Hydrologic and Hydraulic Supplemental Study – Phase II
Draft Report
Hydraulics, Hydrodynamics and Sedimentation in Novato Creek

Prepared For:
U.S. Army Corps of Engineers
San Francisco District

Prepared By:
Noble Consultants, Inc.
Northwest Hydraulic Consultants

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Table of Contents

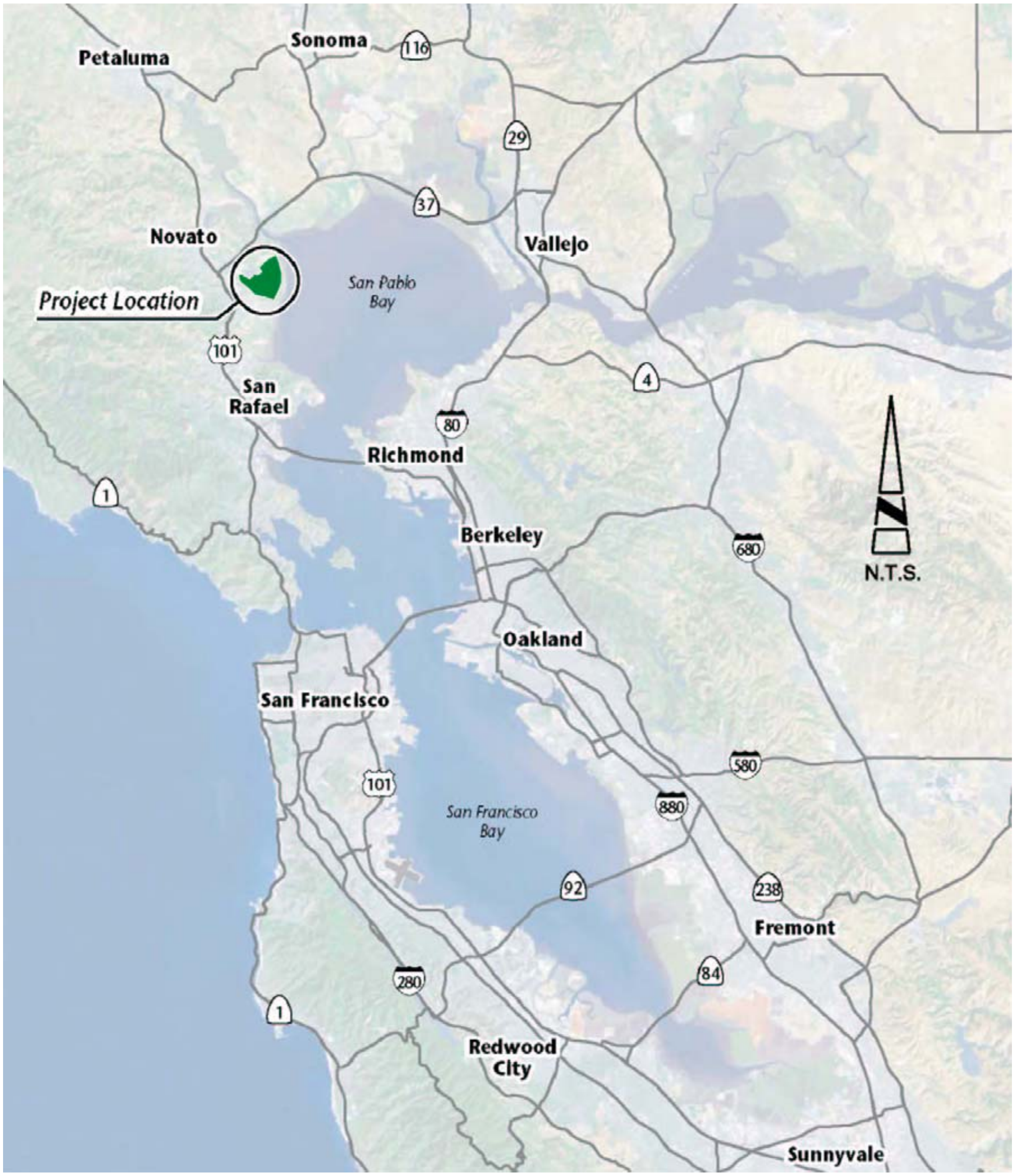
List of Tables

List of Figures

1.0 INTRODUCTION

The proposed Bel Marin Keys Unit V (BMK-V) expansion of the Hamilton Wetland Restoration Project (HWRP) is located in the unincorporated estuary area of Marin County (CSCC & USACE, 1998 & 2003). The expansion site is bounded by Novato Creek and the Bel Marin Keys (BMK) residential development to the north, Pacheco Pond to the west, the authorized HWRP site to the south and San Pablo Bay to the east. **Figure 1-1** illustrates site location in relation to San Francisco Bay, while **Figure 1-2** shows the aerial site map of entire project area along Novato Creek extending from Highway 101 to San Pablo Bay as well as the proposed Northern Wetland Basin (NWB). The U.S. Army Corps of Engineers (USACE) conceptual design proposed a breach on the south levee of Novato Creek at a location approximately 4,200 feet from the creek mouth to serve as an entry point for San Pablo Bay tide water to flow into the Northern Wetland Basin of the BMK-V parcel. Various key features of this originally proposed project plan, as presented in the Phase II study (NCI & **nhc**, 2006), are briefly re-summarized as follows:

- Two tidally influenced basins with each basin being approximately 600 acres in size with tidal water exchange via two artificially breached channels, one (the Northern Wetland Basin) to Novato Creek and the other (the Southerly Wetland Basin) directly to San Pablo Bay.
- An expanded Pacheco Pond of 21 acres in size that is connected to a 136-acre seasonal wetland via six culverts with flap gates, which allow excessive flood water in Pacheco Pond draining only to the seasonal wetland.
- The 136-acre seasonal wetland that receives inflow from Pacheco Pond and drains to the Southern Wetland Basin via a unidirectional adjustable outflow weir that has a width of 200 feet to a catch basin and subsequently through three flap-gated culverts to prevent the water back-flowing from the Southern Wetland Basin into the Seasonal Wetland.
- A swale approximately 388 acres in size surrounding the South Lagoon of the Bel Marin Keys development to accept excessive flood flows via various outflow structures.
- A designated 12-acre emergent marsh without any modification of the existing configuration that is located adjacent to Pacheco Pond.



