Appendix F Groundwater Analysis

The San Joaquin River Restoration Program (SJRRP) conducted a groundwater review and analysis for the Reach 4B/ESB Project. The analysis included:

- Baseline Analysis: Characterize surface water and groundwater interaction in the Reach 4B/ESB Project area under baseline conditions (without Restoration Flows). The main information source for this analysis is groundwater monitoring data collected by the SJRRP in the Project area. Groundwater monitoring data was used to develop hydrologic and hydrogeologic cross-sections in the area.

- Alternatives Analysis: Assess direct impacts of the Reach 4B/ESB Project alternatives to groundwater resources. Potential changes to groundwater levels as a result of increased flows in San Joaquin River Reach 4B and the Eastside Bypass were analyzed using the San Joaquin River Restoration Program Groundwater Model (SJRRPGW). The modeling effort focused on Alternatives 1 (Main Channel Restoration) and 2 (Bypass Restoration) because they represent bookends of potential effects to groundwater. Alternative 3 would split flows between the river and bypass system, so the effects would be less than those estimated for Alternatives 1 and 2.

F.1 Baseline Analysis

The baseline analysis included reviewing groundwater monitoring data in the Reach 4B/ESB Project area to identify groundwater conditions and groundwater-surface water interaction. Reclamation monitors a well network that includes 215 Reclamation-operated monitoring wells and 102 landowner/local agency-operated wells as of June 2018. Reclamation is continuously updating this well network to develop a better understanding of groundwater conditions in the SJRRP Restoration Area (includes Reach 1 to Reach 5 of the San Joaquin River). In the Reach 4B/ESB Project area the monitoring well network includes 45 Reclamation owned/operated monitoring wells and 5 landowner/local agency operated wells. All these wells are shallow, ranging from 20 to 50 feet below ground surface (bgs).

In addition to the monitoring well network, Reclamation has conducted a geotechnical investigation in the SJRRP Restoration Area with up to 1500 soil borings. Information collected from the monitoring well network and the geotechnical information was used to develop hydrogeologic and hydrologic cross-sections to define groundwater-surface water interaction under baseline conditions (without restoration flows).

F.1.1 Hydrogeologic Cross-Sections

The shallow geology in the Reach 4B/ESB Project area consists of alluvial materials such as sands, silts, and clays. Figure F-1 shows the location of four geologic cross-sections within the Reach 4B/ESB Project area. These figures, Figures D-2 through D-5, show the local geologic materials encountered during the drilling of shallow groundwater monitoring wells in the area. These monitoring wells are labeled with the “MW-XX-XXX” notation in Figure F-1. At each of the wells, the geologic materials are listed (e.g., Sandy Clay (SC), Silty Sand (SM), etc.). The color shading in the figures presents a representation of the layering of the geologic materials underlying the area based on the drilling records.

These figures show a great deal of variability, or heterogeneity, in the shallow geology in the Project area. Several of the geologic formations can be connected between wells; however, there is not a simple, uniform layering in this area. It is difficult to draw conclusions for the entire Project area based on the shallow geologic information that is available. In some areas, it appears that the geologic materials may be more conductive to water flow (e.g., sands) on the western portion of the area, closer to Reach 4B, than on the eastern side, closer to the Middle Eastside Bypass.

Figures D-2 through D-5 also show a sample set of groundwater level measurements that were collected at the monitoring wells. These figures show that groundwater levels in many wells vary with time. The elevation of the water in the surface water relative to the groundwater level governs whether water can flow out of the surface water, though the river bed, into the groundwater or if water movement could be from the groundwater to the surface water.

The terms “gaining” and “losing” are often used to characterize the interaction between the surface water and groundwater systems. In a “losing” stream condition, the water level in the stream is higher than the groundwater level under and adjacent to the stream. In this condition, water flows through the riverbed, out of the stream, and into the groundwater system (the water is “lost” from the surface water). In a “gaining” system, the water level in the surface water is lower than the adjacent groundwater level. In this situation, water flows from the groundwater into the surface water system (the surface water is “gaining” additional water). Depending on groundwater and stream levels, portions of the same stream system may be gaining while other portions are losing. The gaining/losing condition can also change at different times based on changes in either the groundwater level, the surface water level, or both.

These changes in gaining and losing conditions can be seen in Figures D-2 through D-5. A gaining condition is seen when the water table line slopes toward the river. A losing condition is noted when the lines slope away from the river. Each of these figures shows that the water levels rise and drop, depending on the time of year. Figure F-2, a transect approximately 1.5 mile downstream of the Sand Slough Control Structure, shows groundwater levels adjacent to Reach 4B1 mostly to be lower than the river bed of Reach 4B, indicating a losing stream condition. However, groundwater levels adjacent to Reach 4B in June 2013, June 2014, and October 2014 are higher than the river bed elevation, indicating gaining stream conditions. Figure F-2 also shows that the Middle Eastside

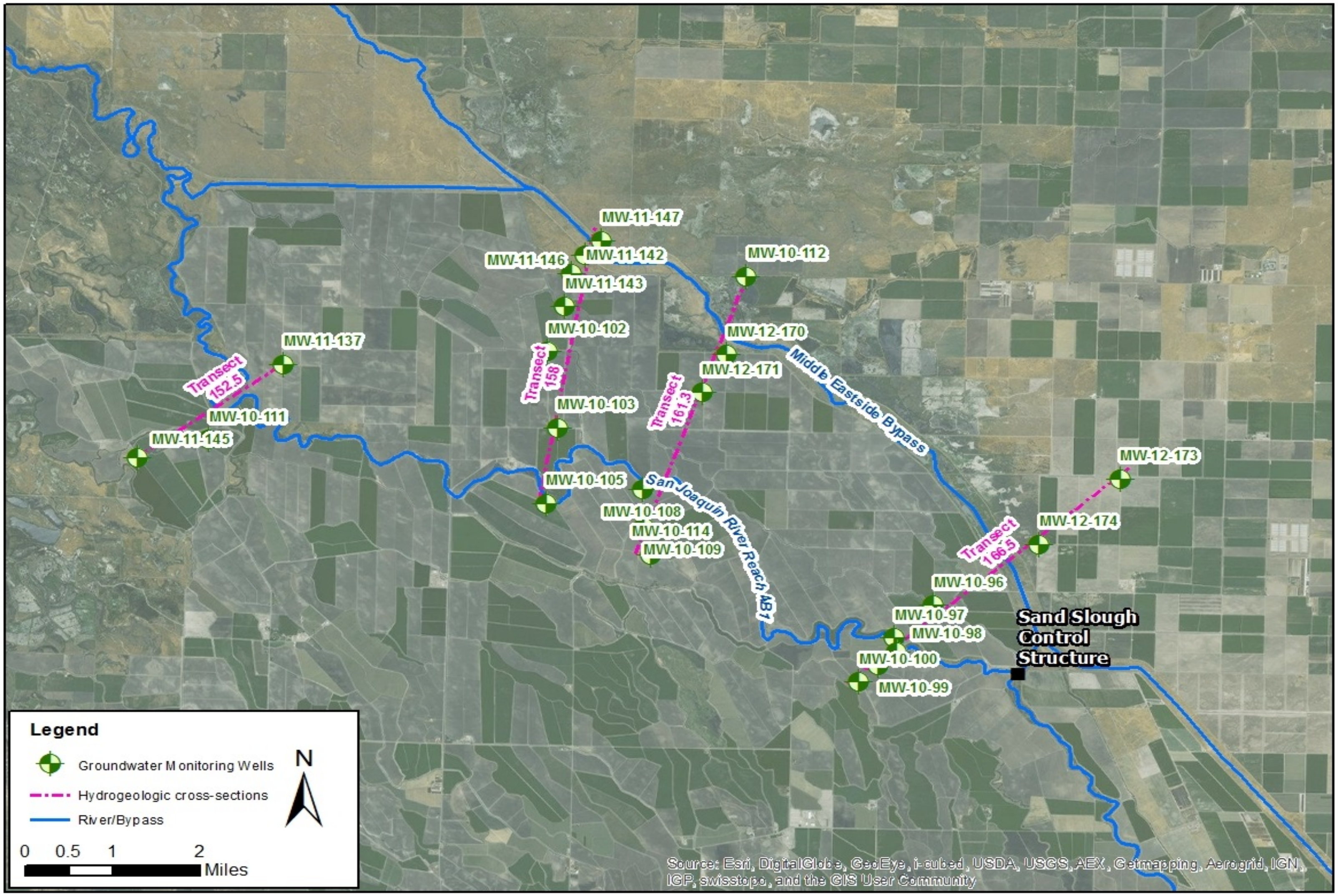

Figure F-1.
Location of Select Groundwater Monitoring Wells within the Reach 4B/ESB Project Area

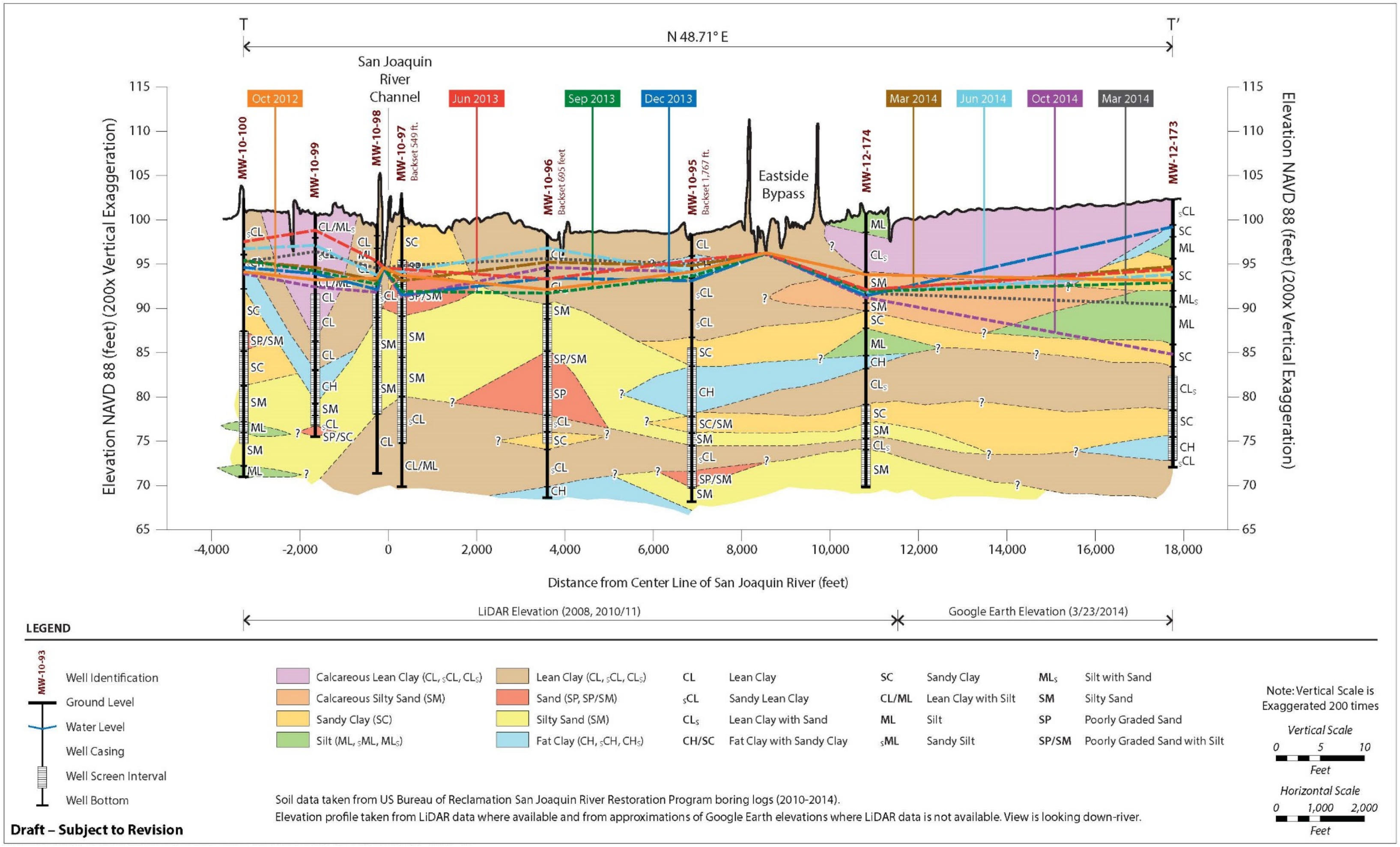

Figure F-2.
Hydrogeologic Cross Section at Transect 166.5

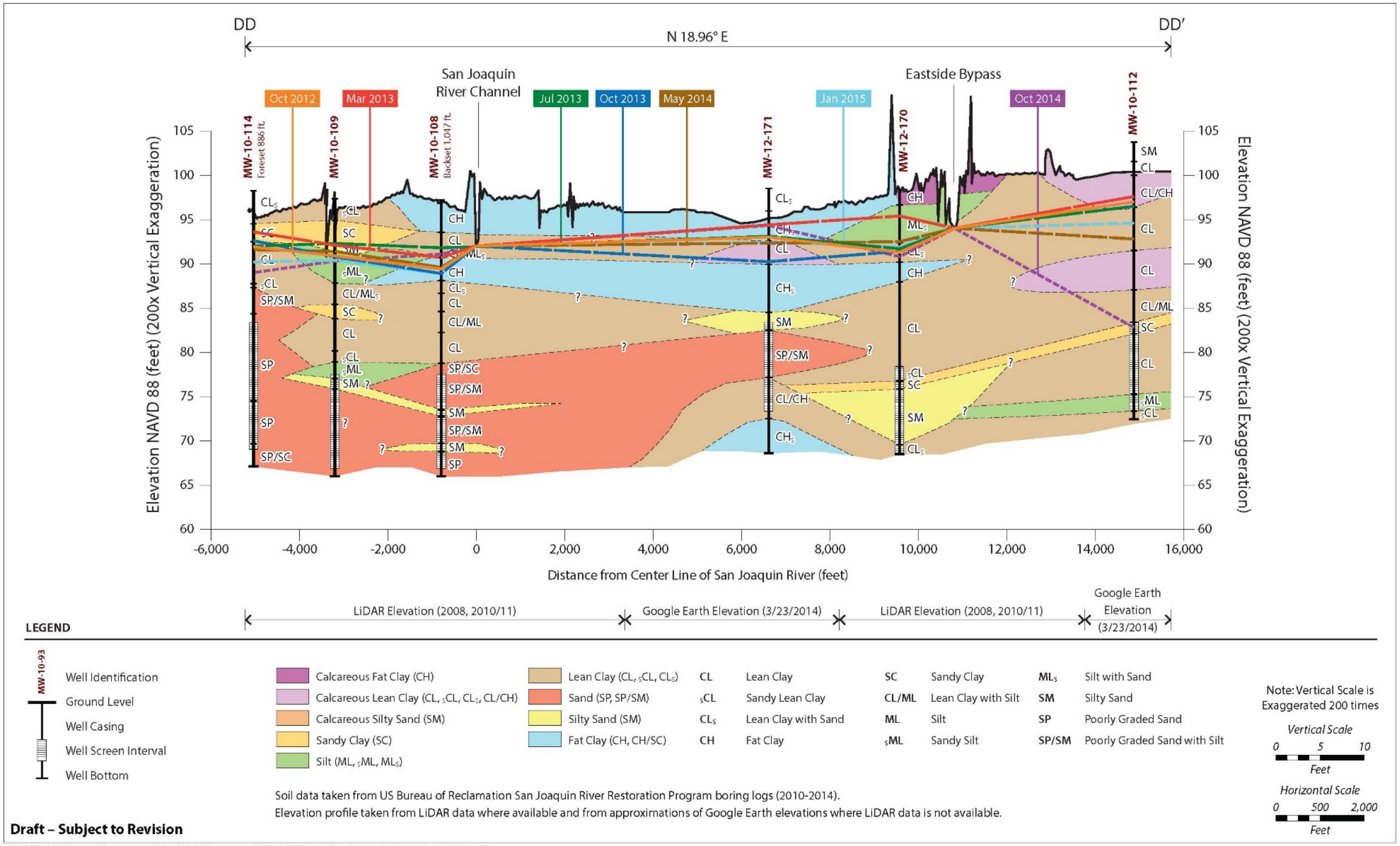

Figure F-3.
Hydrogeologic Cross Section at Transect 161.3

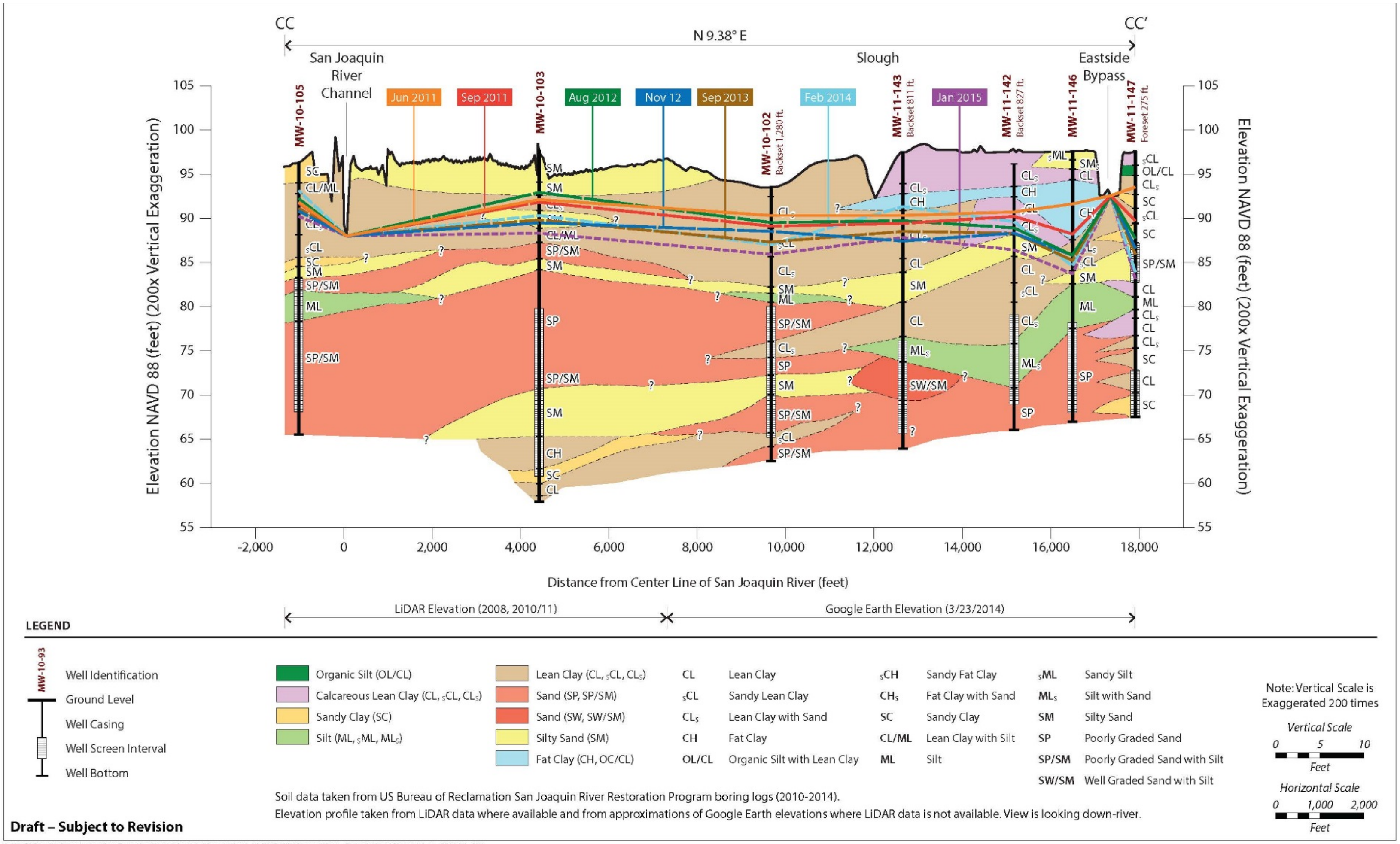

Figure F-4.
Hydrogeologic Cross Section at Transect 158.0

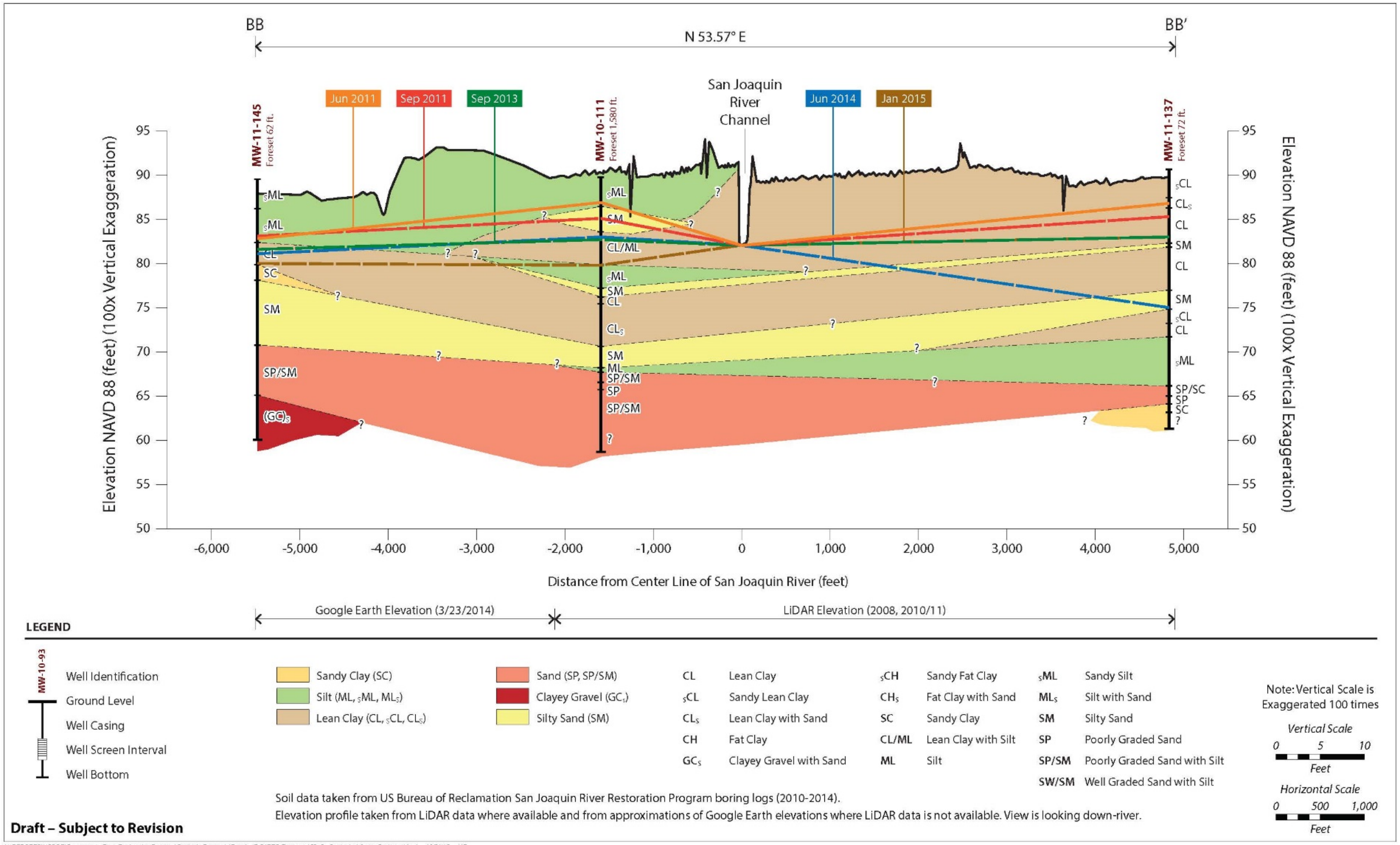

Figure F-5.
Hydrogeologic Cross Section at Transect 152.5

Bypass is typically a losing reach in this area, as groundwater levels are typically lower than the channel bed elevation.

Each of the other transect figures, Figure F-3 through D-5, shows that there is not a consistent pattern of gaining and/or losing conditions along Reach 4B and the Middle Eastside Bypass. Groundwater levels vary with distance from each of the surface water features and also vary based on the time of year. In general, a trend of Reach 4B being more of a gaining stream than the Middle Eastside Bypass is seen in these figures.

F.1.2 Hydrologic cross-section

Groundwater levels in the monitoring wells along Reach 4B and the Middle Eastside Bypass have been collected as early as 2009. Figure F-6 shows the location of several of these monitoring wells. Note that the first set of digits in the monitoring well name (i.e., the “11” in “MW-11-154”) indicates the year that well was installed, 2011 in this case. Figures D-7 through D-15 show the measured groundwater elevation at each of the wells, along the transects shown in Figure F-6. Figures D-7 through D-15 also show the estimated elevation of the bed of Reach 4B or the Middle Eastside Bypass. It should be noted that the data presented in Figures D-7 through D-15 represent a short period of record (four or less years) of groundwater levels along Reach 4B1 and the Middle Eastside Bypass. A longer data set in these areas does not exist. This data does indicate that both Reach 4B1 and the Middle Eastside Bypass have the potential to be gaining or losing streams. The actual direction and rate of flow between groundwater and surface water depends on location along the river/bypass, groundwater levels, local geologic conditions, and the overall hydrologic conditions of the area.

Figures D-7 through D-11, along Reach 4B, show that groundwater levels tend to fluctuate during the year, likely due to agricultural activities. Groundwater levels have also shown a general decline during this period, likely due to the drought conditions. Groundwater levels tend to fluctuate around the elevation of the stream bed in this area, suggesting that Reach 4B may alternate between gaining and losing conditions. Similarly, Figures D-12 through D-15 suggest that groundwater levels fluctuate along the Middle Eastside Bypass. Groundwater levels along the Middle Eastside Bypass may tend to be a bit lower below the riverbed in this area, contributing to a potential losing condition. However, this trend is not consistent among all the monitoring wells and not through the entire data record.

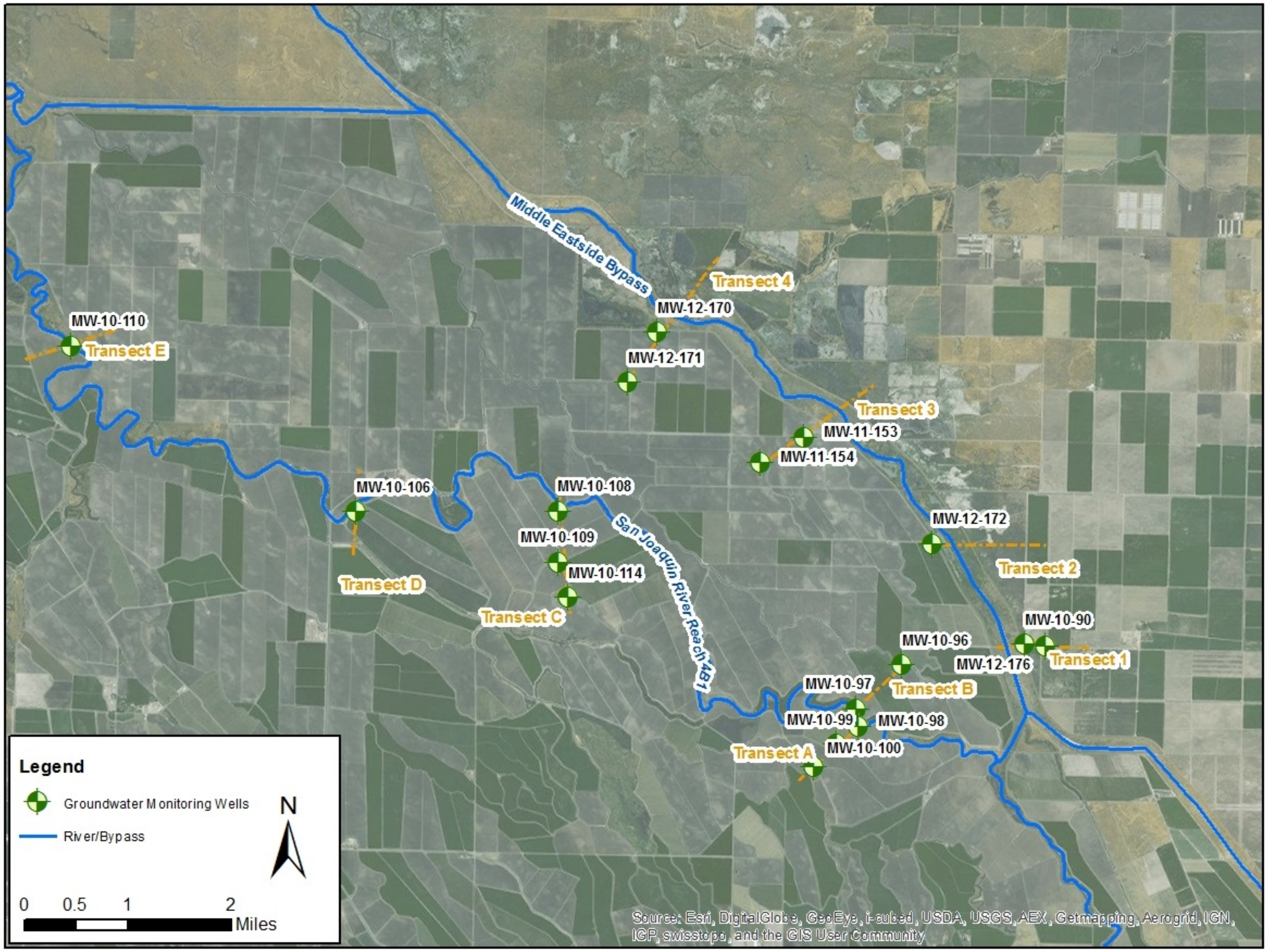

Figure F-6.
Location of Select Groundwater Monitoring Wells within the Reach 4B/ESB Project Area

