Appendix 8B Groundwater Modeling

Appendix 8B Introduction

The information contained in this appendix was originally produced in the 2017 Public Draft Environmental Impact Report/Environmental Impact Statement (2017 Draft EIR/EIS). This information is included so the reader can reference the groundwater modeling results that are applicable to Alternatives 1, 2 and 3 evaluated in Chapter 8, *Groundwater Resources*. Multiple project facilities evaluated in the 2017 Draft EIR/EIS are no longer part of the Project as described in this Revised Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement. These include the Delevan Pipeline, Delevan Intake, and Holthouse Reservoir. As such, these facilities are not discussed in Chapter 8, but appear in this appendix. Line items and numbers identified or noted as "No Action Alternative" represent the "Existing conditions/No Project/No Action Condition" as described in the 2017 Draft EIR/EIS. The figure numbering and page numbering in this appendix reflects the original numbering in the 2017 Draft EIR/EIS.

APPENDIX 10A
Groundwater Modeling

10A.1 Introduction

This technical appendix provides detailed descriptions of numerical groundwater modeling performed to support groundwater resources impacts analyses. Groundwater modeling simulations fell into two categories: (1) those performed to evaluate potential changes in groundwater elevations resulting from reservoir seepage and (2) those performed to evaluate potential changes in groundwater and stream stage elevations and groundwater/surface water interaction resulting from operation of Sites Reservoir Project (Project) diversions. The following sections provide the technical details associated with these analyses.

10A.2 Modeling to Evaluate Impacts of Reservoir Seepage on Groundwater Resources

The construction and operation the Sites and Holthouse Reservoirs would result in inundation of new land within the Primary Study Area. A portion of the water retained in these reservoirs will infiltrate into the underlying subsurface materials, acting as new sources of recharge to the underlying groundwater system. Additional recharge may result in increases in groundwater levels in the aquifer system within the Primary Study Area. Potential direct Project-related impacts resulting from reservoir operation on groundwater resources within the Primary Study Area were evaluated using a combination of analytical and numerical methods ($SACFEM_{2013}$ [CH2M HILL and MBK Engineers, 2014]). The following sections provide the details associated with these methods.

10A.2.1 Approach to Estimating Reservoir Seepage

Because the Sites Reservoir footprint and the majority of the Holthouse Reservoir footprint fall outside of the existing $SACFEM_{2013}$ model domain, potential seepage from these reservoirs was computed external to the numerical model using an analytical solution. This analytical solution assumes that the surface water and groundwater systems are coupled (that is, the groundwater elevation beneath the reservoir has increased over time due to seepage and is now in contact with the bottom of the surface water body). Reservoir seepage was computed as follows:

$$Q = Kh \times \frac{Hres - Haq}{L} \times A \quad (1)$$

Where:

Q	=	reservoir seepage (L^3/T)
K_h	=	horizontal hydraulic conductivity of aquifer (L/T)
H_{res}	=	maximum operating stage of the reservoir (L)
H_{aq}	=	groundwater elevation at the margin of the alluvial basin (L)
L	=	distance from reservoir to the margin of the alluvial basin (L)
A	=	cross-sectional area (L^2)

The following information/data sources were used as the equation input terms:

- The horizontal hydraulic conductivity (K_h) of the bedrock units underlying the reservoir was assumed to be 0.03 feet per day (10^{-5} centimeters per second). This value was considered reasonable for a bulk hydraulic conductivity (that is, based on the cumulative effect of lithology and structure [fractures]) based on literature values (Freeze and Cherry, 1979).
- The maximum reservoir stage (H_{res}) for the Holthouse Reservoir is 206 feet above the North American Vertical Datum of 1988 (NAVD88) for all alternatives. The maximum Sites Reservoir stage is 480 feet NAVD88 for Alternative A and 520 feet NAVD88 for Alternatives B, C, and D.
- The groundwater elevation at the western margin of the alluvial subbasin is approximately 130 feet NAVD88 (Figures 10-3 and 10-4 of Chapter 10 Groundwater Resources).
- The distance from points within the Sites and Holthouse Reservoirs to the western margin of the alluvial subbasin (L) were computed for 10-meter digital elevation model (DEM) grid cells within the reservoir footprints. The distances were computed based on the difference between the easting (x-coordinate) of each DEM cell center and the average easting (x-coordinate) at the alluvial subbasin margin. Because the Holthouse Reservoir is partially within the alluvial subbasin, a minimum distance of 750 feet was assumed for this evaluation.
- The area (a) term was equal to each DEM "cell". It was assumed that each plan-view DEM cell area represents the cross-sectional area of the groundwater flow tube oriented vertically from the base of the reservoir and transitioning to horizontal as groundwater moves laterally through the groundwater system toward the Sacramento Valley aquifer.

Reservoir seepage was computed using Equation 1 for each DEM grid cell within the Sites Reservoir Alternative A; Sites Reservoir Alternatives B, C, and D; and Holthouse Reservoir inundation areas. The seepage values for each of the DEM grid cells were totaled for each of the reservoir inundation areas to yield the total reservoir seepage estimate of:

- Sites Reservoir, Alternative A: 1,500 gallons per minute (gpm) (2,420 acre-feet per year [ac-ft/yr])
- Sites Reservoir, Alternatives B, C, and D: 1,930 gpm 3,100 ac-ft/yr)
- Holthouse Reservoir: 220 gpm (350 ac-ft/yr)

10A.2.2 Numerical Model Simulations

$SACFEM_{2013}$ is a numerical tool composed of a groundwater model and a surface water budgeting module that computes the monthly agricultural pumping and groundwater recharge resulting from applied water and precipitation. The $SACFEM_{2013}$ model domain encompasses the entire Sacramento Valley Groundwater Basin with nodal spacing ranging from 410 feet (125 meters) to 3,280 feet (1,000 meters). The model is calibrated to groundwater levels measured in monitoring wells during a 40-year period (water years 1970 through 2010). Complete documentation of the construction and calibration of $SACFEM_{2013}$ is included in *Sacramento Valley Finite Element Groundwater Flow Model User's Manual* (CH2M HILL and MBK Engineers, 2014). The baseline $SACFEM_{2013}$ simulations represents the Existing Conditions/No Project/No Action Condition to which model output which includes reservoir seepage were compared.

The potential effects of long-term reservoir operation on groundwater elevations within the Sacramento Valley Groundwater Basin (Colusa Subbasin) were evaluated for the combined seepage from the

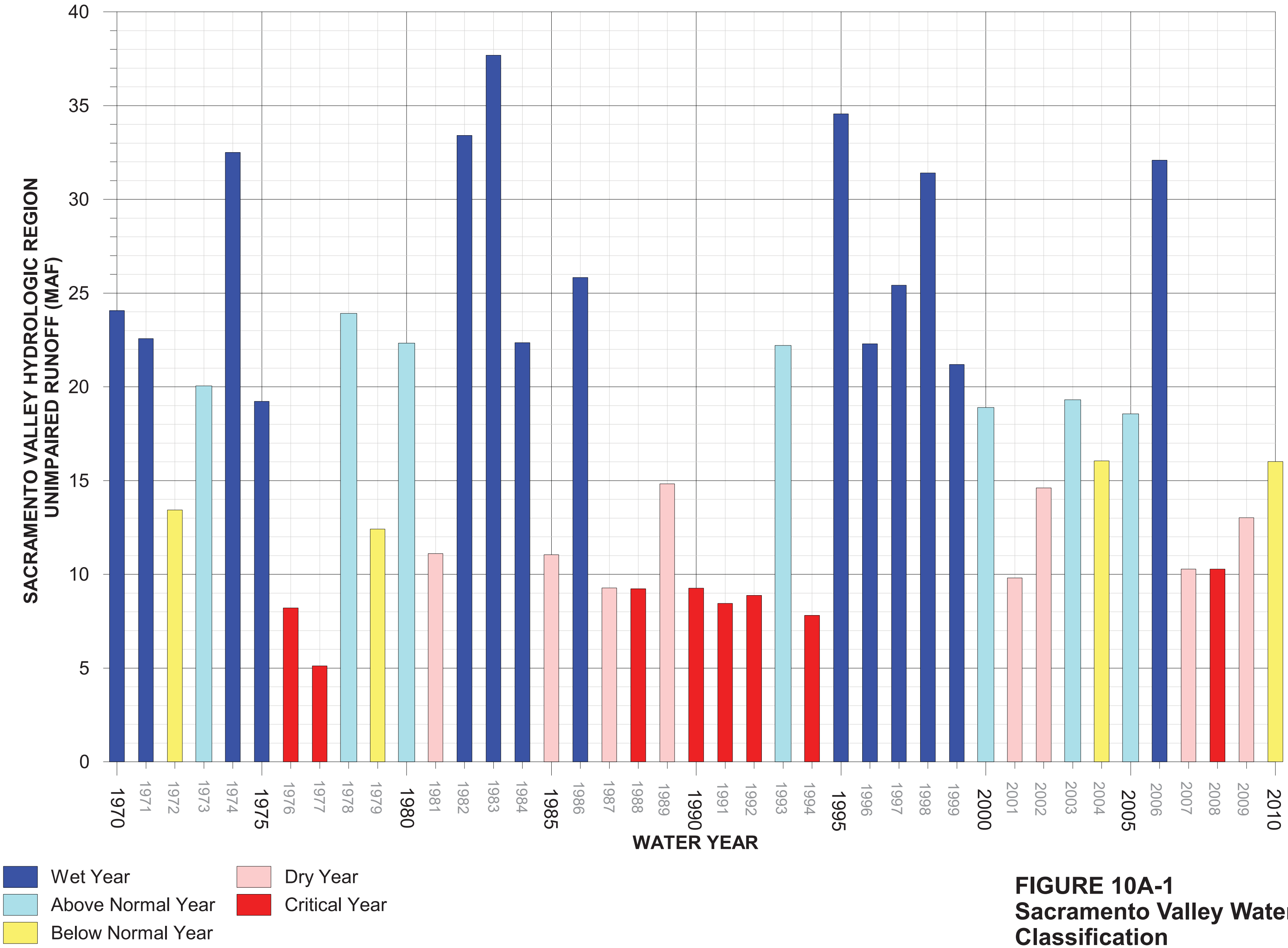
Holthouse and Sites Alternative B, C, D configurations. It was determined that because the estimated seepage under Alternative A was of smaller magnitude, if the impacts associated with the Alternatives B, C, and D configuration were less-than-significant, those for Alternative A would be as well. The estimated reservoir seepage values described above were used as input to $SACFEM_{2013}$ as specified flux boundary conditions. Seepage was assigned as inflow to model nodes along the western $SACFEM_{2013}$ model boundary immediately downgradient (east of) the Sites and Holthouse Reservoir footprints. The seepage inflow was apportioned to these nodes based on the upgradient reservoir widths. That is, nodes where the widths of the Sites and/or Holthouse reservoirs to the west were wider (such as the middle portion of the Sites Reservoir) were assigned relatively more seepage inflow than those nodes where the upgradient reservoirs were of lesser width (such as the northern and southern portions of Sites Reservoir). Seepage inflow was split among the seven model layers based on the relative transmissivity of the layers at each node (that is, layers with higher relative transmissivity were assigned a relatively higher portion of inflow for that node).

As described above, SACFEM2013 includes a 40-year transient simulation period with varying hydrologic conditions. For the purposes of this evaluation, estimated reservoir seepage was simulated in SACFEM2013 for the first 17 years of the simulation period (water year 1970 through water year 1985). This simulation period was considered appropriate for this evaluation because it included a critical drought (water years 1976 and 1977) and the wettest year in the simulation period (water year 1983) (Figure 10A-1). The baseline groundwater levels (the Existing Conditions/No Project/No Action Condition) were defined as the groundwater conditions resulting from the SACFEM2013 calibration simulation described and documented in CH2M HILL and MBK Engineers (2014). A second simulation was performed assigning additional inflow along the portion of the western model boundary as described above. The model forecast groundwater elevations from the Existing Conditions/No Project/No Action Condition and Alternatives B, C, D simulations were compared to evaluate the magnitude and distribution of potential increase in groundwater elevations in the Sacramento Valley Groundwater Basin (Colusa Subbasin) due to reservoir seepage. Increases in groundwater levels are presented/discussed for the shallow portions of the aquifer system as this represents zones where increases in groundwater levels could impact shallow root zones in agricultural areas or wetlands/wildlife areas. Spring 2016 depth to groundwater measurements, collected as part of the semi-annual DWR groundwater level monitoring program, are provided for context (DWR, 2017). Spring generally represents the period of seasonally high groundwater (that is, shallowest depth to water) in the Sacramento Valley Groundwater Basin.

10A.2.3 Results

Potential rates of seepage from the Sites and Holthouse Reservoirs under the maximum Alternative B through D reservoirs were estimated to be approximately 2,150 gpm. Figures 10A-2A and 10A-2A present simulated Existing Conditions/No Project/No Action Condition and Alternative B groundwater elevations in the vicinity of Funks Reservoir (the point with the largest increase in groundwater levels) and for a location within the orchards southeast of Funks Creek. Figures 10A-2A and 10A-2B also present bar charts representing the Sacramento Valley water year classification for the period simulated. These data show that following the onset of reservoir operation (simulated as beginning in water year 1971), simulated groundwater levels begin to increase as compared to the Existing Conditions/No Project/No Action Condition. The rate and magnitude of increase varies over time; however, in most years the inflow to the groundwater system from reservoir seepage provides a benefit in terms of an additional source of water to groundwater users in the valley. For example, as shown on Figure 10A-2A, groundwater levels are projected to be over 20-feet higher during critical drought years (1976-1977).

During extremely wet hydrologic conditions, such as water year 1983, the increased groundwater levels may result in additional discharge to streams and/or low lying areas. If groundwater levels rising to or near ground surface occur in agricultural areas, crops may be impacted. Figure 10A-2B presents hydrographs for a location within the orchards southeast of Funks creek where groundwater levels are projected to increase. These hydrographs indicate that even during extremely wet conditions, groundwater levels are forecast to be several feet below ground surface in these critical locations (at the highest simulated elevations).



