best predictor of the annual diversion to EPCWID. Several predictors were considered, including annual allocation to EPCWID and annual usable water available for release. It should be noted that total annual release was not considered, as total annual release for each year depends on the districts' and Mexico's diversions during the year. The strongest relationship was found to be a piece-wise relationship between the annual diversion to EPCWID (D_{EPCWID}) and the total usable water available for release (U_t).

Figure 2 shows the historical annual diversion to EPCWID (ordinate) as a function of annual total usable water (abscissa). Because complete records of Project charges and credited return flows are not available for the full period of analysis (1951-2012), analysis focused on annual gross diversions to EPCWID rather than annual net diversions (i.e., annual Project charges). For the purposes of this analysis, the annual diversions to EPCWID under Prior Operating Practices during the period 2008-2012 are calculated according to the piece-wise relationship provided in Equation 12:

$$D_{EPCWID,t} = \begin{cases} 0.4945 \cdot U_t - 58{,}713; & U_t \leq 680{,}000\text{AF} \\ 0.0414 \cdot U_t + 253{,}884; & 680{,}000 < U_t < 3{,}000{,}000\text{AF} \\ 376{,}000; & 3{,}000{,}000\text{AF} \geq U_t \end{cases} \qquad (12)$$

The coefficients of determination (R^2) for the linear relationships between historical annual diversions and total usable water available for release are 0.63 and 0.21, respectively, for $U_t \leq$ 275,000 AF and 275,000 ≤ U_t ≤ 3,000,000 AF. It should be noted that the annual diversion to EPCWID is capped at 376,000 AF due to the 2006 Texas adjudication.

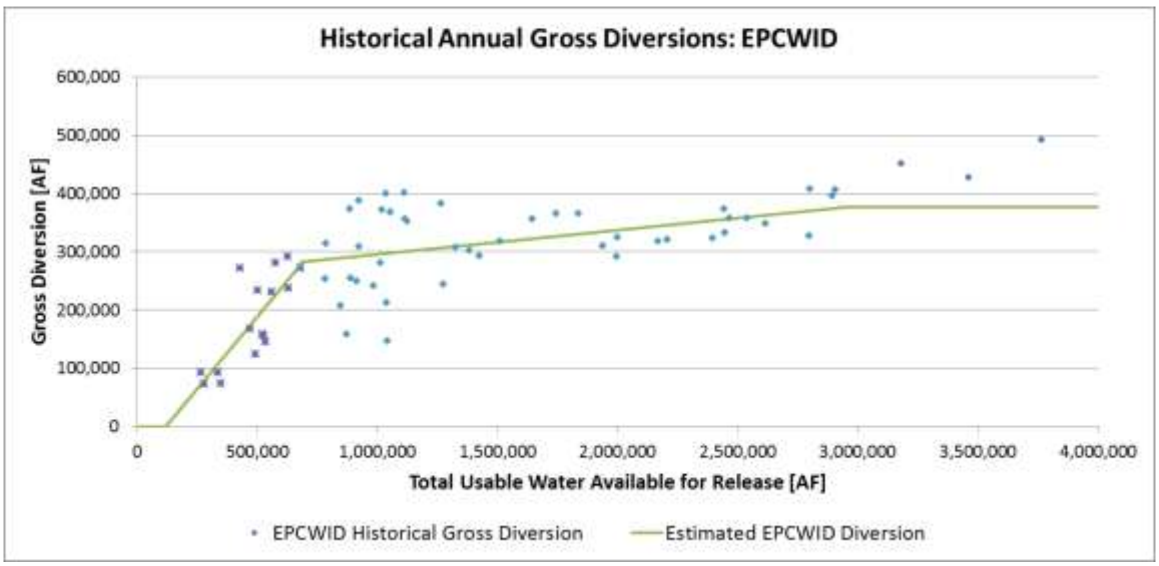

Figure 2: Historical annual diversions to EPCWID over the period 1951-2012 plotted as a function of the historical total usable water available for release (points). The green line shows the piece-wise equation relating annual diversion to EPCWID to total usable water available for release.

It should be noted that the relatively low R^2 value for the range 680,000 ≤ U_t ≤ 3,000,000 AF reflects the complex mix of factors affect district operations within EPCWID and corresponding Project diversions by the district. In addition to diverting Project water for irrigation purposes, EPCWID supplies water to El Paso Water Utilities (EPWU) for municipal and industrial uses. Diversions to meet municipal and industrial demands are affected by availability of other water sources (i.e., whether EPWU has access to alternative supplies in a given year) as well as water quality considerations associated with blending of multiple sources of water. As a result, annual diversions to EPCWID are highly variable under a broad range of total usable water.

As noted above, Equation 12 was developed from historical gross diversion records as historical net diversion records (i.e., historical Project charges) are not available for the full period of analysis (1951-2012). Under Prior Operating Practices, credited return flows from EPCWID to the Rio Grande were generally small. Based on the lack of available data, this analysis assumes that credited return flows from EPCWID are negligible.

Annual Diversion Ratio (ρ)

For the purposes of this analysis, annual releases from Project storage under Prior Operating Practices for the period 2008-2012 are estimated from the annual diversion to EBID, EPCWID, and Mexico and the annual Project diversion ratio (ρ_t). Annual diversions to EBID, EPCWID, and Mexico are estimated as described above. In order to calculate the annual release from Project storage required to satisfy the estimated diversions, it is necessary to estimate the annual diversion ratio for each year.

Extensive analysis of historical Project operations data was carried out in an effort to identify a reliable predictor of the annual diversion ratio for a given year based on data available at the start of the irrigation season for that year. Analysis considered relationships between annual diversion ratio and total Project storage at the end of the prior irrigation season; total Project storage at the start of the current irrigation season; total usable water available for current-year release; total usable water available for current-year allocation; total Project allocations to EBID, EPCWID, and Mexico; total Project releases during the prior year; total Project diversions during the prior year; annual gross diversion ratio for the prior year; and combinations of the above. The only predictor that was found to exhibit a statistically significant relationship with current-year diversion ratio is the prior year diversion ratio—i.e., the only reliable predictor of the annual diversion ratio is the year-to-year persistence (serial correlation) of the diversion ratio itself.

Due to the generally weak relationships between the annual diversion ratio and the available predictors, historical (actual) annual diversion ratios were used in the analysis of the period 2008-2012. The annual diversion ratio under Prior Operating Practices for each year during the period 2008-2012 was assumed to equal the actual annual diversion ratio for that year calculated from historical Project operations data. While it is likely that diversion ratios would have been different during this period if the Project had been operated under Prior Operating Practices, analysis of the available data indicates that estimates of the annual diversion ratio are highly uncertain. These results suggest that actual Project operations data provide the best available estimate of the annual diversion ratio for this period. Annual Project diversion ratios used for years 2008-2012 are provided in Table 2.