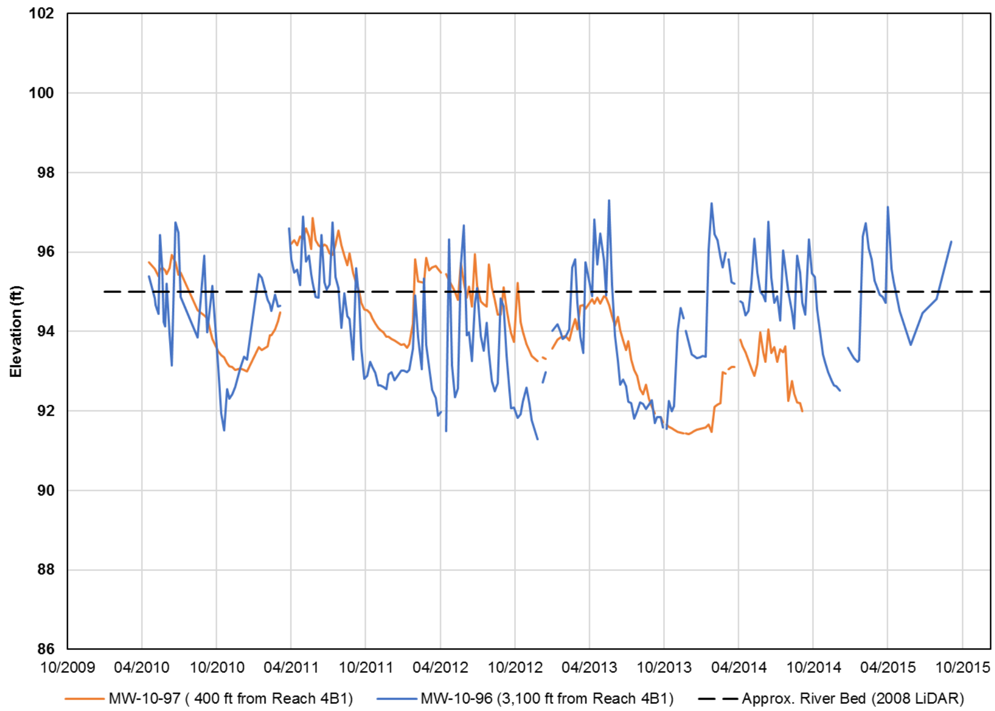

Figure F-7.
Groundwater Elevation and Ground Surface Elevation at Transect A
(San Joaquin River Reach 4B1, Right Bank)

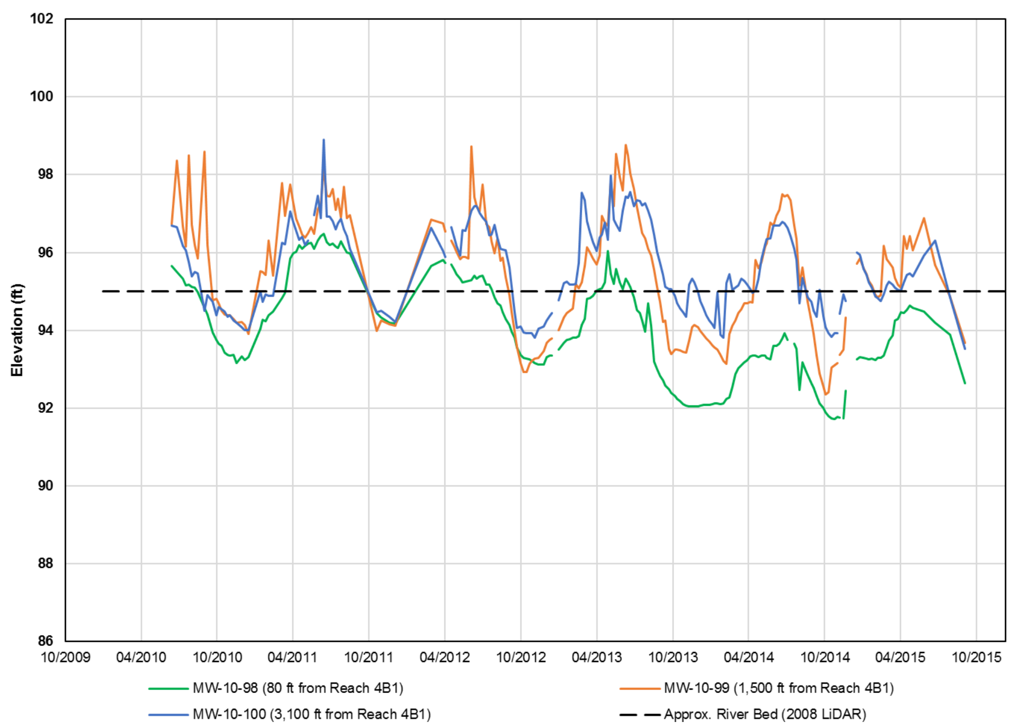

Figure F-8.
Groundwater Elevation and Ground Surface Elevation at Transect B
(San Joaquin River Reach 4B1, Left Bank)

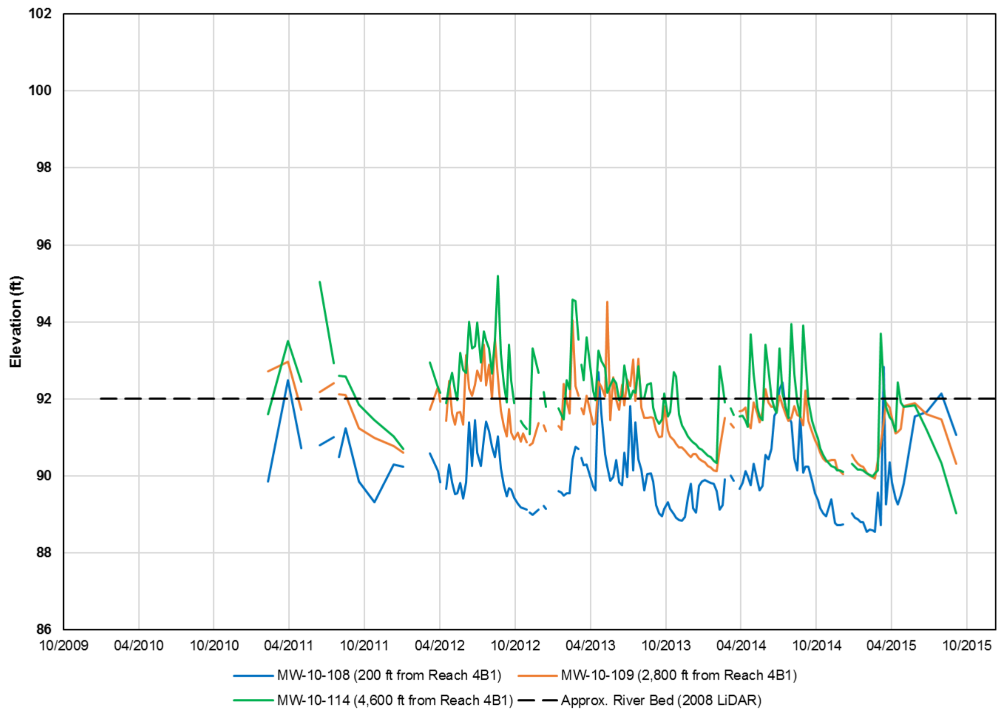

Figure F-9.
Groundwater Elevation and Ground Surface Elevation at Transect C
(San Joaquin River Reach 4B1, Left Bank)

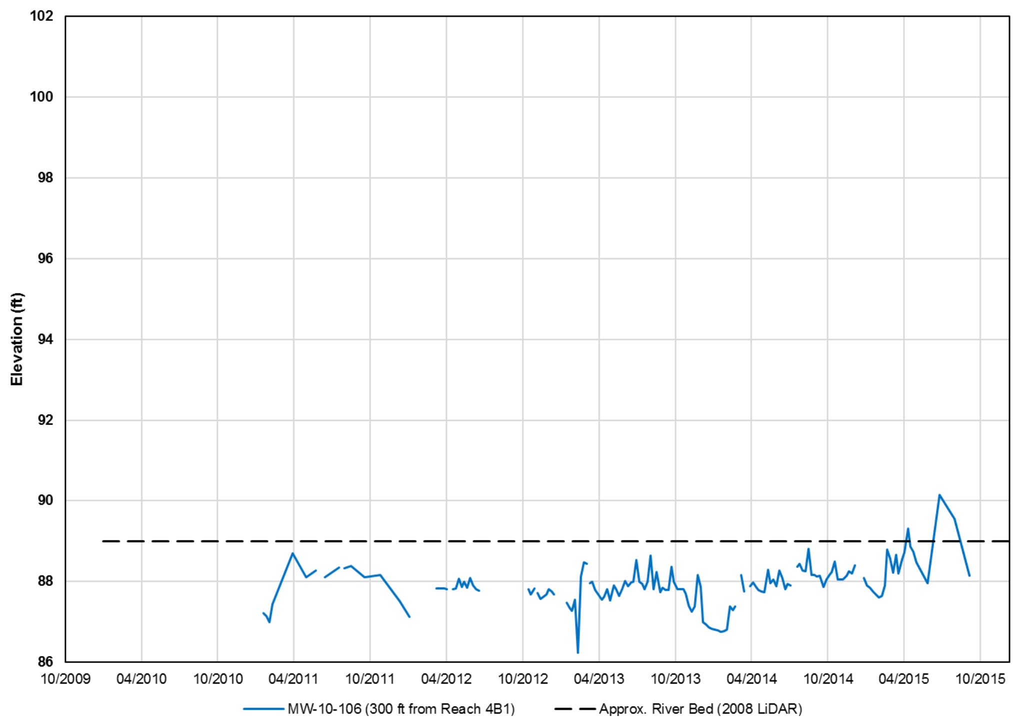

Figure F-10.
Groundwater Elevation and Ground Surface Elevation at Transect D
(San Joaquin River Reach 4B1, Left Bank)

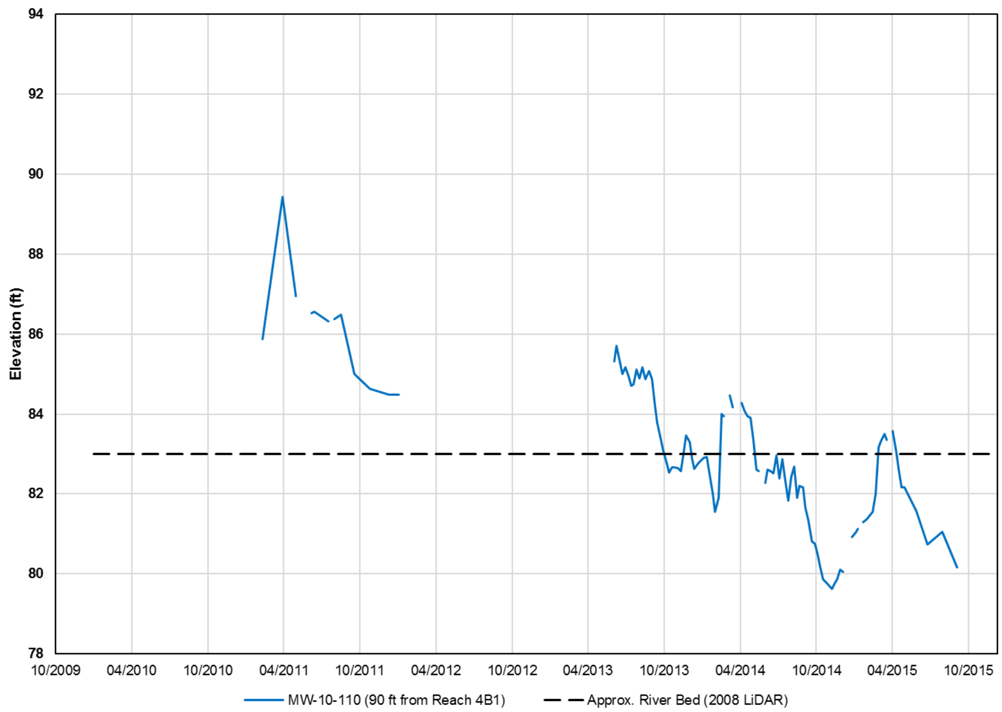

Figure F-11.
Groundwater Elevation and Ground Surface Elevation at Transect E (San Joaquin River Reach 4B1, Left Bank)

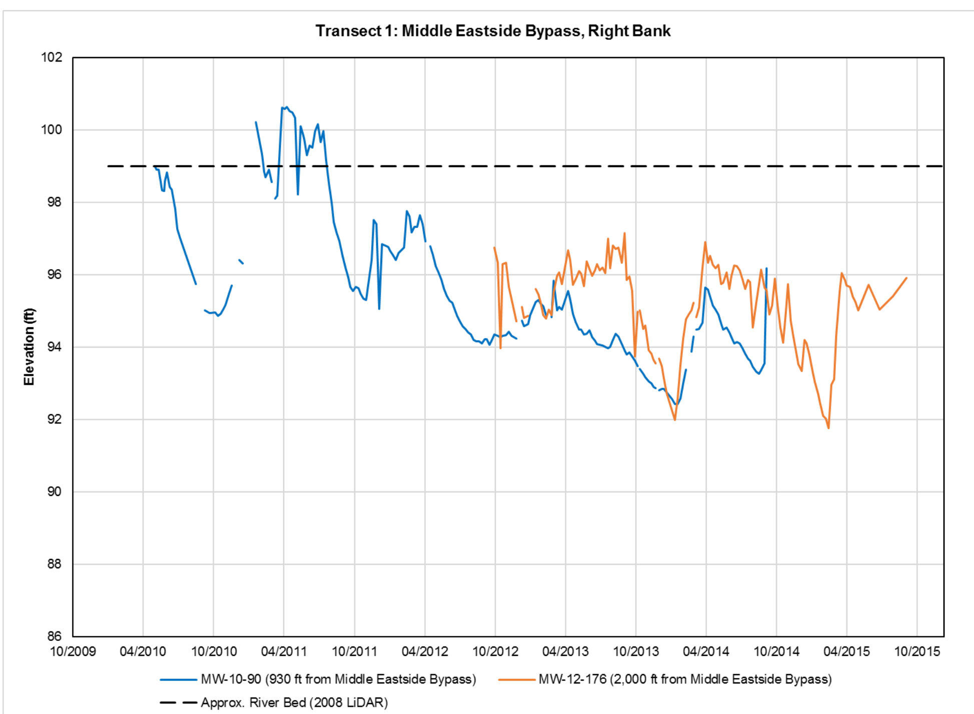

Figure F-12.
Groundwater Elevation and Ground Surface Elevation at Transect 1 (Middle Eastside Bypass, Right Bank)

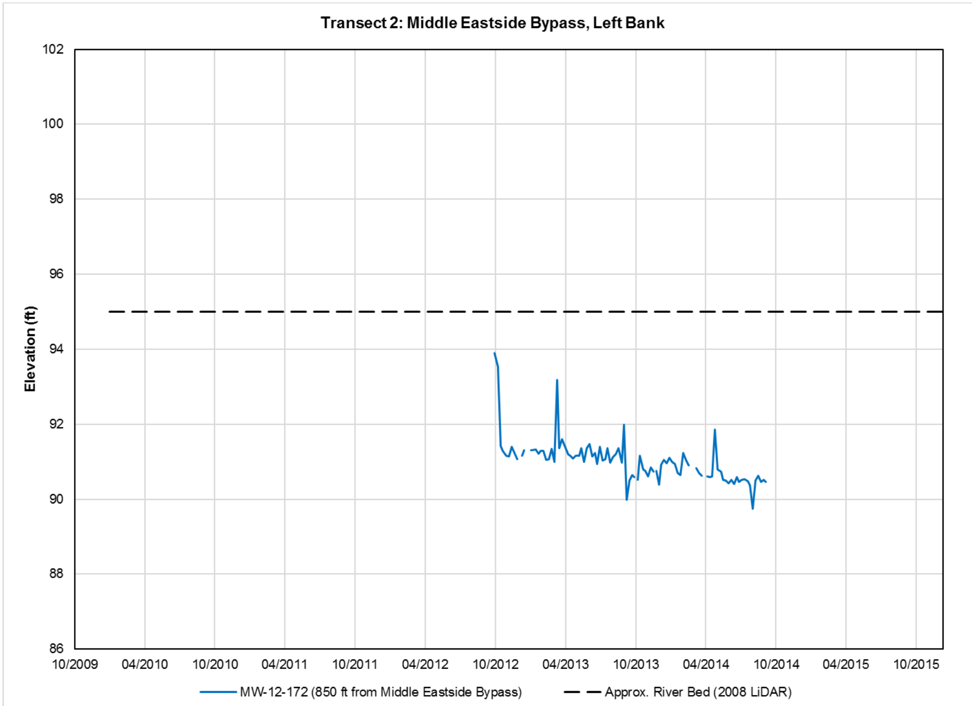

Figure F-13.
Groundwater Elevation and Ground Surface Elevation at Transect 2
(Middle Eastside Bypass, Left Bank)

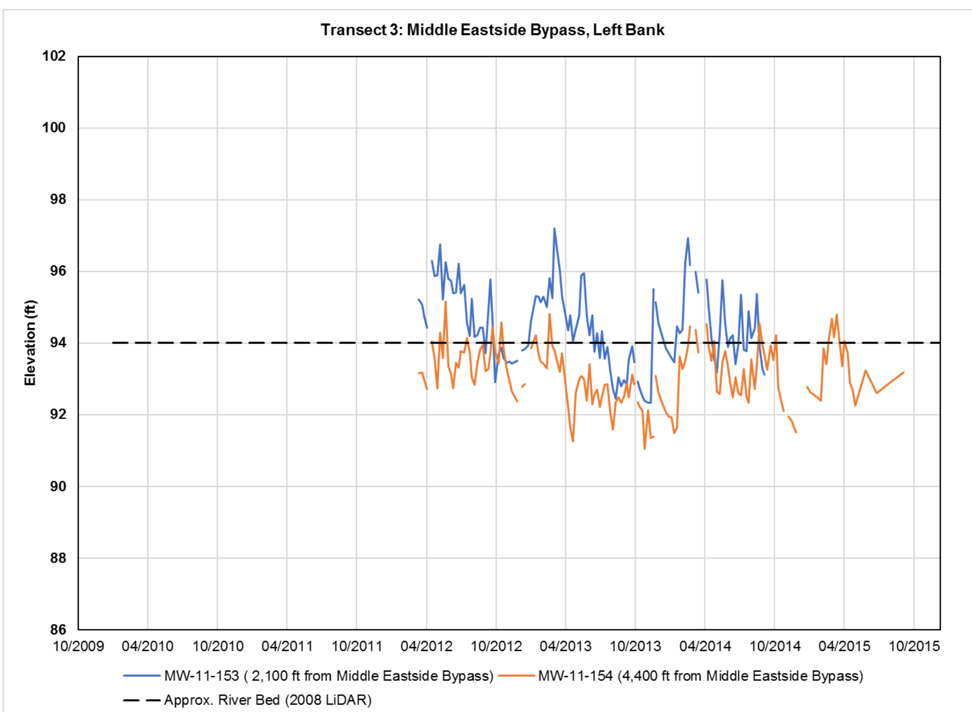

Figure F-14.
Groundwater Elevation and Ground Surface Elevation at Transect 3
(Middle Eastside Bypass, Left Bank)

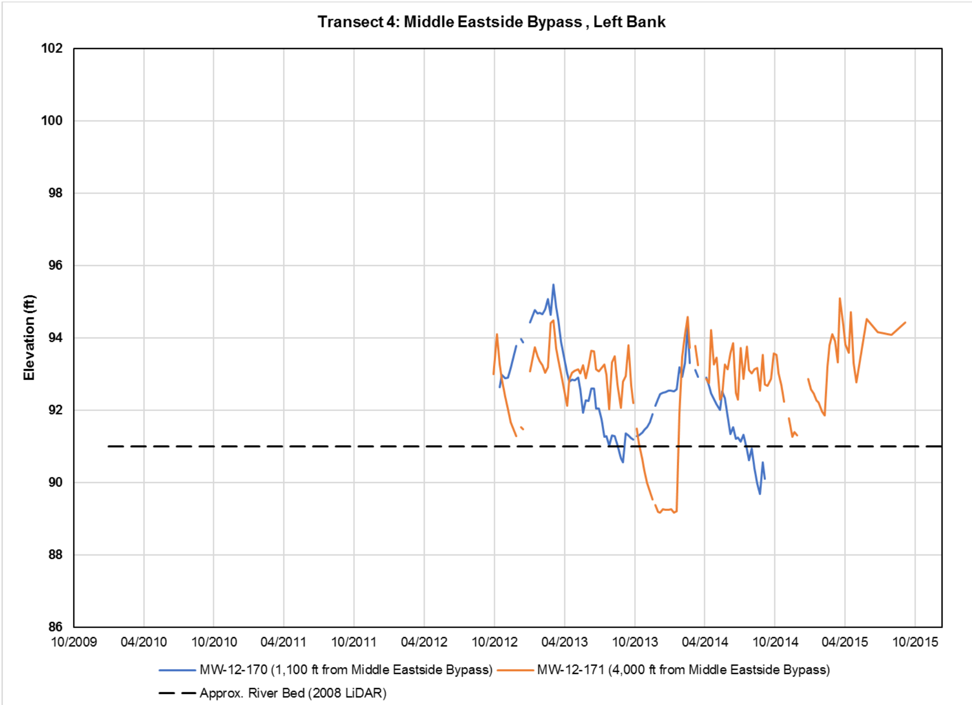

**Figure F-15.
Groundwater Elevation and Ground Surface Elevation at Transect 4
(Middle Eastside Bypass, Left Bank)**

F.1.3 Water Quality Analysis

In addition to the groundwater level monitoring activities Reclamation also conducts water quality monitoring in area near Reaches 3,4A, and 4B to inform potential seepage management decisions (Reclamation 2012, 2013). There are several sampling locations, including both surface water and groundwater, that are local to the Reach 4B/ESB Project area. Table F-1 shows the water quality results from the December 2012 and May 2013 sampling events within the Reach 4B/ESB Project area. Figure F-16 shows the location of the monitoring wells.

Table F-1.
Water Quality Sampling Results

Compound	Alkalinity	Aluminum	Ammonia as N	Arsenic	Bicarbonat e as $CaCO_3$	Boron	Cadmium	Calcium	Carbonate as $CaCO_3$	Chloride	Copper	Electrical Conductivit	Hardness	Lead	Magnesium	Mercury
units	**mg/L**	**µg/L**	**mg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**mg/L**	**µg/L**	**µS/cm**	**mg/L**	**µg/L**	**mg/L**	**ng/L**
Water Quality Objective		87 [1]		10 [2]		700 [3]	0.21 [1]			106,000 [3]	10 [2]	150 [2,7]		1.9 [4]		770 [1]
Water Quality Sampling Results (December 2012 above, May 2013 below)																
San Joaquin River (Surface Water Quality)																
San Joaquin River at Sack Dam	69 79	**270** **540**	< 0.5 < 0.5	1.6 2.1	69 79	320 250	< 0.10 < 0.5	31 26	< 2.0 < 2.0	68 -	1.4 2.1	**575** **532**	135 127	0.23 0.35	14 15	2.4 3.8
Sand Slough at El Nido Road	270 220	**1,000** **2,900**	< 0.5 < 0.5	**22** **15**	260 210	94 92	< 0.10 < 0.5	44 73	11 6.9	140 -	1.8 4.0	**1,067** **1,287**	246 326	0.3 0.9	33 35	< 2.0 3.8
Middle Eastside Bypass – Right Bank (Groundwater Quality)																
MW-10-94	- 340	**-** **280**	- < 0.5	**-** **12.0**	- 340	69 73	< 0.10 < 0.5	59 77	< 2.0 < 2.0	270 -	3.0 0.78	- **2,506**	328 427	0.49 < 0.2	44 57	3.0 < 2.0
MW-12-174	250 260	**690** **550**	< 0.5 < 0.5	**11.0** 7.9	250 260	88 85	< 0.10 < 0.5	70 120	< 2.0 < 2.0	360 -	1.3 1.4	**1,969** **2,682**	319 534	< 0.2 < 0.2	35 57	< 2.0 < 2.0
MW-10-90	280 280	**3,600** **2,000**	< 0.5 < 0.5	**15.0** **14.0**	280 280	150 150	< 0.20 < 0.5	150 150	< 2.0 < 2.0	870 -	5.3 3.1	**4,375** **4,608**	716 704	0.64 0.40	83 80	24 35
Middle Eastside Bypass – Left Bank (Groundwater Quality)																
MW-12-170	- 380	**-** **870**	- < 0.5	- 9.0	- 380	- 57	- < 0.5	- 62	- < 2.0	- -	- 1.6	**-** **2,021**	- 381	- 0.22	- 55	- 4.8
MW-12-172	290 310	**400** 86	< 0.5 < 0.5	9.7 9.2	290 310	56 56	< 0.10 < 0.5	54 52	< 2.0 < 2.0	230 -	0.99 0.83	**1,402** **1,330**	271 253	< 0.2 < 0.2	33 30	4.3 2.3

Compound	Molybdenum	Nickel	Nitrate As NO_3	Orthophosphate as PO_4	pH	Potassium	Selenium	Sodium	Soil Absorption Ratio	Sulfate	Total Dissolved Solids	Temperature	Total Kjeldahl Nitrogen	Turbidity	Zinc
units	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**units**	**mg/L**	**µg/L**	**mg/L**	**-**	**mg/L**	**mg/L**	**°C**	**mg/L**	**NTU**	**µg/L**
Water Quality Objective	19 [4]	37 [4]	5000 [5]				2 [6]	69,000 [3,5]			450,000 [3,5]				84 [4]
Water Quality Sampling Results (December 2012 above, May 2013 below)															
San Joaquin River (Surface Water Quality)															
San Joaquin River at Sack Dam	2.9 1.8	1.3 2.0	3.0 -	< 0.6 -	8.7 8.1	2.4 3.0	1.0 0.7	70 61	2.61 -	89 -	330 310	9.9 21.8	< 0.50 < 0.50	- 13.6	< 20 < 20
Sand Slough at El Nido Road	17 12	1.7 3.9	6.4 -	< 0.6 -	8.8 8.4	1.1 3.3	< 0.4 < 0.4	160 160	4.42 -	57 -	620 770	9.7 23.7	0.82 < 0.50	29.6 93.6	< 20 22
Middle Eastside Bypass – Right Bank (Groundwater Quality)															
MW-10-94	18 16	8.7 6.4	28 -	< 0.6 -	- 7.6	2.0 1.9	1.6 2.5	340 410	8.13 -	250 -	1,200 1,500	18.0 18.4	< 0.50 < 0.50	26.4 8.1	< 20 < 20
MW-12-174	15 9.0	1.7 3.3	63 -	< 3.0 -	7.8 7.7	1.6 1.5	**2.1** **3.1**	330 380	8.01 -	140 -	1,200 1,500	16.5 17.9	< 0.50 < 0.50	16.5 11.4	< 20 < 20
MW-10-90	**56** **51**	8.4 7.5	120 -	< 3.0 -	7.4 7.6	3.0 3.0	1.9 1.8	710 650	11.5 -	470 -	2,700 2,800	17.5 17.7	0.57 < 0.50	22.3 52.9	**360** **130**
Middle Eastside Bypass – Left Bank (Groundwater Quality)															
MW-12-170	- 6.3	- 2.1	- -	- -	- 7.4	- 0.94	- < 0.4	- 270	- -	- -	- 1,100	- 19.0	- < 0.50	- 16.1	- < 20
MW-12-172	**19** **22**	1.3 < 0.5	8 -	< 0.6 -	7.7 7.4	0.72 0.65	< 0.4 < 0.4	210 190	5.53 -	51 -	810 760	17.6 18.4	< 0.50 < 0.50	6.8 1.5	< 20 34

Key:
- = Not Sampled
mg/L = milligrams per liter
Bold/shaded cells represent measurements exceeding the listed water quality standard.
Notes:
[1] National Recommended Water Quality Criteria Aquatic Life Protection - Freshwater NRAWQC Continuous Concentration
[2] Basin Plan
[3] Agricultural goals
[4] Regional Water Quality Control Board (RWQCB) Aquatic Life Protection – Freshwater California Toxics Rule and/or National Toxics Rule Continuous Concentration
[5] Irrigation Suitability
[6] Toxicity threshold based on reproductive effects on fish and other wildlife.
[7] Applies to Reaches 1 and 2.

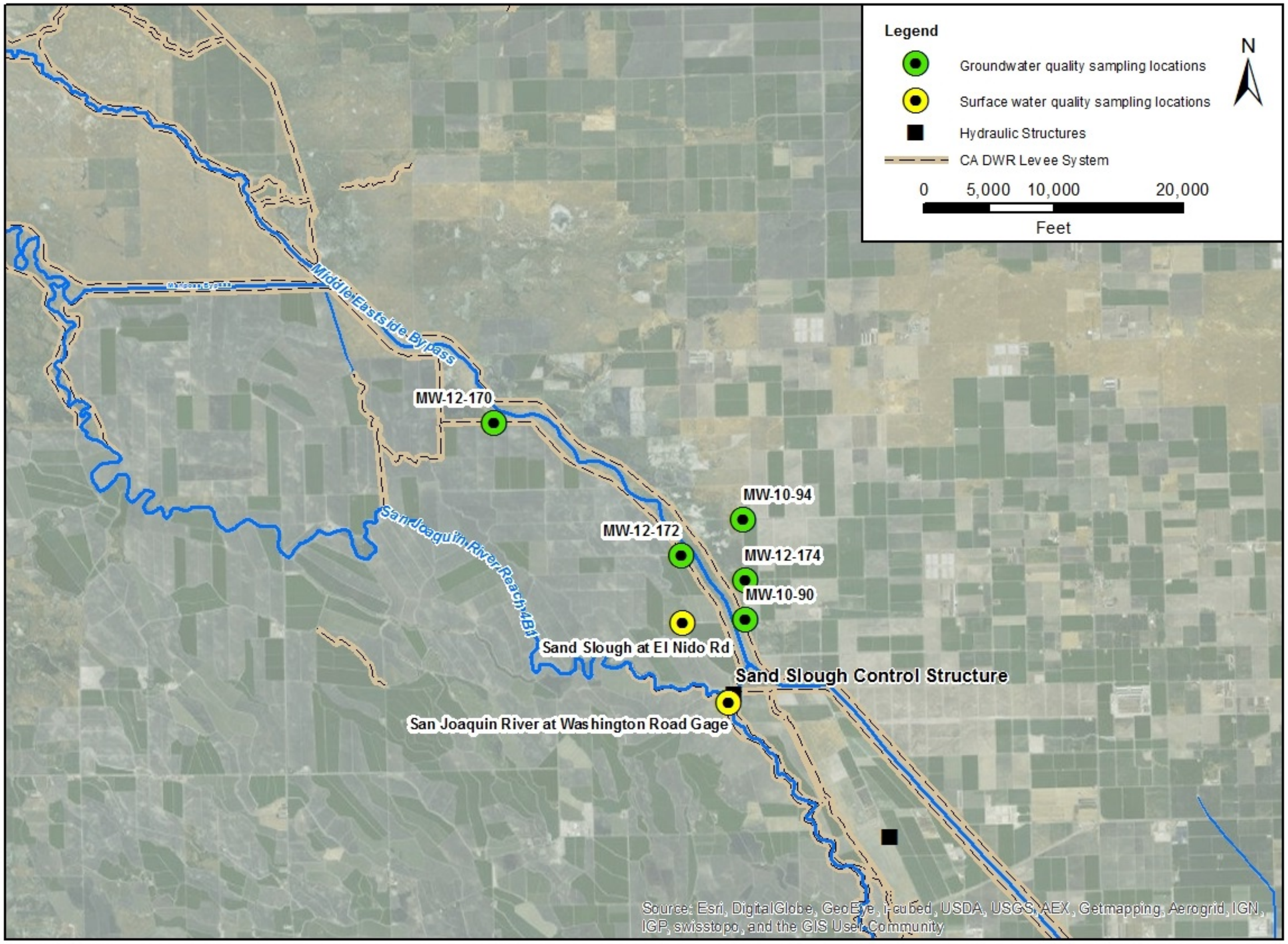

Figure F-16.
Water Quality Sampling Locations

F.2 Alternative Analysis

- Direct impacts of the Reach 4B/ESB Project alternatives on groundwater resources were analyzed using the San Joaquin River Restoration Program Groundwater Model (SJRRPGW). The SJRRPGW was developed by the USGS from the framework of the existing CVHM (Traum et al. 2014). To allow for a more refined assessment of groundwater levels along the SJRRP Restoration Area, as compared to the CVHM, the following changes were made to CVHM to create the SJRRPGW (Traum et al. 2014):

- The model domain was downsized to an area extending 5 miles from the San Joaquin River and adjacent bypass system, from Friant Dam to the Merced River. Vertically, the SJRRPGW includes the aquifer system above the Corcoran Clay, or about the upper 250 feet of aquifer material in the area.