Data Source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST

FIGURE 10A-1
Sacramento Valley Water Year Classification
Sites Reservoir Project EIR/EIS

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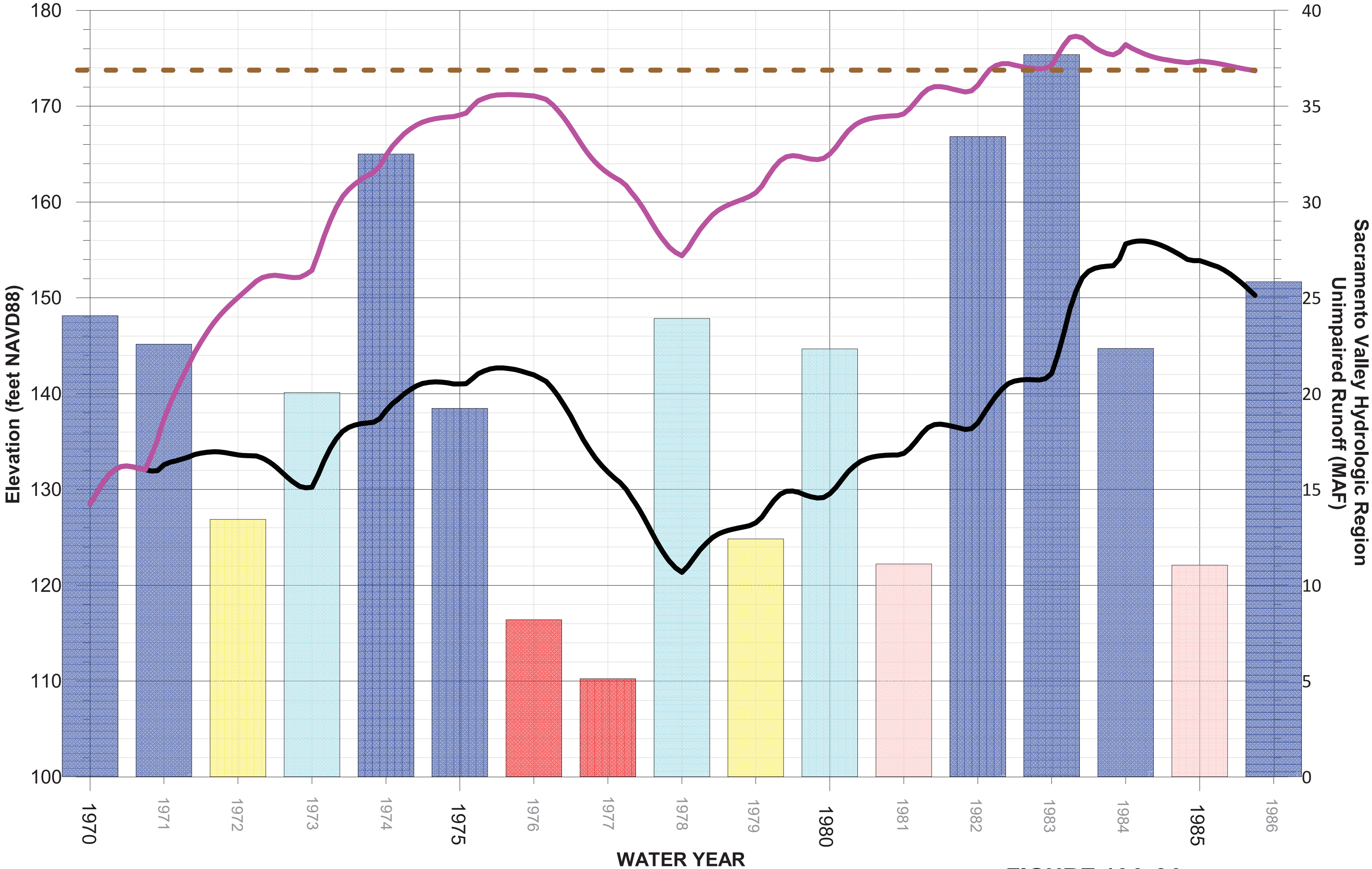

Wet Year
Above Normal Year
Below Normal Year
Dry Year
Critical Year
Simulated Groundwater Elevation (Baseline)
Simulated Groundwater Elevation (Alternative B)
Ground Surface Elevation

Notes:

1. Data Source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST
2. MAF = million acre-feet
3. NAVD88 = North American Vertical Datum of 1988

FIGURE 10A-2A
Simulated Groundwater Elevations versus Time Near the $SACFEM_{2013}$ Model Boundary
Sites Reservoir Project EIR/EIS

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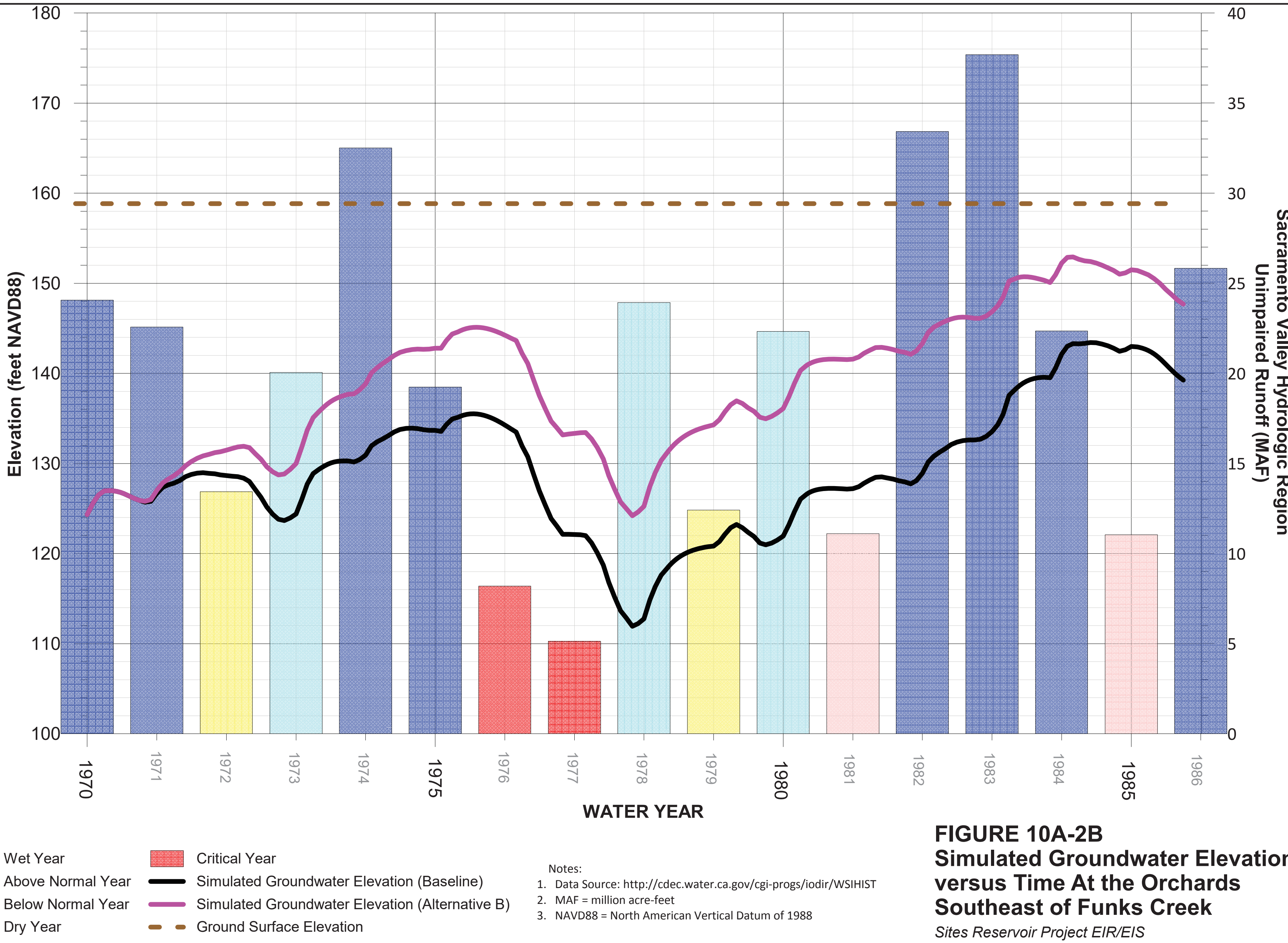

Notes:
1. Data Source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST
2. MAF = million acre-feet
3. NAVD88 = North American Vertical Datum of 1988

FIGURE 10A-2B
Simulated Groundwater Elevations versus Time At the Orchards Southeast of Funks Creek
Sites Reservoir Project EIR/EIS

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Figures 10A-3A and 10A-3B present the simulated increases in groundwater levels in the shallow aquifer for hydraulic conditions consistent with February 1980 and April 1983, respectively. In addition to groundwater level increases, these figures present the simulated areas of groundwater discharge to streams and low-lying topographic areas, and the spring 2016 depth to water measurements.
Figure 10A-3A presents the distribution of simulated increase in groundwater levels for February 1980, which represents the period of maximum difference in groundwater elevations between Alternative B and the Existing Conditions/No Project/No Action Condition. These data suggest that groundwater levels could increase nearly 35 feet along the western SACFEM_{2013} model boundary near Funks Creek.
Figure 10A-3B presents the distribution of simulated increase in groundwater levels for April 1983, which represents the period of highest groundwater elevations during the wettest year in the simulation period. These data suggest that groundwater levels could increase over 25 feet along the western SACFEM_{2013} model boundary near Funks Creek. As shown on Figures 10A-3A and 10A-3B, the distribution of larger magnitude increases in groundwater levels is restricted to the western margin of the Colusa Subbasin, with model forecast increases in groundwater levels of less than 0.5 foot over most of the Primary Study Area. Further, the spring 2016 depths to water posted on Figures 10A-3A and 10A-3B suggest that the depths to water are larger than model forecast increases in groundwater levels (DWR, 2017) where the data and contours coincide. Finally, Figures 10A-3A and 10A-3B present the areas where SACFEM_{2013} forecasts groundwater discharge to streams and low-lying areas. These data indicate that areas of groundwater levels at or near ground surface are primarily coincident with streams, flood bypasses, and wildlife refuges. Further, the model output suggests that there are a very limited number of locations where groundwater levels at or near ground surface are projected to occur under Alternative B through D that are not forecast to occur under the Existing Conditions/No Project/No Action Condition.

10A.2.4 Seepage Estimate Uncertainties

The seepage estimates described above are subject to uncertainty with respect to input values for Equation 1 and numerical model limitations. For example, increasing or decreasing the assumed horizontal hydraulic conductivity would result in proportional decreases or increases in the estimated reservoir seepage. The input parameters are within the mid-range of literature values (Freeze and Cherry, 1979) and are considered reasonable. Additionally, mathematical models can only approximate processes of physical systems. The models are inherently inexact because the mathematical description of the physical system is imperfect, the understanding of interrelated physical processes is incomplete, and the solution non-unique. SACFEM_{2013} incorporated as many details of the physical system as practicable and is considered a powerful tool that can provide useful insights into the physical processes of the aquifer system. However, the nodal resolution in the area of projected increases in groundwater levels is coarse (3,280 feet [1,000 meters]), lending a degree of uncertainty to the estimated increases in groundwater levels.

10A.3 Modeling to Evaluate Impacts of Sacramento River Diversions on Groundwater/Surface Water Interaction

The surface water and groundwater systems are strongly connected in the Primary and Secondary (Sacramento Valley Groundwater Basin) study areas and are highly variable spatially and temporally. Within the Sacramento Valley Groundwater Basin, the Sacramento and Feather Rivers act as drains and are recharged by groundwater throughout most of the year. The exceptions are areas of depressed groundwater elevations attributable to groundwater pumping (inducing leakage from the rivers) and localized recharge to the groundwater system. In contrast, the upper reaches of tributary streams flowing into the Sacramento River from upland areas are generally losing streams (they recharge the groundwater system). These tributary streams usually transition to gaining streams (they receive groundwater) farther downstream, closer to their confluences with the Sacramento or Feather Rivers. Estimates of these surface water and groundwater exchange rates have been developed for specific reaches on a limited number of streams in the Sacramento Valley Groundwater Basin (USGS, 1985), but a comprehensive Valley-wide accounting has not been performed to date. Changes in operation of the surface water conveyance and distribution system will result in changes in the nature and magnitude of the interaction between the Sacramento River and the underlying aquifer system.

Potential changes in groundwater and surface water interaction were evaluated using the CALSIM II surface water routing model in conjunction with the Central Valley Hydrologic Model (CVHM) (USGS, 2009). The Central Valley Hydrologic Model (CVHM) encompasses the alluvial deposits of the entire Central Valley extending from the Cascade Ranges on the north to the Tehachapi Mountains on the south. It is bounded on the east by the Sierra Nevada and on the west by the Coast Ranges (USGS, 2017a). The latest version of the model was downloaded from the USGS web site (USGS, 2016). The model is built on a USGS modification of MODFLOW-2000 (Harbaugh et al., 2000) that incorporates the farm package (Schmid et al., 2006).

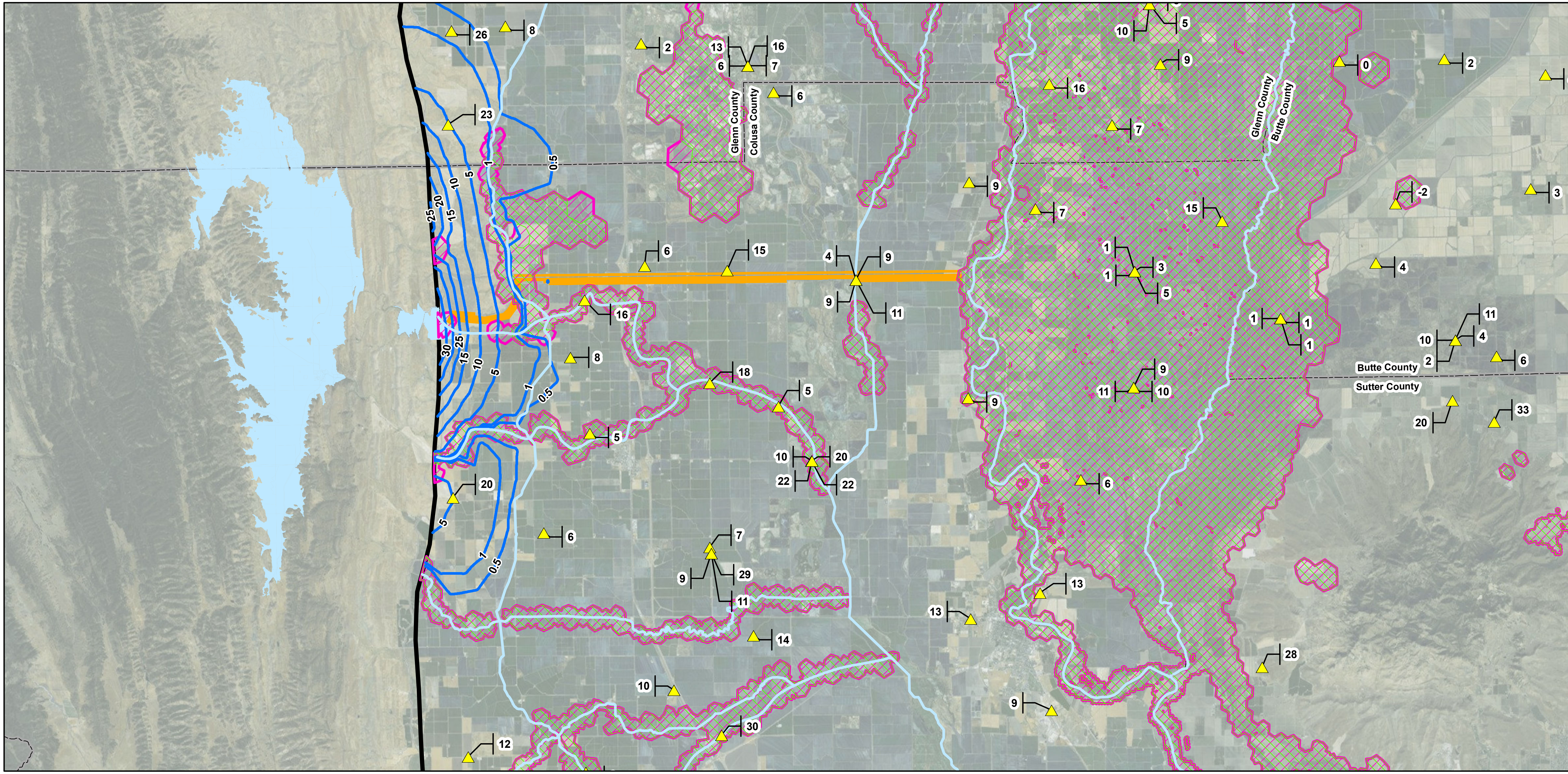
For the purposes of this analysis, the CVHM was modified to incorporate simulation results from the CALSIM II surface water model developed to evaluate the Project alternatives; refer to Appendix 6B Water Resources System Modeling for discussion of the CALSIM II model. Five simulations were performed, one for the Existing Conditions/No Project/No Action Condition (NAA), and one each for Alternatives A through D. The details of these alternatives are provided in EIR Chapter 2 Alternatives Analysis and EIR Chapter 3 Description of the Sites Reservoir Project Alternatives, and will only be discussed as needed herein.