Source: Jones & Stokes & **nhc**, 2002

Figure 1-1. Vicinity Map

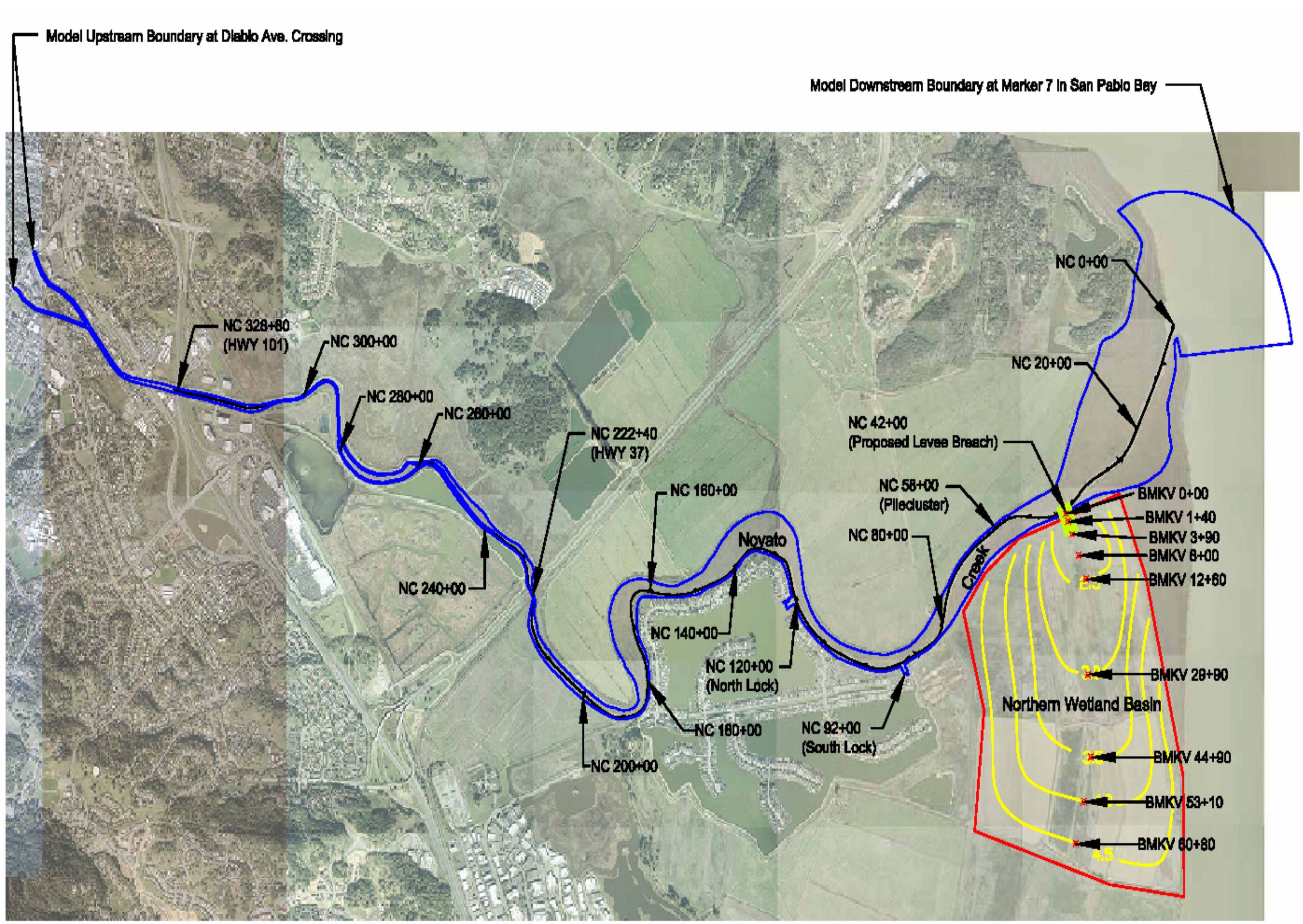


Figure 1-2. Project Site Map and Representative Creek Stations

- Modification of the levee system within the project site, which consists of raising the crest elevations in some segments for a better flood protection and lowering in other segments to allow more water exchanges of the tidal wetland basins.

The hydraulics, hydrodynamics, and sedimentation study that was performed under the Phase II tasks (NCI & **nhc**, 2006) indicated that the originally proposed project alternative would significantly alter the hydraulic, hydrodynamic and sedimentation characteristics in Novato Creek. For the reach downstream of the breach location, tidal currents would be drastically increased, which would induce significant channel erosion and increase the complexity in boat operation. In the upstream reach from the breach location to the North Lock of the Bel Marin Keys (BMK) Lagoon, significant tidal muting would occur, which would lower water levels during high tides and reduce current velocities. The significant decrease in tidal circulation would increase the existing sedimentation rate and thus adversely impact to the channel navigability.

This supplemental hydrologic and hydraulic study was commenced to modify the originally proposed project conditions for Novato Creek so that the adverse impacts of the project to Novato Creek can be mitigated. The study included numerical simulations of creek hydrodynamics and sedimentation during the typical tidal cycles as well as the hydrologic & hydraulic characteristics during the combined severe flood and high tide events. Based on the model results, the potential flooding and navigational impacts to Novato Creek resulting for the modified project alternative were assessed.

In the following sections, the iterative process of optimizing the channel geometry in Novato Creek is first delineated. The modeled results of the creek hydraulics, hydrodynamics and sedimentation for the selected optimal project alternative are then discussed. Lastly, the potential improvements of the optimal project plan on the boat navigability in Novato Creek as well as the creek morphology and flooding dynamics are identified.

2.0 TIDAL FLOW CONDITIONS AND MORPHOLOGOCAL ADJUSTMENT

The previous modeling study (NCI & **nhc**, 2006) indicted that the originally proposed project plan would have adverse impacts to creek morphology and boat navigation on Novato Creek. Therefore, several modifications of the project plan have been made in this supplemental study to mitigate these impacts. The hydrodynamic conditions and sedimentation patterns within Novato Creek were re-investigated for these modified project conditions using the Corps approved models, RMA2 and SED2D. Similar to the previous model simulations for the existing and the originally proposed project conditions, the present RMA2 and SED2D modeling focuses on the tidally dominated hydrologic and hydraulic conditions in Novato Creek.