Table 2: Actual Annual Project Charges, Releases, and Diversion Ratios (2008-2012)

Year	EBID Net Diversion (Charge) [AF]	EPCWID Net Diversion (Charge) [AF]	Mexico Net Diversion (Charge) [AF]	Total Net Diversion [AF]	Total Project Release [AF]	Project Diversion Ratio [-]
2008	262,292	279,173	56,048	647,634	675,170	0.959
2009	291,830	320,072	58,688	670,590	694,199	0.966
2010	285,856	290,201	56,882	632,939	660,300	0.959
2011	59,771	258,772	25,650	344,193	396,876	0.867
2012	133,060	136,380	23,187	292,627	372,600	0.785

Annual Release from Project Storage ($R_{Caballo}$)

The annual release from Project storage required to meet Project diversions is determined from the calculated annual diversion to EBID, EPCWID, and Mexico and the calculated annual Project diversion ratio. Additional release from Project storage due to reservoir spill is calculated as the difference between the end-of-year total Project storage and the total Project storage capacity. The total annual Project release is thus calculated according to Equation 13:

$$R_{Caballo,t} = \frac{D_{EBID,t}+D_{EPCWID,t}+D_{Mexico,t}}{\rho_t} + \max\left[0.0, \left(S^{EoY}_{initial,t} - S_{cap}\right)\right] \quad (13)$$

The annual allocation model cannot resolve flood operations within a given year. In the event that the initial estimated end-of-year storage $S^{EoY}_{initial,t}$ exceeds the total Project storage capacity S_{cap}, the annual release due to reservoir spill is therefore calculated simply as the difference between the initial estimated end-of-year storage and the total Project storage capacity.

Annual End-of-Year Project Storage (S^{EoY})

Total Project storage remaining at the end of the current irrigation season (S^{EoY}_t) is calculated from the total Project storage at the end of the prior irrigation season (S^{EoY}_{t-1}), annual Project inflows during the current year (I_t), and total Project releases during the current year ($R_{Caballo,t}$) according to Equation 14:

$$S^{EoY}_t = S^{EoY}_{t-1} + I_t - R_{Caballo,t} \quad (14)$$

2. What month is the final allocation made in the "Prior Operations" scenario?

Details regarding calculation of Project allocations under Prior Operating Practices for the period 2008-2012 are provided above in response to Question 1.

As stated above, during the period 1980-2007, Reclamation determined initial Project allocations at the start of each calendar year based on the total usable water available for current-year allocation. If the total usable water available at the start of the year was not sufficient to provide a full allocation, Reclamation reevaluated allocations on a monthly basis throughout the irrigation season until a final annual allocation was determined. During this period, the total usable water available for current-year allocation was equal to the lesser of 790,000 AF and the total usable water available for release, where the total usable water available for release is given by the total water in Project storage minus non-Project water in storage (i.e., total storage minus San Juan-Chama Water and Rio Grande Compact Credit Water).

As described above, for the purposes of this study, the total usable water available for release in a given year is estimated as the total water in Project storage at the end of the prior irrigation season (i.e., storage on October 31 of prior year) plus the historical net inflow to Project storage between the end of the prior irrigation season and the end of the current irrigation season (i.e., net inflow between November 1 of prior year and October 31 of current year), minus the historical non-Project water in storage. Values of historical non-Project storage were obtained from the Rio Grande Project annual allocation spreadsheets for years 2008-2012. Refer to response to Question 1 for additional details.

The method used here to calculate total usable water available for release during each year considers all storage and inflows available for use during a given year. Calculated annual allocations under Prior Operating Practices for the period 2008-2012 therefore correspond to the final annual allocation at the end of each irrigation season.

It should be noted, however, that annual Project allocations under Prior Operating Practices are calculated with respect to the usable water available for release, not with respect to total Project storage at any specific point in time. This stems from the fact that the D-2 Curve (Equation 3) used in the annual allocation procedure was developed based on the relationship between historical Project releases and diversions, not on the relationship between storage and diversions. Because inflows and releases occur continuously and simultaneously throughout the year, the gross D-2 allocation generally does not correspond to Project storage on any given date during the water year. The use of total usable water available for allocation—rather than Project storage—to estimate Project allocations under Prior Operating Practices accounts for the facts that Project allocations may be reevaluated and updated through the end of the irrigation season and that inflows and releases occur throughout the year.

3. **How is the "Carryover Water Accrued to Date" calculated for the "Prior Operations" scenario?**
   Annual Allocated Water and Accrued Carryover Water are not explicitly defined under Prior Operating Practices. However, the lack of explicit carryover accounting under Prior Operating Practices resulted in an implicit carryover balance and implicit transfer of allocation balance between districts in years when one or both districts did not use their full allocation. Under Prior

Operating Practices, the unused portion of each district's annual diversion allocation contributed to the total usable water available for release during the following year; as a result, a portion of the unused allocation balance became part of the other district's annual allocation the following year—in essence, EBID lost 43% of its unused allocation balance to EPCWID, and EPCWID lost 57% of its unused allocation balance to EBID. The lack of explicit carryover accounting thus resulted in implicit carryover balance and implicit transfer of allocation balance between the districts.

In order to provide a complete comparison of annual allocations under the OA and Prior Operating Practices, it is necessary to consider each component of a district's allocation. This is particularly important in evaluating the potential effects of the OA on the initial allocation of water between districts, where initial allocation refers to allocation of "new" or previously unallocated water (i.e., Annual Allocated Water, defined below).

Under the OA, each district's Total Diversion Allocation for a given year consists of three components: Accrued Carryover Balance, Annual Allocated Water, and Transfer of Excess Carryover Balance. Project allocations to EBID and EPCWID under Prior Operating Practices during the period 1980-2007 consisted of a single value, equivalent to the Total Diversion Allocation under the OA. For comparison purposes, however, district allocations under Prior Operating Practices can be parsed into components analogous to those defined in the OA. While these components were not explicitly defined or considered under Prior Operating Practices, these components are implicit in the calculation and accounting of Project allocations under prior operations.

The procedures defined in the OA to calculate allocations to EBID and EPCWID include three separate allocation components, outlined below:

- **Accrued Carryover Balance (OA)**
  Each district's Accrued Carryover Balance for the current year is equal to the balance on its Project water account on January 1 of the current year, which in turn is equal to the district's prior-year unused allocation balance after accounting for all Project charges as well as any transfer of excess carryover balance per Section 1.11 of the OA. Accrued Carryover Balance reflects the cumulative balance on a district's Project water account over all prior years under the OA, including allocations, charges, and transfers. The term Accrued Carryover Balance used here is equivalent to the term Actual Carryover Water defined in the OA.

- **Annual Allocated Water (OA)**
  Each district's Annual Allocated Water for the current year is equal to the increase in the balance on its Project water account balance between January 1 and the end of the current-year irrigation season. Annual Allocated Water thus represents the allocation received by each district during the current year based on current-year inflows to Project storage and prior-year inflows to Project storage that did not contribute to prior-year Project allocations.