10A.3.1 Modifications to the CVHM

The components of the modifications included the following:

Add three new diversions to the stream-flow routing package (SFR) to account for water needed to fill the Sites Reservoir. This includes new withdrawals from two existing diversions, the Tehama Colusa Canal (TCC) and the Glenn Colusa Canal (GCC), and one new diversion called the Delevan Pipeline (DEL). These diversions were unique for each of the five simulations (NAA plus Alternatives A through D). In NAA, the new diversions were set to zero throughout the simulation period.

- Modify existing semi-routed diversions to be consistent with CALSIM II. This included diversions to satisfy agricultural deliveries to the Corning, Tehama Colusa, and Glenn Colusa canals. Table 10A-1 indicates the relationship between CVHM SFR diversions and CALSIM II equivalent nodes. These diversions were unique for each of the five simulations that were performed.



Legend

- Spring 2016 Depth to Groundwater (feet bgs)
- SACFEM2013 Stream
- Simulated Change in Groundwater Level (feet)
- SACFEM2013 Model Boundary
- County Boundary
- Area of Groundwater Discharge Alternative B
- Area of Groundwater Discharge Existing Condition/No Project/No Action Condition

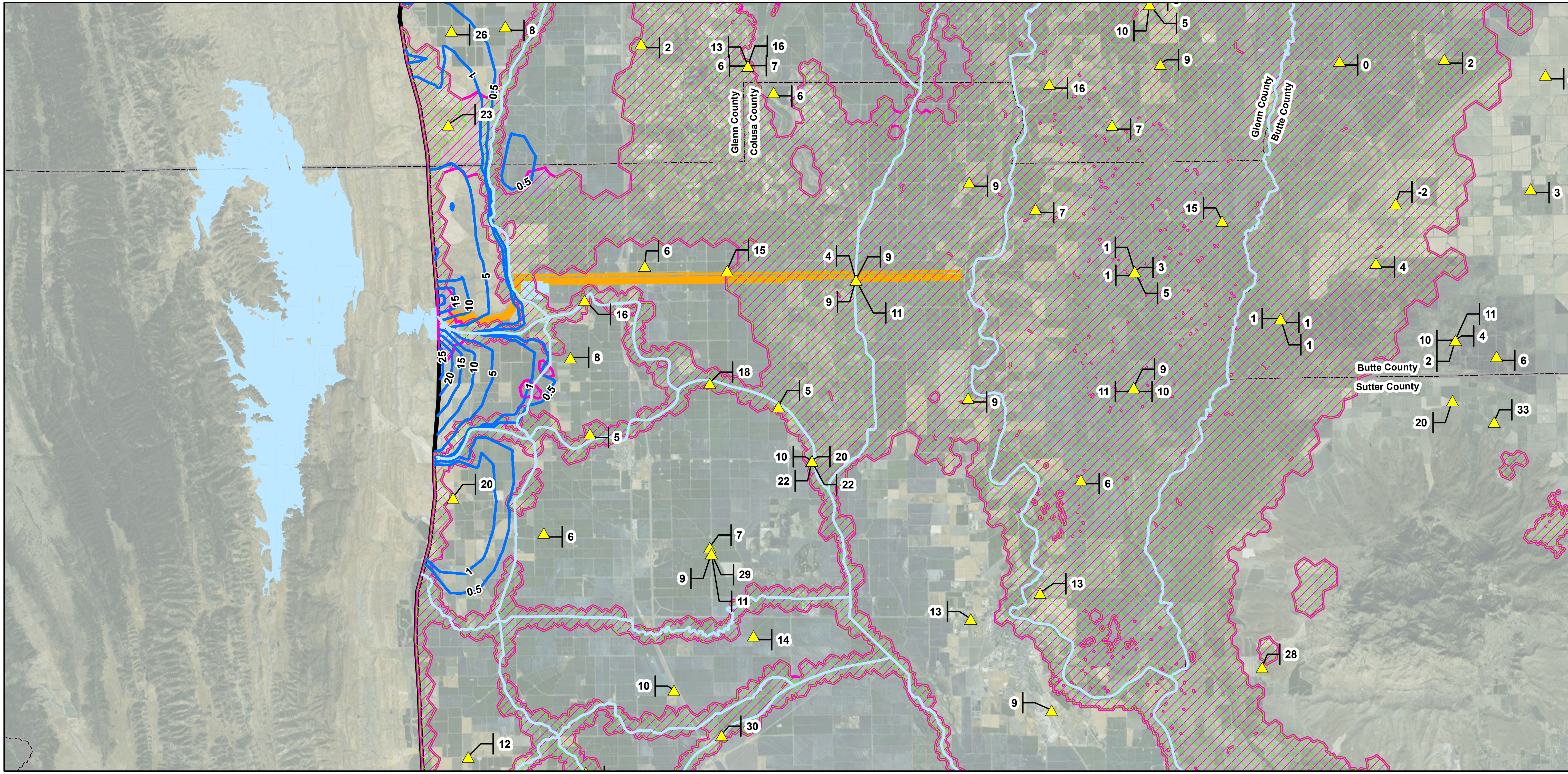
Select Project Features (Locations Approximate)

- Pipeline Construction Disturbance Area
- Reservoir

0 1.25 2.5 5
Miles

Notes:
1. Groundwater Subbasin Boundary and Spring 2016 Depth to Groundwater Source: https://gis.water.ca.gov/app/gicima/
2. bgs = below ground surface
3. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 10A-3A
Simulated Increase in Groundwater Level due to Seepage from Sites and Holthouse Reservoirs, Alternative B Shallow Aquifer, February 1980
Sites Reservoir Project EIR/EIS



Legend

- Spring 2016 Depth to Groundwater (feet bgs)
- SACFEM2013 Stream
- Simulated Change in Groundwater Level (feet)
- SACFEM2013 Model Boundary
- County Boundary
- Area of Groundwater Discharge Alternative B
- Area of Groundwater Discharge Existing Condition/No Project/No Action Condition

Select Project Features (Locations Approximate)

- Pipeline Construction Disturbance Area
- Reservoir

N

0 1.25 2.5 5
Miles

Notes:
1. Groundwater Subbasin Boundary and Spring 2016 Depth to Groundwater Source: https://gis.water.ca.gov/app/gicima/
2. bgs = below ground surface
3. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 10A-3B
Simulated Increase in Groundwater Level due to Seepage from Sites and Holthouse Reservoirs, Alternative B Shallow Aquifer, April 1983
Sites Reservoir Project EIR/EIS

- Add non-routed deliveries to two farming water-balance sub-regions (see Table 10A-1) in CVHM, out of a total of 21, per CALSIM II calculation. These sub-regions are described in the CVHM documentation (USGS, 2017b). The relationship between the two sub-regions that receive non-routed deliveries and the CVHM diversions in the SFR package are also shown in Table 10A-1. These deliveries were non-zero only for Project Alternative D.
- Add 12 additional gage locations downgradient of each new diversion to allow for calculation of the changes in Sacramento River stage due to surface water diversions associated with each of the Project alternatives. These additional gages were at the same locations in all five simulations, so that results were comparable. Table 10A-2 indicates the row-column locations of the gages within the CVHM model in order of their downgradient locations.

Table 10A-1
Relationship Between CVHM Nodes, CALSIM II Nodes, and CVHM Farm Package Sub-regions
Sites Project CVHM Modeling Documentation

CVHM Diversion Node	CALSIM II Equivalent Node	CVHM Description	CVHM Farm Package Sub-region
CORN_0232	D171	Corning Canal	2
TE10_0232	D172	Tehama Colusa Canal	3
TE12_0323	D174 + D178	Tehama Colusa Canal	3
GLEN_0261	D143A + D145A	Glenn Colusa Canal	3

Table 10A-2
Model Row and Column Locations of New Gages for River Stage Output
Sites Project CVHM Modeling Documentation

Sites Diversion	Approximate Downgradient Distance (Miles)	Model Row Location of Sacramento River Node	Model Column Location of Sacramento River Node
TCC	1[a]	41	79
TCC	2	42	78
TCC	3	43	78
TCC	4	44	78
TCC	5	44	77
TCC	6	45	77
TCC	7	46	77
TCC	8	46	76
TCC	9	47	76
TCC	10	47	77
TCC	11	48	76
TCC	12	49	76
GCC	1[a]	59	72
GCC	2	60	72
GCC	3	61	73
GCC	4	61	72
GCC	5	62	72

Sites Diversion	Approximate Downgradient Distance (Miles)	Model Row Location of Sacramento River Node	Model Column Location of Sacramento River Node
GCC	6	63	72
GCC	7	64	72
GCC	8[b]	65	72
GCC	9[b]	66	72
GCC	10[b]	66	73
GCC	11[b]	67	73
GCC	12[b]	68	73
DEL	1[A]	87	56
DEL	2	88	55
DEL	3	88	56
DEL	4	89	56
DEL	5	89	55
DEL	6	90	54
DEL	7	90	55
DEL	8	91	55
DEL	9	91	54
DEL	10	92	53
DEL	11	92	54
DEL	12	93	54

[a] The first model cell for each diversion's new gages was the cell of the diversion itself. Subsequent cells are the consecutive model cells of the Sacramento River in the model, downgradient of the diversion.

[b] The baseline USGS version of the CVHM model has inactive groundwater cells in model layer 1.

The USGS's CVHM simulates Central Valley groundwater conditions from April 1961 through September 2003. Thus, by applying the above modifications, the Project adaptation of the CVHM model is a hybrid of past conditions and various future additions associated with the Project. These simulations are therefore not necessarily forecasts of future groundwater and surface water conditions in the valley, but nevertheless, the potential effects of the four Project Alternatives A through D on groundwater and surface water can be compared against the NAA with this modeling tool, because all of these alternatives are implemented upon the same baseline, which is the USGS CVHM.

The results of the simulations were processed through Zonebudget (Harbaugh, 1990) and GW-Chart (Winston, 2000) to collect the relevant groundwater-surface water exchange data out of the raw cell-by-cell flow terms and water budgets. The purpose of this post-processing was to estimate the changes in flows due to the projects at the same 12 nodes downgradient of the three Sites-filling diversions (Table 10A-2). These flow changes, along with the corresponding groundwater head and Sacramento River stage changes, were the basis for assessing the potential Project impacts to groundwater and surface water via the CVHM. The difference between the groundwater-surface water exchange of a Project alternative and the NAA was calculated for three cumulative distances downstream: 5 miles, 10 miles, and 12 miles. This was done to forecast how the groundwater-surface water exchange might change downstream of each diversion as a result of the Project alternatives.

10A.3.2 Results

For all Project alternatives, simulated heads and Sacramento River stages downgradient of the Project diversions were compared to the NAA after 4.2 years, 24.8 years, and 39.2 years of simulation, reflecting early, middle, and late stages of the 40-year Project simulation period. Groundwater-surface water interaction water budget terms were also reviewed.