Based on the originally proposed project plan, the existing channel bathymetry of Novato Creek will remain unchanged. However, several geometric modifications were made to the Novato Creek in this analysis in order to minimize the adverse impacts that were identified for the originally proposed project plan. The RMA2 hydrodynamic modeling was performed for each of the modified projection scenarios. Based on the hydrodynamic results, an optimal project alternative was selected. The SED2D model was then conducted for this optimal project alternative to investigate the resulting sedimentation within Novato Creek.

This selected optimal project alternative involves the major changes to the existing bathymetry of Novato Creek that include (1) expansion (widening and deepening) of the channel that is downstream of the levee breach, and (2) deepening of the channel between the levee breach and the North Lock of the BMK Lagoon. The expanded creek channel downstream of the levee breach extending to the San Pablo Bay will have a trapezoidal cross-section with a bottom elevation at -6 feet, NAVD 88, a base width of approximately 195 feet and a side slope of 10 (Horizontal) to 1 (Vertical) upward to the existing floodplain, as shown in **Figure 2-1**. The expanded cross-section will increase the flow area under the mean water level to approximately six times of the existing conditions. The cross-sections of the deepened channel that is upstream of the levee breaches are shown in **Figure 2-2** for the reach with the bottom elevation lower than -2.0 feet, NAVD 88, and in **Figure 2-3** for the reach with the bottom elevation higher than -2.0 feet, NAVD 88. The deepened upstream channel will have a composite cross-section with a 0.5-foot vertical drop on the bottom and a trapezoidal section with a side slope of 6 to1 (horizontal to vertical) upward to the existing cross-sections at the elevation of -2.0 feet, NAVD 88 or -1.0 feet, NAVD 88. Compared to the existing conditions, the channel between the levee breach and the North Lock of the BMK Lagoon will be deepened by approximately one foot.