- **Transfer of Excess Carryover Balance (OA)**
  Each district's Transfer of Excess Carryover Balance is equal to the change in the balance on its Project water account between the end of the current-year irrigations season (October 31) and the end of the current Water Year (December 31) due to transfer of excess carryover per Section 1.11 of the OA. Transfer of Excess Carryover Balance is negative if water is transferred from the district's balance to the other district's balance and is positive if water is transferred to the district's balance from the other district's balance. For the purposes of this analysis, it is assumed that no charges or credits are accrued between the end of irrigation season and the end of the Water Year, and that the only change in a district's water account during this period is due to transfer of excess carryover.

The methods and assumptions used to calculate each of analogous allocation components under Prior Operating Practices are outlined below:

- **Implicit Accrued Carryover Balance (Prior Operating Practices)**
  As under the OA, each district's Implicit Accrued Carryover Balance for the current year under Prior Operating Practices is equal to the balance on its Project water account on January 1 of the current year, which in turn is equal to the district's prior-year unused allocation balance after accounting for all Project charges as well as any implicit transfer of carryover balance between districts (see below). Implicit Accrued Carryover Balance reflects the cumulative balance on a district's Project water account over all prior years, including allocations, charges, and transfers. As carryover accounting did not exist under Prior Operating Practices, this term is defined here for comparison purposes.

- **Annual Allocated Water (Prior Operating Practices)**
  As under the OA, each district's Annual Allocated Water for the current year under Prior Operating Practices is equal to the increase in the balance on its Project water account balance between January 1 and the end of the current-year irrigation season. Annual Allocated Water thus represents the allocation received by each district during the current year based on current-year inflows to Project storage and prior-year inflows to Project storage that did not contribute to prior-year Project allocations.

- **Implicit Transfer of Carryover Balance (Prior Operating Practices)**
  As noted above, under Prior Operating Practices, each district effectively lost a portion of its unused allocation balance at the end of each year due to the lack of carryover accounting. This implicit loss of unused allocation balance by each district (and corresponding gain of allocation balance by the other district) is referred to here as the Implicit Transfer of Carryover Balance. For the purposes of this analysis, Implicit Transfer of Allocation Balance under Prior Operating Practices is considered comparable to Transfer of Excess Carryover Balance under the OA. Implicit Transfer of Carryover Balance to EBID is calculated as the sum of 57% of EBID's allocation balance at the end of the current-year irrigation season (taken as negative) and 57%

of EPCWID's allocation balance at the end of the current-year irrigation season (taken as positive). Implicit Transfer of Carryover Balance to EPCWID is calculated as the sum of 43% of EBID's allocation balance at the end of the current-year irrigation season (taken as positive) and 43% of EPCWID's allocation balance at the end of the current-year irrigation season (taken as negative).

The Total Diversion Allocation to each district for a given year is the sum of the three allocation components for that district. It should be noted that each district's Total Diversion Allocation is thus determined after the current-year irrigation season has ended, rather than at the start of the current-year irrigation season. This is consistent with the fact that actual historical operations under both Prior Operating Practices (1980-2007) and under the OA (2008-2012) allowed Reclamation and the districts to update Project allocations regularly throughout the irrigation season and determined final Project allocations even after all releases for the season had been made.

4. **Data and calculation of for the Historical Annual Project Inflows shown in Figure 4.2.**

The methods and assumptions used to calculate historical annual project inflows shown in Figure 4.2 of the Draft Supplemental EA are described above in the response to Question 1.

Figure 4.2 of the Draft Supplemental EA shows historical net inflows to Project storage, which corresponds to the usable inflow during each year after accounting for evaporation and seepage losses. Historical net inflows are calculated using Equation 7 as described above. For comparison, Figure 4.2 also shows annual Project inflows measured at San Marcial, which includes measured flows in the Rio Grande conveyance channel (USGS gage 08358300) and measured flows in the Rio Grande floodway (USGS gage 08358400).

Annual values shown in Figure 4.2 were calculated from daily storage and streamflow records. Annual flows at San Marcial (conveyance channel and floodway) and below Caballo Dam, total Project storage at the end of irrigation season, and calculated annual net inflow to Project storage are provided in the attached Microsoft Excel file named RGP_ HistoricalProjectData_2008-2012_FinalClean.xlsx. Historical Project storage values were obtained from Reclamation's El Paso Field Office. Annual flow values were calculated from daily flow records for stream gages located below Caballo Dam (USGS gage 08362500), in the Rio Grande conveyance channel at San Marcial (USGS gage 08358300), and in the Rio Grande floodway at San Marcial (USGS gage 08358400). Annual net inflows were calculated from project storage and release data as detailed above. Note that annual flows were calculated for the period November 1 to October 31 to coincide with the end of irrigation season.

5. **Copy of the project annual allocation model used in developing Tables 4.3 to 4.7, including documentation, [*sic*] if the documentation is not available please provide the model assumptions, equations used in the calculations and associated input/output data for both scenarios.**

Tables 4.3 – 4.6 contain estimated non-exceedance values of Project allocations to EBID, EPCWID, and Mexico, respectively, during the 2015 irrigation season; Table 4.7 contains estimated non-exceedance values of total Project releases from Caballo Dam during the 2015 irrigation season.

Non-exceedance values were estimated by developing probability distributions of Project operations during the 2015 irrigation season. Probability distributions were developed by conducting multiple simulations of Project operations over the period 2013–2015 with annual allocation models of the OA and of Prior Operating Practices, respectively, where simulations differ only with respect to the hydrologic conditions during the three-year simulation period as reflected by the annual inflow sequence used to drive the annual allocation model. Individual simulations were carried out by driving annual allocation models with many different three-year inflow sequences drawn from the historical record—e.g., simulations were carried out for the periods 1951-1953, 1952-1954, 1953-1955, and so on through 2008-2010, for a total of 60 three-year simulations under each operating procedure. Probability distributions were developed by compiling model results for the 2015 irrigation season from simulations with many different inflow sequences. All simulations were initialized based on historical (actual) Project conditions at the end of the 2012 irrigation season (November 1, 2012).

In order to facilitate multiple simulations and associated data processing and management, allocation calculations for the period 2013-2015 were implemented in the form of computer scripts, rather than spreadsheets. Computer scripts were developed in the Python scripting language (www.python.org) and were verified against spreadsheet calculations for the period 2008-2012. Python scripts and input files used to conduct multiple three-year simulations of the 2013-2015 period under the OA and under Prior Operating Practices are included with this response, along with the Microsoft Excel workbook used to produce non-exceedance curves and related tables.

In order to estimate Project operations in future years, two annual allocation models were developed—one representing Project operations as defined in the OA and one representing Project operations under Prior Operating Practices. Annual allocation and operating procedures under Prior Operating Practices are summarized above in response to Question 1, along with a detailed summary of calculations used in this study to estimate Project operations under Prior Operating Practices. The assumptions and calculations used in the annual allocation model of Prior Operating Practices for the period 2013-2015 are identical to those used in the spreadsheet model of Prior Operating Practices for the period 2008-2012, with one minor exception: different assumptions are required to estimate inputs to the model of the 2013-2015 period where actual historical values were used as inputs to the spreadsheet model of the 2008-2012 period (see above for details). For the period 2013-2015, for example, assumptions are required to estimate the annual diversion ratio and non-Project water for each year. Assumptions used in estimating these inputs to the annual allocation model of Prior Operating Practices are identical to those used in the annual allocation model of the OA, described below.