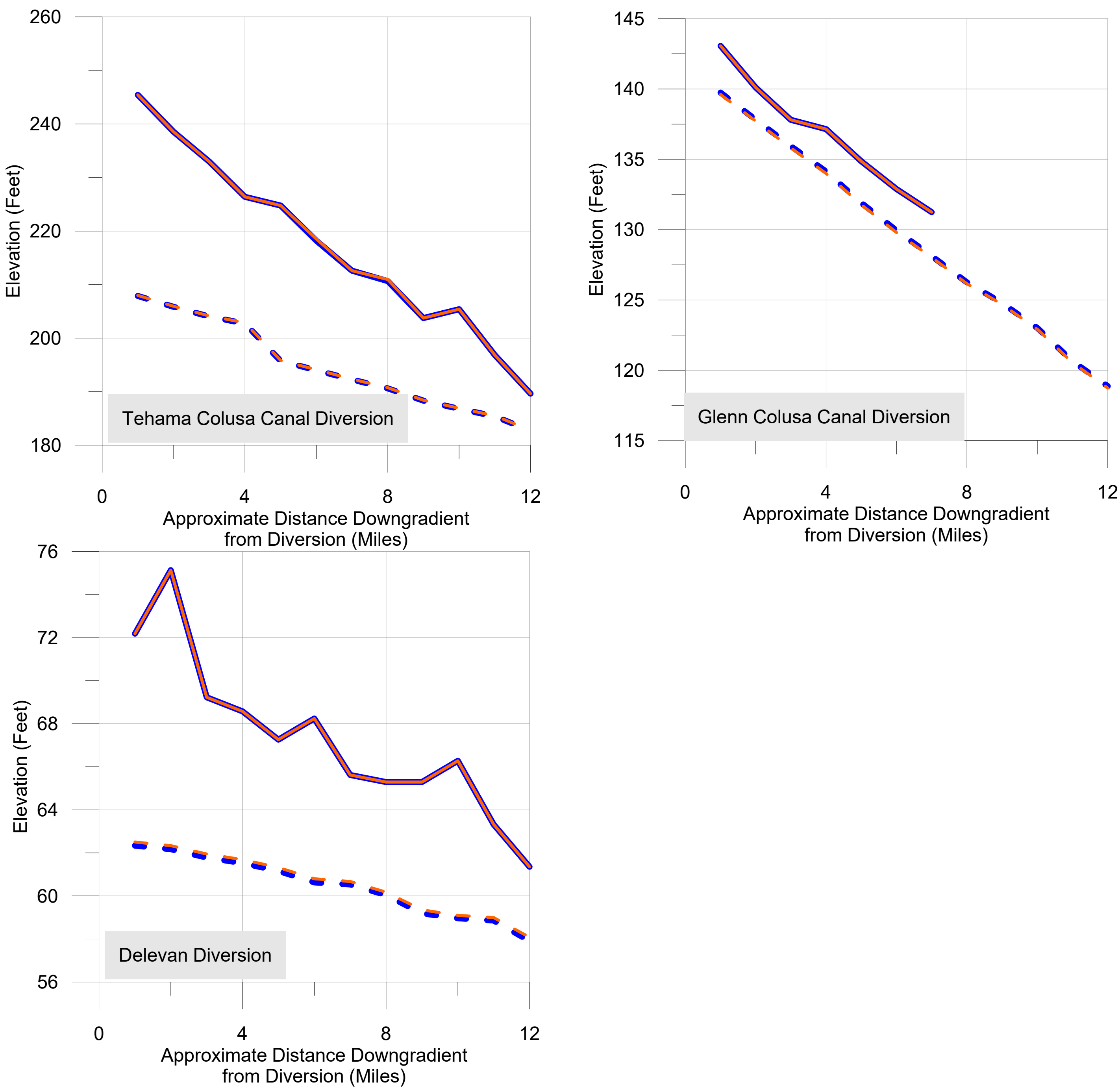
The plots of heads downgradient of the GCC diversion in the following section are truncated at 7 miles downstream, whereas the stages at GCC, and both the heads and stages at the other diversions, are continued out to 12 miles downstream. The reason for this truncation of GCC heads is that the USGS CVHM has inactive cells in model layer 1 for the subsequent downgradient reach of the river at this location. Given that the analysis indicates little difference between NAA and the Project alternatives groundwater heads in the active cells, it is assumed that turning on these cells would have made very little difference.

10A.3.2.1 Alternative A

Figures 10A-4 through 10A-6 present plots of CVHM simulated Sacramento River stage and underlying groundwater elevations with distance for the two diversions and one intake/discharge facility, for Alternative A and the NAA, for the three snapshots in time that were compared (4.2 years, 24.8 years, and 39.2 years). The middle time, 24.8 years, had the greatest simulated differences in river stage and groundwater elevations. As shown on Figure 10A-5, the simulated Sacramento River stages and groundwater elevations for the Existing Conditions/No Project/No Action Condition and Alternative A are very similar (Alternative A simulated stages are nearly identical and groundwater elevations are up to 1.1 feet lower) for the Red Bluff Pumping Plant and GCID Canal intakes. For the Delevan Pipeline Intake, CVHM simulations show that stream stage for Alternative A is less than one foot lower than the Existing Conditions/No Project/No Action Condition, and groundwater elevations for Alternative A are up to 3.8 feet lower compared to the Existing Conditions/No Project/No Action Condition. Figure 10A-7 presents plots of changes in groundwater/surface water interaction over time at three distances downstream from the diversions. CVHM results show that for Alternative A there would be an increase in groundwater recharge of up to 3 cubic feet per second (cfs) at the Red Bluff Pumping Plant and GCID Canal intakes compared to the Existing Conditions/No Project/No Action Condition. The average annual volumetric difference in groundwater/surface water exchange between the NAA and Alternative A is forecasted by the CVHM to be 0.25% at TCC, and 2.0% at GCC. At the Delevan Pipeline intake under Alternative A, groundwater recharge will be reduced by less than 40 cfs in most months, with a maximum decrease of approximately 140 cfs compared to the Existing Conditions/No Project/No Action Condition. The average annual volumetric difference in groundwater/surface water exchange between the NAA and Alternative A is forecasted by the CVHM to be 0.44% at the Delevan Pipeline intake. The model forecast changes in Sacramento River stage, underlying groundwater elevations, and groundwater/surface water interaction under Alternative A are negligible to minor as compared to the Existing Conditions/No Project/No Action Condition.

10A.3.2.2 Alternative B

Figures 10A-8 through 10A-10 presents plots of CVHM simulated Sacramento River stage and underlying groundwater elevations with distance for the two diversions and one discharge facility, for Alternative B and the NAA, for the three snapshots in time that were compared (4.2 years, 24.8 years, and 39.2 years). The middle time, 24.8 years, again had the greatest simulated differences in river stage and groundwater elevations. As shown on Figure 10A-9, the simulated Sacramento River stages and groundwater elevations for the Existing Conditions/No Project/No Action Condition and Alternative B were very similar (Alternative B simulated stages for Alternative B are almost identical to the Existing Conditions/No Project/No Action Condition and groundwater elevations are up to 2.5 feet lower under Alternative B than for the Existing Conditions/No Project/No Action Condition) for the Red Bluff Pumping Plant and GCID Canal intakes. At the Delevan Pipeline discharge facility, CVHM simulations for Alternative B show a decrease in stream stage of up to 1 foot and a decrease in groundwater elevations of up to 5.5 feet. Figure 10A-11 presents plots of changes in groundwater/surface water interaction over time at three distances downstream from the diversions and discharge facility under Alternative B. Maximum projected increases of up to 3 cfs in groundwater recharge are simulated under Alternative B (compared to the Existing Conditions/No Project/No Action Condition) at the Red Bluff Pumping Plant. At the GCID Canal intakes, the changes in groundwater recharge under alternative B range from increases of up to 2 cfs to decreases of up to 1.5 cfs compared to the Existing Conditions/No Project/No Action Condition. The average annual volumetric difference in groundwater/surface water exchange between the NAA and Alternative B is forecasted by the CVHM to be 0.22% at TCC, and 2.3% at GCC. At the Delevan Pipeline discharge facility, increases and decreases in groundwater/surface water interaction were less than 40 cfs in most months, with a maximum of approximately 125 cfs compared to the Existing Conditions/No Project/No Action Condition). The average annual volumetric difference in groundwater/surface water exchange between the NAA and Alternative B is forecasted by the CVHM to be 0.32% at the Delevan Pipeline intake. The model forecast changes in Sacramento River stage, underlying groundwater elevations, and groundwater/surface water interaction under Alternative B are negligible to minor as compared to the Existing Conditions/No Project/No Action Condition.



Legend

- River Stage, No Action Alternative
- Groundwater Elevation, No Action Alternative
- River Stage, Alternative A
- Groundwater Elevation, Alternative A

FIGURE 10A-4
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 4.2 Years for Alternative A and No Action Alternative
Sites Reservoir Project EIR/EIS

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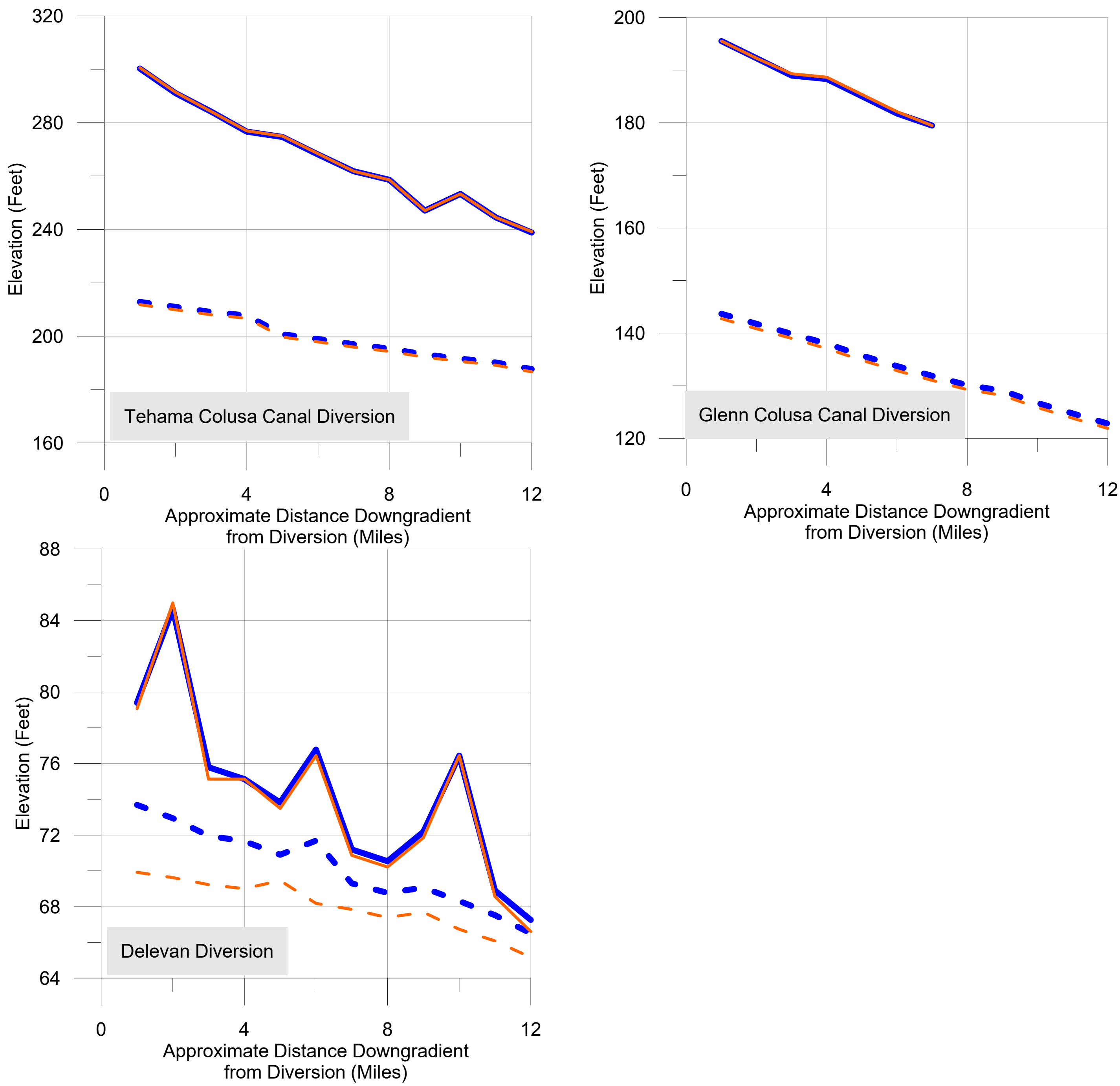

Legend

- River Stage, No Action Alternative
- Groundwater Elevation, No Action Alternative
- River Stage, Alternative A
- Groundwater Elevation, Alternative A

FIGURE 10A-5
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 24.8 Years for Alternative A and No Action Alternative
Sites Reservoir Project EIR/EIS

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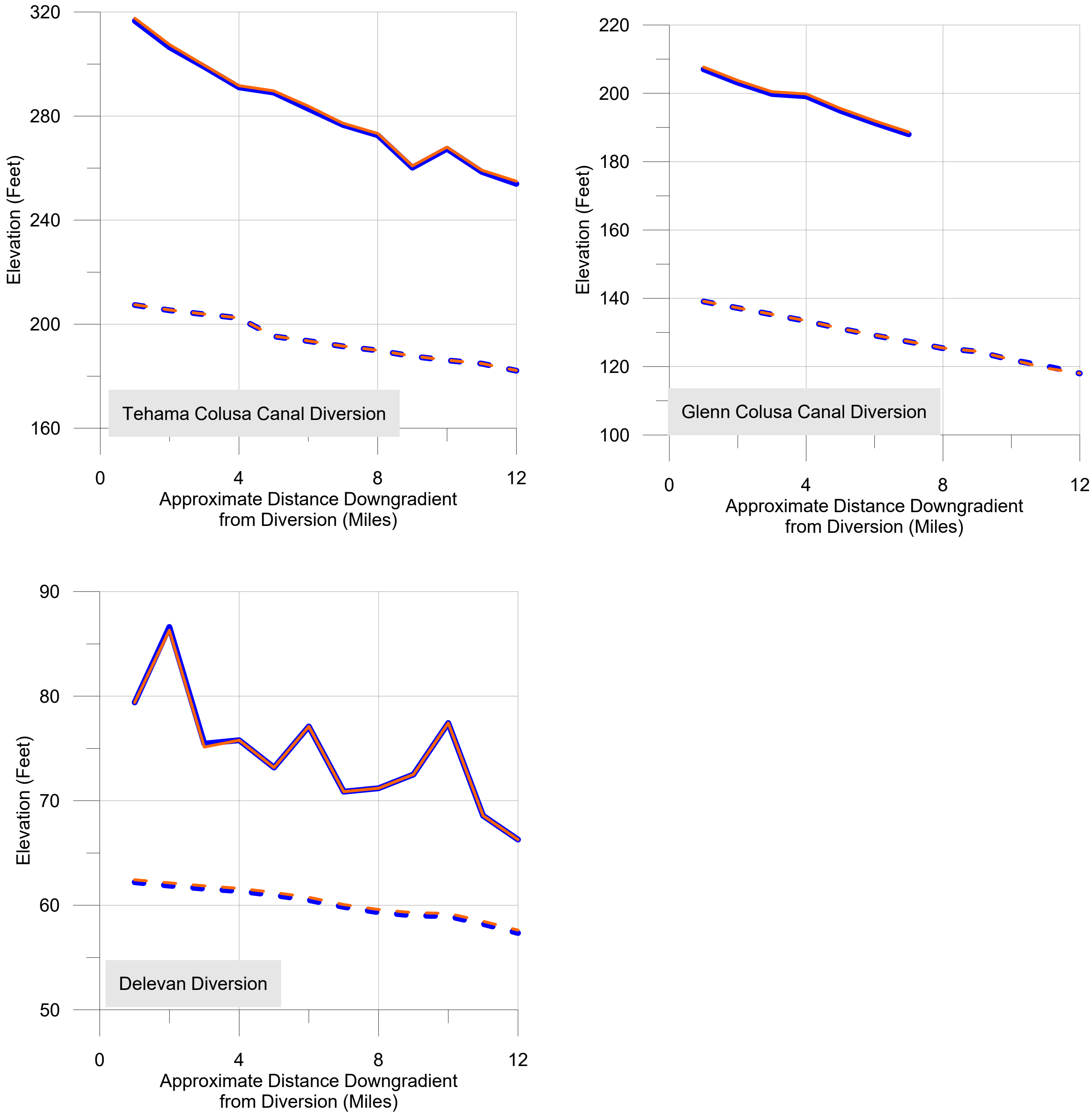