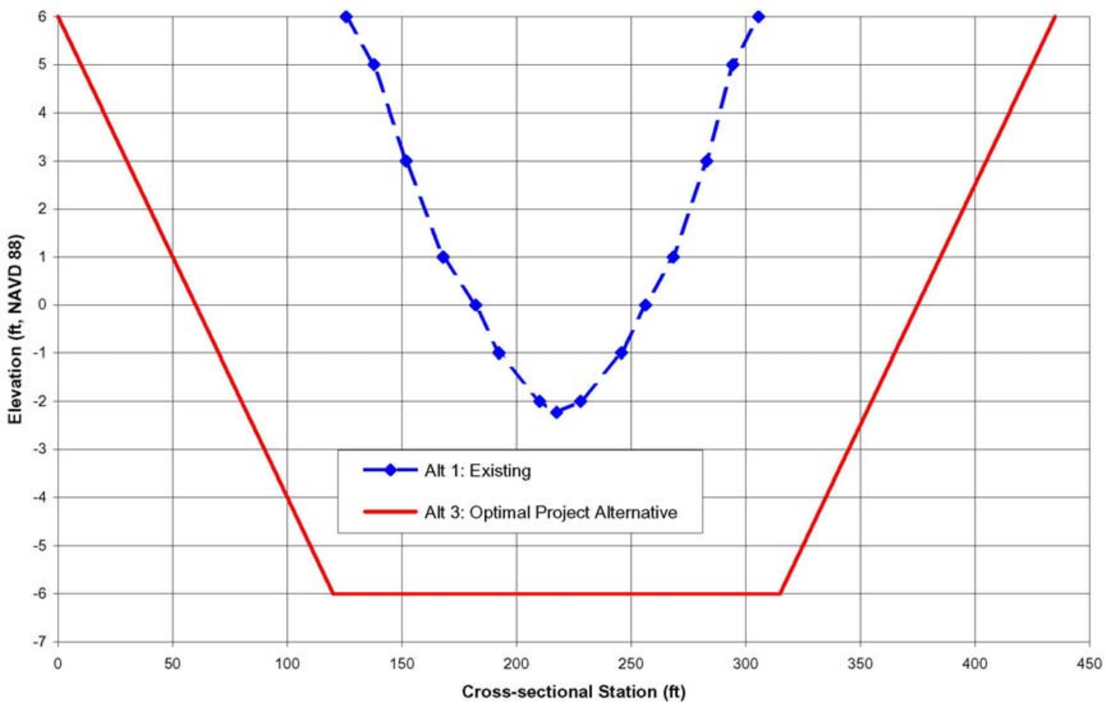


Figure 2-1. Comparison of Cross-sections downstream of Levee Breach

Although the hydrodynamic simulations were performed for several project scenarios, only the hydrodynamic characteristics predicted for the optimal project alternative was presented in this report together with the simulated sedimentation results. In order to better assess the changes to the existing creek conditions and the improvements over the originally proposed project plan, the hydrodynamic and sedimentation conditions predicted for the optimal project alternative were respectively compared to the modeled results for the existing and originally proposed project conditions that were performed in the previous study. In this report, the existing baseline conditions are referred to as Alternative 1, the originally proposed project conditions