Below is a brief overview of annual allocation procedures under the OA, followed by a detailed description of data, calculations, and assumptions used to estimate annual operations under the OA for the period 2013-2015.

The Python scripts and associated input and output files, as well as the Microsoft Excel files used to develop tables and figures provided in the Draft Supplemental EA, are included with this response. The digital files accompanying this response are briefly summarized at the end of this document.

<u>Overview of Annual Allocation Procedure under the OA</u>
General procedures for allocation of Project water under the OA are defined in the text of the OA. Complete details of specific data and calculations used in the allocation procedure under the OA are provided in Table 4 of the OA and in the accompanying Rio Grande Project Operations Manual.

Under the OA, as under Prior Operating Practices, Reclamation determines annual Project allocations to EBID, EPCWID, and Mexico at the start of each calendar year based on the total usable water available for current-year allocation. Total usable water available for current-year allocation is calculated in a similar manner as under Prior Operating Practices (see above), except that adjustment is made to account for district carryover allocations. Total usable water available for current year allocation is thus calculated as the total water in Project storage minus non-Project water in storage (i.e., total storage minus San Juan-Chama Water and Rio Grande Compact Credit Water) <u>and</u> minus the estimated release required to satisfy carryover obligations. As under Prior Operating Practices, if the total usable water available for current-year allocation at the start of the year is not sufficient to provide a full allocation, Reclamation reevaluates allocations on a monthly basis throughout the irrigation season until a final annual allocation is determined.

As under Prior Operating Practices, pursuant to the Convention of 1906, the annual Project allocation to Mexico is 60,000 AF/year, except under extreme drought conditions in which case the annual allocation to Mexico is equal to 11.3486% of the sum of the quantity of Project water delivered to lands in the United States plus the quantity of Project water delivered to the heading of the Acequia Madre for diversion by Mexico. As under Prior Operating Practices, the total annual Project delivery to Project lands within the United States (i.e., delivery to individual farm gates within EBID and EPCWID) plus total deliveries to the heading of the Acequia Madres is calculated from the estimated annual release of Project water ($R_{Caballo}^{Est}$) based on the D-1 Curve (Equation 1, above). The estimated release of Project water is determined by Reclamation in conjunction with EBID, EPCWID, and IBWC (on behalf of Mexico). For the purposes of this analysis, the annual release is estimated for allocation purposes as the sum of the total usable water available for current-year allocation and the estimated release to meet carryover obligations, minus the storage for EBID and EPCWID estimated end-of-year allocation balances (see Table 4, Rows 13 and 14, of the OA; estimated end-of-year allocation balances for EBID and EPCWID are assumed equal to zero for purposes of this analysis). As under Prior Operating Practices, the annual diversion allocation to Mexico (A_{Mexico}) is subsequently calculated as the minimum of 60,000 AF or 11.3486% of the total annual Project delivery to Project lands within the United States plus total deliveries to the heading of the Acequia Madres (D_{D1}) per Equation 2, above.

As under Prior Operating Practices, the total amount of water available for diversion at river headings for the year ($A_{GrossD2}$) is calculated from the total usable water available for current-year allocation (W) based on the D-2 Curve (Equation 3), where W is again calculated as the minimum of the total usable water available for current-year allocation and the normal annual release of 790,000 AF. The total annual diversion allocation to EBID and EPCWID, referred to as the Net D-2 allocation (A_{NetD2}), is then calculated from Equation 4 in the same manner as under Prior Operating Practices.

Up to this point, the only difference between annual calculations under the OA compared to Prior Operating Practices is adjustment of total usable water available for current-year allocation to account for district carryover allocations—all other calculations are identical to those carried out under Prior Operating Practices. As described below, apportioning of the total annual diversion allocation to EBID and EPCWID (A_{NetD2}) also differs from Prior Operating Practices due to the adjustment of annual district allocations to account for effects of conjunctive use within EBID on the Project diversion ratio ($R_{Project}$).

Under the OA, annual D-2 diversion allocations to EBID and EPCWID are first calculated as under Prior Operating Practices according to Equations 5 and 6, respectively. The annual D-2 diversion allocation to EPCWID is then adjusted to account for the district's carryover allocation from the previous year and estimated end-of-year allocation balance as defined in Equations 14 and 15:

$$A'_{EPCWID} = A^{D2}_{EPCWID} + A^{Carryover}_{EPCWID} \quad (14)$$

$$A''_{EPCWID} = A'_{EPCWID} - C_{EPCWID} \quad (15)$$

Where $A^{Carryover}_{EPCWID}$ is EPCWID's unused prior-year allocation balance after transfer of any excess carryover balance, C_{EPCWID} is EPCWID's projected end-of-year allocation balance for the current year, and A'_{EPCWID} and A''_{EPCWID} are intermediate adjusted EPCWID allocations used in subsequent calculations.

The annual diversion ratio (ρ_t) for the year is then calculated based on the most recent Project operations data; the Project diversion ratio is monitored during the irrigation seasons, and allocations are updated as needed throughout the season to accurately reflect current Project performance conditions. The diversion ratio is used to calculate the diversion ratio adjustment (*D*), which is used to adjust allocations to EBID and EPCWID to account for the effects of conjunctive use of groundwater and surface water within EBID and surrounding areas of New Mexico on current-year Project performance as characterized by the diversion ratio. The diversion ratio adjustment is calculated from the diversion ratio (ρ_t) and the estimated annual release of Project water ($R_{Caballo}$) according to Equation (16):

$$D = (\rho_t - 1) \cdot R_{Caballo} \quad (16)$$

The annual diversion ratio allocation to EBID is then calculated according to Equation (17):

$$A_{EBID}^{DivRatio} = (R_{Caballo} + D) - \left(A_{Mexico} + A''_{EPCWID} + C_{EPCWID} + ACE\right) \quad (17)$$

where $A_{EBID}^{DivRatio}$ is the annual diversion ratio allocation to EBID, *ACE* is the annual conservation credit accredited to EPCWID for water salvaged due to the American Canal Extension, and the remaining terms are defined above.

The diversion ratio adjustment (*D*) is the projected difference between the amount of water released from Project storage and total (net) diversion during the current year, where total (net) diversion is given by the total Project diversions by EBID, EPCWID, and Mexico minus the total metered return flows at authorized locations (i.e., total net diversions equals total Project charges). When the diversion ratio is greater than 1.0, the diversion ratio adjustment is positive; when the diversion ratio is less than 1.0, the diversion ratio is negative. The corresponding annual diversion ratio allocation to EBID ($A_{EBID}^{DivRatio}$) is the estimated water available for diversion in a given year after satisfying the diversion obligations to Mexico and EPCWID. The diversion ratio allocation reflects current Project performance and accounts for any difference between the D-2 Curve and actual current conditions within the Project. The diversion ratio adjustment and diversion ratio allocation thus more accurately reflect the effects of seepage losses, return flows, and groundwater-surface water interactions on current-year Project operations than the D-2 Curve.