Legend

- River Stage, No Action Alternative
- Groundwater Elevation, No Action Alternative
- River Stage, Alternative A
- Groundwater Elevation, Alternative A

FIGURE 10A-6
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 39.2 Years for Alternative A and No Action Alternative
Sites Reservoir Project EIR/EIS

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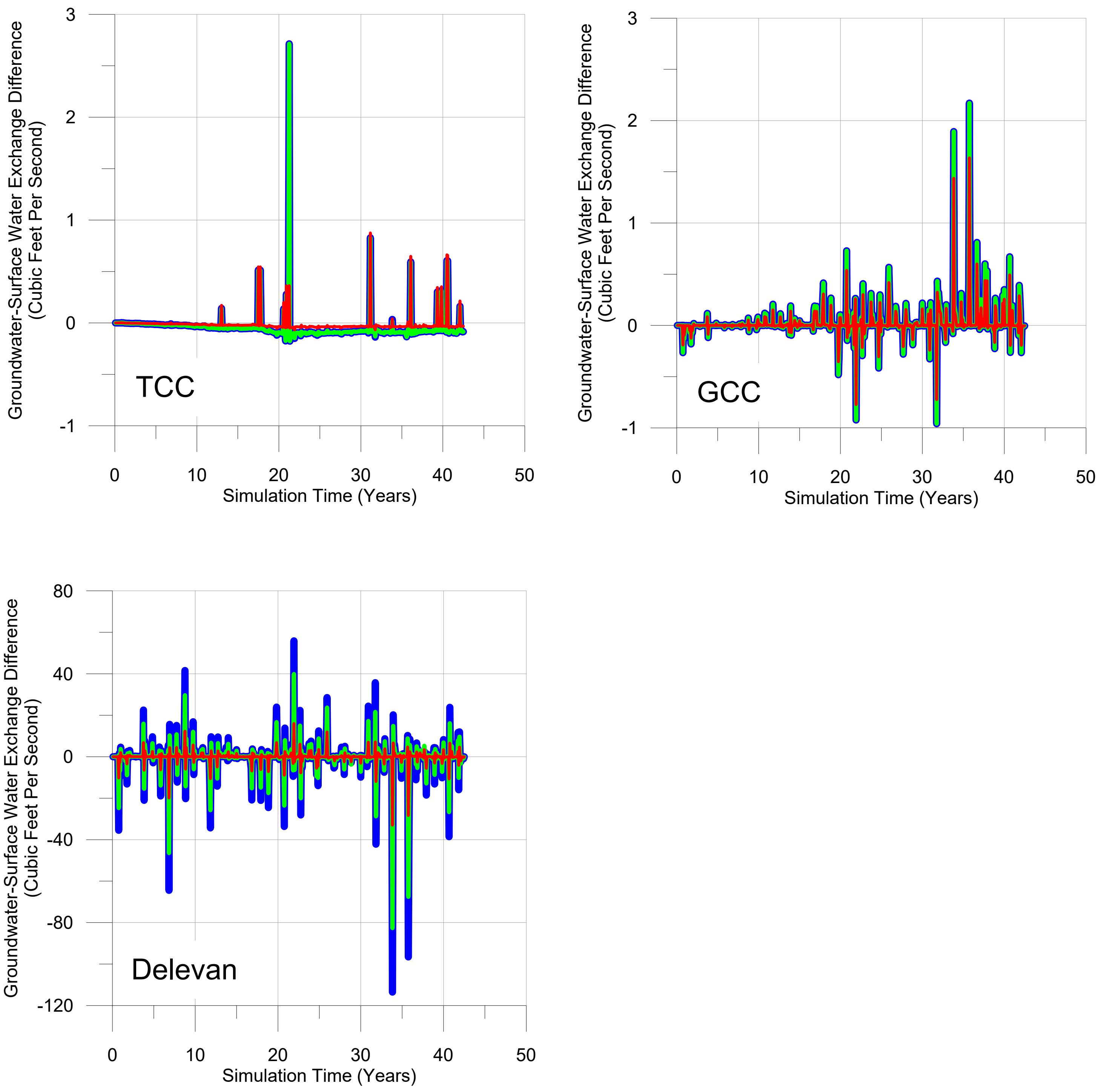

FIGURE 10A-7
Groundwater-Surface Water Exchange Differences between Sites Alternative A and No Action Alternative
Sites Reservoir Project EIR/EIS

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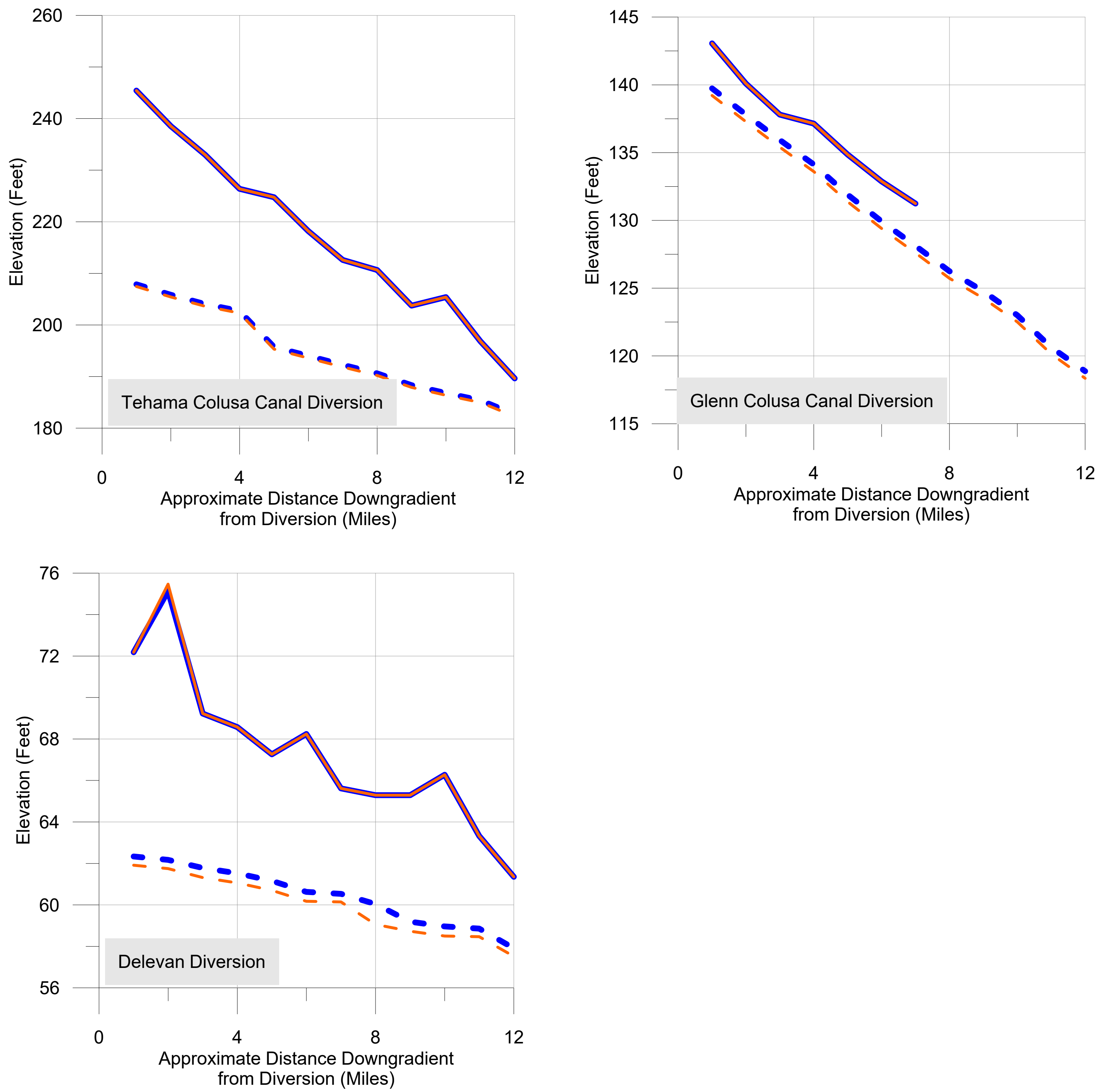

Legend

- River Stage, No Action Alternative
- Groundwater Elevation, No Action Alternative
- River Stage, Alternative B
- Groundwater Elevation, Alternative B

FIGURE 10A-8
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 4.2 Years for Alternative B and No Action Alternative
Sites Reservoir Project EIR/EIS

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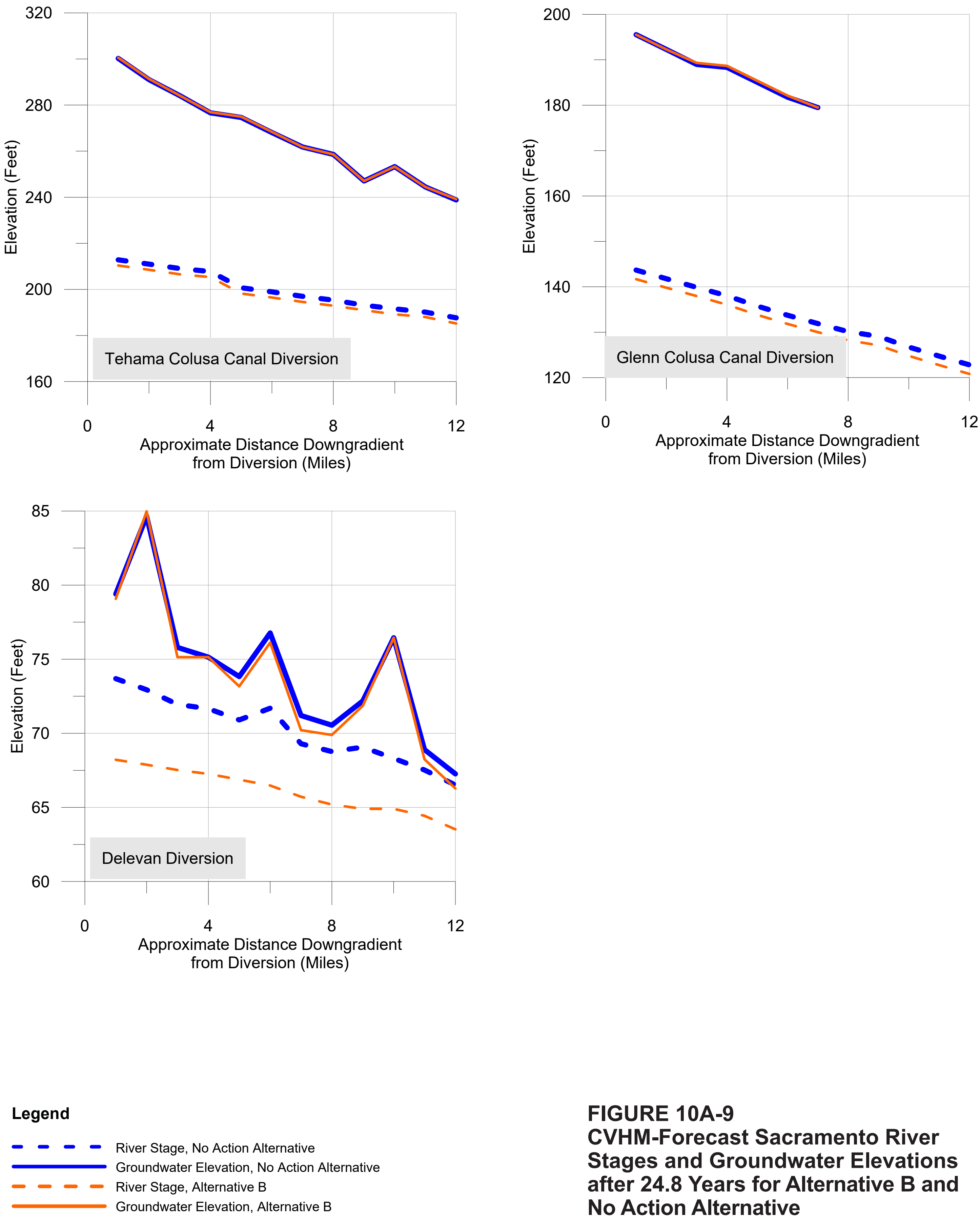

FIGURE 10A-9
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 24.8 Years for Alternative B and No Action Alternative
Sites Reservoir Project EIR/EIS

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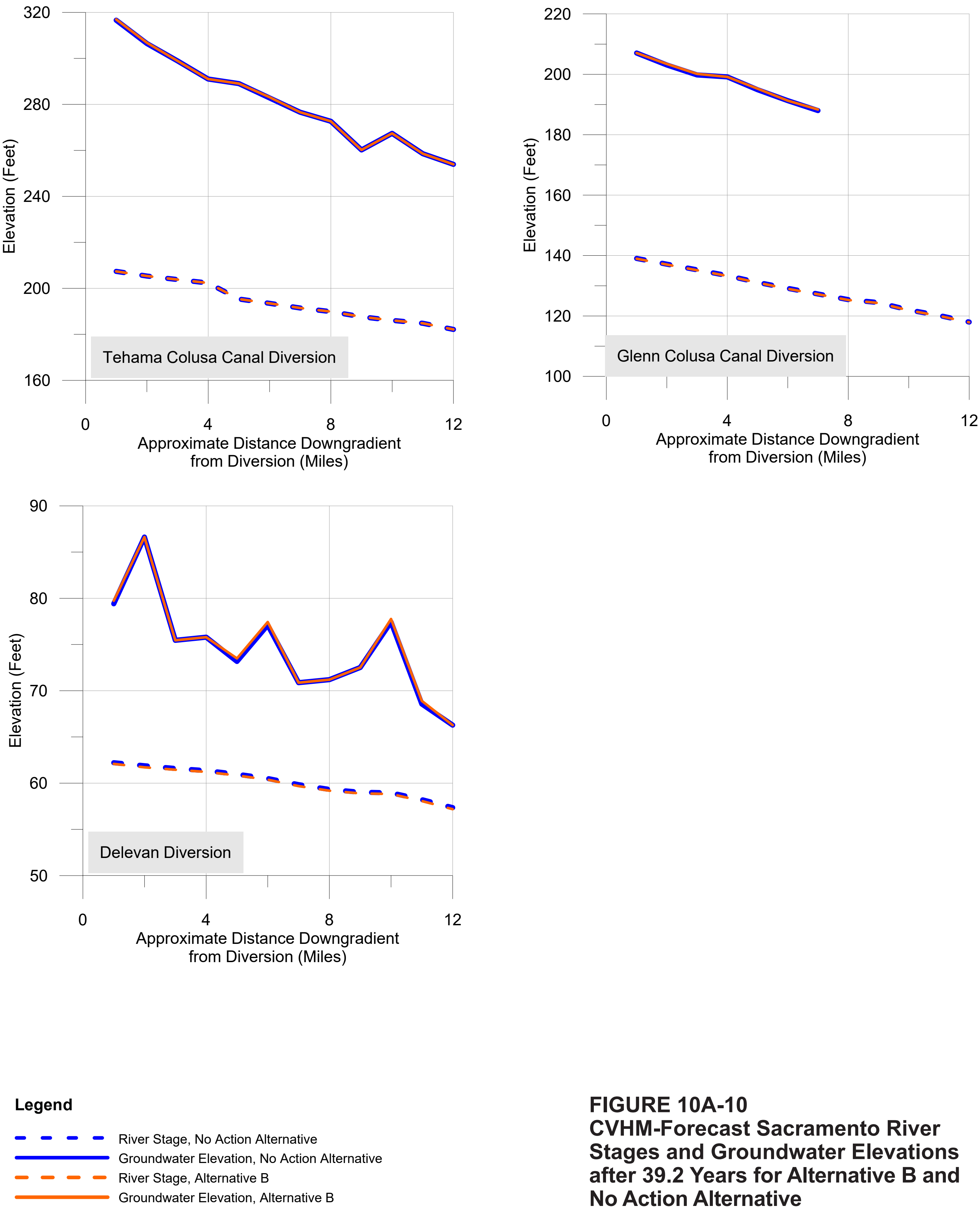