- The model grid was reduced to a 0.25-mile square grid cell, as compared to the 1-mile grid size in CVHM.

- The sediment texture of the aquifer system, which was used to distribute hydraulic properties by model cell, was refined from that used in the CVHM to better represent the natural heterogeneity of aquifer-system materials within the SJRRPGW domain.

- The stream properties were updated to better simulate stream-aquifer interactions within the SJRRPGW domain.

- The water budget subregions were refined to better simulate agricultural water supply and demand.

- Stress periods were reduced from 1 month to 1 week. Each stress period simulates two time steps. The total simulation period is 42.5 years, extending from April 1961 through September 2003.

- Simulated flows in the San Joaquin River and bypass systems were based on RiverWare model results.

Figure 12-30 shows the SJRRPGW model domain and the SJRRPGW active study area.

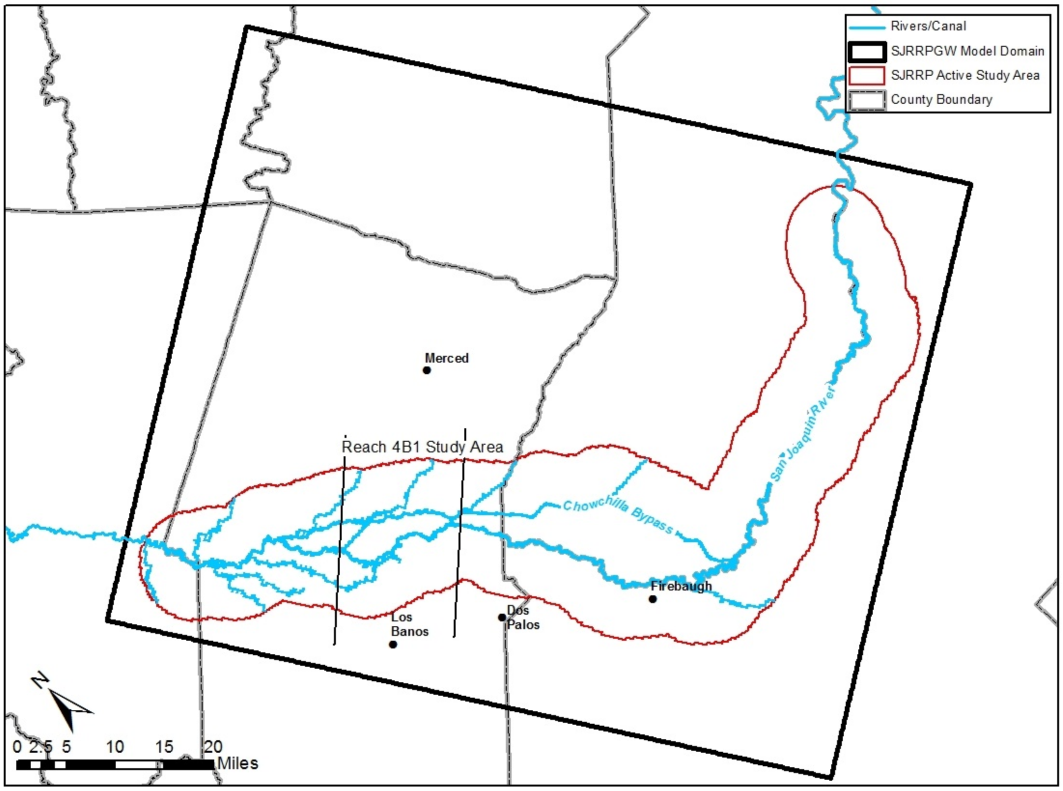

Figure F-17.
SJRRPGW Model Domain

F.2.1 Alternative 1 – Main Channel Restoration Alternative

Alternative 1 (includes Alternatives 1A, 1B and 1C) evaluates Restoration Flows being released down Reach 4B. Under these alternatives up to 4,500 cfs of Exhibit B flows would be released into Reach 4B and additional flows would be released down Eastside Bypass.

The SJRRPGW groundwater model was used to simulate conditions to better characterize the interaction between surface water and groundwater. The model calculates groundwater conditions over the 42.5-year simulation period based on regional conditions and hydrology. In addition to the background conditions, the Alternative 1 flow regime (flow down Reach 4B1) is simulated. The difference between simulation with and without the Alternative 1 simulations is the change in groundwater conditions due to Restoration Flows down Reach 4B1.

Figures D-18 and D-19 show the average monthly variability of gains and losses in Reach 4B1 and the Middle Eastside Bypass. These figures show that the gains and losses vary temporally along Reach 4B1 and the Middle Eastside Bypass. These figures show that both gains and losses are calculated to occur within an average month (that is, portions of Reach 4B1 and the Middle Eastside Bypass switch between gaining and losing conditions even within the same month). April is the month where the most losses, on average, are calculated to occur. The most gain, on average, is calculated to occur in July.

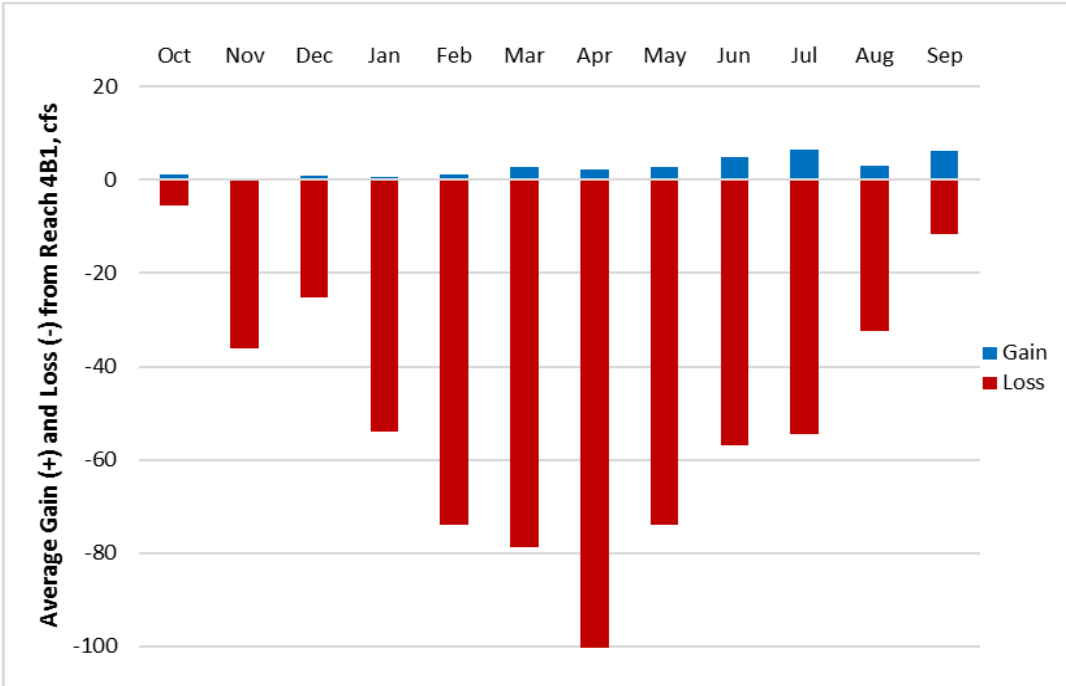

Figure F-18.
Simulated Average Monthly Gains/Losses from Reach 4B1, based on May 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

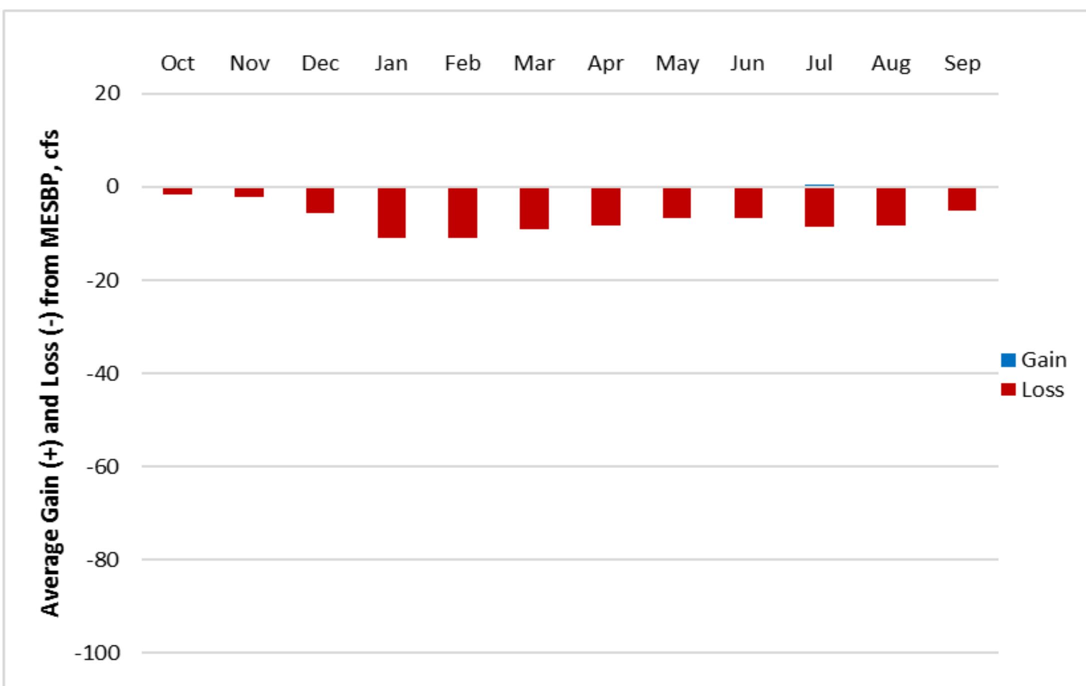

Figure F-19.
Simulated Average Monthly Gains/Losses from the Middle Eastside Bypass, based on May 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

Figures D-20 through D-31 show example SJRPPGW results, demonstrating the spatial variability of groundwater gains and losses along Reach 4B1 and the Middle Eastside Bypass under wet hydrologic conditions. During this period, flows in Reach 4B1 range from 27 to 3,500 cfs. Flows in Middle Eastside Bypass range from 19 to 2,300 cfs. Figures D-20 through D-31 show Reach 4B1 to have a higher rate of seepage loss than the Middle Eastside Bypass. The figures also show that the distribution of areas with gain and/or loss is not uniform across the entire length and time.

Figures D-32 through D-37 show example SJRRPGW results, demonstrating groundwater level increases under all hydrologic year types. The contour maps show a comparison of shallow groundwater levels between Alternative 1 and the No Action Alternative in May 1975 (normal-wet year type), May 1976 (critical high year type), May 1977 (critical low year type), May 1983 (wet year type), May 1992 (dry year type), and May 2003 (normal-dry year type). This time period represents the groundwater levels in the Reach 4B/ESB Project area after spring pulse flows (March 1 to May 1) under different hydrologic conditions and therefore represents the highest increase in groundwater levels under varying hydrologic conditions. Representative hydrographs were extracted from the model along Transect 1 and Transect 2 within the Reach 4B/ESB Project area (transect locations shown in Figure F-32).

Figures D-38 through D-40 show the simulated groundwater elevations under Alternative 1 along transect 1. As shown in Figure F-38, the shallowest groundwater levels along Reach 4B1 (left bank) range from 5 to 7.5 ft bgs. Groundwater levels along Reach 4B1 (right bank) ranges from 4.8 to 10 ft bgs (see Figure F-38). The influence of increased flows on groundwater elevation along Reach 4B1 right bank extends farther from the San Joaquin River due to higher hydraulic conductivity in comparison to Reach 4B1 left bank.

Figures D-41 through D-43 show the simulated groundwater elevations under Alternative 1 along transect 2. As shown in Figure F-41, the shallowest groundwater level along the Reach 4B2 (left bank) ranges from 4.3 to 12.5 ft bgs. Groundwater levels along Reach 4B2 (right bank) range from 7.6 to 9.3 ft bgs (see Figure F-42).

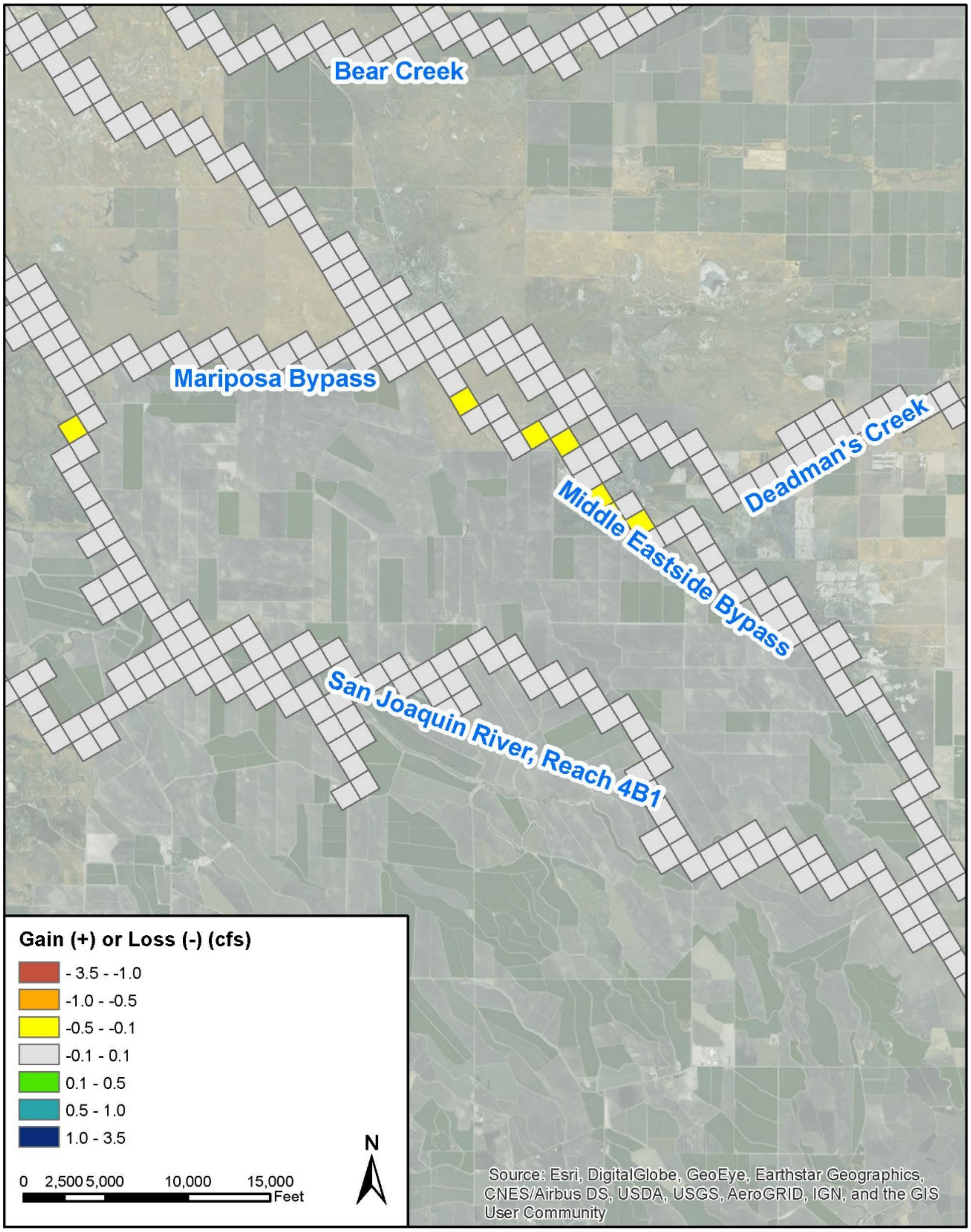

Figure F-20.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on October 1982 (Wet Year Type) Hydrologic Conditions under Alternative 1

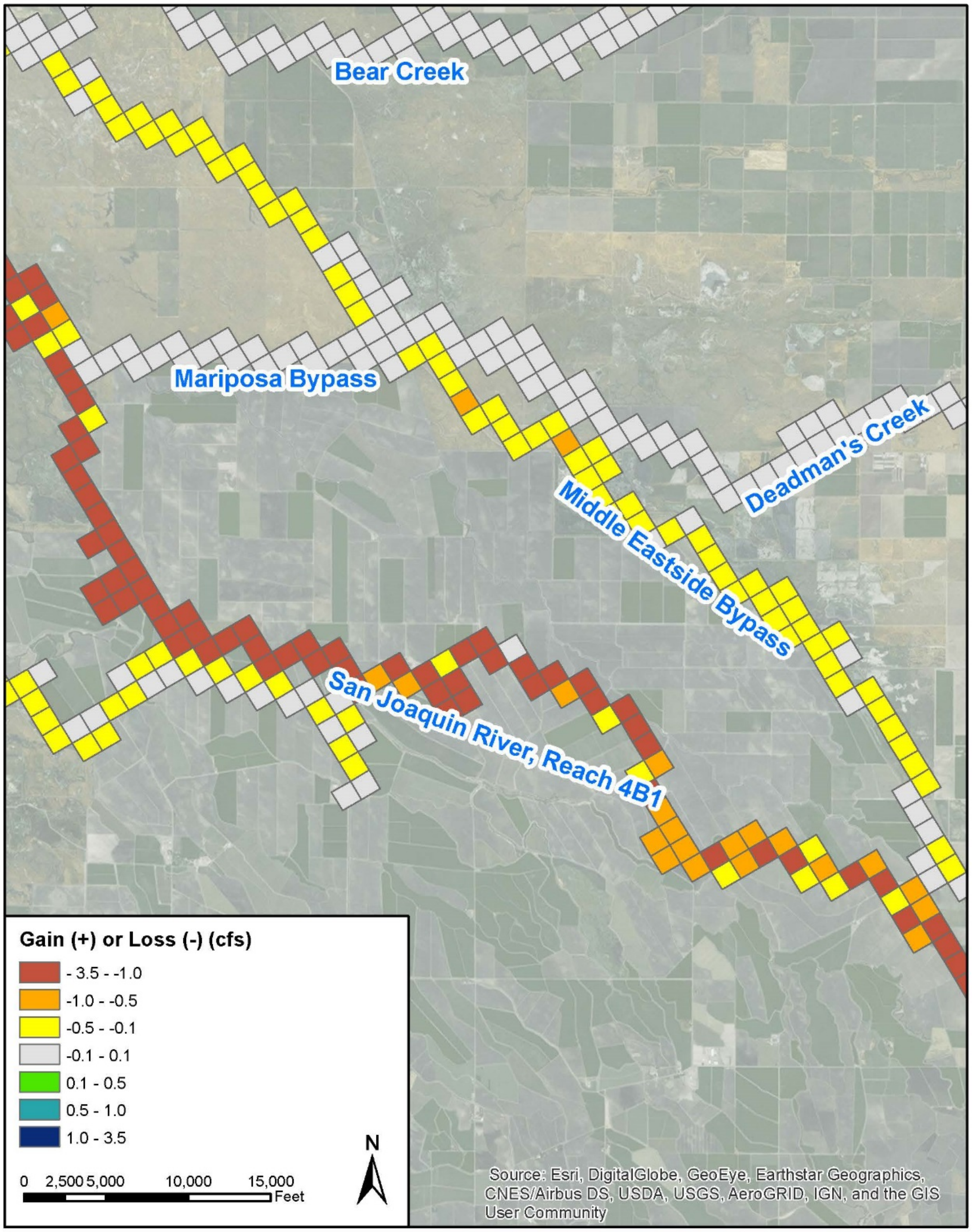

Figure F-21.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on November 1982 (Wet Year Type) Hydrologic Conditions under Alternative 1

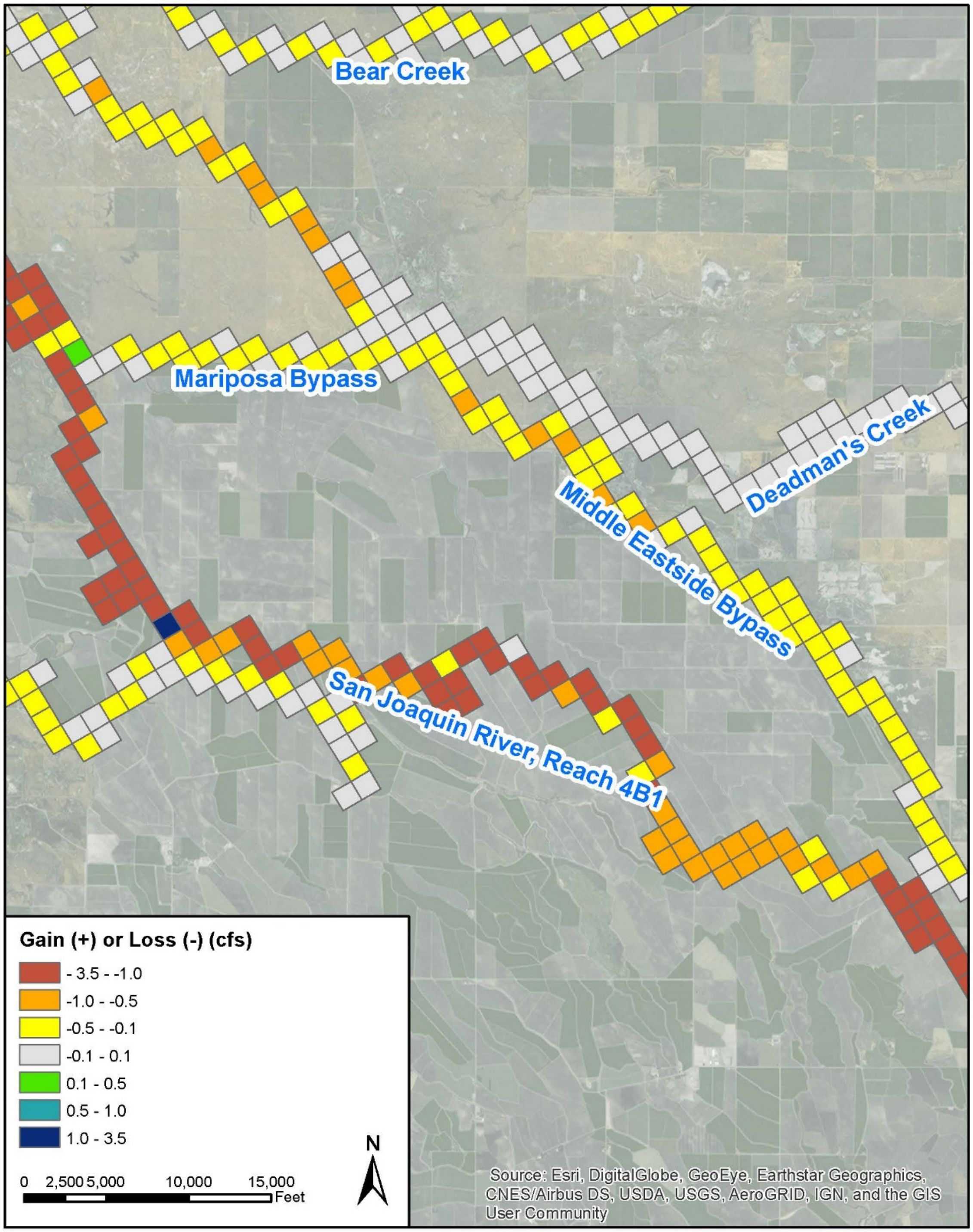

Figure F-22.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on December 1982 (Wet Year Type) Hydrologic Conditions under Alternative 1

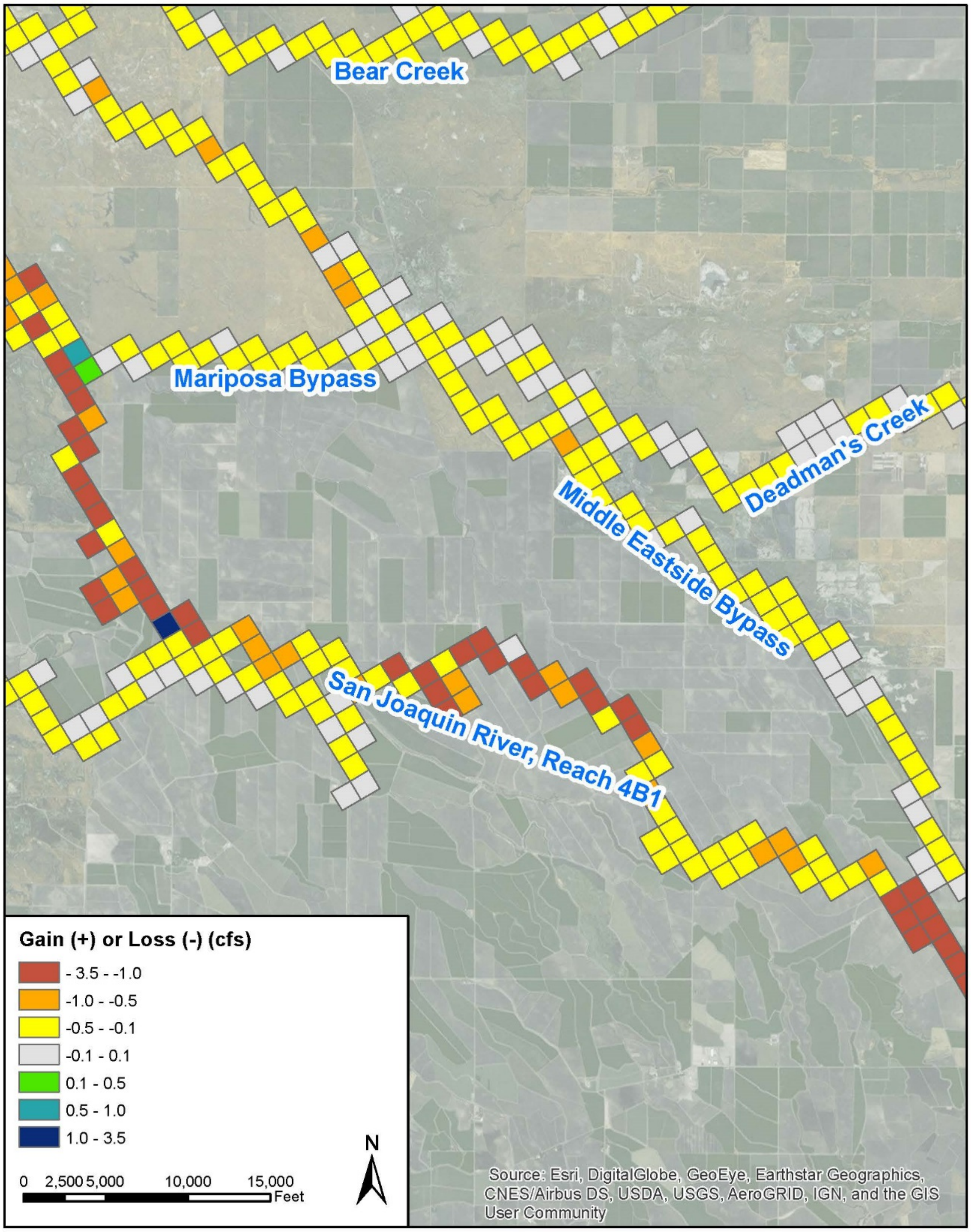

Figure F-23.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on January 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

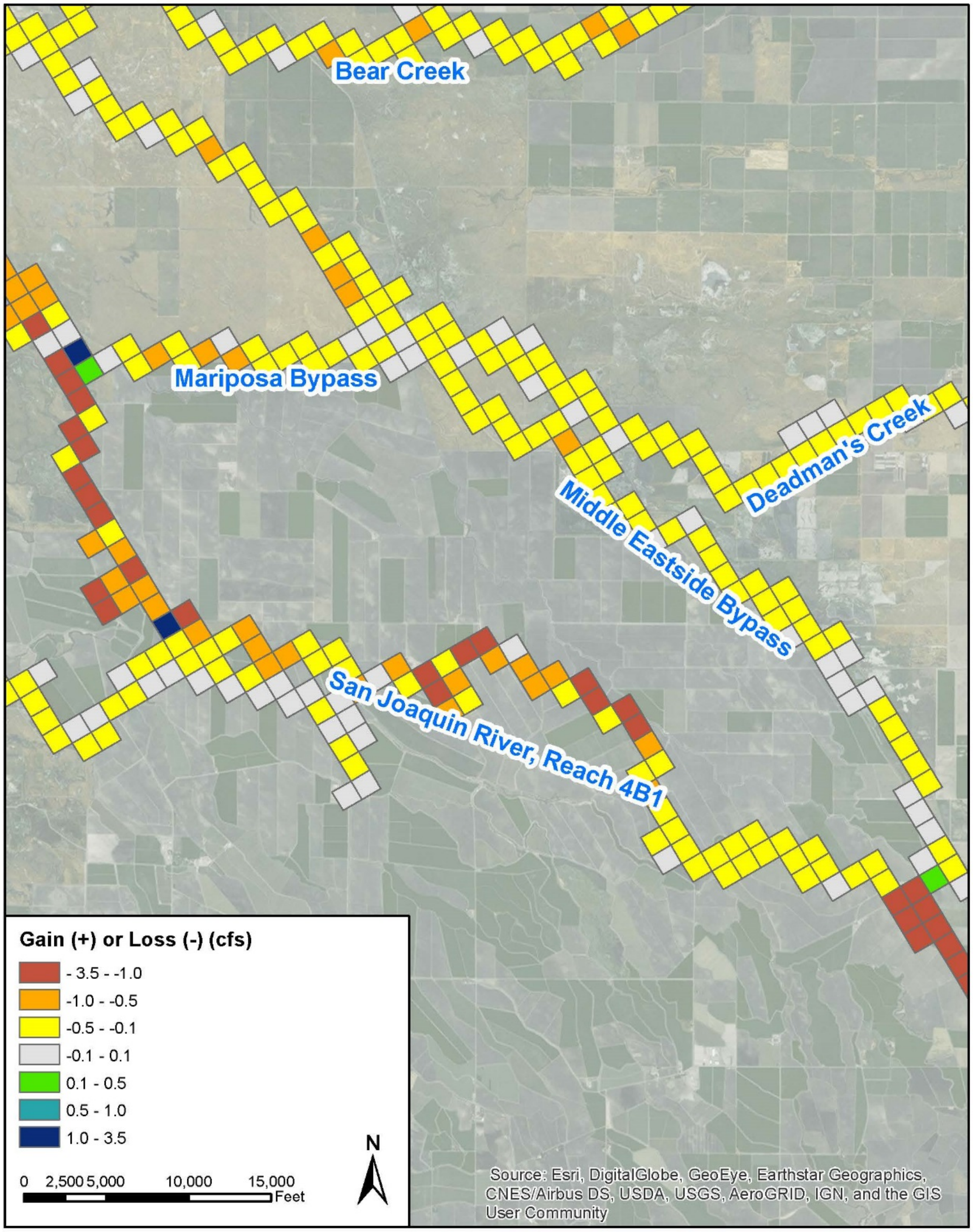

Figure F-24.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on February 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