The adjusted difference between the annual D-2 allocation and diversion ratio allocation to EBID (Δ) is calculated per Equation 18:

$$\Delta \quad = \mathrm{IF}\left\{ [R_{Caballo} < 600{,}000], \max\left[0.0, \left(A_{EBID}^{DivRatio} - A_{EBID}^{D2}\right)\right], [0.0]\right\} \quad (18)$$

The intermediate adjusted diversion allocation to EBID is then determined based on the districts D-2 and diversion ratio allocation and the estimated release of Project water during the current year. Equation 19:

$$A'_{EBID} = \mathrm{IF}\left\{ [R_{Caballo} < 600{,}000], \min\left[A_{EBID}^{DivRatio}, A_{EBID}^{D2}\right], \left[A_{EBID}^{DivRatio}\right]\right\} \quad (19)$$

where A'_{EBID} is the intermediate adjusted annual diversion allocation to EBID, which is used in subsequent calculation of the district's total diversion allocation.

Finally, total diversion allocation to EPCWID is calculated from the intermediate annual allocation A''_{EPCWID} detailed above, the annual American Canal Extension (ACE) conservation credit, and 43% of the adjusted difference between the annual D-2 allocation and diversion ratio allocation to EBID (Δ); note that the intermediate annual allocation A''_{EPCWID} includes the districts initial D-2 diversion allocation as well as its carryover allocation. The total diversion allocation to EBID is calculated from the intermediate adjusted diversion allocation A'_{EBID}, the district's unused prior-year allocation balance after transfer of any excess carryover balance ($A_{EBID}^{Carryover}$), and 57% of the adjusted difference between the annual D-2 allocation and diversion ratio allocation to EBID (Δ). Final total Project allocations to EBID and EPCWID are calculated from Equations 20 and 21, respectively:

$$A_{EPCWID}^{Final} = A''_{EPCWID} + ACE + \left(\frac{67}{155}\right) \cdot \Delta \quad (20)$$

$$A_{EBID}^{Final} \quad = A'_{EBID} + A_{EBID}^{Carryover} + \left(\frac{88}{155}\right) \cdot \Delta \quad (21)$$

<u>Summary of Data, Assumptions, and Calculations used to Estimate Project Operations under the OA for the Period 2013-2015</u>

Total Usable Water Available for Release (U_t)

Under the OA, the total usable water available for release is calculated from Equation 8 as under Prior Operating Practices, as detailed above.

EBID Allocation Balance (Previous Year) ($A_{EBID}^{Carryover}$)

The EBID allocation balance at the end of the previous year is the difference between the prior-year total diversion allocation to EBID and the prior-year total project charges (net Project diversions) to EBID, accounting for any transfer of excess carryover balance between districts. EBID Allocation Balance (previous year) is equal to EBID's Accrued Carryover Balance, defined above (see response to Question 3).

EPCWID Allocation Balance (Previous Year) ($A_{EPCWID}^{Carryover}$)

The EPCWID allocation balance at the end of the previous year is the difference between the prior-year total diversion allocation to EPCWID and the prior-year total project charges (net Project diversions) to EPCWID, accounting for any transfer of excess carryover balance between districts. EBID Allocation Balance (previous year) is equal to EPCWID's Accrued Carryover Balance, defined above (see response to Question 3).

EBID Estimated Allocation Balance (End-of-Year) (C_{EBID})

Under the OA, each district may specify its projected end-of-year allocation balance; the specified end-of-year allocation balance is considered part of the carryover obligation and is not available for current-year allocation. For the purposes of this analysis, the EBID estimated end-of-year allocation balance was assumed to be zero for all years in the period 2013-2015.

EPCWID Estimated Allocation Balance (End-of-Year) (C_{EPCWID})

For the purposes of this analysis, the EBID estimated end-of-year allocation balance was assumed to be zero for all years in the period 2013-2015.

Carryover Obligation using Estimated Diversion Ratio (X_t)

Because each district's Accrued Carryover Water is applied as a diversion allocation, the carryover obligation is the amount of water that must be released from Project storage in order to divert a volume equal to the specified carryover. The current-year carryover obligation is thus calculated from the estimated Project diversion ratio ($R^{Est}_{Project}$) according to Equation 22:

$$X_t \quad = \frac{A^{Carryover}_{EBID} + A^{Carryover}_{EPCWID}}{R^{Est}_{Project}} \tag{22}$$

where the estimated annual Project diversion ratio is calculated as described below.

Storage for EBID and EPCWID Estimated Allocation Balance ($S_{Carryover}$)

The total storage required to satisfy carryover obligations to EBID and EPCWID is calculated from the estimated Project diversion ratio (ρ^{Est}_t) in a similar manner to the current year carryover obligation (Equation 23).

$$S_{Carryover} \; = \frac{C_{EBID} + C_{EPCWID}}{R^{Est}_{Project}} \tag{23}$$

Total Usable Water Available for Current-Year Allocation (W_t)

Under the OA, the total usable water available for current-year allocation is equal to the minimum of the total usable water available for current-year release minus the current-year carryover obligation and the normal annual release of 790,000 AF, minus storage for the estimated end-of-year allocation balance ($S_{Carryover}$). Total usable water available for current-year allocation is thus calculated from Equation 24:

$$W_t \quad = \min[(U_t - X_t), 790{,}000] - S_{Carryover} \tag{24}$$

Estimated Release of Current Usable Water ($R^{Est}_{Caballo}$)

Under the OA, the annual D-1 delivery (D_{D1}), the annual diversion ratio adjustment (D), and the adjusted difference between the annual D-2 allocation and diversion ratio allocation to EBID (Δ) are all calculated based on the annual release of Project water during the current year. Because the actual annual release of Project water ($R_{Caballo}$) during a given irrigation season is not known at the start of the season, the estimated annual release of Project water ($R^{Est}_{Caballo}$) is used to calculate these values.

For the period 2013-2015, the estimated release of current usable water used in this analysis is assumed to equal the total usable water available for current-year allocation:

$$R^{Est}_{Caballo,t} = W_t \tag{25}$$

It should be noted that for both periods of analysis, the annual allocation model calculates actual annual releases are based on annual total Project diversions and the annual diversion ratio as detailed below. The actual annual releases may therefore differ from the estimated release of current usable water used to calculate the annual D-1 delivery, annual diversion ratio adjustment, and the adjusted difference between the annual D-2 allocation and diversion ratio allocation to EBID.