FIGURE 10A-10
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 39.2 Years for Alternative B and No Action Alternative
Sites Reservoir Project EIR/EIS

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10A.3.2.3 Alternative C

Figures 10A-12 through 10A-14 presents plots of CVHM simulated Sacramento River stage and underlying groundwater elevations with distance for the two diversions and one discharge facility, for Alternative C and the NAA, for the three snapshots in time that were compared. The middle time period, 24.8 years, again had the greatest simulated differences in river stage and groundwater elevations. As shown on Figure 10A-13, the simulated Sacramento River stages and groundwater elevations for the Existing Conditions/No Project/No Action Condition and Alternative C were very similar. Simulated Sacramento River stages for Alternative C are almost identical to the Existing Conditions/No Project/No Action Condition and groundwater elevations are up to 2.3 feet lower under Alternative C than for the Existing Conditions/No Project/No Action Condition) for the Red Bluff Pumping Plant and GCID Canal intakes. At the Delevan Pipeline discharge facility, CVHM simulations for Alternative C show a decrease in stream stage of up to 5.6 feet and a decrease in groundwater elevations of up to 1 foot. Figure 10A-15 presents plots of changes in groundwater/surface water interaction over time at three distances downstream from the diversions and discharge facility under Alternative C. Maximum projected increases of up to 3 cfs in groundwater recharge are simulated under Alternative C (compared to the Existing Conditions/No Project/No Action Condition) at the Red Bluff Pumping Plant. At the GCID Canal intakes, the changes in groundwater recharge under alternative C range from increases of up to 2 cfs to decreases of up to 2 cfs compared to the Existing Conditions/No Project/No Action Condition. The average annual volumetric difference in groundwater/surface water exchange between the NAA and Alternative C is forecasted by the CVHM to be 0.30% at TCC, and 1.4% at GCC. At the Delevan Pipeline discharge facility, increases and decreases in groundwater/surface water interaction were less than 40 cfs in most months, with a maximum increase of nearly 80 cfs and decrease of nearly 120 cfs (compared to the Existing Conditions/No Project/No Action Condition). The average annual volumetric difference in groundwater/surface water exchange between the NAA and Alternative C is forecasted by the CVHM to be 0.08% at the Delevan Pipeline intake. As shown on Figures 10A-12 through 10A-15, the model forecast changes in Sacramento River stage, underlying groundwater elevations, and groundwater/surface water interaction under Alternative C are negligible to minor as compared to the Existing Conditions/No Project/No Action Condition

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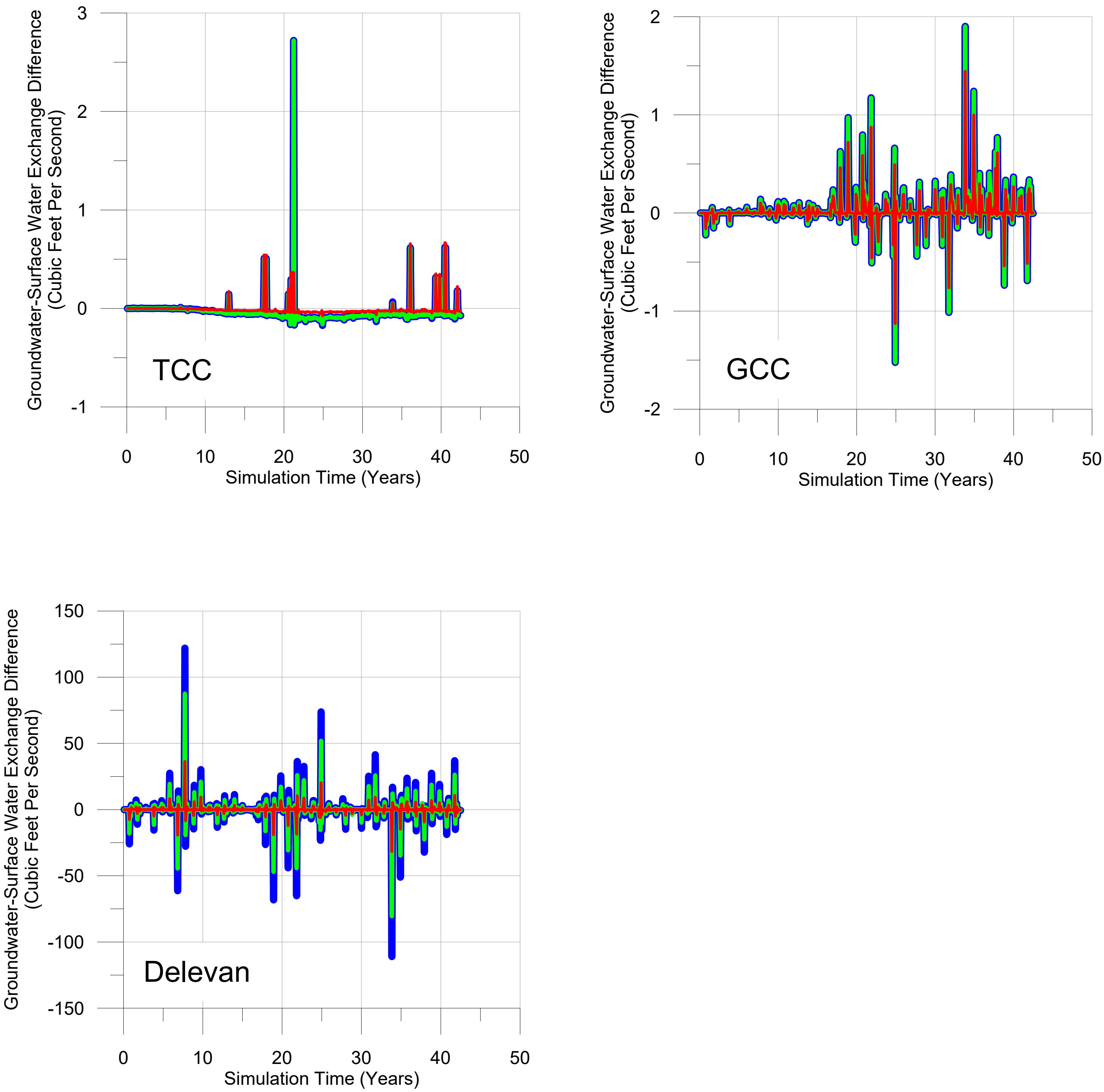

Legend

- 5 Model Cells (~5 miles)
- 10 Model Cells (~10 miles)
- 12 Model Cells (~12 miles)

FIGURE 10A-11
Groundwater-Surface Water Exchange Differences between Sites Alternative B and No Action Alternative
Sites Reservoir Project EIR/EIS

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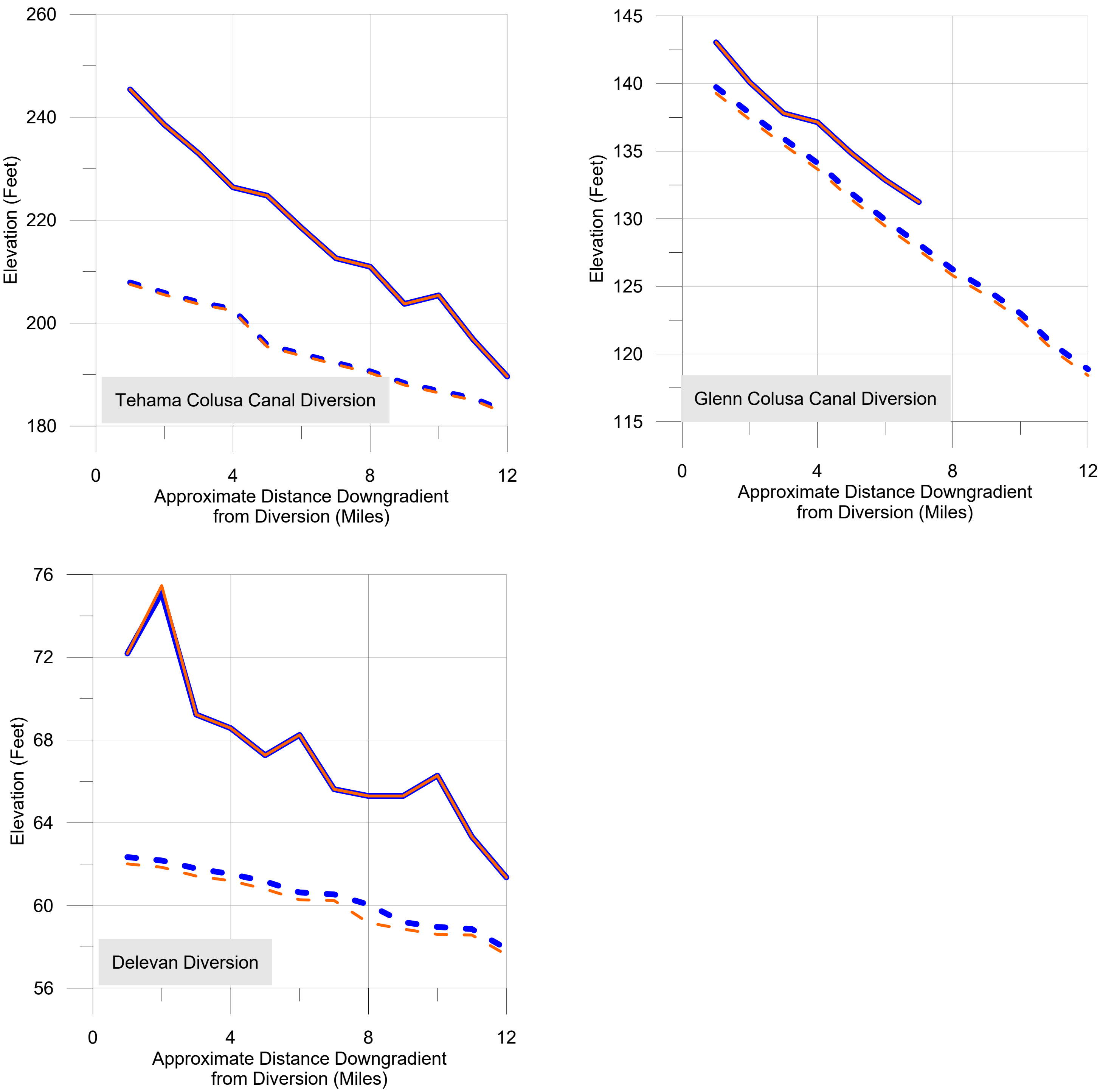

FIGURE 10A-12
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 4.2 Years for Alternative C and No Action Alternative
Sites Reservoir Project EIR/EIS

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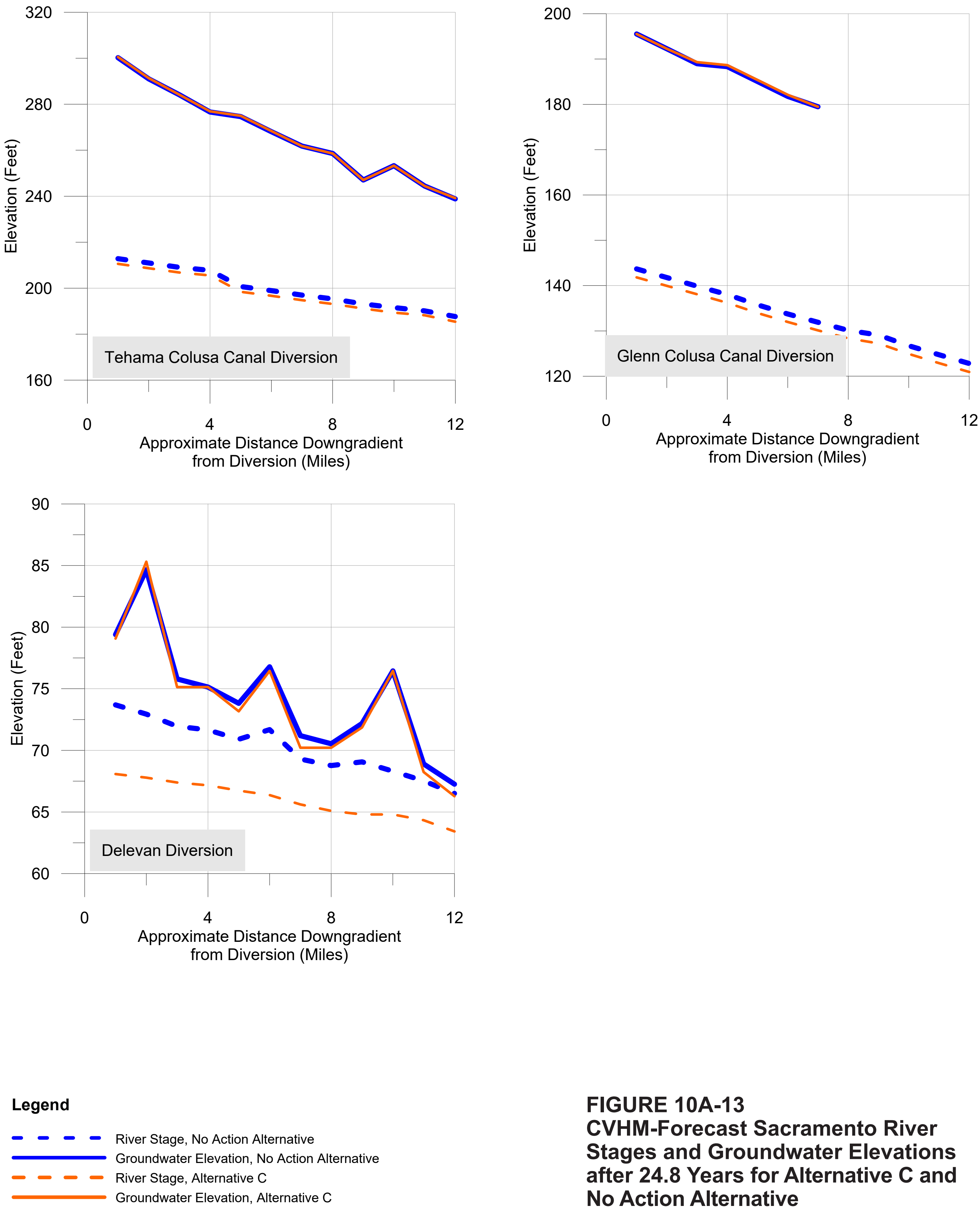