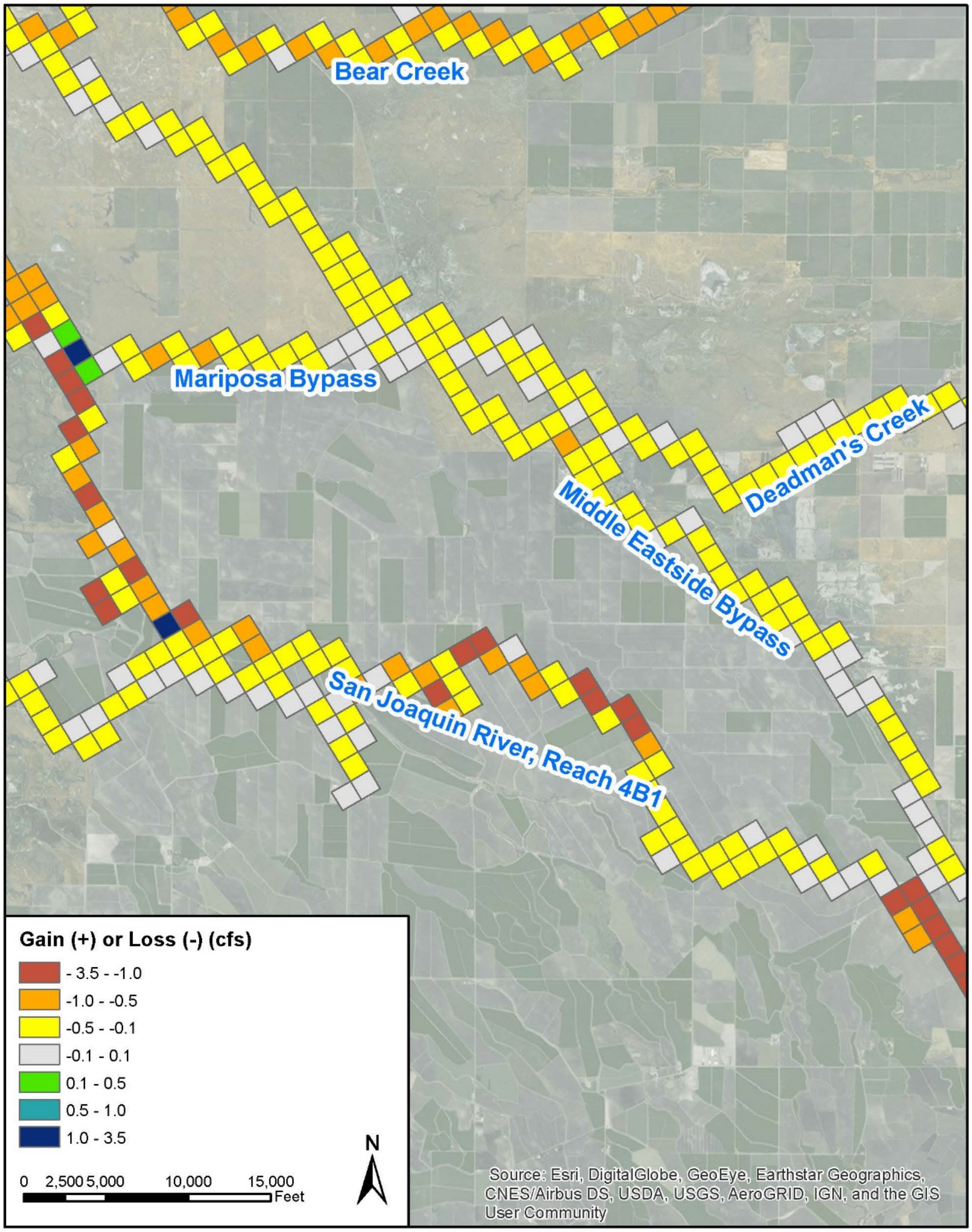

Figure F-25.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on March 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

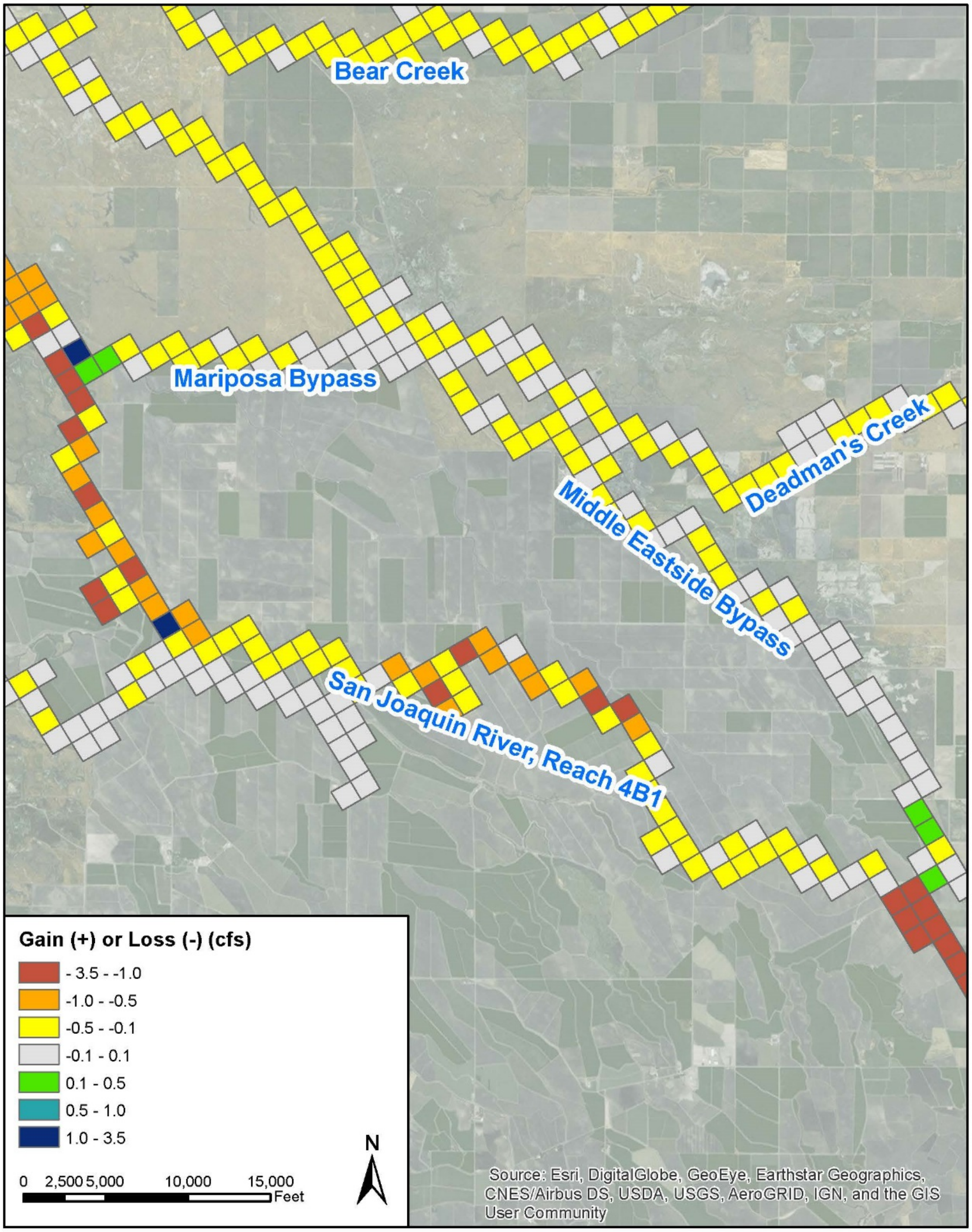

Figure F-26.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on April 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

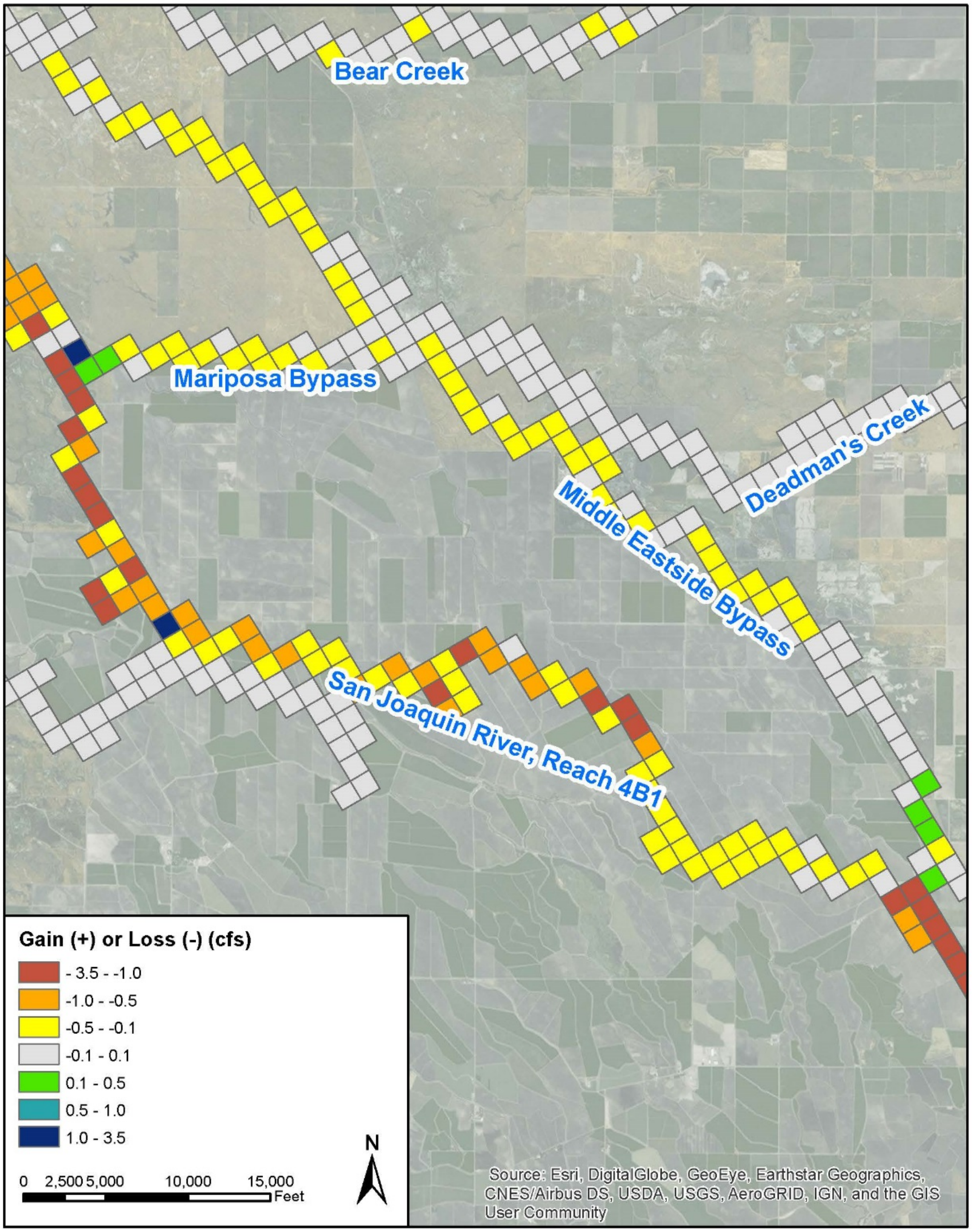

Figure F-27.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on May 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

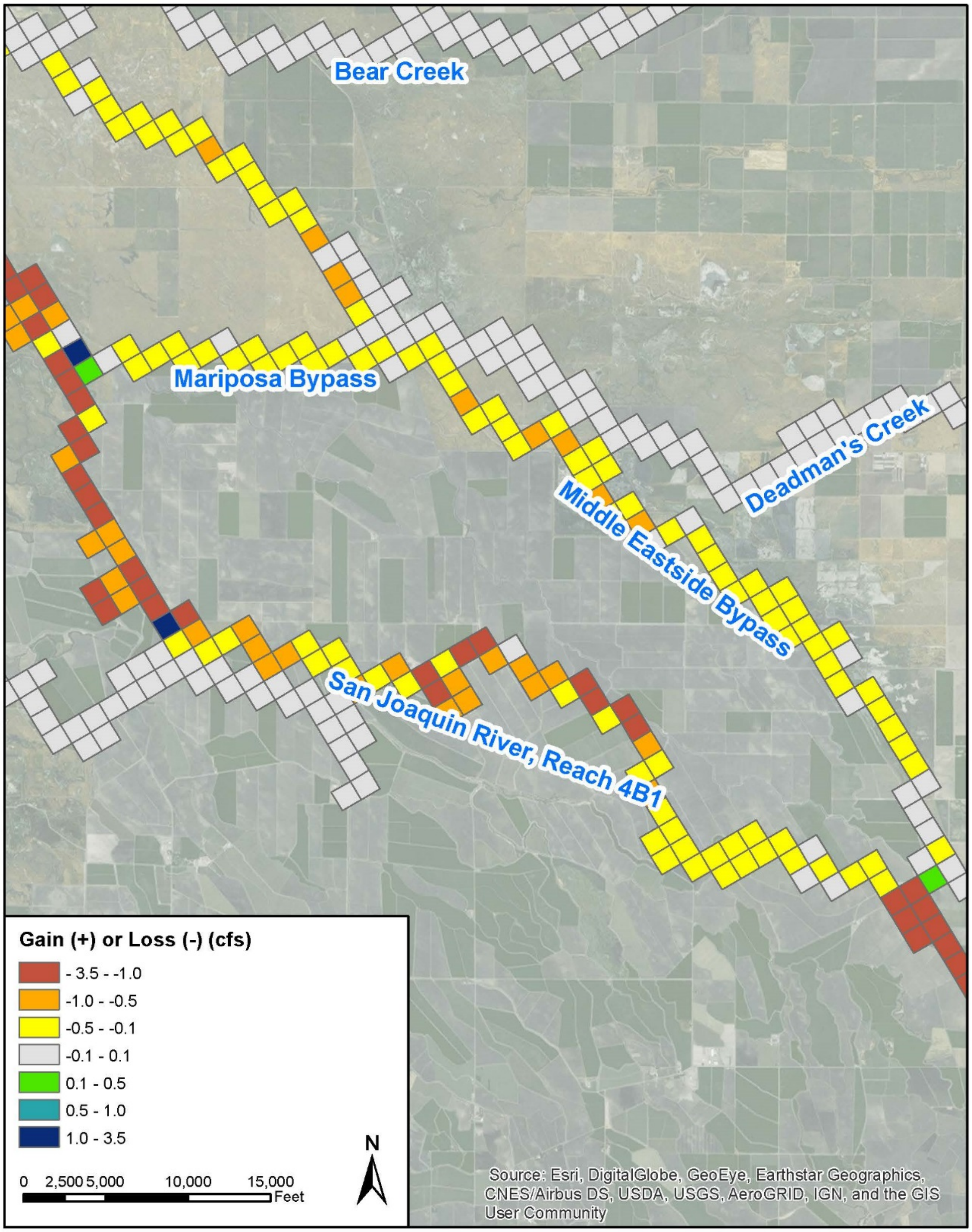

Figure F-28.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on June 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

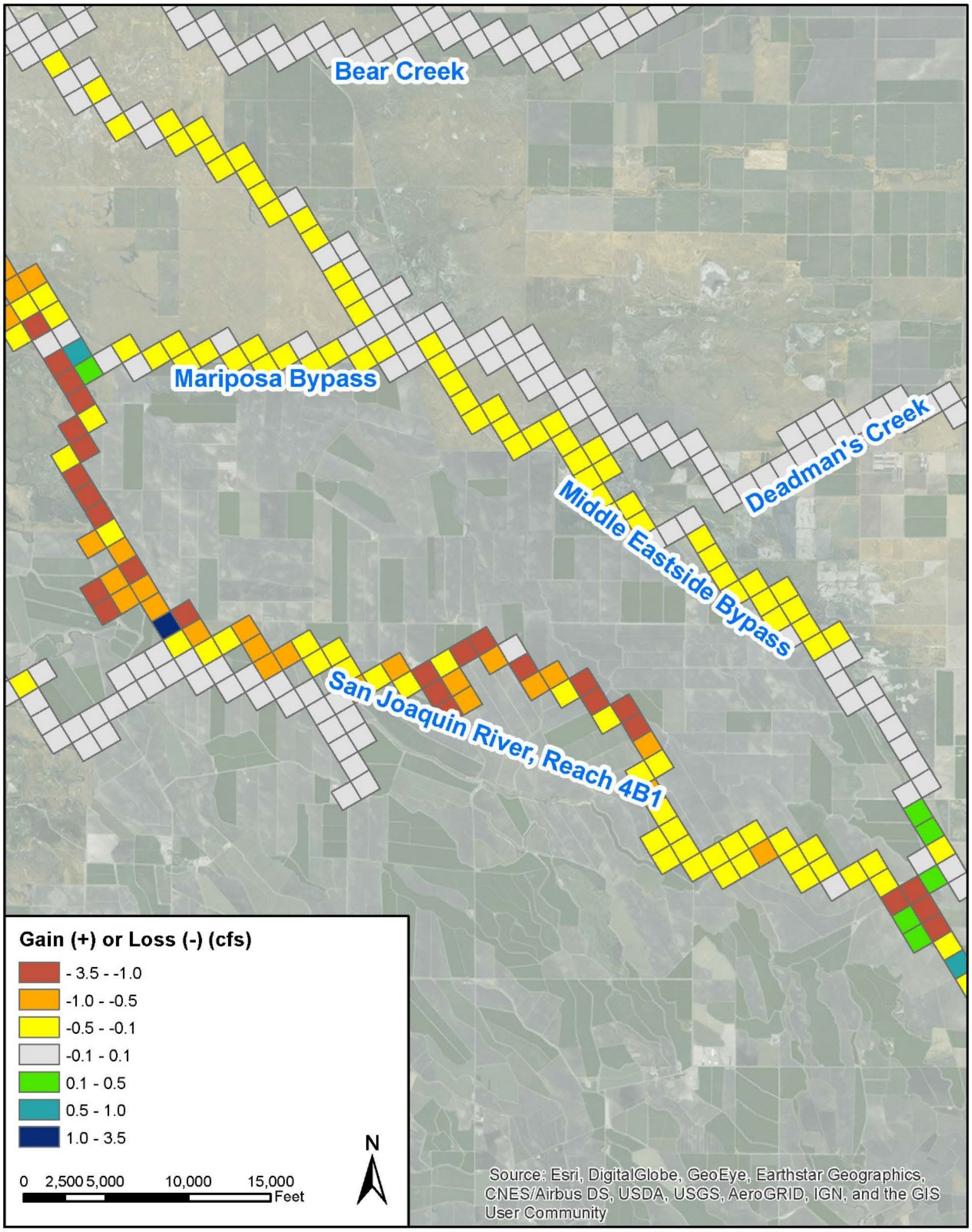

Figure F-29.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on July 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

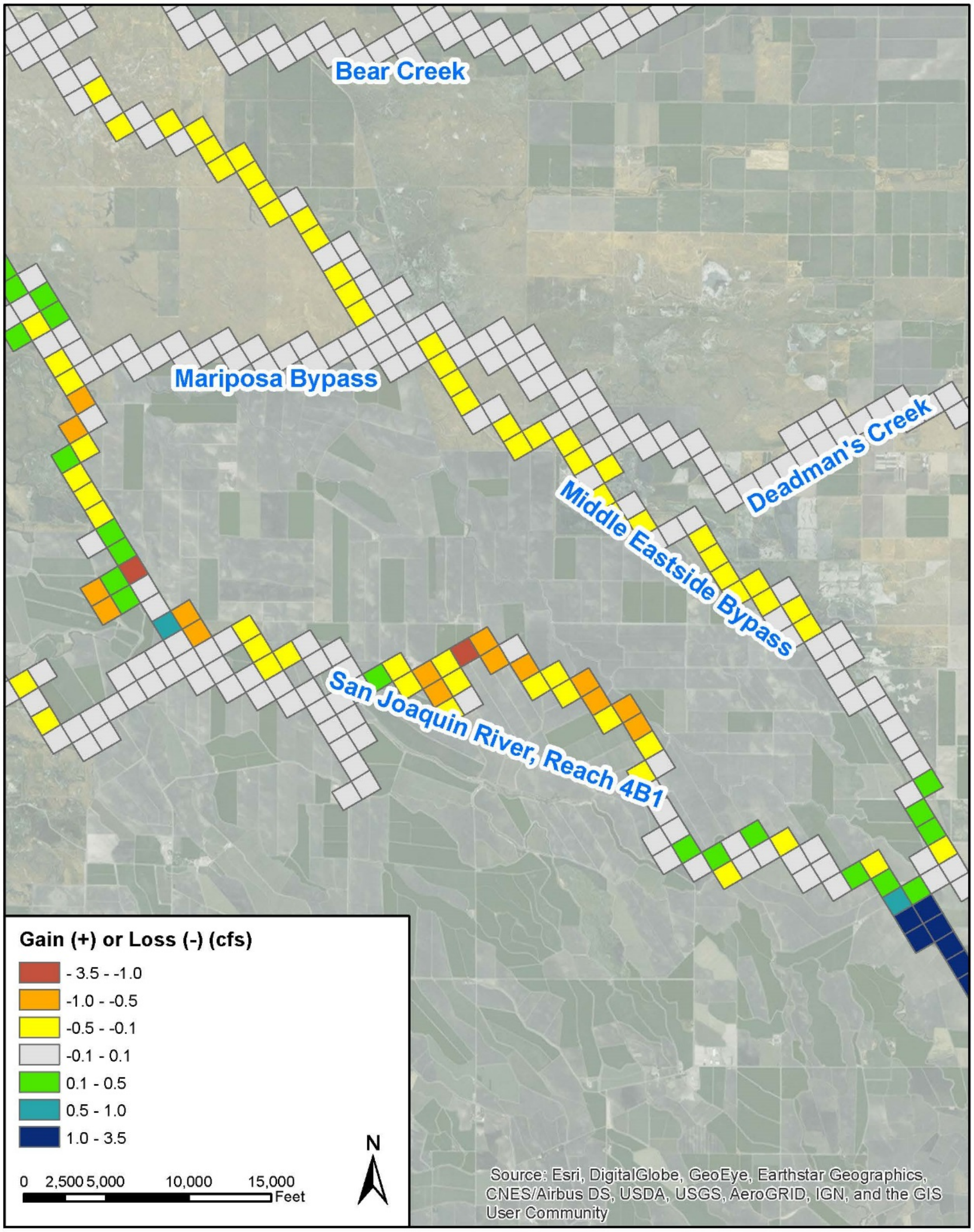

Figure F-30.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on August 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

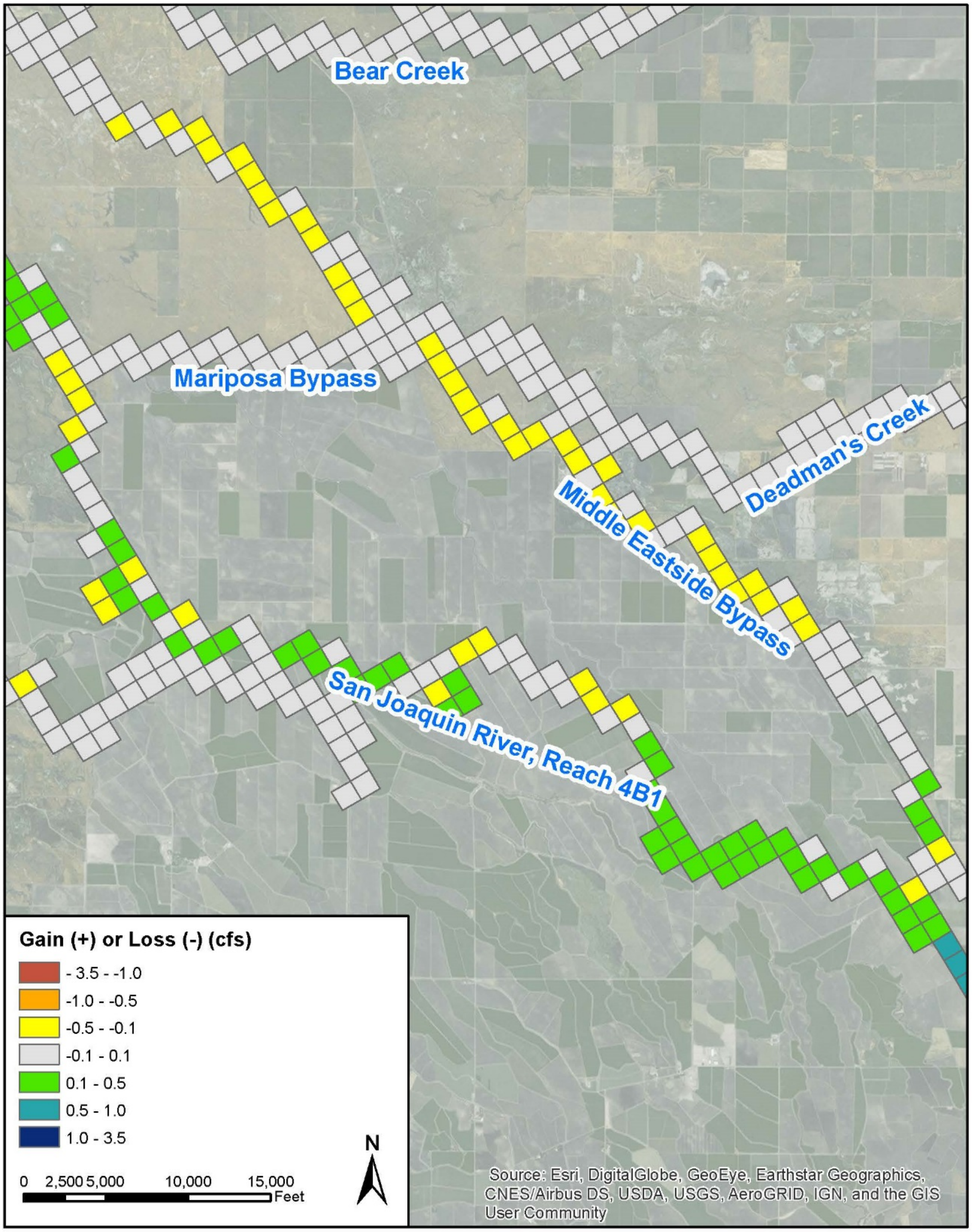

Figure F-31.
Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on September 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

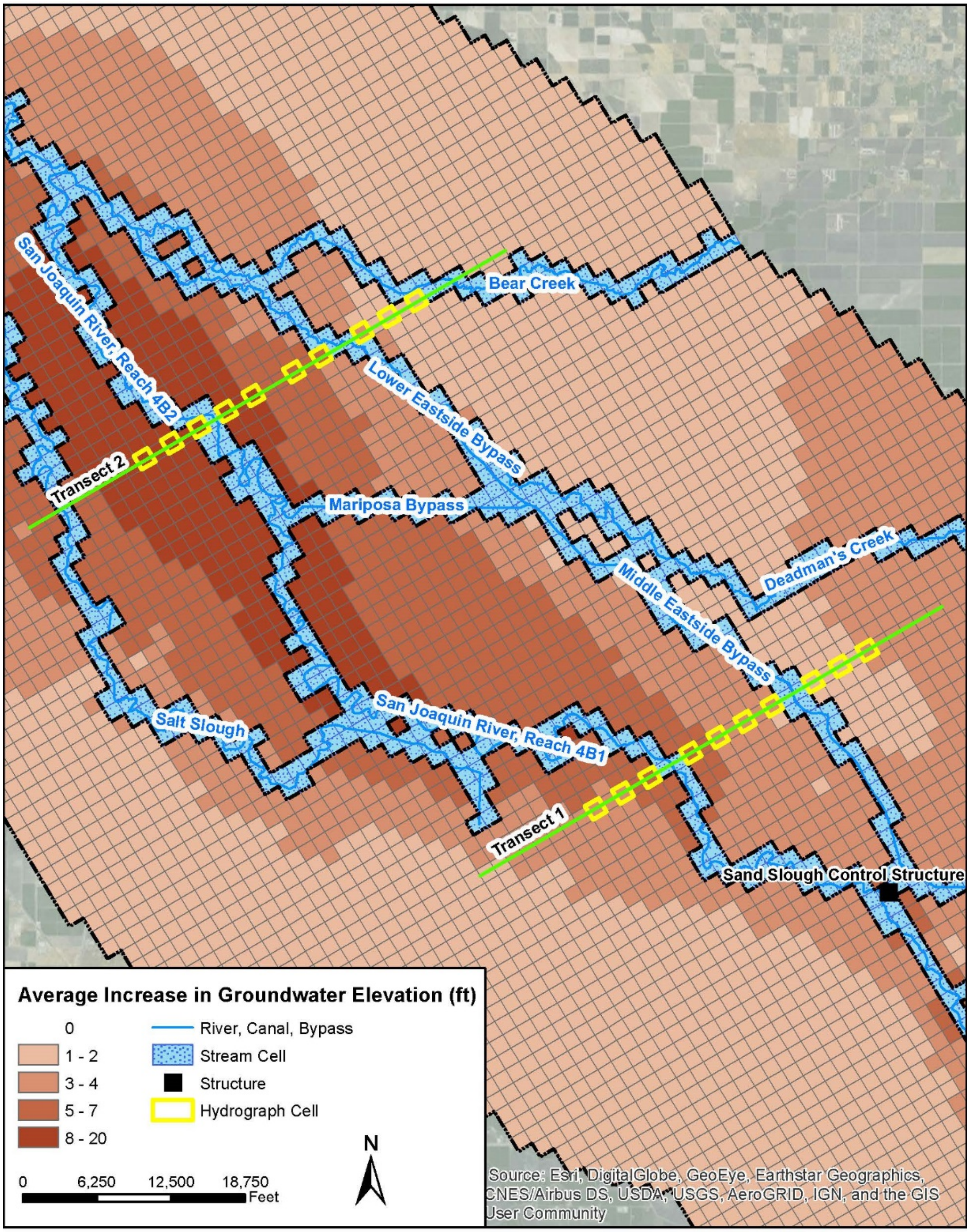

Figure F-32.
Simulated Increase in Shallow Groundwater Elevation (Alternative 1A vs. Baseline), based on May 1975 (Normal-Wet Year Type) Hydrologic Conditions under Alternative 1