Annual Diversion Ratio (ρ_t)

Analysis of the period 2013-2015 requires estimating the annual diversion ratio in future years. As discussed above in response to Question 1, extensive analysis of historical Project operations data was carried out in an effort to identify a reliable predictor of the annual diversion ratio for a given year based on data available at the start of that year's irrigation season. However, the only predictor that was found to exhibit a statistically significant relationship with the current-year diversion ratio is the prior year diversion ratio—i.e., the only reliable predictor of the annual gross diversion ratio is the year-to-year persistence (serial correlation) of the gross diversion ratio itself. Because the only available predictor of the current-year diversion ratio is the prior-year diversion ratio, the annual Project diversion ratio for each year in the period 2013-2015 was calculated based on the serial regression relationship defined in Equation 26:

$$\rho_t \quad = 0.8399 \cdot \rho_{t-1} + 0.1829 \qquad (26)$$

The annual Project diversion ratio for year 2013 is calculated from the actual Project diversion ratio for 2012 calculated from Project operations data using Equation 26. The annual Project diversion ratio for each subsequent year was determined from the calculated prior-year Project diversion ratio per Equation 26. Annual Project diversion ratios estimated from Equation 26 were used to calculate annual Project allocations as well as to determine the annual Project release required to satisfy Project diversions.

Annual D-1 Delivery (D_{D1})

Under the OA, the annual D-1 delivery (D_{D1}) is calculated from Equation 1 as under Prior Operating Practices.

Annual Allocation to Mexico (A_{Mexico})

Under the OA, the annual D-1 allocation to Mexico (A_{Mexico}) is calculated from Equation 2 as under Prior Operating Practices.

Annual Gross D-2 Diversion Allocation ($A_{GrossD2}$)

Under the OA, the annual gross D-2 diversion allocation ($A_{GrossD2}$) is calculated from the total usable water available for current-year allocation (W_t) in a similar manner to Prior Operating Practices. However, the equation used to calculate the annual gross D-2 allocation is modified to account for differences between the total usable water available for current-year release and the annual release under normal conditions, which may arise due to the annual carryover obligation. The annual gross D-2 allocation is thus calculated according to Equation 27:

$$A_{GrossD2,t} = \min[763{,}842;\ W_t] \cdot 1.3377994 - 89{,}970 + \max[0.0;\ 763{,}842 - W_t] \quad (27)$$

A drought adjustment factor is required under Prior Operating Practices in order to ensure the gross D-2 diversion allocation can be satisfied from the usable water available for release. The OA allocation procedure largely avoids the need for a drought adjustment factor. For the purposes of this analysis, a drought adjustment factor of 0.88 is applied to the gross D-2 allocation under the OA in calculating the 2012 annual Project allocation. This factor corresponds to the actual drought adjustment factor used in the project allocation worksheet for water year 2012. In the analysis of the future period 2013-2015, a drought adjustment factor of 0.88 is applied if the total usable water available for release is less than 400,000 AF.

Annual Net D-2 Diversion Allocation (A_{NetD2})
Under the OA, the annual net D-2 diversion allocation ($A_{GrossD2}$) is calculated from the gross D-2 diversion allocation and the annual allocation to Mexico (A_{Mexico}) using Equation 4.

EPCWID ACE Conservation Credit (ACE)
Under the OA, EPCWID is credited for water salvaged by conveyance of water from the American Dam to the Riverside Canal Heading via the American Canal Extension (ACE) rather than the Rio Grande, where salvage occurs due to reduced seepage losses from the concrete-lined ACE compared to the seepage losses from the unlined river channel. In practice, the annual ACE conservation credit (ACE) is calculated based on a non-linear relationship between the annual flow through the ACE and the estimated salvage. However, the procedure for calculating the annual ACE conservation credit (ACE) is not specified in the OA or the Rio Grande Project Operations Manual.

For the purposes of this analysis, ACE conservation credits were assumed to be zero for the period 2013-2015. ACE conservation credits are likely to be zero during this period if the current drought persists; if Project supplies return to normal, conservation credits will constitute a small portion of the final annual allocation to EPCWID. This assumption is therefore not likely to substantially affect the results of this analysis.

D-2 Diversion Allocation to EPCWID (A_{EPCWID}^{D2})
Under the OA, the annual D-2 diversion allocation to EPCWID (A_{EPCWID}^{D2}) is calculated as 43% of the annual net D-2 diversion allocation according to Equation 6.

EPCWID Diversion Allocation (without ACE) (A'_{EPCWID})
Under the OA, the annual diversion allocation to EPCIWD without the annual ACE conservation credit (A'_{EPCWID}) is calculated as an intermediate step in the allocation calculation procedure. The annual EPCIWD diversion allocation without ACE conservation credit is calculated according to

Equation 14 as the sum of the annual D-2 diversion allocation to EPCWID and the annual carryover allocation to EPCWID.

EPCWID Diversion Allocation (without ACE or 67/155ths of Row 30) (A''_{EPCWID})
Under the OA, the annual diversion allocation to EPCIWD without the annual ACE conservation credit or 67/155^ths (43%) or the adjusted difference between the D-2 and diversion ratio allocations to EBID (Row 30 of Table 4) (A''_{EPCWID}) is calculated as an intermediate step in the allocation calculation procedure; A''_{EPCWID} is calculated according to Equation 15.

D-2 Diversion Allocation to EBID (A^{D2}_{EBID})
Under the OA, the annual D-2 diversion allocation to EBID (A^{D2}_{EBID}) is calculated as 57% of the annual net D-2 diversion allocation according to Equation 5.

Diversion Ratio Adjustment (D)
The diversion ratio adjustment (D) is calculated from the estimated annual Project diversion ratio ($R^{Alloc}_{Project}$) and the estimated annual release of Project water ($R^{Est}_{Caballo}$) according to Equation 16.

Diversion Ratio Allocation to EBID ($A^{DivRatio}_{EBID}$)
The annual diversion ratio allocation to EBID ($A^{DivRatio}_{EBID}$) is calculated from the estimated annual release from Project storage ($R^{Est}_{Caballo}$), the diversion ratio adjustment (D), the annual allocation to Mexico (A_{Mexico}), the annual diversion allocation to EPCWID without *ACE* or 67/155ths of Row 30 (A''_{EPCWID}), and the annual ACE conservation credit (ACE) according to Equation 17.

Adjusted Difference between D-2 and Diversion Ratio Allocations to EBID (Δ)
The adjusted difference between the annual D-2 allocation and diversion ratio allocation to EBID (Δ) is used in calculating the final annual allocations to EBID and EPCWID under the OA. The adjusted difference is calculated according to Equation 18.

Adjusted Annual Diversion Allocation to EBID (A'_{EBID})
The adjusted annual diversion allocation to EBID is calculated from the estimated annual release from Project storage and the annual D-2 and diversion ratio allocations to EBID according to Equation 19.

Final Annual Diversion Allocation to EBID (A^{Final}_{EBID})
The final annual diversion allocation to EBID is calculated from the adjusted annual diversion allocation A'_{EBID}, the district's unused prior-year allocation balance after transfer of any excess carryover balance ($A^{Carryover}_{EBID}$), and 88/155^ths (57%) of the adjusted difference between the annual D-2 allocation and diversion ratio allocation to EBID (Δ) according to Equation 20.