FIGURE 10A-13
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 24.8 Years for Alternative C and No Action Alternative
Sites Reservoir Project EIR/EIS

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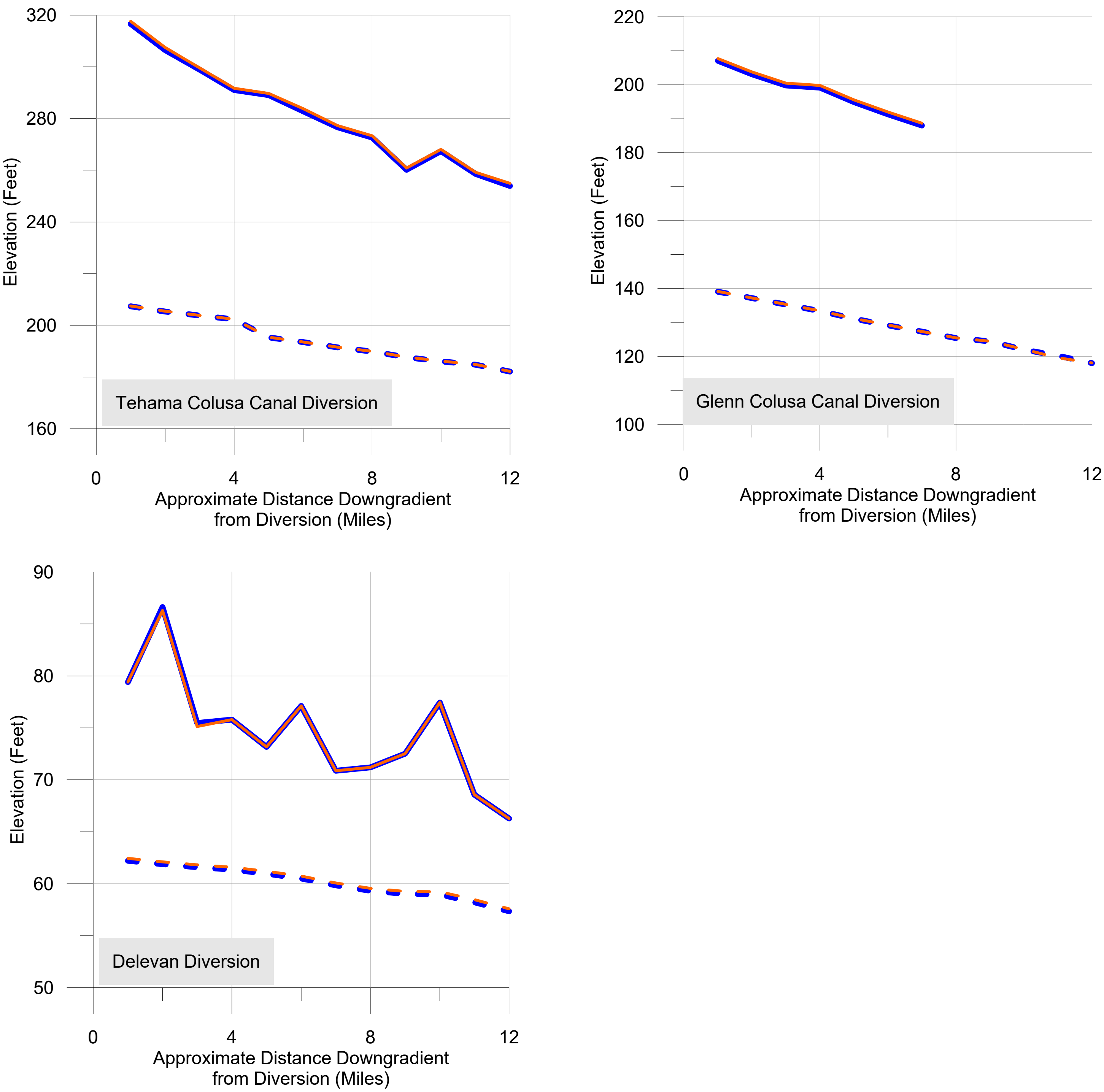

Legend

- River Stage, No Action Alternative
- Groundwater Elevation, No Action Alternative
- River Stage, Alternative C
- Groundwater Elevation, Alternative C

FIGURE 10A-14
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 39.2 Years for Alternative C and No Action Alternative
Sites Reservoir Project EIR/EIS

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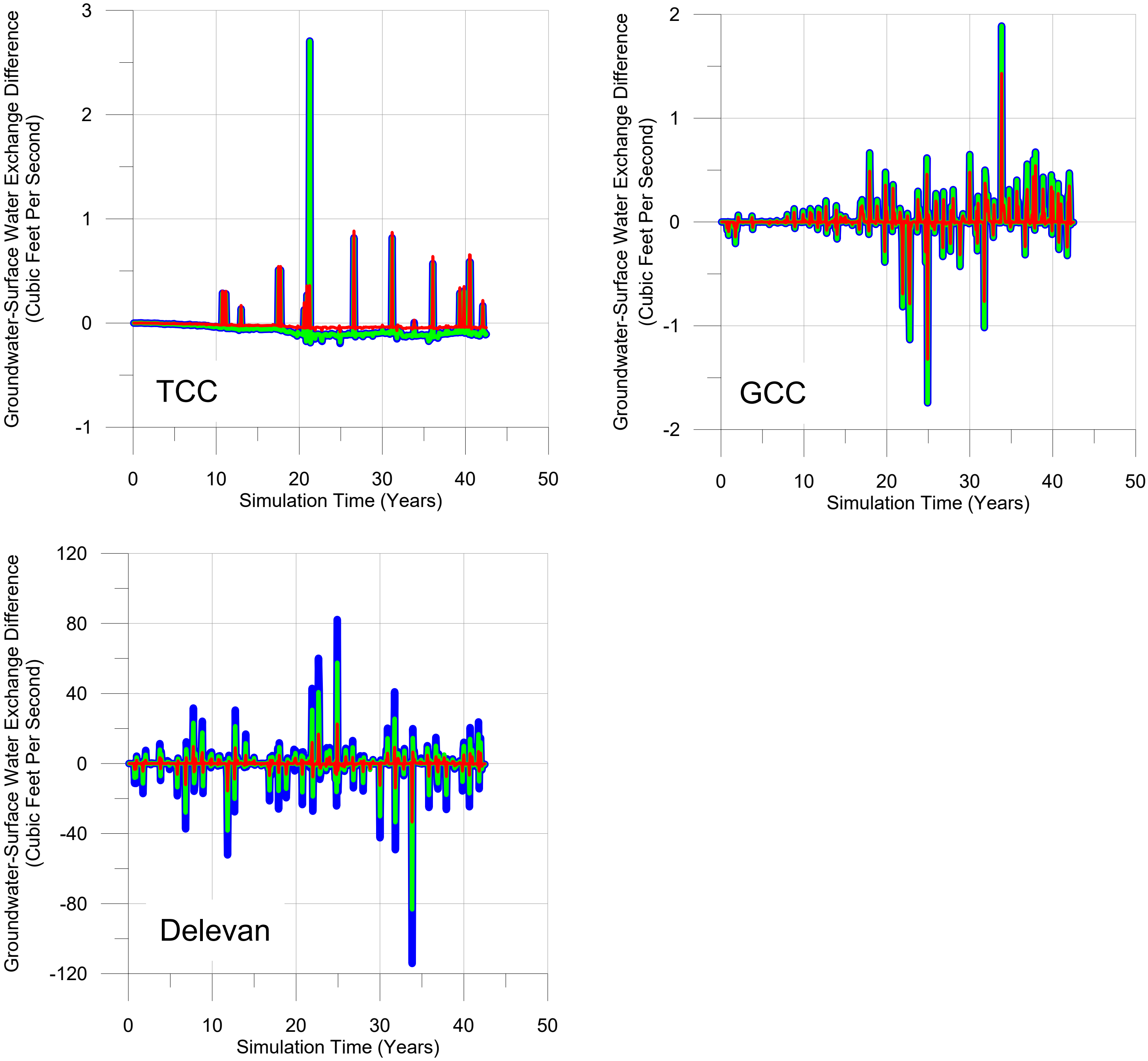

Legend

- 5 Model Cells (~5 miles)
- 10 Model Cells (~10 miles)
- 12 Model Cells (~12 miles)

FIGURE 10A-15
Groundwater-Surface Water Exchange Differences between Sites Alternative C and No Action Alternative
Sites Reservoir Project EIR/EIS

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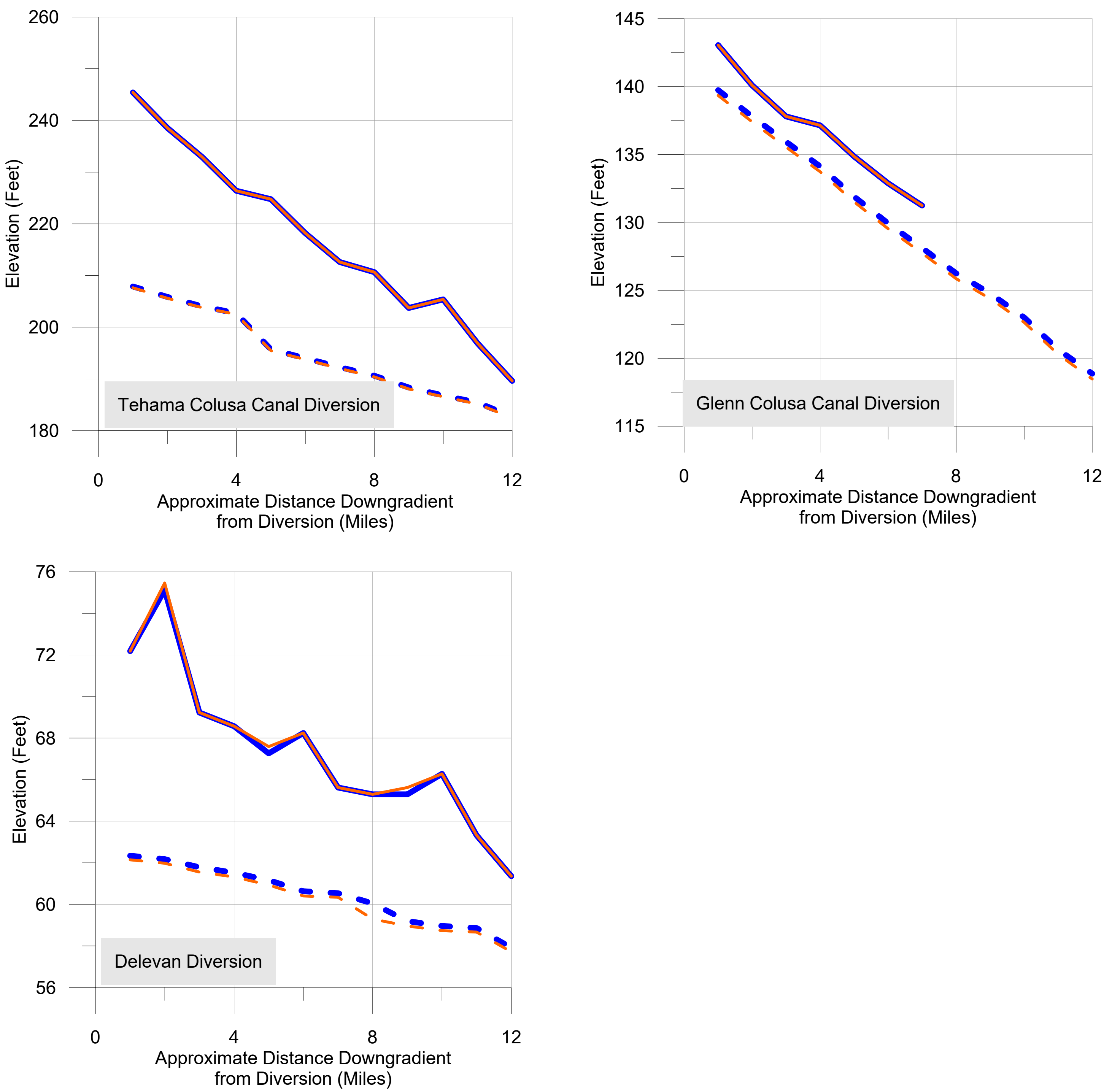
10A.3.2.4 Alternative D

Figures 10A-16 through 10A-18 presents plots of CVHM simulated Sacramento River stage and underlying groundwater elevations with distance for the two diversions and one discharge facility, for Alternative D and the NAA, for the three snapshots in time that were compared. The middle time period, 24.8 years, again had the greatest simulated differences in river stage and groundwater elevations. As shown on Figure 10A-17, the simulated Sacramento River stages and groundwater elevations for the Existing Conditions/No Project/No Action Condition and Alternative D were very similar. Simulated Sacramento River stages for Alternative D and groundwater elevations are almost identical to the Existing Conditions/No Project/No Action Condition (up to 0.2 feet higher) for the Red Bluff Pumping Plant and GCID Canal intakes. At the Delevan Pipeline discharge facility, CVHM simulations for Alternative D show an increase in stream stage of up to 0.3 feet and an increase in groundwater elevations of up to 3 feet. Figure 10A-19 presents plots of changes in groundwater/surface water interaction over time at three distances downstream from the diversions and discharge facility under Alternative D. Maximum projected increases of up to 3 cfs in groundwater recharge are simulated under Alternative D (compared to the Existing Conditions/No Project/No Action Condition) at the Red Bluff Pumping Plant. At the GCID Canal intakes, the changes in groundwater recharge under alternative C range from increases of up to 1.5 cfs to decreases of up to 1.5 cfs compared to the Existing Conditions/No Project/No Action Condition. The average annual volumetric difference in groundwater/surface water exchange between the NAA and Alternative D is forecasted by the CVHM to be 0.22% at TCC, and 1.4% at GCC. At the Delevan Pipeline discharge facility, increases and decreases in groundwater/surface water interaction were less than 20 cfs in most months, with a maximum increase of nearly 60 cfs and decrease of nearly 60 cfs (compared to the Existing Conditions/No Project/No Action Condition). The average annual volumetric difference in groundwater/surface water exchange between the NAA and Alternative D is forecasted by the CVHM to be 0.23% at the Delevan Pipeline intake. As shown on Figures 10A-16 through 10A-19, the model forecast changes in Sacramento River stage, underlying groundwater elevations, and groundwater/surface water interaction under Alternative D are negligible to minor as compared to the Existing Conditions/No Project/No Action Condition

10A.3.2.5 Combined Analysis

Overall, the plots discussed above suggest that the volumetric and head/stage differences between the Project alternatives and the NAA in the vicinity of the Sites diversions are relatively small. Furthermore, these results suggest that there is generally small differences between the Project alternatives, because their heads, stages, and groundwater-surface water exchanges are forecasted to be similar to the NAA for each alternative. While the Sacramento River stage is lower for the Project Alternatives under most of the conditions that were investigated, the model forecasts that the difference is a fraction of a foot under most circumstances that were reviewed. The one case where the river stage differences were larger was the 24.8-year model snapshot of stages and heads downgradient of the Delevan diversion (the lower-left plot on Figures 10A-5, 10A-9, 10A-13, and 10A-17). But even these differences were a matter of a few feet of river stage at most in the simulations, for the time periods investigated.