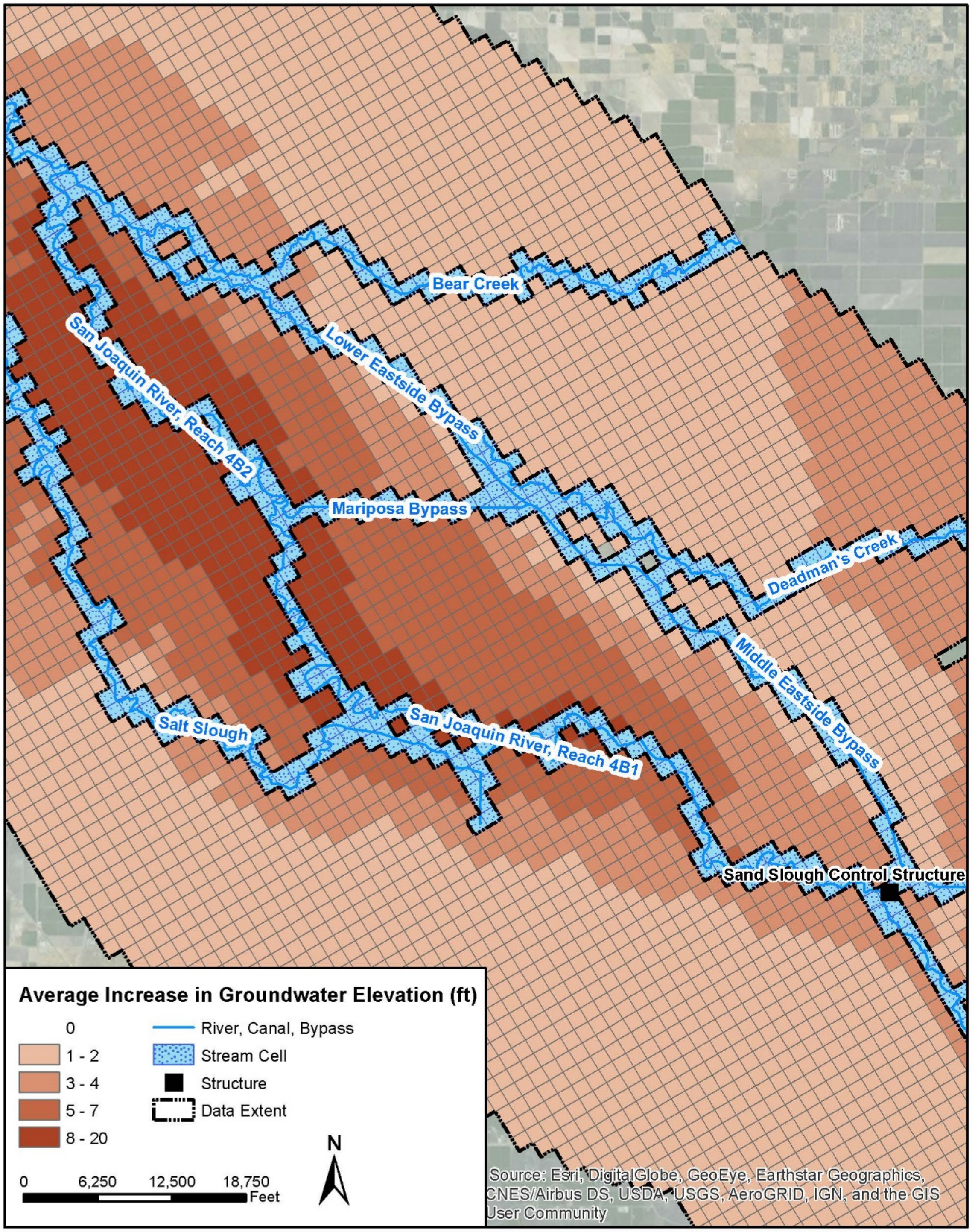

Figure F-33.
Simulated Change in Shallow Groundwater Elevation, based on May 1976 (Critical High Year Type) Hydrologic Conditions under Alternative 1

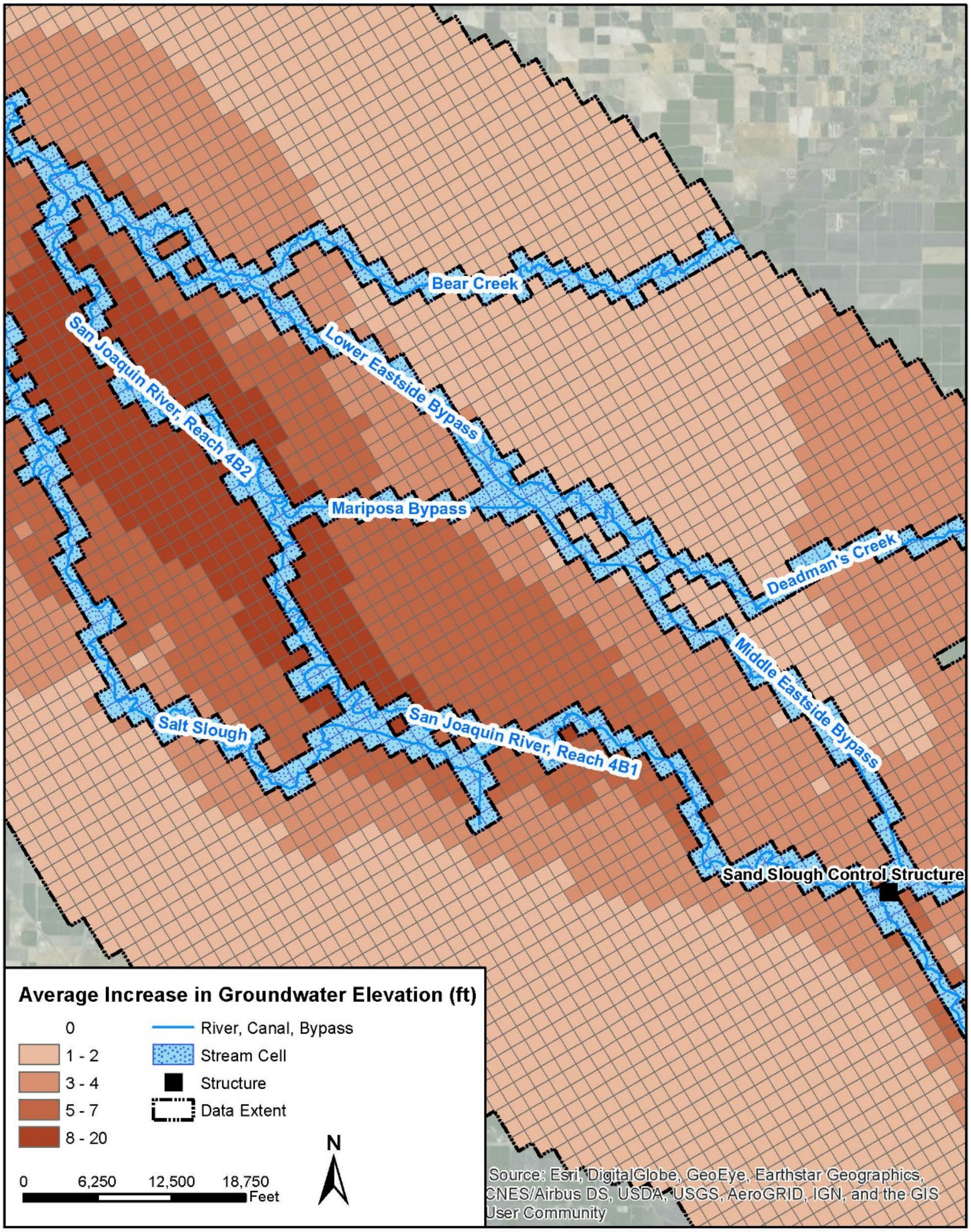

Figure F-34.
Simulated Change in Shallow Groundwater Elevation, based on May 1977 (Critical Low Year Type) Hydrologic Conditions under Alternative 1

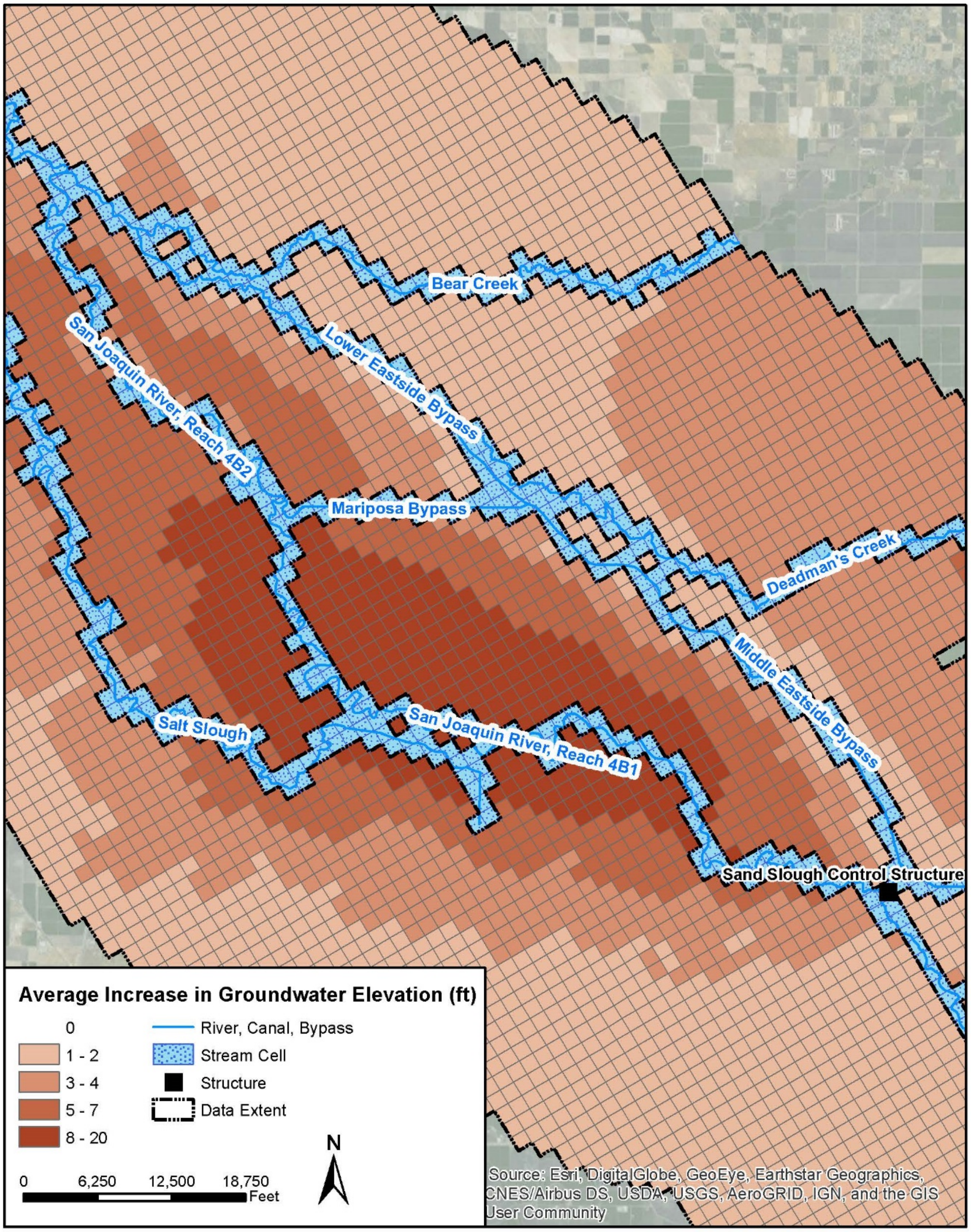

Figure F-35.
Simulated Change in Shallow Groundwater Elevation, based on May 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

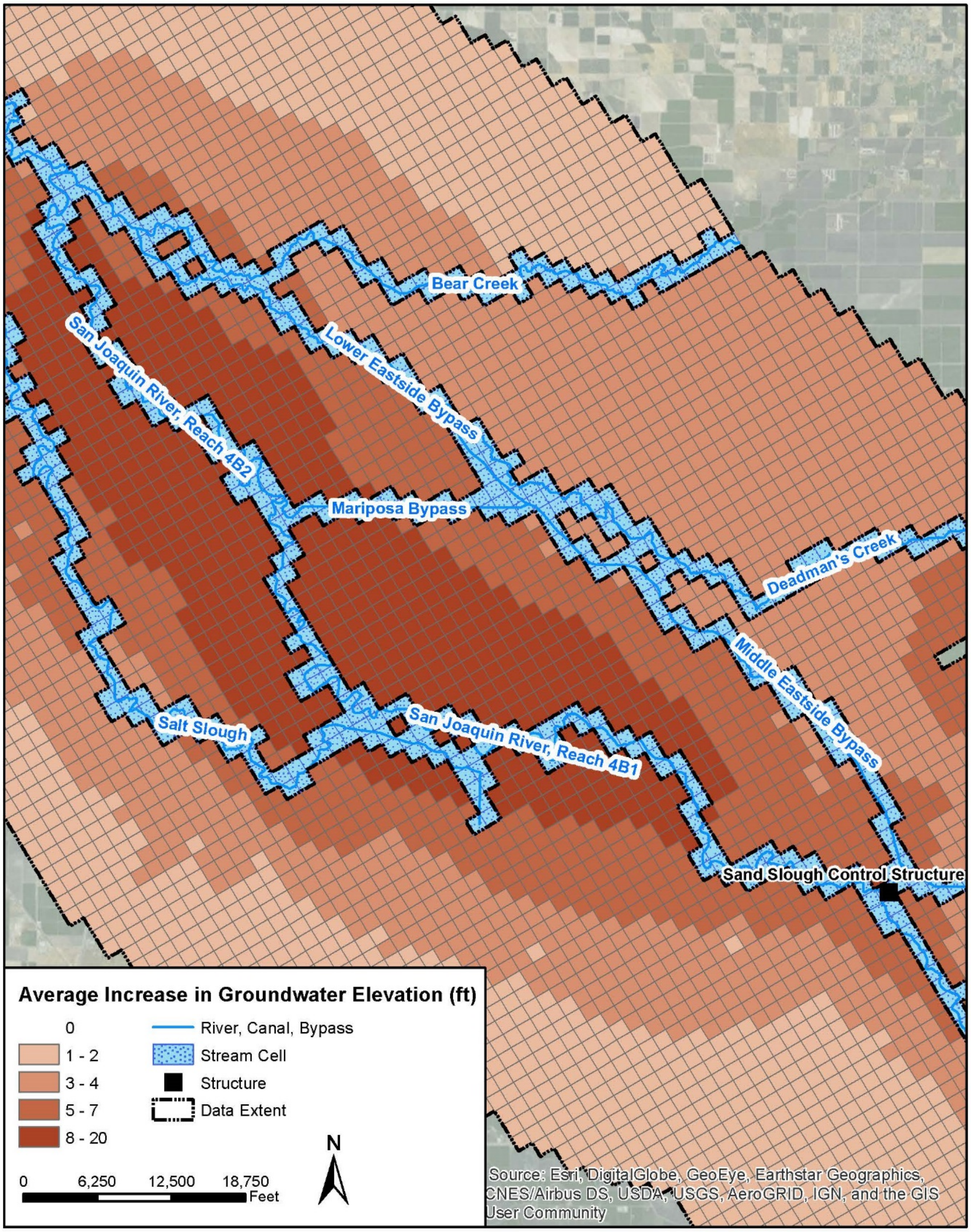

Figure F-36.
Simulated Change in Shallow Groundwater Elevation, based on May 1992 (Dry Year Type) Hydrologic Conditions under Alternative 1

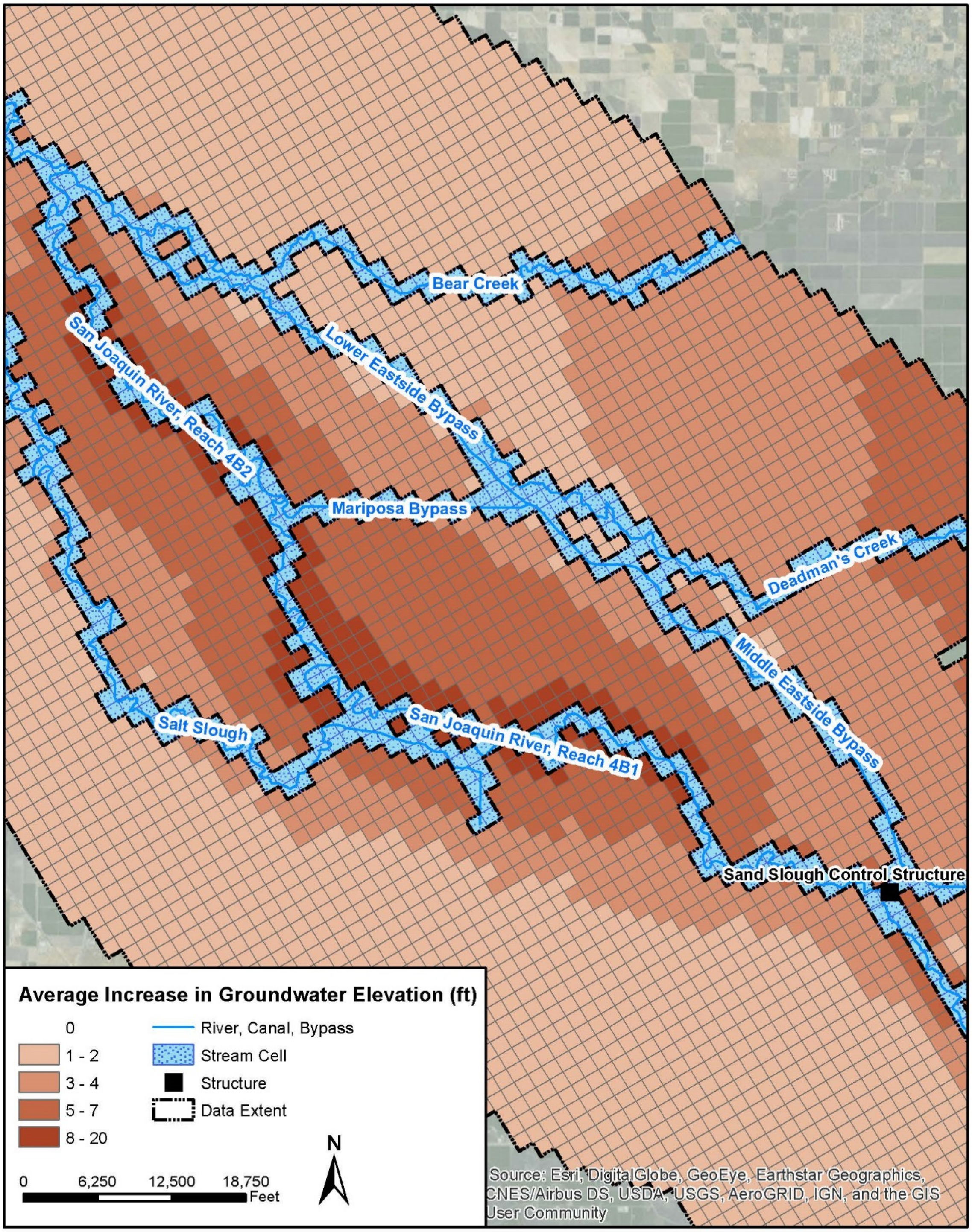

Figure F-37.
Simulated Change in Shallow Groundwater Elevation, based on May 2003 (Normal-Dry Year Type) Hydrologic Conditions under Alternative 1

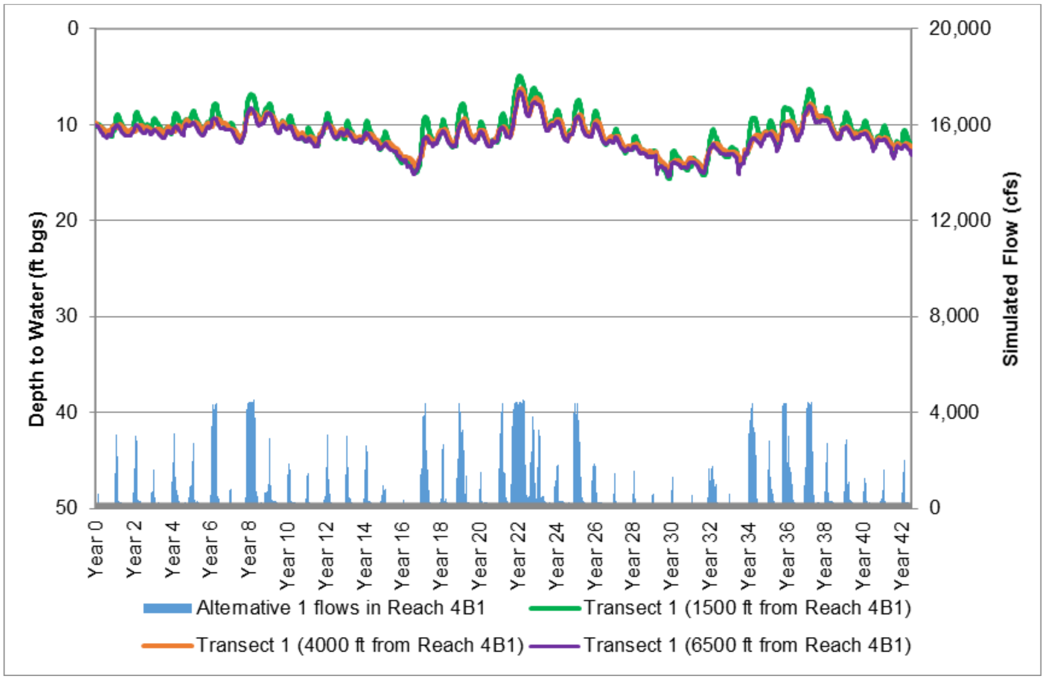

Figure F-38.
Simulated Groundwater Elevation, Left Bank of San Joaquin River, Transect 1 under Alternative 1

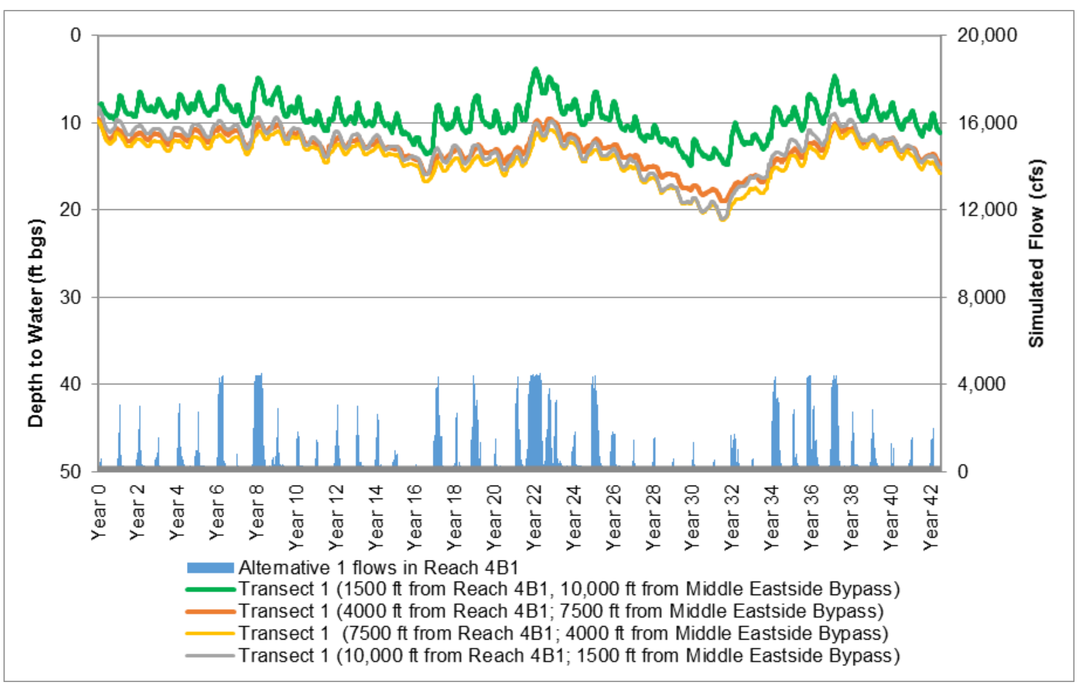

Figure F-39.
Simulated Groundwater Elevation, Right Bank from San Joaquin River and Left Bank from Eastside Bypass, Transect 1 under Alternative 1

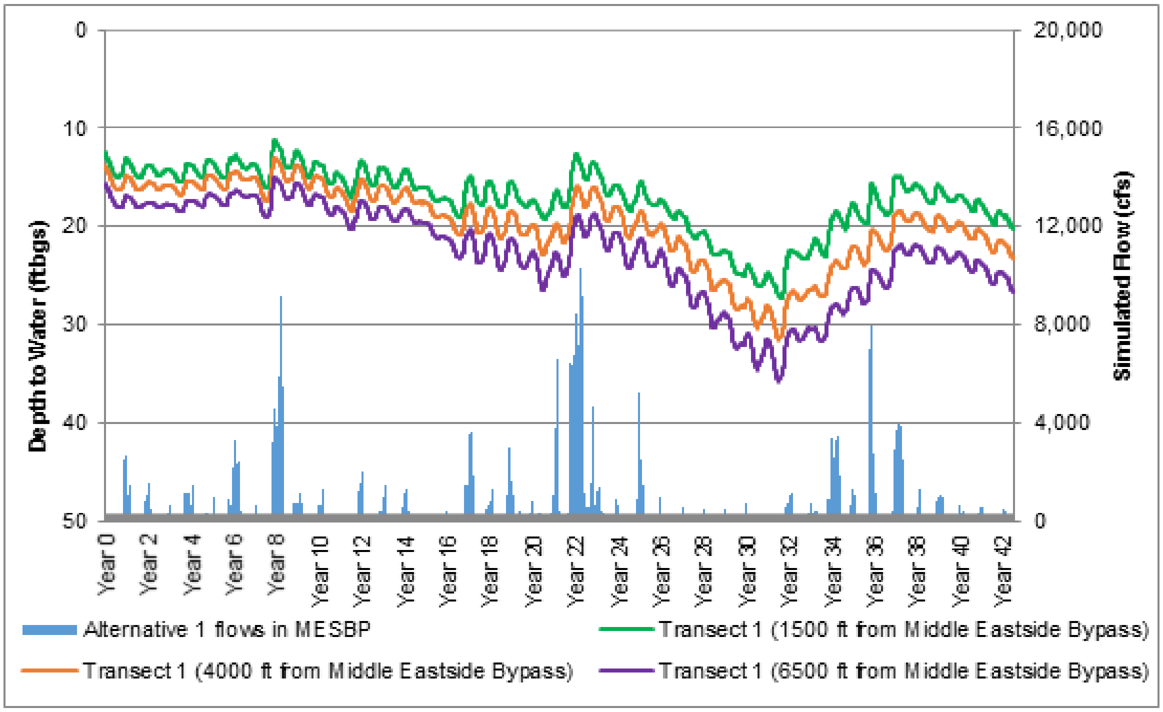

Figure F-40.
Simulated Groundwater Elevation, Right Bank from Eastside Bypass, Transect 1 under Alternative 1

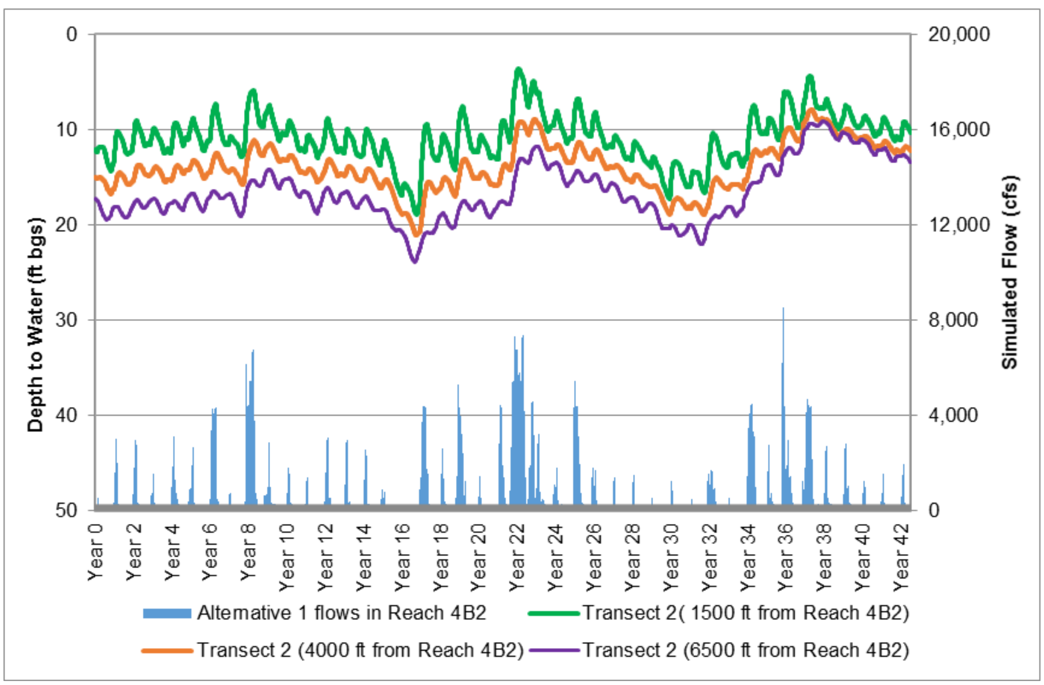

Figure F-41.
Simulated Groundwater Elevation, Left Bank from San Joaquin River, Transect 2 under Alternative 1

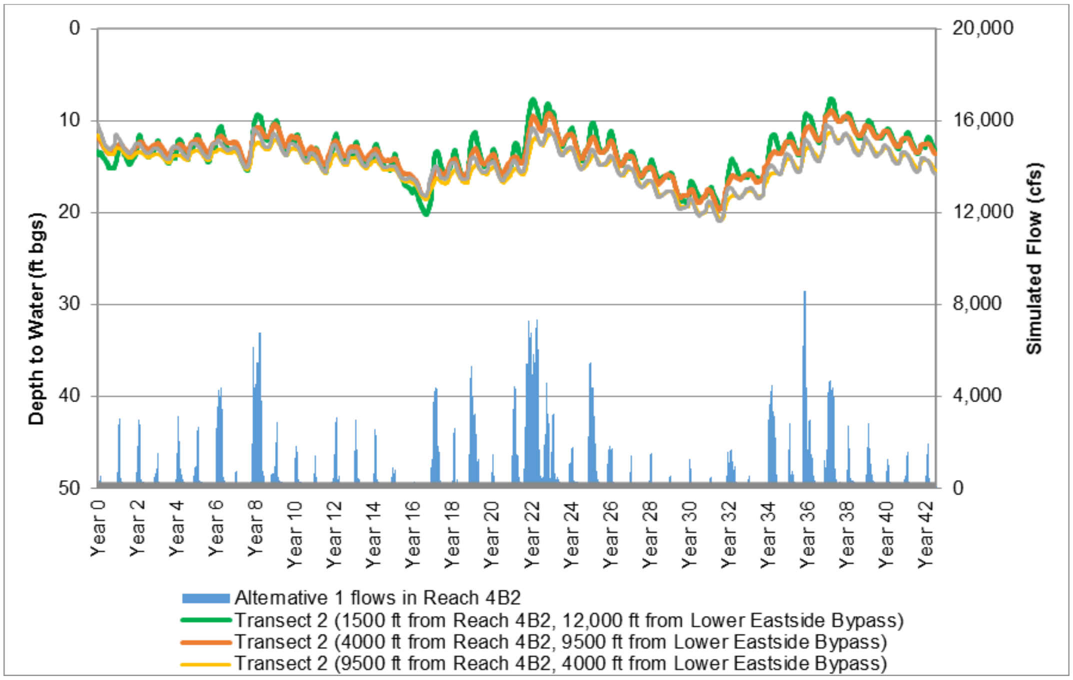

Figure F-42.
Simulated Groundwater Elevation, Right Bank from San Joaquin River and Left Bank from Eastside Bypass, Transect 2 under Alternative 1

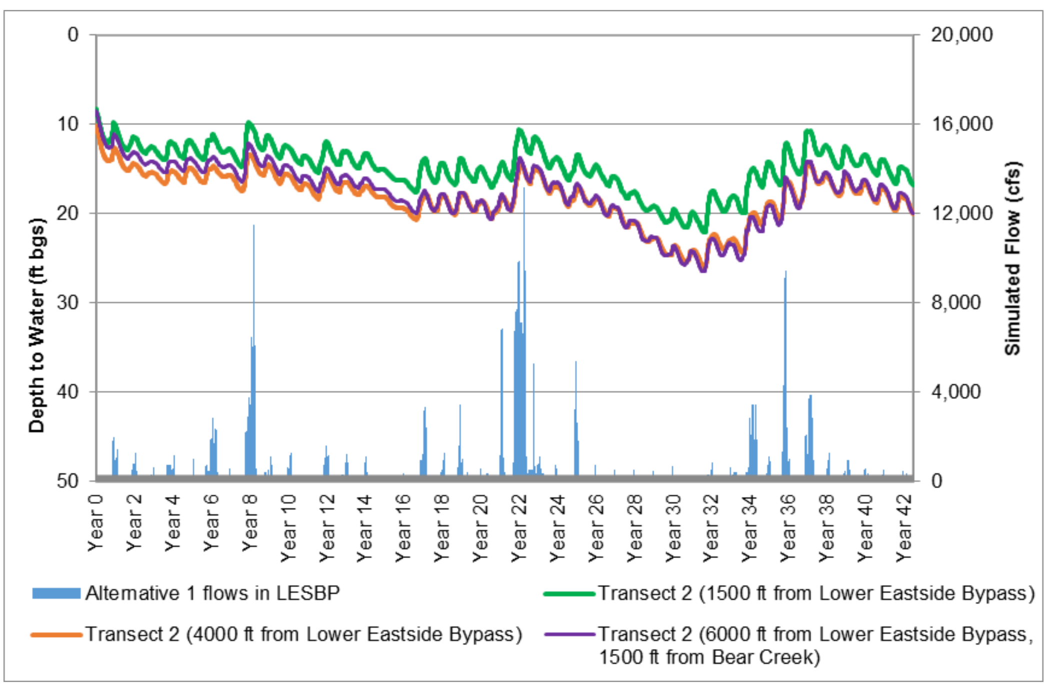

Figure F-43.
Simulated Groundwater Elevation, Right Bank from Eastside Bypass, Transect 2 under Alternative 1

F.2.2 Alternative 2 - Bypass Restoration Alternative

Alternative 2 (includes Alternatives 2A and 2B) evaluates Restoration Flows being released down the Eastside Bypass. Under these alternatives all flows would be released down the Eastside Bypass with flows greater than 16,000 cfs going into Reach 4B (up to 475 cfs).