Final Annual Diversion Allocation to EPCWID (A^{Final}_{EPCWID})
The final annual diversion allocation to EBID is calculated from the annual diversion allocation to EPCWID without *ACE* or 67/155^ths (43%) of Row 30 (A''_{EPCWID}), the annual American Canal Extension

(ACE) conservation credit (ACE), and 67/155ths (43%) of the adjusted difference between the annual D-2 allocation and diversion ratio allocation to EBID (Δ) according to Equation 21.

Annual Diversion to Mexico (D_{Mexico})

For the purposes of this analysis, it is assumed that Mexico diverts its full allocation in all years.

Annual Diversion to EBID (D_{EBID})

Historically, the annual diversion to EBID (D_{EBID}) was generally equal to the district's annual allocation (A_{EBID}). For the purposes of this analysis, for the period 2013-2015, annual diversion to EBID is assumed to equal the calculated annual allocation to EBID.

Annual Diversion to EPCWID (D_{EPCWID})

The annual diversion to EPCWID (D_{EPCWID}) for most years during the period 1951-2007 was less than or equal to the district's final annual allocation (A_{EPCWID}^{Final}). As noted above in response to Question 1, in order to estimate EPCWID's annual diversions during the period 2013-2015, historical project data were evaluated to identify the best predictor of the annual diversion to EPCWID. For the purposes of this analysis, the annual diversions to EPCWID during the period 2013-2015 are calculated according to the piece-wise relationship provided in Equation 12, above.

Annual Release from Project Storage ($R_{Caballo}$)

Annual release from Project storage is estimated as the total annual release required to meet annual Project diversions to EBID, EPCWID, and Mexico plus any reservoir spill that occurs due to Project storage exceeding total Project storage capacity as per Equation 13, above.

Annual End-of-Year Project Storage (S^{EoY})

Total Project storage remaining at the end of the current irrigation season (S_t^{EoY}) is calculated from the total Project storage at the end of the prior irrigation season (S_{t-1}^{EoY}), annual Project inflows during the current year (I_t), and total Project releases during the current year ($R_{Caballo,t}$) according to Equation 14, above.

6. Assumptions and methods for estimating annual release from 2008-2012 [*sic*] prior Op, as well as associated data if any.

The methods and assumptions used to estimate annual releases from Project storage under Prior Operating Practices during the period 2008-2012 are described above in the response to Question 1. All data and equations used in these calculations are provided in the Microsoft Excel file named RGP_AllocationAnalysis_2008-2012_FinalClean.xlsm, included with this response.

7. **Data and calculations for [*sic*] figs 4.8, 4.9, and 4.10 (total project storage at start and end of season and Elephant Butte Reservoir Elevation)**
   Values in Figures 4.8 – 4.10 corresponding to actual Project operations under the OA (blue diamonds) are based on actual historical Project operations data; values corresponding to estimated operations under Prior Operating Practices are calculated as described above. Under Prior Operating Practices, it was assumed that 95.5% of the total water in Project storage resides in Elephant Butte Reservoir and 4.5% resides in Caballo Reservoir, which is consistent with the average distribution of storage in the two reservoirs over the period 2008-2012. It should also be noted that in all cases, reservoir elevation in Elephant Butte was estimated from total storage in Elephant Butte based on the latest Area-Capacity-Elevation curves for the reservoir. All data and calculations used to develop Figures 4.8 – 4.10 is provided in the Microsoft Excel file named RGP_AllocationAnalysis_2008-2012_FinalClean.xlsm, included with this response.

8. **Data and calculations for [*sic*] figs 4.11, 4.12, 4.13, and 4.14 (annual inflow and annual allocations)**
   Figures 4.11 – 4.14 display non-exceedance curves (probability distributions) of annual Project inflows and annual Project allocations to EBID, EPCWID, and Mexico under the OA and under Prior Operating Practices for the 2015 irrigation season.

   Probability distributions were developed by conducting multiple simulations of Project operations over the 2013 – 2015 irrigation seasons with annual allocation models of the OA and of Prior Operating Practices, both of which are described above in response to Question 5. All simulations were initialized based on Project conditions at the end of the 2012 irrigation season (November 1, 2012). Individual simulations were carried out by driving the annual allocation model with a three-year inflow sequences drawn from the historical record. Probability distributions were developed by compiling model results for the 2015 irrigation season from simulations with many different inflow sequences. Simulations were carried out for the periods 1951-1953, 1952-1954, and so on through 2008-2010, for a total of 60 three-year simulations under each operating procedure.

   As noted above, the Python scripts and input files used to conduct multiple three-year simulations of the 2013 – 2015 period under the OA and under Prior Operating Practices are included with this response, along with the Microsoft Excel workbook used to produce non-exceedance curves shown in Figures 4.11 – 4.14.

9. **Equation 22 (for calculating diversion ratio; it is supposed to be in Section 2.2.2, but this section does not exist).**
   As discussed above in response to Questions 1 and 5, extensive analysis of historical Project operations data was carried out in an effort to identify a reliable predictor of the annual diversion ratio for a given year based on data available at the start of that year's irrigation season. However, the only predictor that was found to exhibit a statistically significant relationship with the current-year diversion ratio is the prior year diversion ratio—i.e., the only reliable predictor of the annual

gross diversion ratio is the year-to-year persistence (serial correlation) of the gross diversion ratio itself.

Due to the generally weak relationships between the annual gross diversion ratio and the available predictors, historical (actual) annual diversion ratios were used in the analysis of the period 2008-2012. Due to the lack of Project operations data for future periods, however, analysis of the period 2013-2015 requires estimating the annual diversion ratio in future years. Because the only available predictor of the current-year diversion ratio is the prior-year diversion ratio, the annual Project diversion ratio for each year in the period 2013-2015 was calculated based on the serial regression relationship defined in Equation 28:

$$\rho_t = 0.8399 \cdot \rho_{t-1} + 0.1829 \quad (28)$$

Figure 3 shows the historical Project diversion ratio data used to develop Equation 28. For analysis of the period 2013-2015, the annual Project diversion ratio for year 2013 is estimated using Equation 28 based on the actual diversion ratio for 2012 as calculated from Project operations data. The annual diversion ratio for each subsequent year was determined from the estimated prior-year Project diversion ratio per Equation 28.