The difference in simulated groundwater-surface water interactions for the river reaches downgradient of the TCC and GCC indicate that what differences there are increase between 5 and 10 miles downstream, but that the 10-mile and 12-mile cumulative differences are nearly identical. This result suggests that volumetric groundwater-surface water exchange differences at these locations may be confined to within 10 miles of the diversion. This result does not hold for the Delevan diversion, where the cumulative 12-mile exchange differences are generally still increasing. This suggests that yet larger groundwater-surface water exchange differences would be forecasted for longer reaches downstream of the Delevan diversion.



Legend

- River Stage, No Action Alternative
- Groundwater Elevation, No Action Alternative
- River Stage, Alternative D
- Groundwater Elevation, Alternative D

FIGURE 10A-16
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 4.2 Years for Alternative D and No Action Alternative
Sites Reservoir Project EIR/EIS

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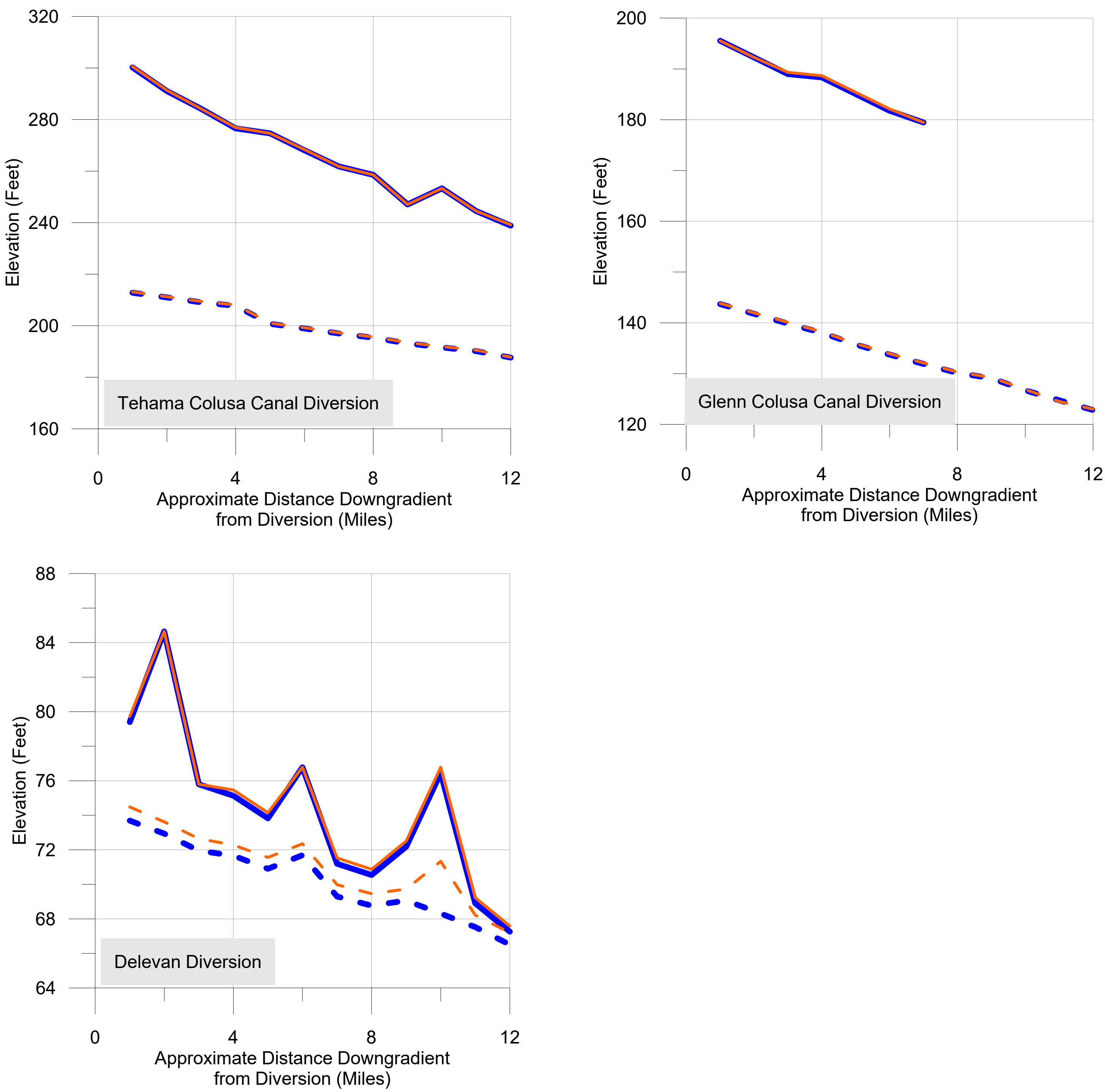

Legend

- River Stage, No Action Alternative
- Groundwater Elevation, No Action Alternative
- River Stage, Alternative D
- Groundwater Elevation, Alternative D

FIGURE 10A-17
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 24.8 Years for Alternative D and No Action Alternative
Sites Reservoir Project EIR/EIS

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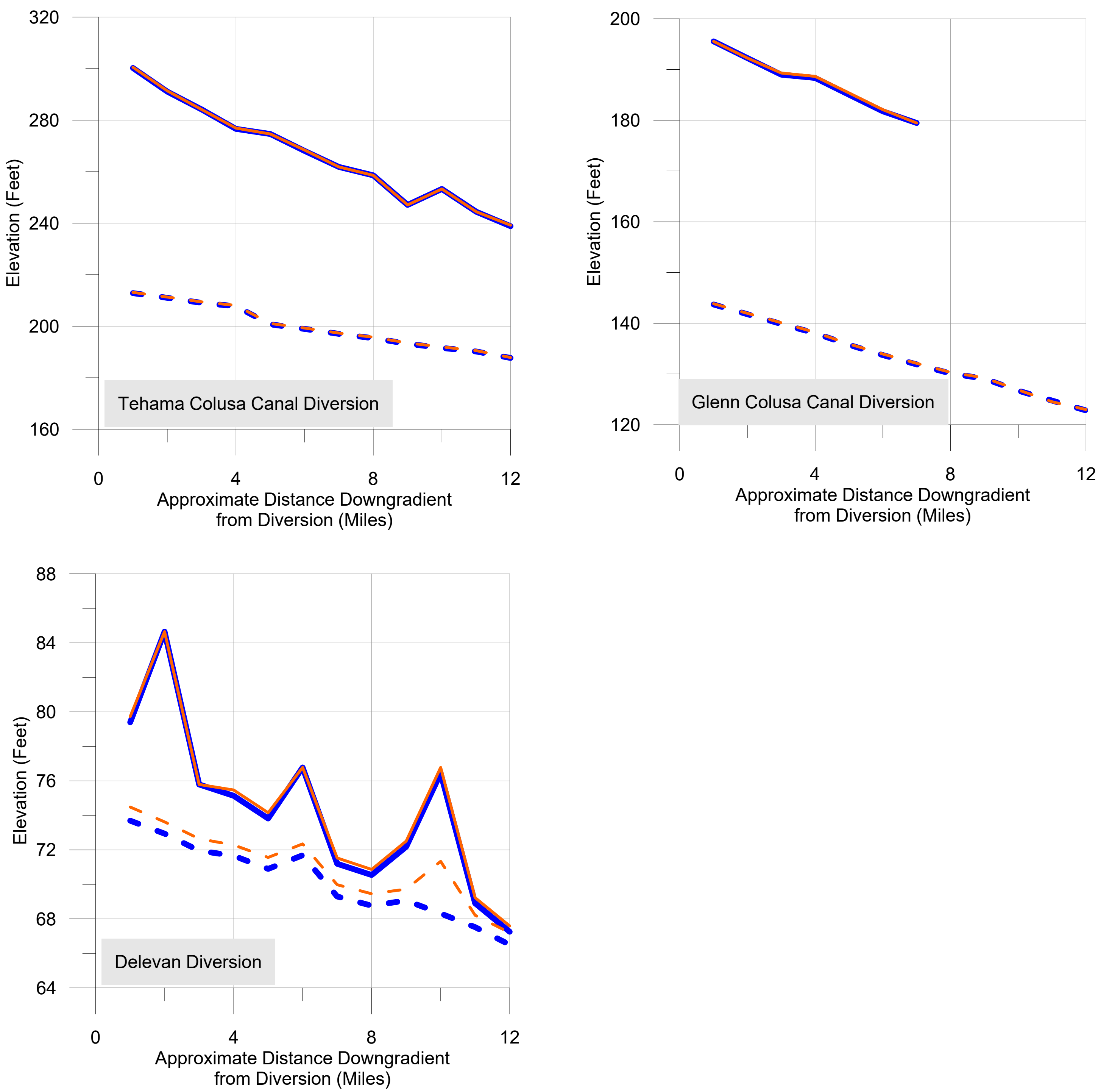

Legend

- River Stage, No Action Alternative
- Groundwater Elevation, No Action Alternative
- River Stage, Alternative D
- Groundwater Elevation, Alternative D

FIGURE 10A-18
CVHM-Forecast Sacramento River Stages and Groundwater Elevations after 39.2 Years for Alternative D and No Action Alternative
Sites Reservoir Project EIR/EIS

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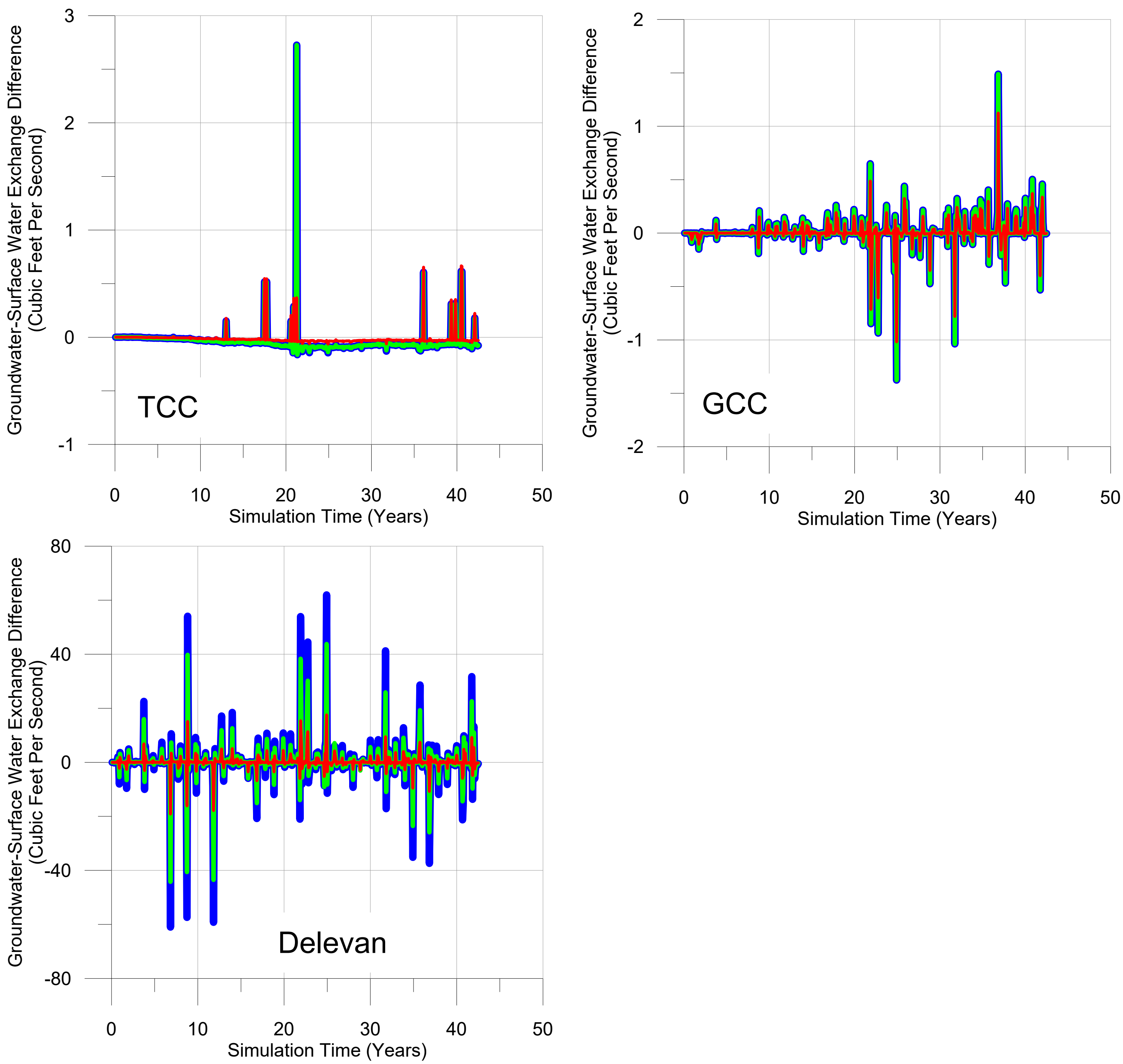

Legend

5 Model Cells (~5 miles)
10 Model Cells (~10 miles)
12 Model Cells (~12 miles)

FIGURE 10A-19
Groundwater-Surface Water Exchange Differences between Sites Alternative D and No Action Alternative
Sites Reservoir Project EIR/EIS

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However, the model also indicates that the exchange differences after 12 miles are still generally very small relative to the annual average Sacramento River flow, and that sometimes the exchange is greater for the NAA than it is for the Project alternatives, and sometimes it is less.

10A.4 Works Cited

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