Compared to the No Action Alternative, Alternative 2 would have increased Restoration Flow in the Mariposa and Middle Eastside bypasses. Adding flows to this reach would change the local hydrogeology. As compared to the No Action Alternative, the increase in flow in the Middle Eastside Bypass could cause additional seepage of water from the bypass to the groundwater system in areas where Middle Eastside Bypass is a losing stream. The increase in flow could also cause less gain of groundwater into the river in areas where Middle Eastside Bypass is gaining.

As under Alternative 1, the SJRRPGW groundwater model was used to simulate conditions to better characterize the interaction between surface water and groundwater. Similar to results under Alternative 1 flows, the model found that groundwater flows into and out of the river would vary spatially and temporally, with some segments of Reach 4B1 and the Middle Eastside Bypass switching from gaining to losing streams within the same month.

Figure F-44 and Figure F-45 show the average monthly variability of gains and losses in Reach 4B1 and the Middle Eastside Bypass; the Middle Eastside Bypass is mostly a losing reach. April is the month where the most losses, on average, are calculated to occur.

Figures D-46 through D-57 show the spatial variability of groundwater flows within Reach 4B1 and the Middle Eastside Bypass under wet hydrologic conditions. During this period, all Restoration Flow would be routed through the Middle Eastside Bypass (ranges from 45 to 5,600 cfs). The Middle Eastside Bypass is mostly a losing a stream during the wet year. The figures show the distribution of areas with gain and/or loss is not uniform across the entire length and time.

Figures D-58 through D-63, show the effects of increased flows in the Middle Eastside Bypass channel on groundwater levels. The figures compare shallow groundwater levels between Alternative 2 and the No Action Alternative in May 1975 (normal-wet year type), May 1976 (critical high year type), May 1977 (critical low year type), May 1983 (wet year type), May 1992 (dry year type), and May 2003 (normal-dry year type). This time period represents the groundwater levels in the Reach 4B/ESB Project area after spring pulse flows (March 1 to May 1) under different hydrologic conditions and therefore represents the highest increase in groundwater levels under varying hydrologic conditions. Representative hydrographs were extracted from the model along transect 1 and transect 2 within the Reach 4B/ESB Project area (transect locations shown in Figure F-58).

Figures D-64 through D-66 show the simulated groundwater elevations under Alternative 2 along Transect 1. As shown in Figure F-66, the shallowest groundwater level along the Middle Eastside Bypass (right bank) ranges from 10.8 to 15.3 ft bgs. The shallowest groundwater level on the left bank is approximately 8.2 feet (see Figure F-65).

Figures D-67 through D-69 show the simulated groundwater elevations under Alternative 2 along Transect 2. As shown in Figure F-67, the shallowest groundwater level along the Reach 4B2 left bank ranges from 3.3 to 9.9 ft bgs. Groundwater levels along Reach 4B2 right bank range from 7.5 to 10.4 ft bgs (see Figure F-68). Groundwater levels along the Lower Eastside Bypass right bank range from 8.3 to 8.4 ft bgs (see Figure F-69).

Figure F-44.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on May 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

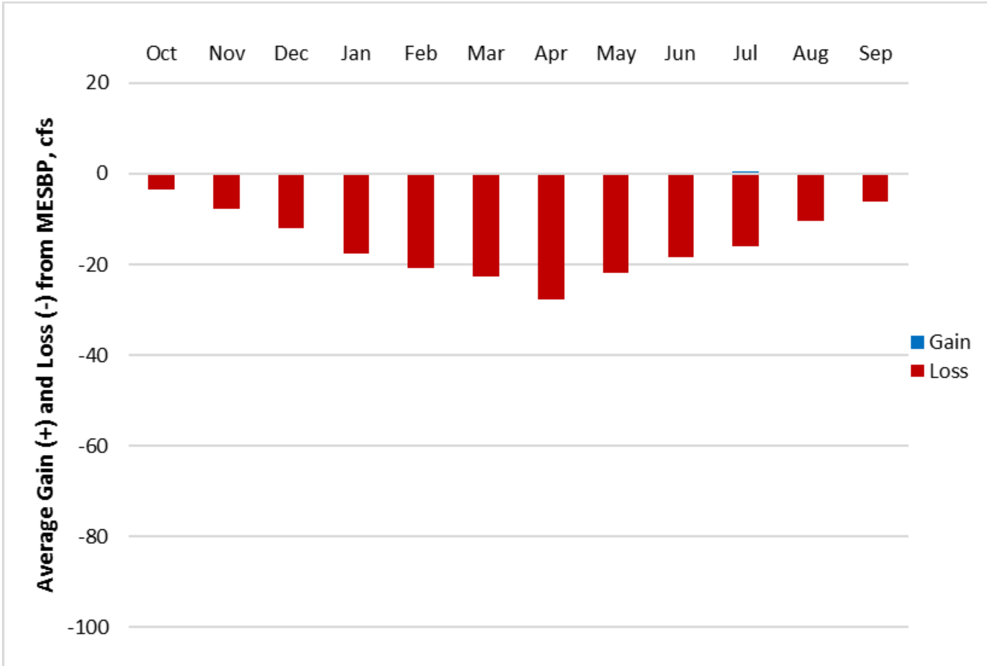

Figure F-45.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on May 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

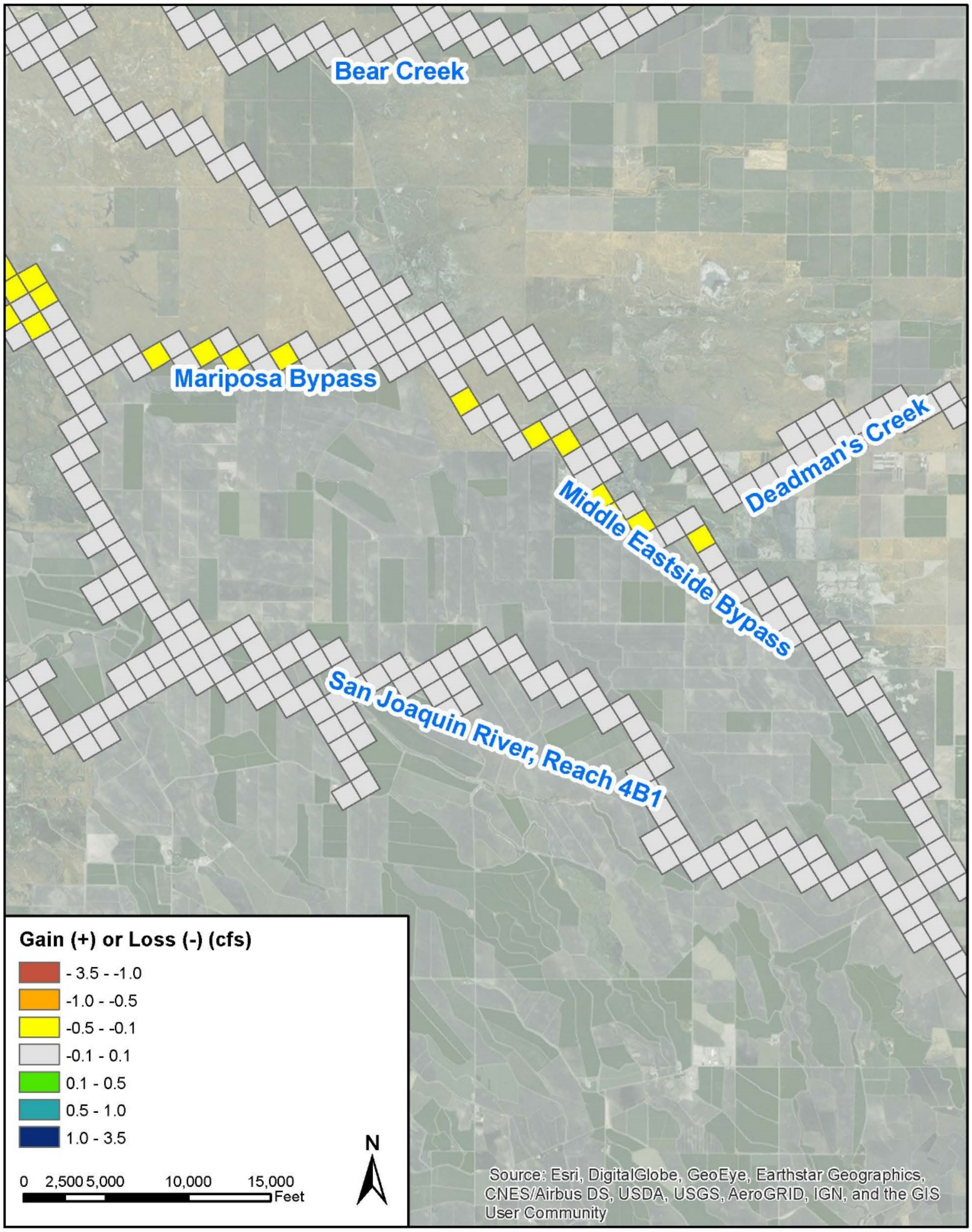

Figure F-46.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on October 1982 (Wet Year Type) Hydrologic Conditions under Alternative 2

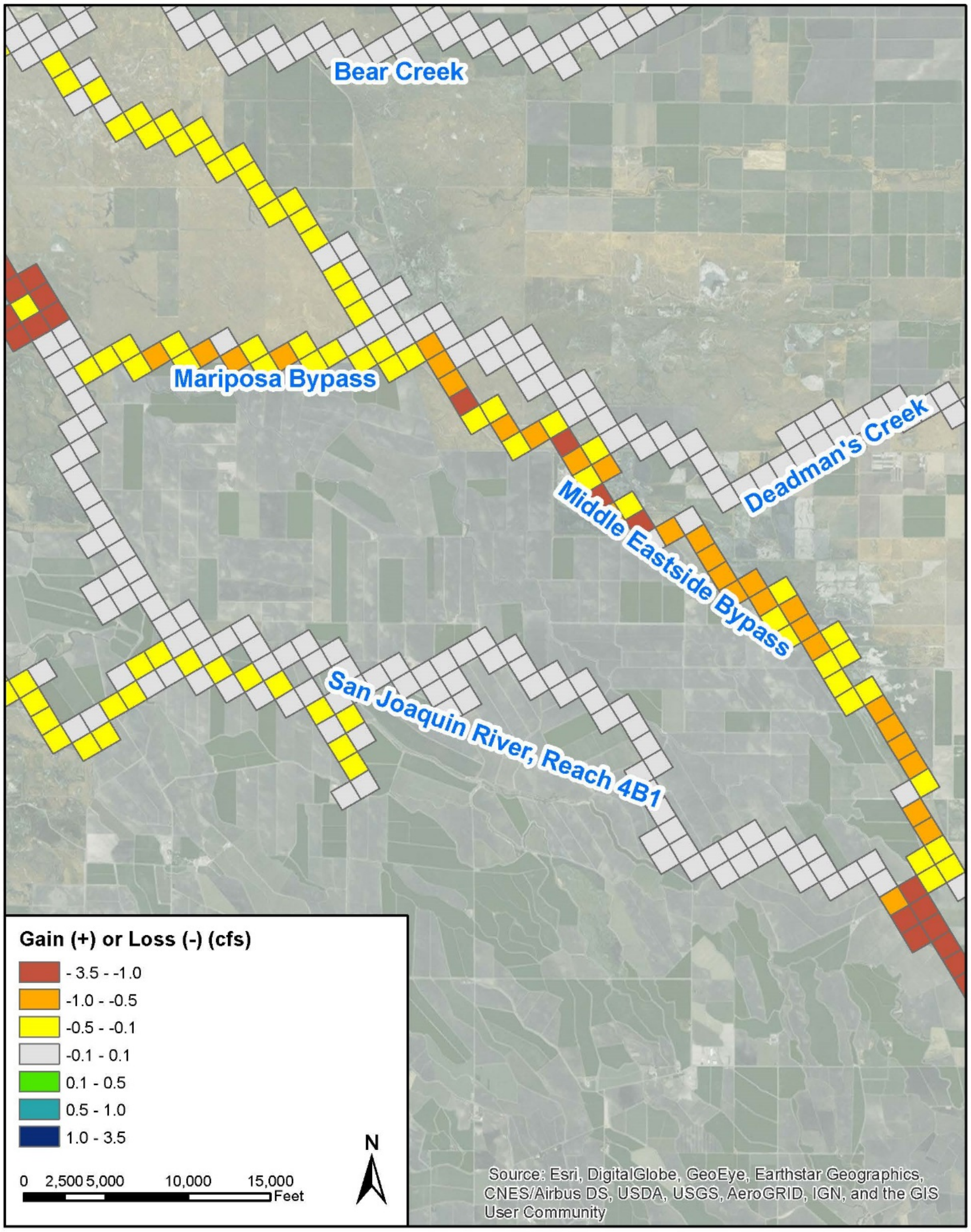

Figure F-47.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on November 1982 (Wet Year Type) Hydrologic Conditions under Alternative 2

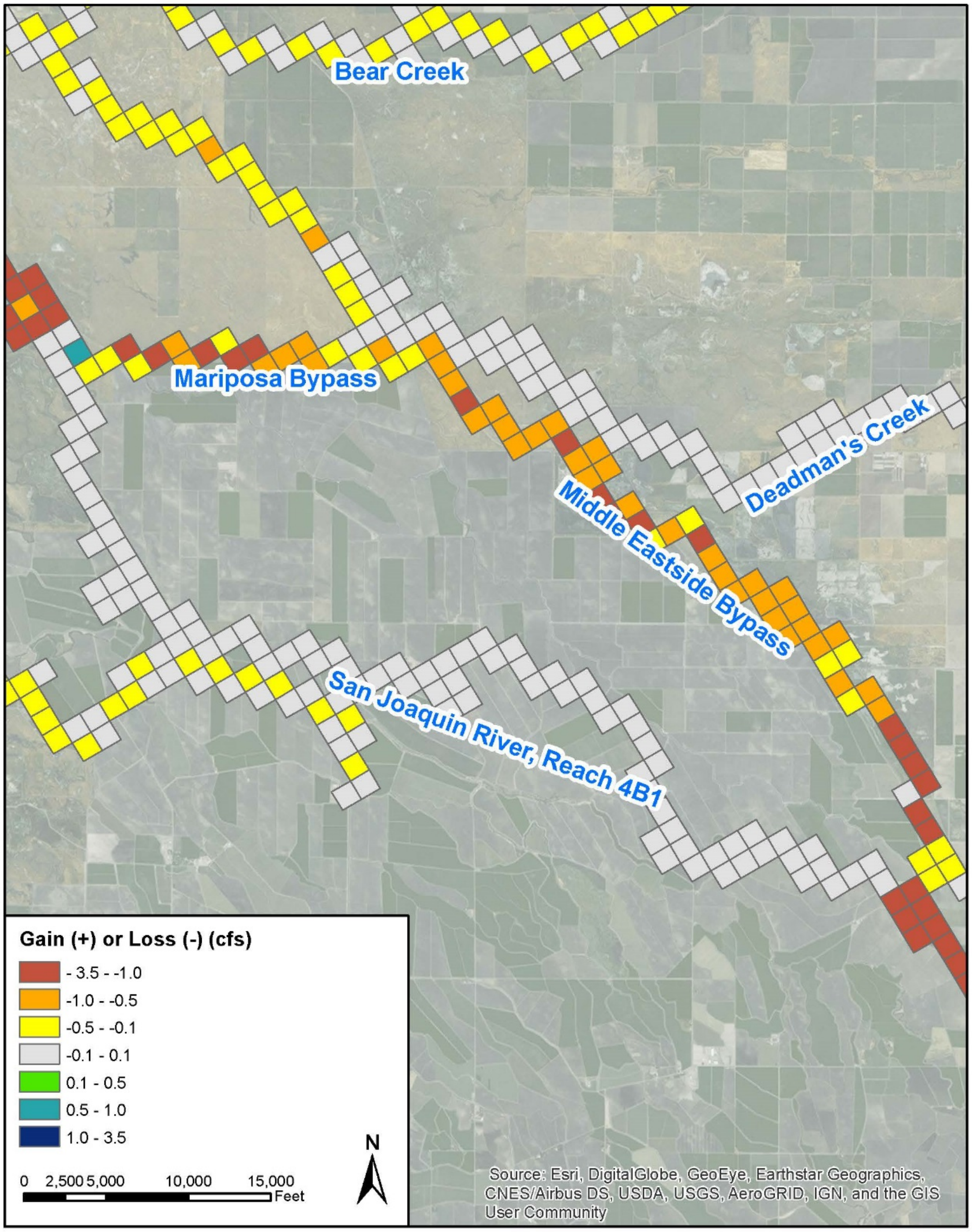

Figure F-48.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on December 1982 (Wet Year Type) Hydrologic Conditions under Alternative 2

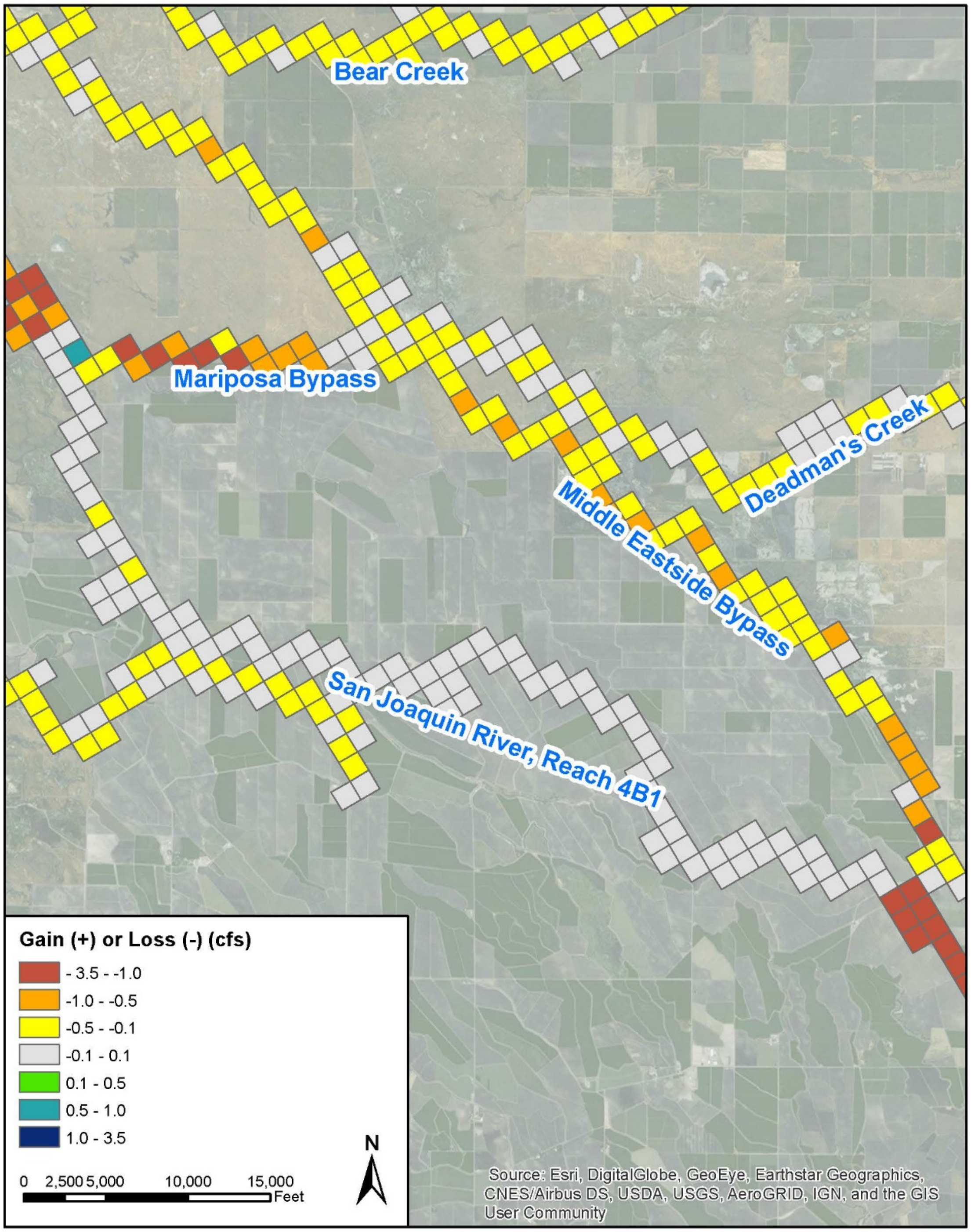

Figure F-49.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on January 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

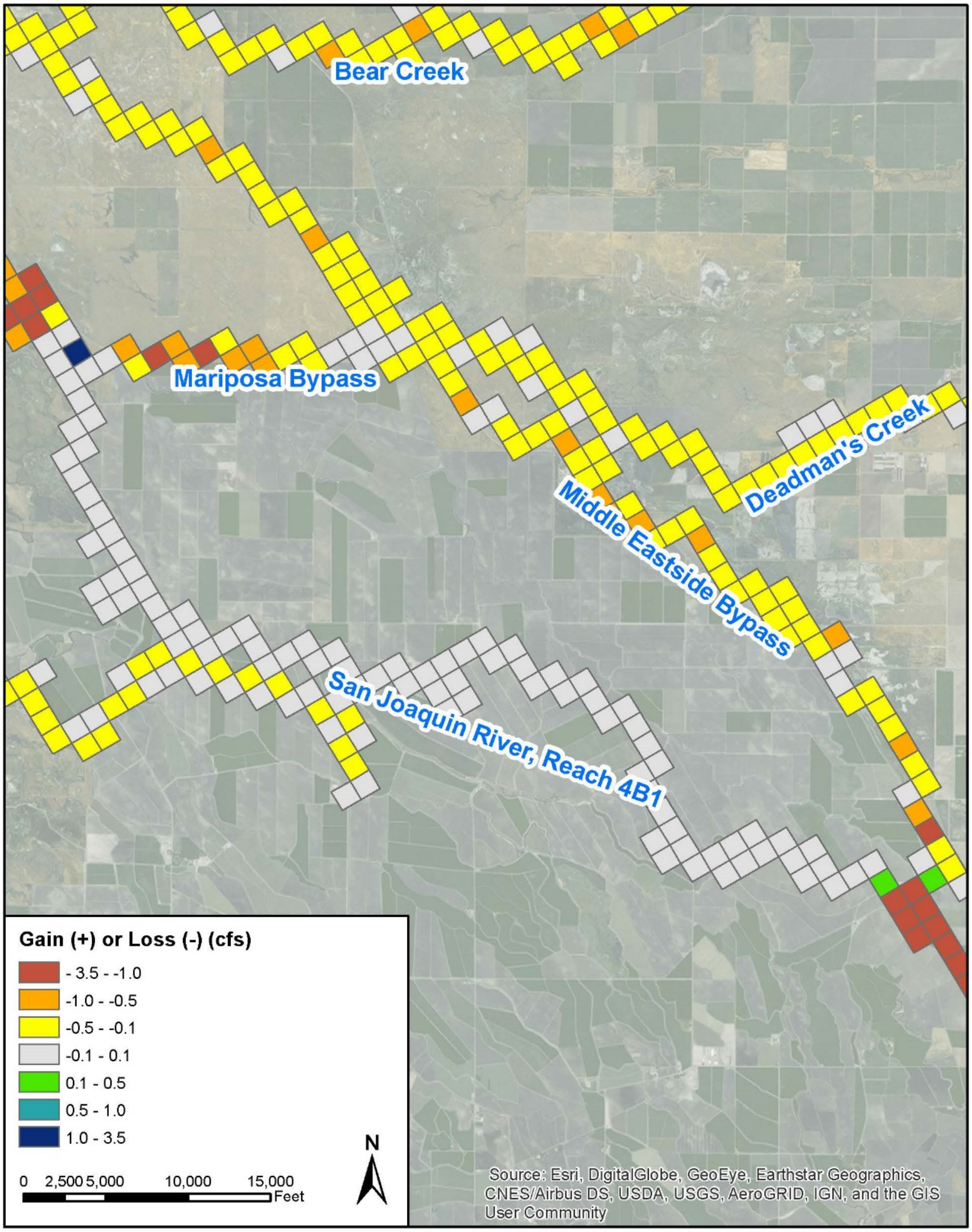

Figure F-50.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on February 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

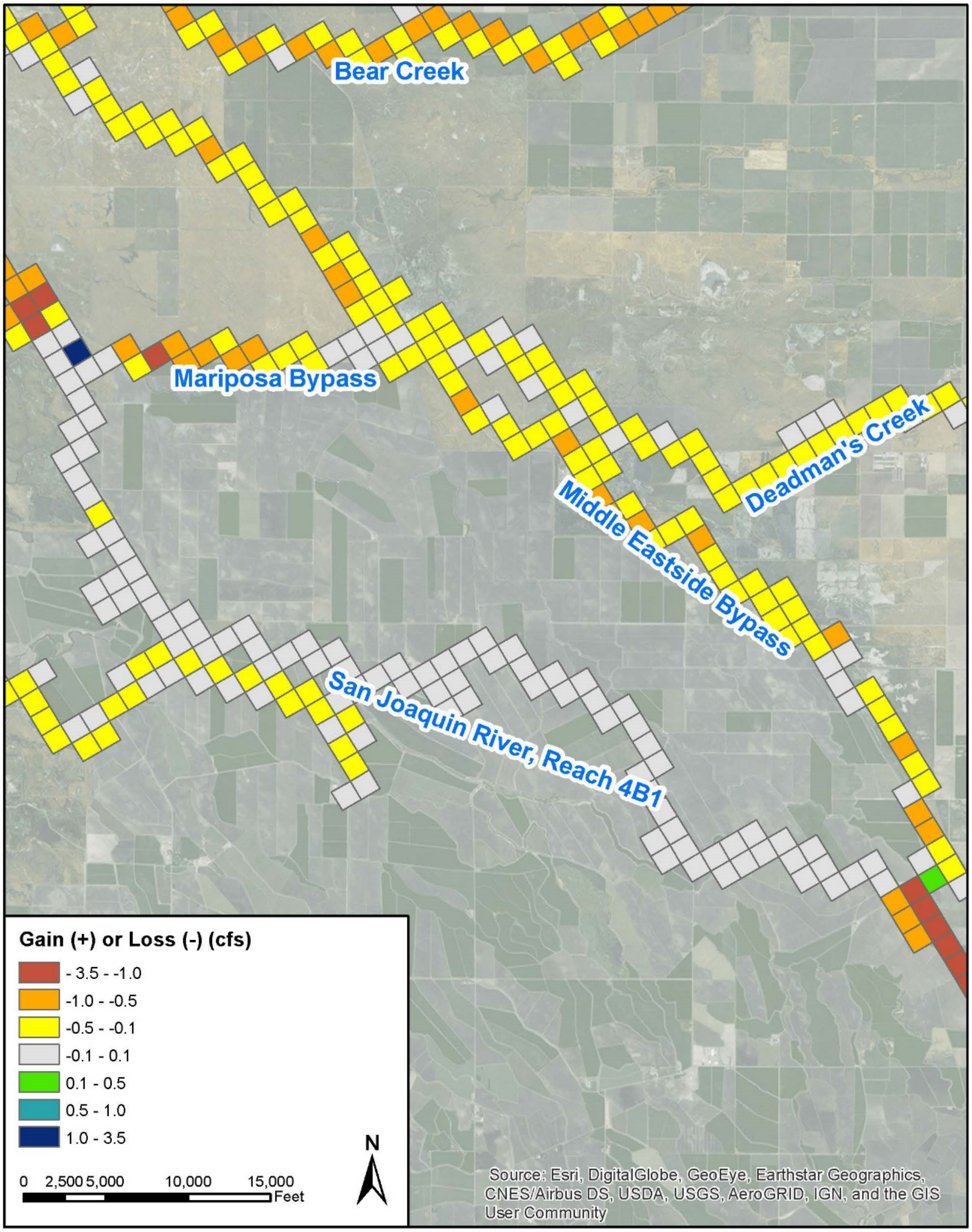

Figure F-51.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on March 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