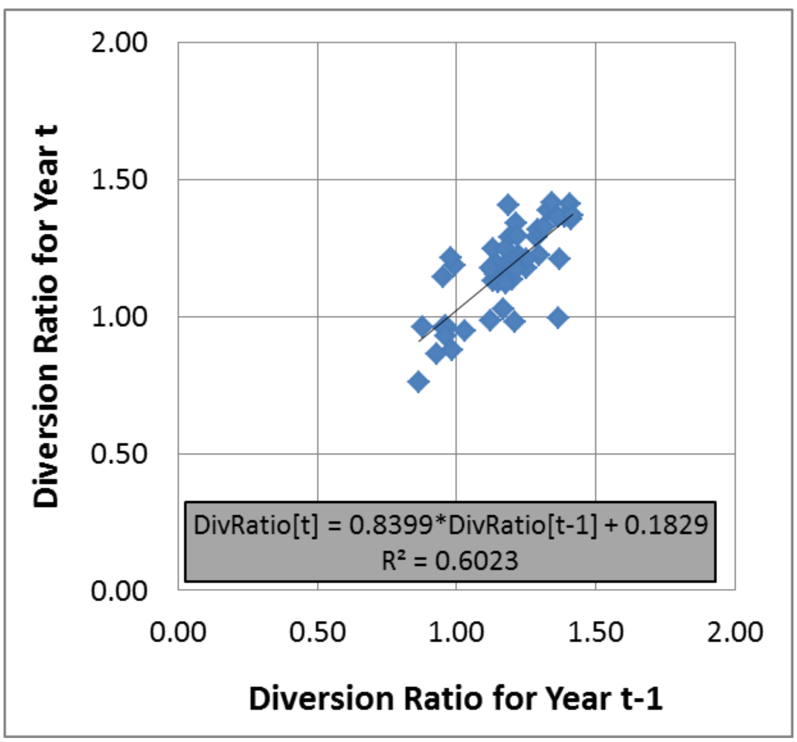

Figure 3: Current-year annual diversion ratio plotted as a function of prior-year annual diversion ratio. Annual diversion ratios were calculated from historical Project operations data for the period 1951-2012; the following years were excluded as outliers: 1972, 1986, 1987, 1995.

It should be noted that the estimated diversion ratios used to simulate Project operations during the period 2013-2015 are a key uncertainty in this analysis. As shown in Figures 4.15 – 4.17 of the Draft Supplemental EA, estimated differences in Project allocations—particularly differences in total diversion allocation to EBID—are highly sensitive to the diversion ratio used in the annual allocation models. Despite the large uncertainties in estimated values of the diversion ratio based on Equation 28, a more reliable predictor of the diversion ratio is not available for this analysis. Uncertainties associated with Equation 28 affect calculation of project operations under both the OA and Prior Operating Practices for the period 2013-2015. In simulations of Prior Operating Practices, these uncertainties affect calculation of releases and end-of-year total Project storage, as well as the drought year adjustment applied to the gross D-2 allocation in years with low inflows. Under the OA, these uncertainties affect calculation of the carryover delivery obligation, the diversion ratio allocation to EBID, the diversion ratio adjustment, and the drought year adjustment applied to gross D-2 allocation under dry inflow scenarios, as well as Project releases and end-of-year total Project storage. A sensitivity analysis was conducted to assess the sensitivity of estimated Project operations to uncertainties in the annual Project diversion ratio for the period 2013-2015; results of the sensitivity analysis summarized in Figures 4.14 – 4.17 of the Draft Supplemental EA.

10. Data and calculations for [*sic*] figs 4.15, 4.16, and 4.17 (annual allocation-diversion ratio), [*sic*] fig 4.18 (release), and [*sic*] figs 4.19 and 4.20 (storage).

Figures 4.15 – 4.17 display the difference between non-exceedance curves (probability distributions) of annual Project allocations to EBID, EPCWID, and Mexico, respectively, under the OA compared to Prior Operating Practices for the 2015 irrigation season. In each figure, differences between non-exceedance curves used in this study are indicated by the dark black line with filled black diamonds ("Estimated"). For example, the dark black line on Figure 4.15 corresponds to the difference between the blue and red lines from Figure 4.12. The other lines shown on these figures correspond to results based on different assumed values of the diversion ratio ranging from 0.7 to 1.3. Figures 4.15 – 4.18 illustrate that the estimated difference in annual allocations during the 2013 – 2015 period under the OA compared to Prior Operating Practices is highly sensitive to the estimated diversion ratio (scatter between data series) as well as the hydrologic conditions during this period (differences between non-exceedance values, i.e., variations along horizontal axis).

As discussed above, probability distributions of annual allocations were developed by conducting multiple simulations of Project operations over the 2013 – 2015 irrigation seasons with annual allocation models of the OA and of Prior Operating Practices. Figures 4.15 – 4.18 were created by developing additional probability distributions in a similar manner for various fixed values of the diversion ratio (0.7, 0.8, 0.9, …, 1.3), and then calculating the differences between values under the OA and under Prior Operating Practices at each non-exceedance probability. The codes, data, and spreadsheets used to develop these figures are provided with this response.

Figures 4.18 – 4.20 display non-exceedance curves (probability distributions) of estimated annual release from Project storage, total Project storage at the start of irrigation season, and total Project storage at the end of irrigation season for the 2015 irrigation season, respectively. These figures were developed in a manner similar to Figures 4.12 – 4.14, described above. As noted above, the Python scripts and input files used to conduct multiple three-year simulations of the 2013 – 2015 period under the OA and under Prior Operating Practices are included with this response, along with the Microsoft Excel workbook used to produce non-exceedance curves shown in Figures 4.18 – 4.20.

Overview of Supporting Digital Files:

- **RGP_EA_SupportingFiles.zip**
  - ProjectData (1950-2012)
    - File Name: RGP_HistoricalProjectData_1951-2012_FinalClean.xlsx
      Format: Microsoft Excel workbook
      Summary: File contains historical Project operations data used in analysis in support of Supplemental EA
  - Analysis (2008-2012)
    - File Name: RGP_AllocationAnalysis_2008-2012_FinalClean.xlsm
      Format: Microsoft Excel workbook (Macro-enabled)
      Summary: File contains data, calculations, and analysis of Project operations during the period 2008-2012 carried out in support of Supplemental EA, including complete calculations of actual Project allocations under the OA and estimated Project allocations under Prior Operating Practices during this period. File also contains calculations of district allocation components (i.e., Annual Allocated Water, Accrued Carryover Balance, Transfer of Excess Carryover Balance, and Total Diversion Allocation).
  - Analysis (2013-2015)
    - File Name: RGP_AllocationAnalysis_NonExceedanceCurves_SummaryPlots_FinalClean.xlsx
      Format: Microsoft Excel workbook
      Summary: File contains data and non-exceedance curves of Project operations during the period 2013-2015 developed in support of Supplemental EA. Data contained in this file was imported from text files located in directories:
      AnnualAllocationModels/Outputs.AdHoc
      AnnualAllocationModels/Outputs.OA.
    - File Name: RGP_AllocationAnalysis_DivRatioSensitivity_SummaryPlots_FinalClean.xlsx
      Format: Microsoft Excel workbook
      Summary: File contains data and sensitivity plots developed to assess sensitivity of estimated Project operations during period 2013-2015 to assumptions regarding the diversion ratio. Data contained in this file was imported from text files located in directory:
      AnnualAllocationModels/Outputs.DivRatioEffect
    - Directory: AnnualAllocationModel
      Summary: Directory contains Python scripts used to simulate Project operations under the OA and under Prior Operating Practices during the period 2013-2015 based on many inflow conditions sampled from the historic record. Subdirectories contain inputs and outputs from the annual allocation models. Python scripts, input files, and output files may all be viewed using a standard text editor (VI, TextPad, NotePad++, etc.)