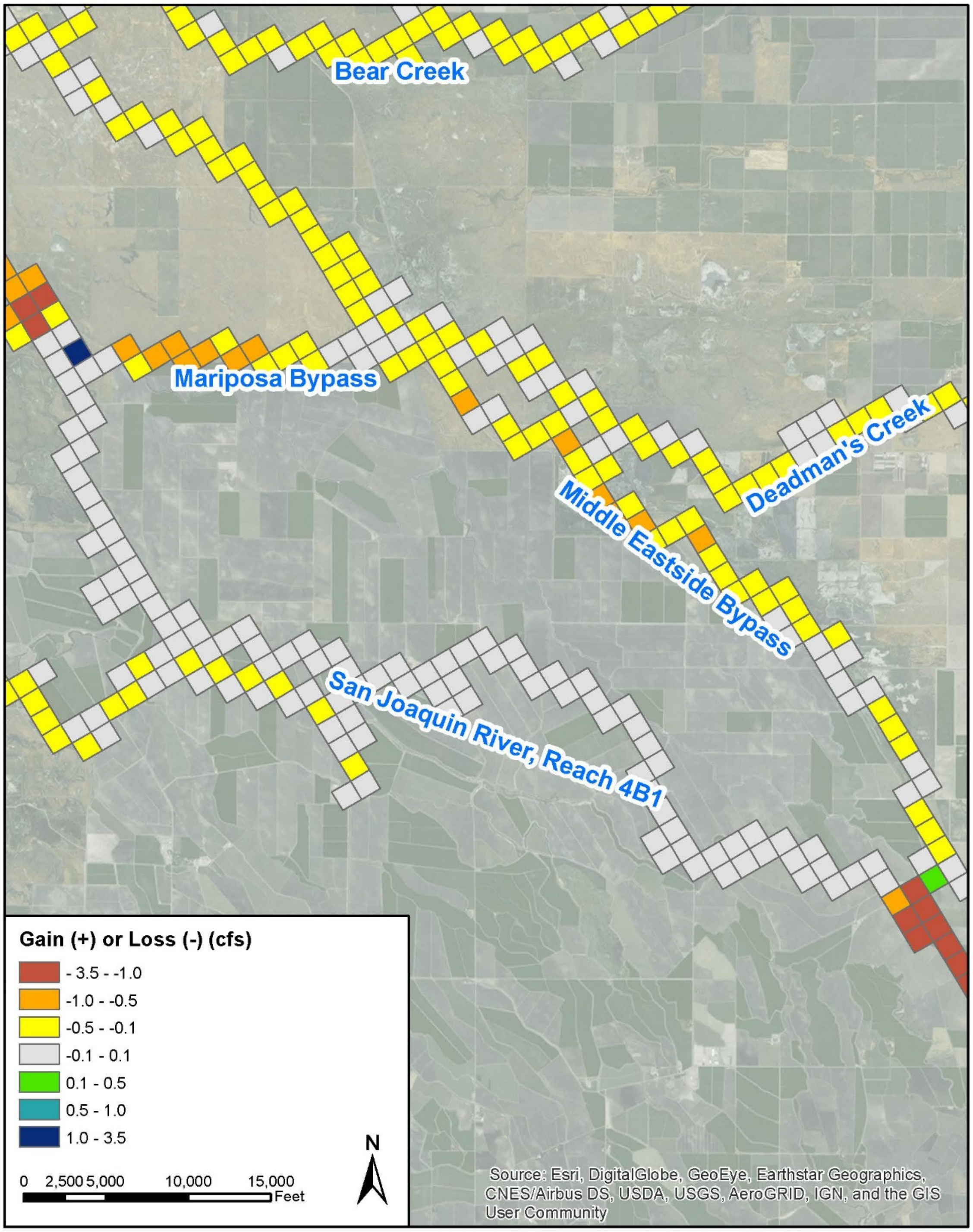

Figure F-52.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on April 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

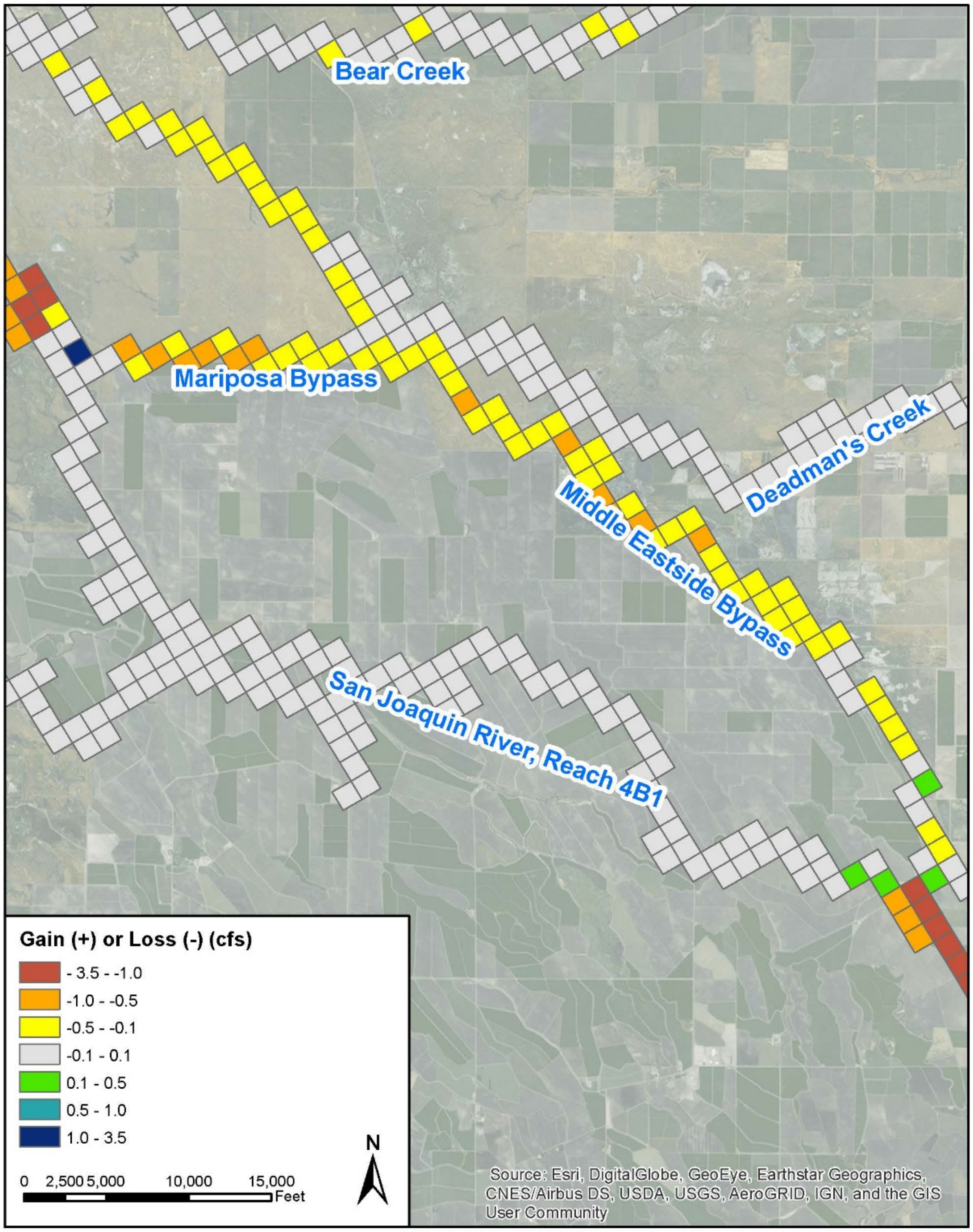

Figure F-53.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on May 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

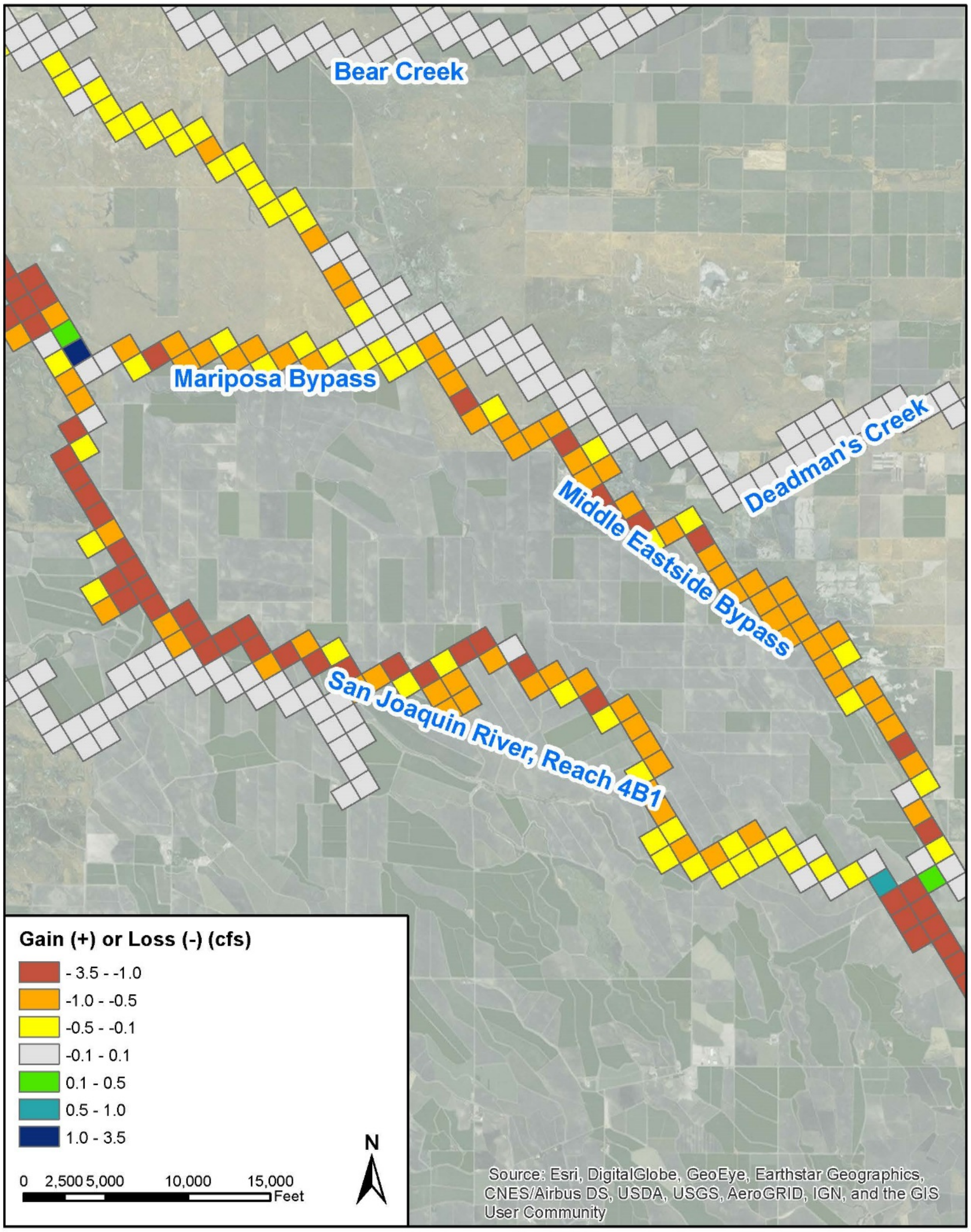

Figure F-54.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on June 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

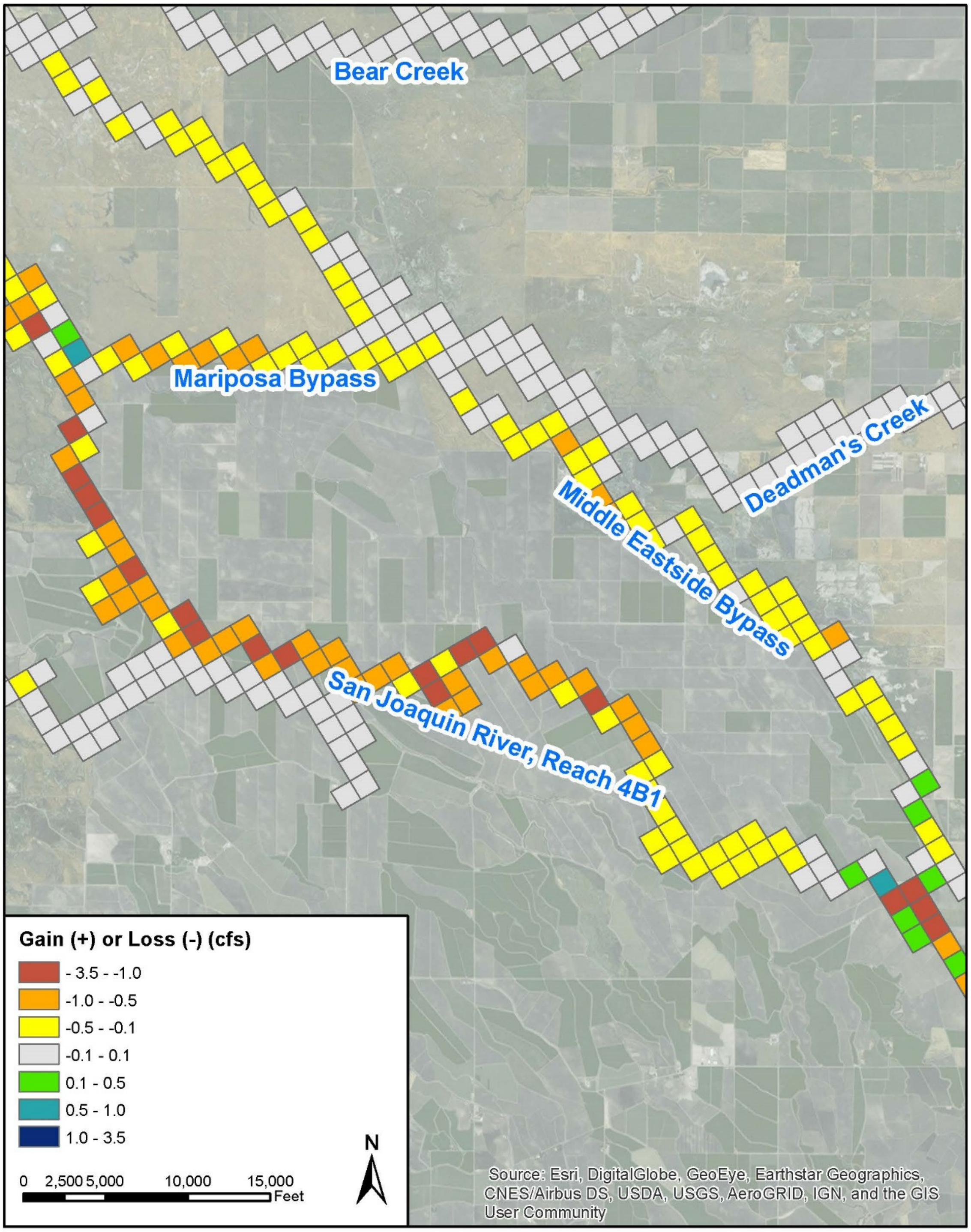

Figure F-55.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on July 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

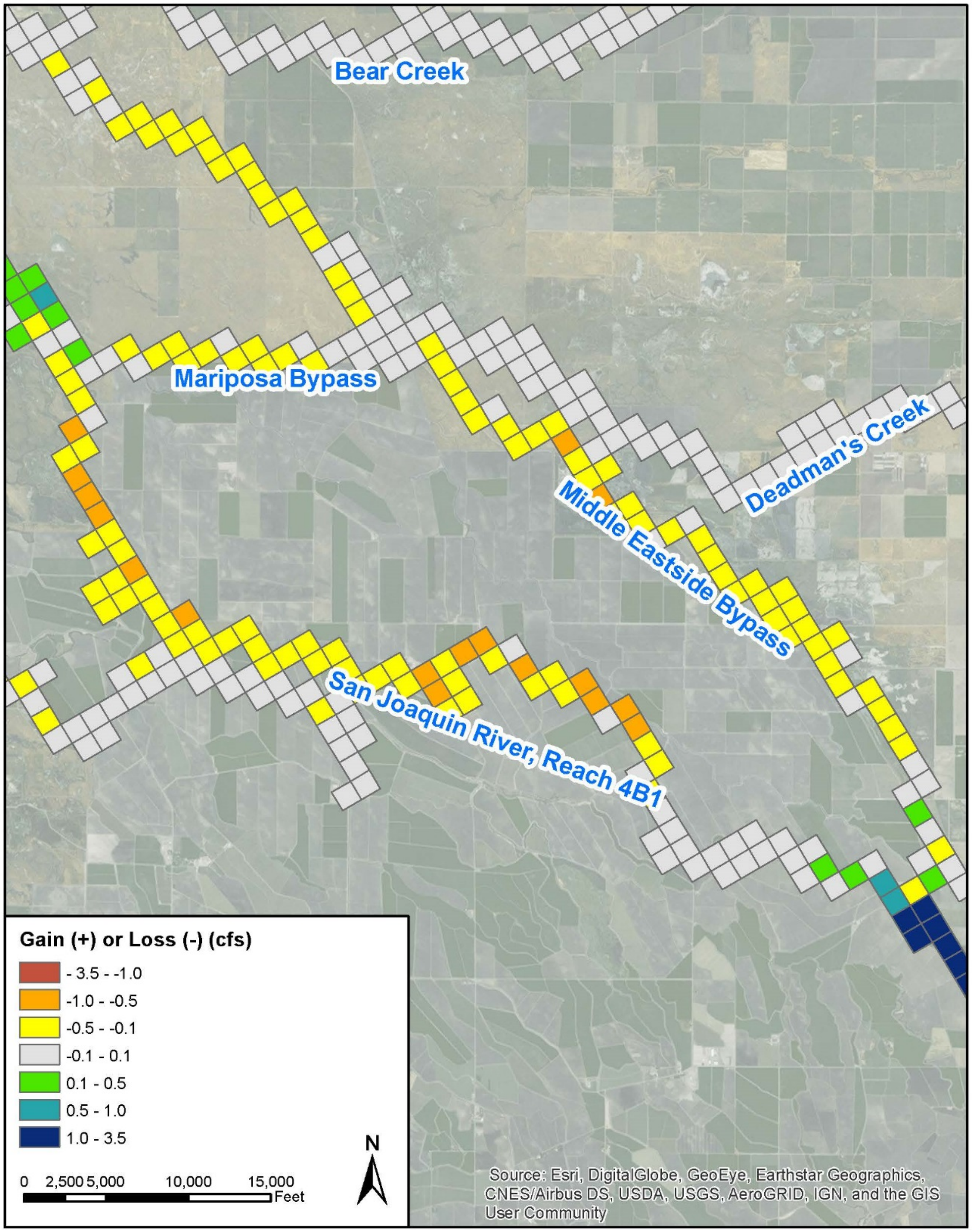

Figure F-56.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on August 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

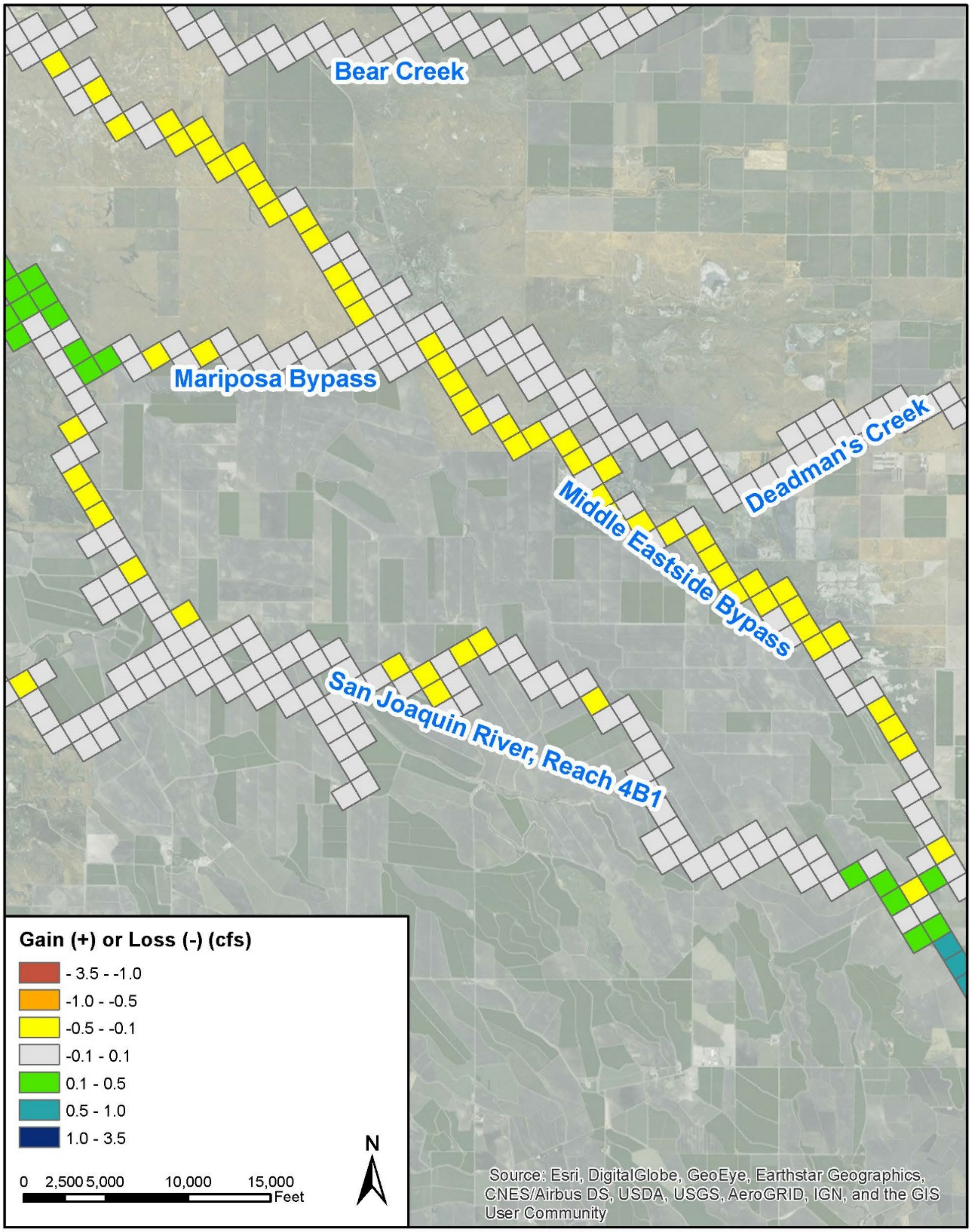

Figure F-57.
Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on September 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

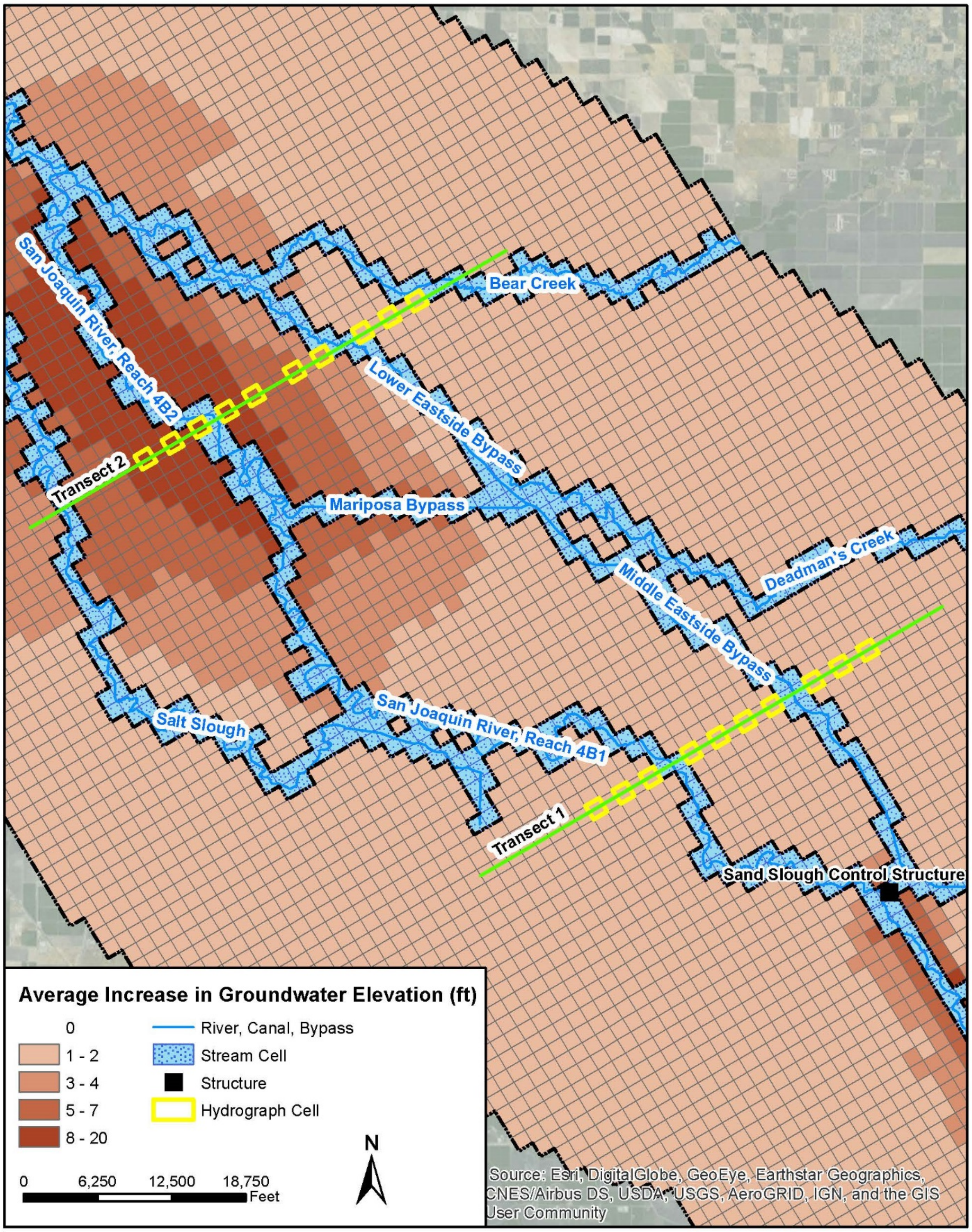

Figure F-58.
Simulated change in shallow Groundwater Elevation, based on May 1975 (Normal-Wet Year Type) Hydrologic Conditions under Alternative 2

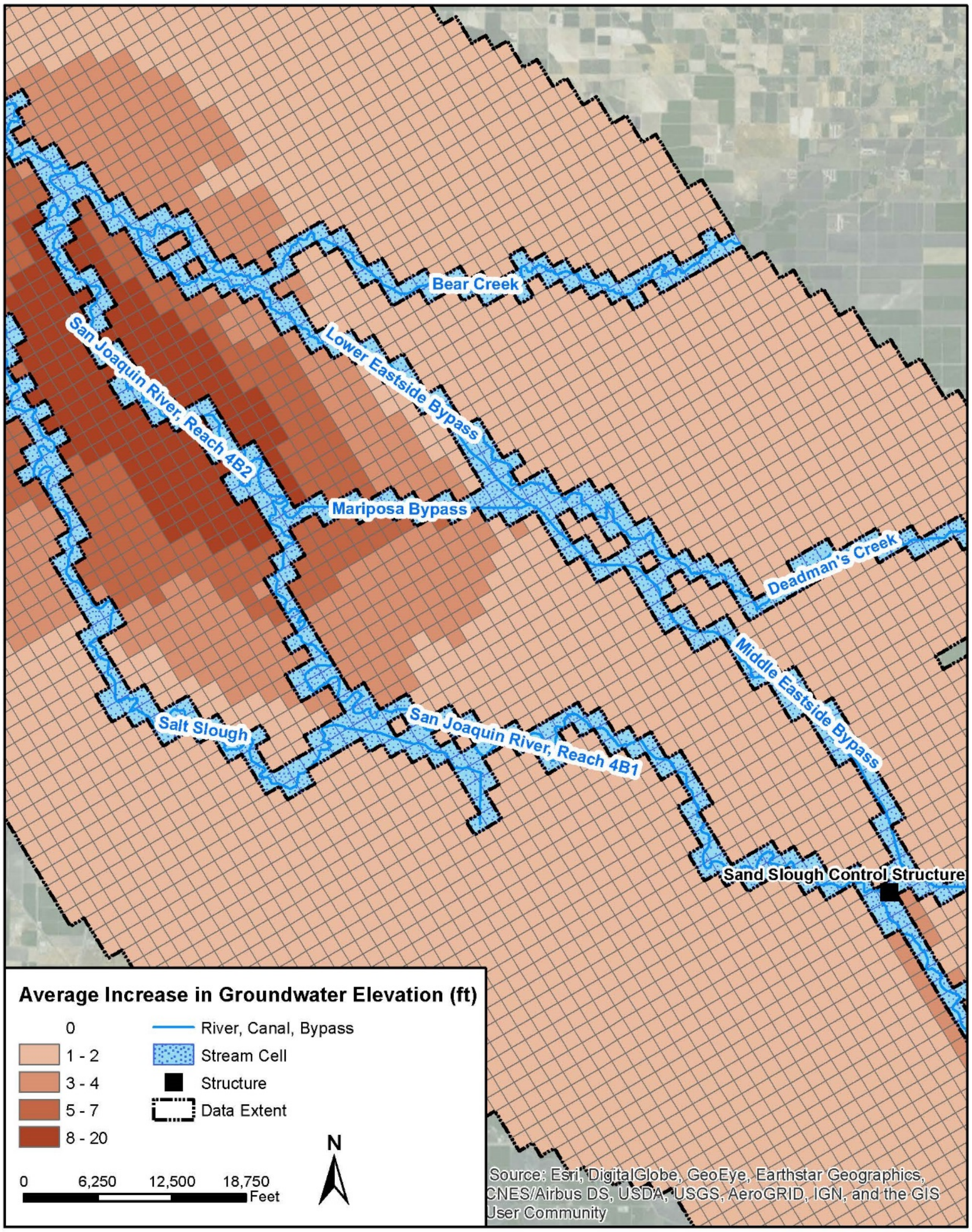

Figure F-59.
Simulated Change in Shallow Groundwater Elevation, based on May 1976 (Critical High Year Type) Hydrologic Conditions under Alternative 2

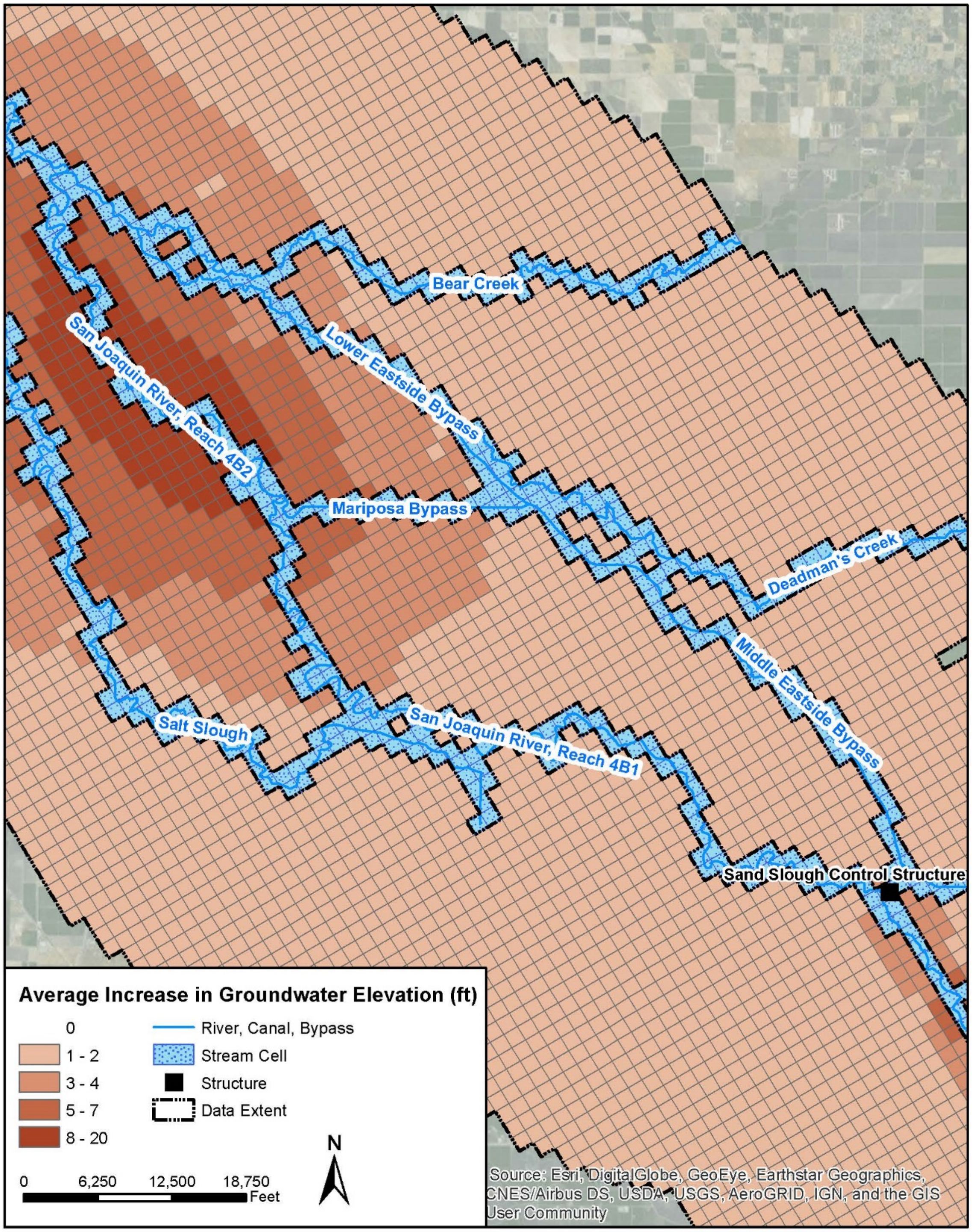

Figure F-60.
Simulated Change in Shallow Groundwater Elevation, based on May 1977 (Critical Low Year Type) Hydrologic Conditions under Alternative 2

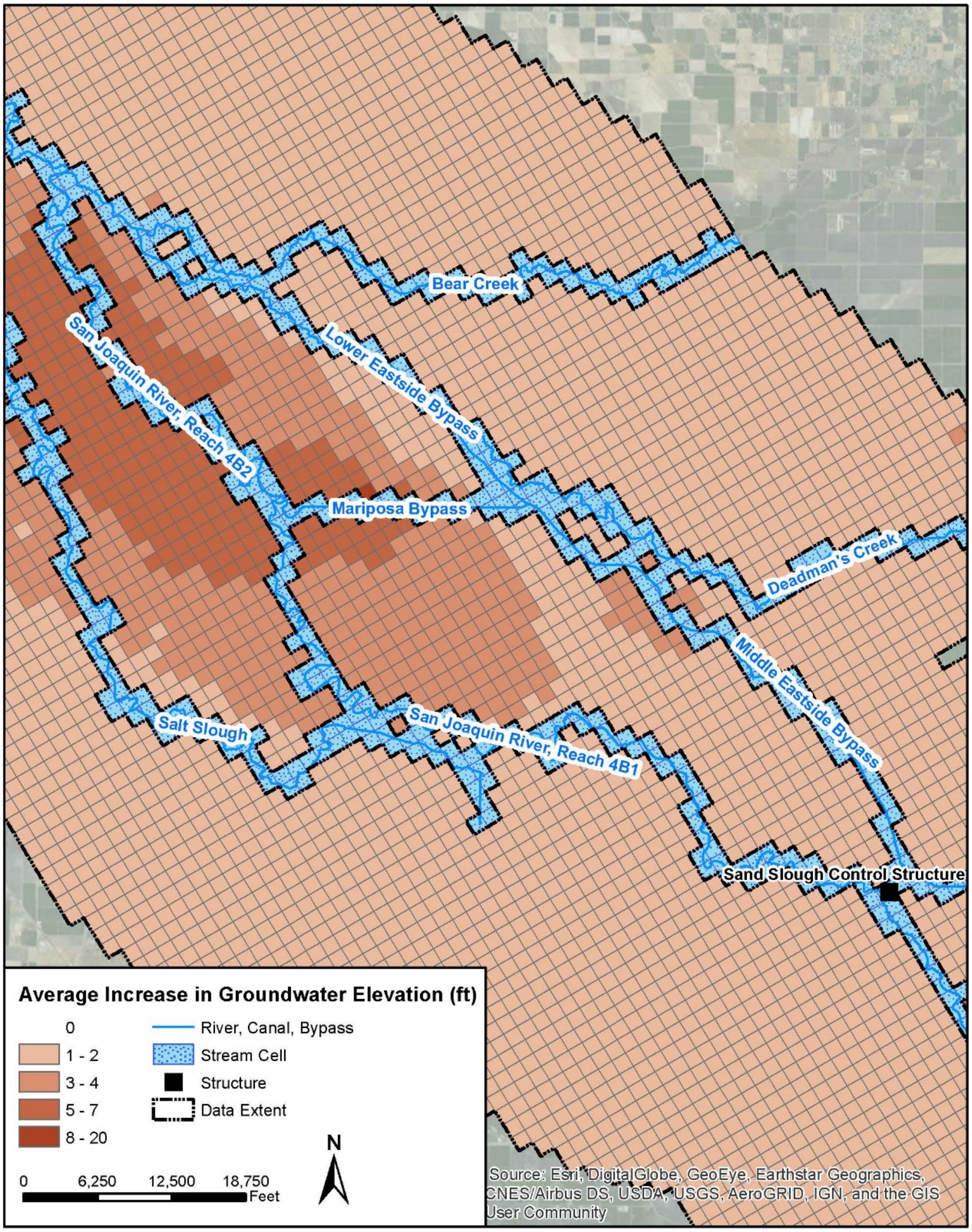

Figure F-61.
Simulated Change in Shallow Groundwater Elevation, based on May 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

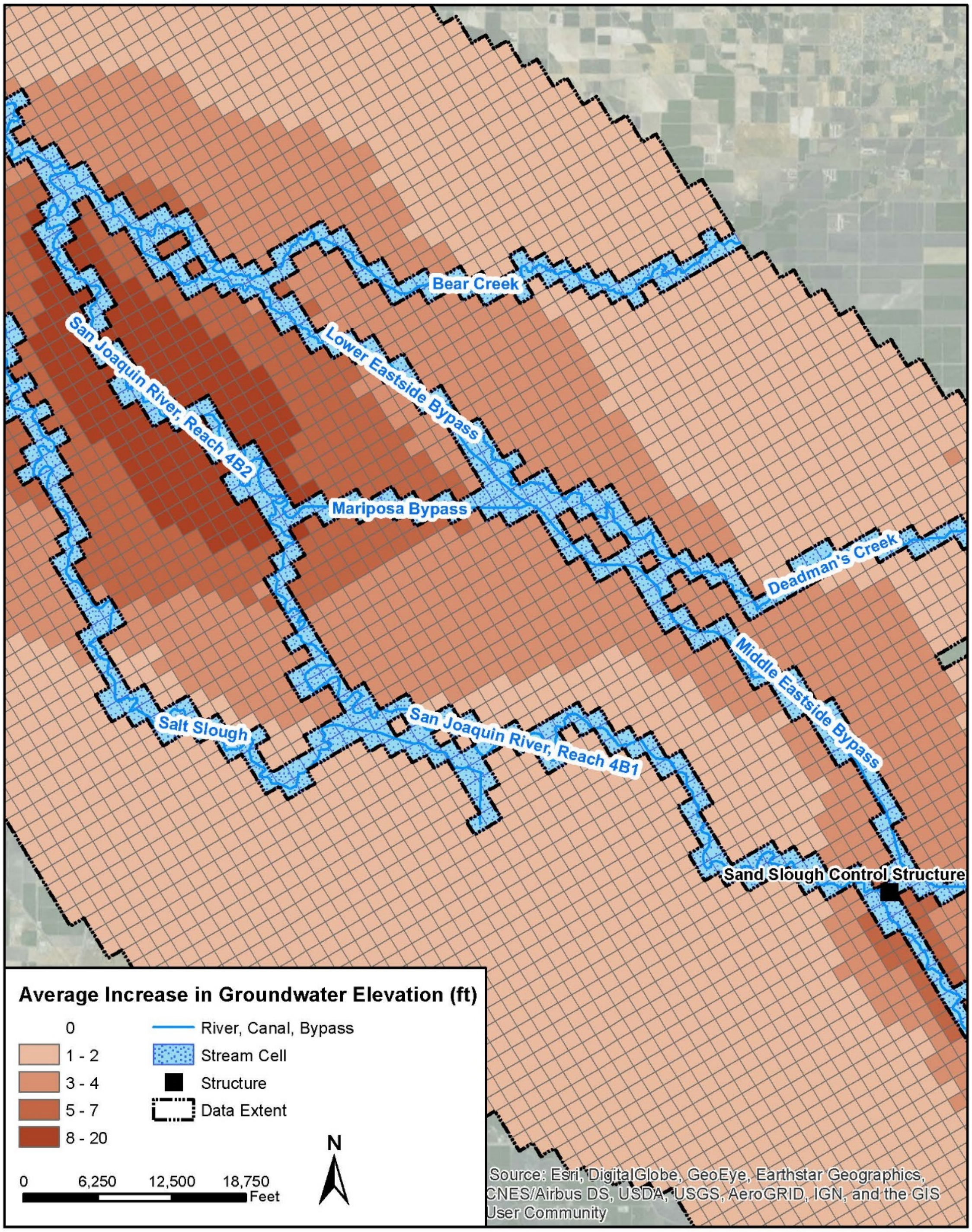

Figure F-62.
Simulated Change in Shallow Groundwater Elevation, based on May 1992 (Dry Year Type) Hydrologic Conditions under Alternative 2

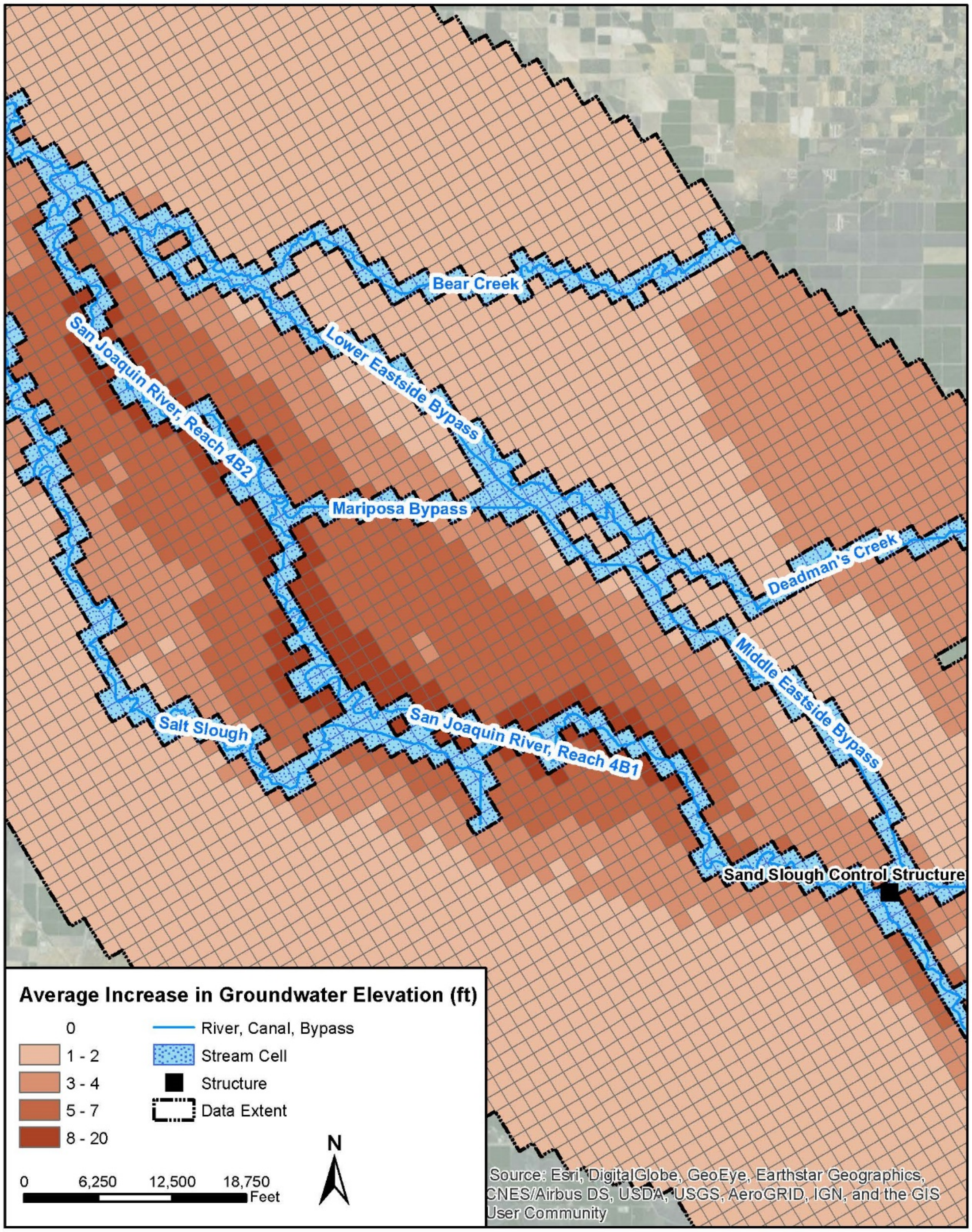

Figure F-63.
Simulated Change in Shallow Groundwater Elevation, Based on May 2003 (Normal-Dry Year Type) Hydrologic Conditions under Alternative 2

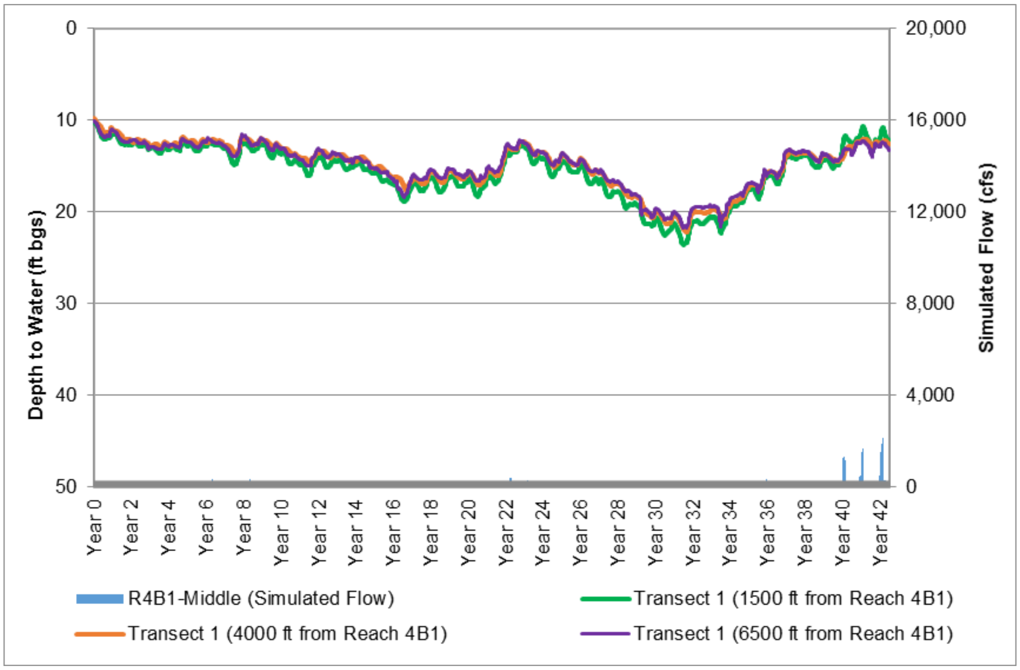

Figure F-64.
Simulated Groundwater Elevation along Transect 1 (Left Bank from San Joaquin River) under Alternative 2

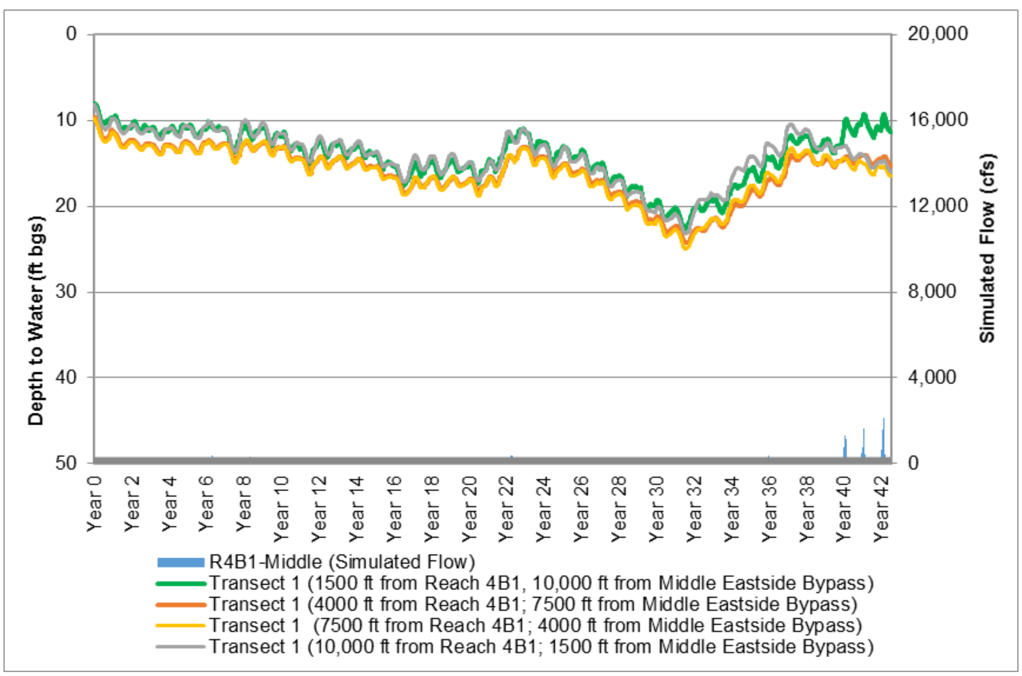

Figure F-65.
Simulated Groundwater Elevation along Transect 1 (Right Bank from San Joaquin River and Left Bank from Eastside Bypass) under Alternative 2

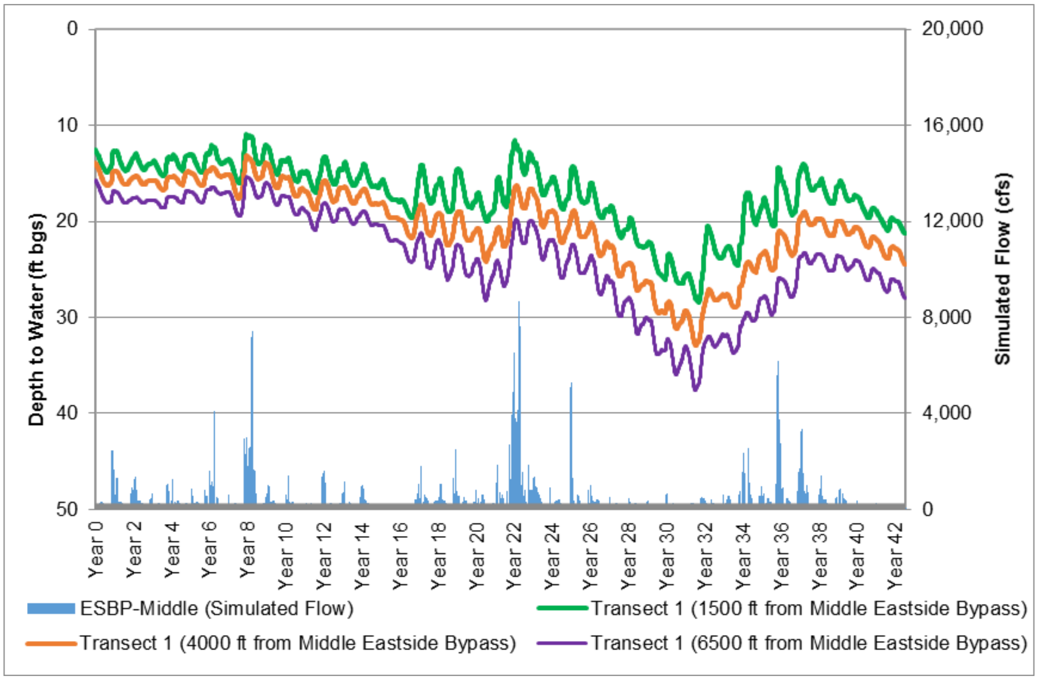

Figure F-66.
Simulated Groundwater Elevation along Transect 1 (Right Bank from Eastside Bypass) under Alternative 2

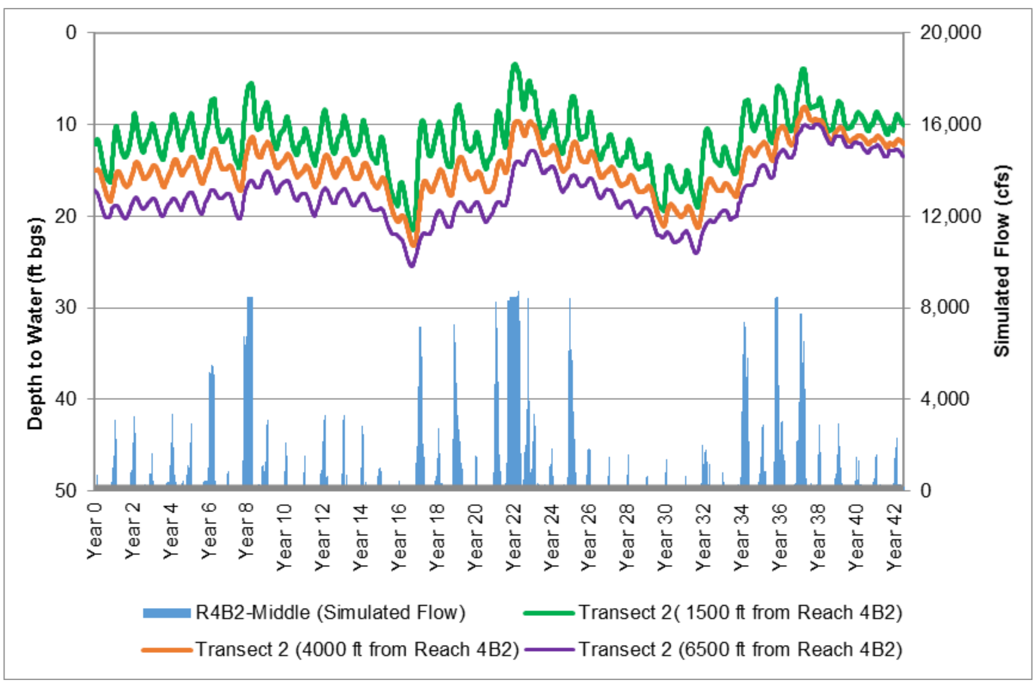

Figure F-67.
Simulated Groundwater Elevation along Transect 2 (Left Bank from San Joaquin River) under Alternative 2

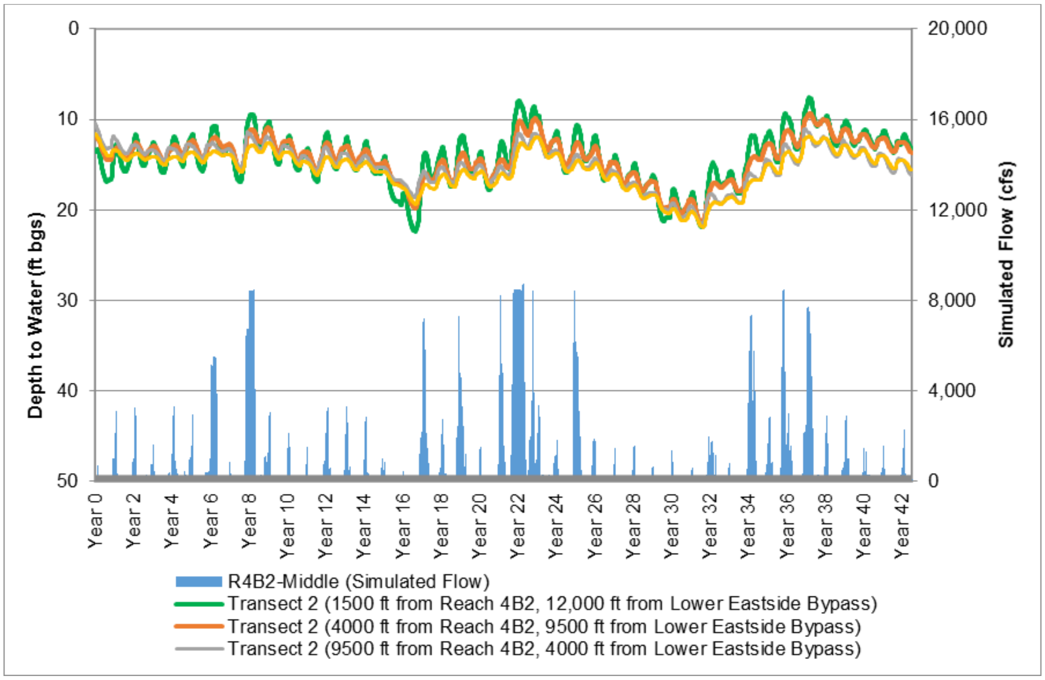

Figure F-68.
Simulated Groundwater Elevation along Transect 2 (Right Bank from San Joaquin River and Left Bank from Eastside Bypass) under Alternative 2

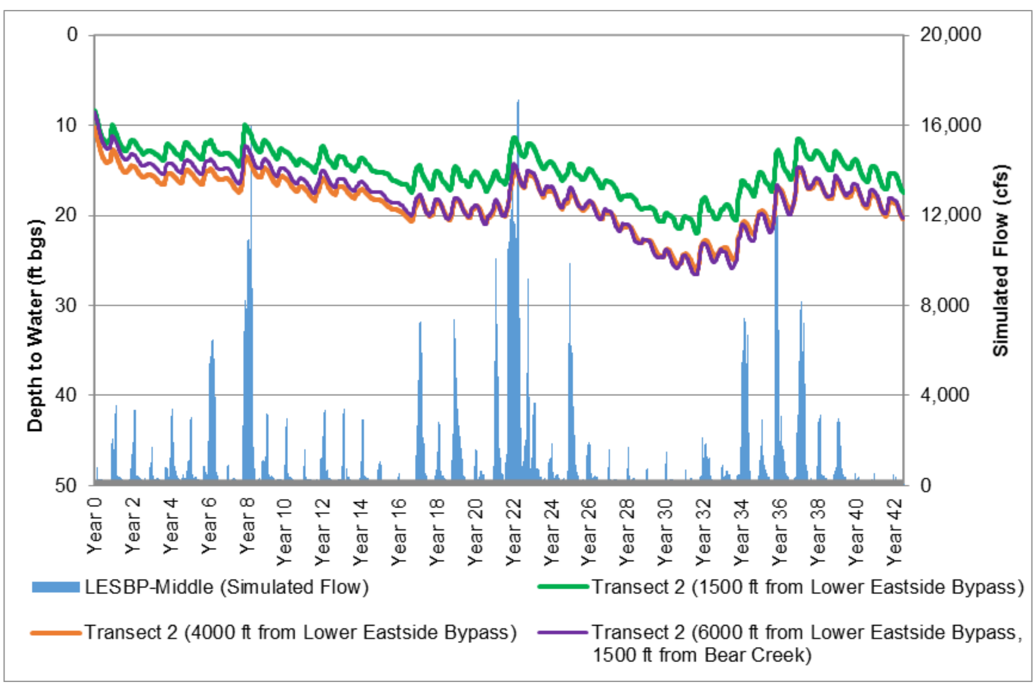

Figure F-69.
Simulated Groundwater Elevation along Transect 2 (Right Bank from Eastside Bypass) under Alternative 2