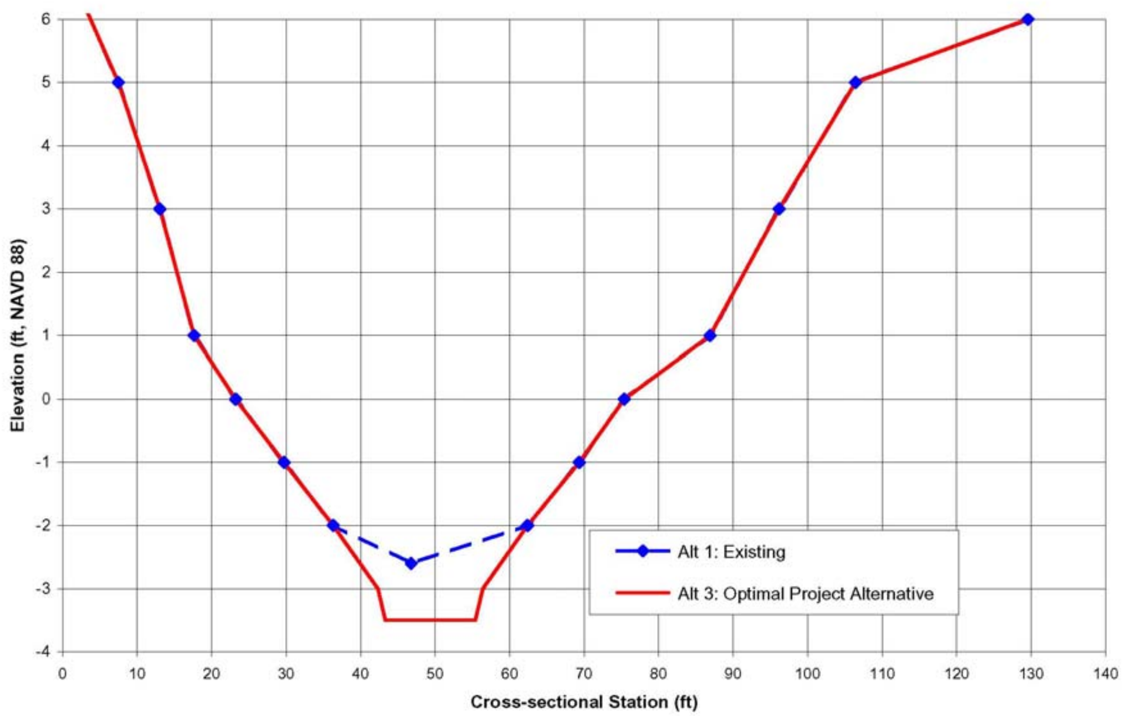


Figure 2-2. Comparison of Cross-sections at CS 70+00

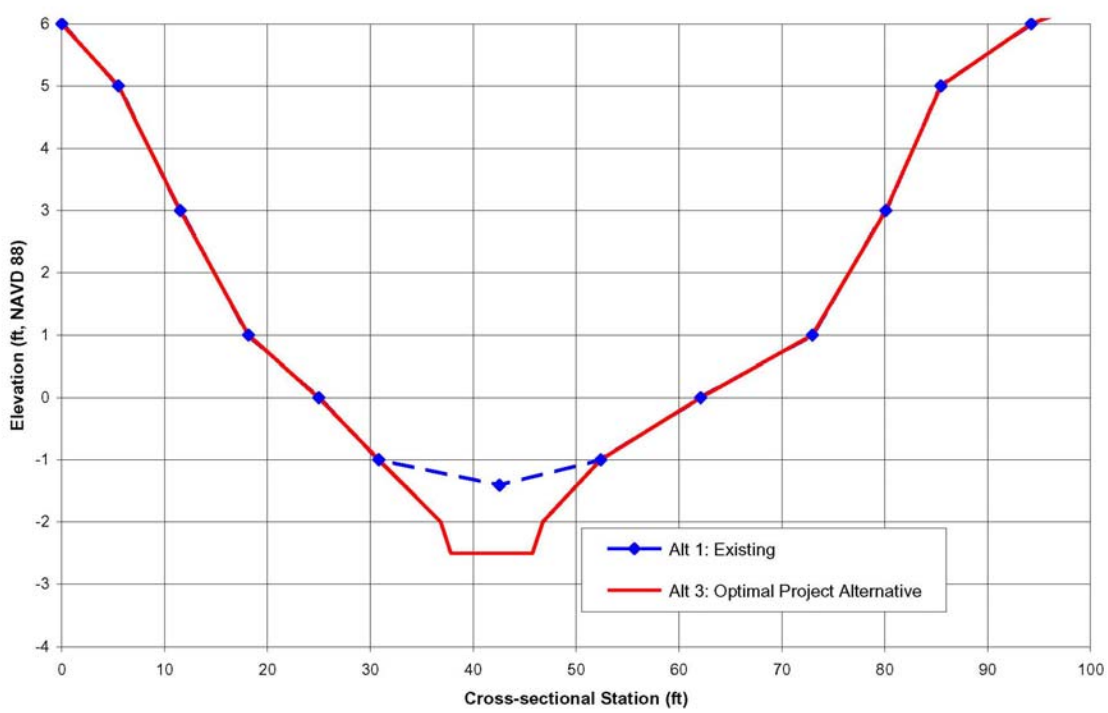


Figure 2-3. Comparison of Cross-sections at CS 118+00

as Alternative 2, and the selected optimal project alternative (i.e. modified project conditions) as Alternative 3. The geometric conditions for the modeled alternatives are summarized in **Table 2-1**.

Table 2-1.   Summary of Geometric Conditions for Modeled Alternatives

Alt	Description
1	Existing baseline conditions: – No connection between Novato Creek and the BMK-V Northern Wetland Basin
2	Originally proposed project conditions: – Novato Creek connected to the BMK-V Northern Wetland Basin by a levee breach
3	Modified project conditions: – Novato Creek connected to the BMK-V Northern Wetland Basin by a levee breach – Channel cross-section expanded to six times of existing size for the reach downstream of levee breach – Channel deepened by approximately one foot for the reach between the North Lock and levee breach

2.1 Model Setup

Similar to the previous modeling study for Alternative 1 and Alternative 2, the modeled domain for the optimal project alternative (Alternative 3) covers the Novato Creek from the Diablo Avenue Crossing, which is approximately 4,200 feet upstream of the Highway 101 crossing, downstream along the creek and to approximately 2,600 feet into the San Pablo Bay. The domain also includes the Northern Wetland Basin. A finite element mesh consisting of 5,907 elements and 18,508 nodes was developed to characterize the entire modeled area for Alternative 3, as summarized in **Table 2-2**.

Table 2-2.   Comparison of Finite Element Meshes for Modeled Alternatives

Alternative	Number of Nodes	Number of Elements
1	4,599	14,544
2	5,659	17,776
3	5,907	18,508

The finite elements and associated bathymetry for Alternative 3 were constructed in accordance with the selected optimal project alternative. **Figure 2-4** and **Figure 2-5** show the finite element mesh developed for the Novato Creek approximately between the creek mouth and the North Lock. **Figure 2-6** and **Figure 2-7** demonstrate the topographic elevation contours within this creek reach in which the major geometric modification was made to the originally proposed project conditions.

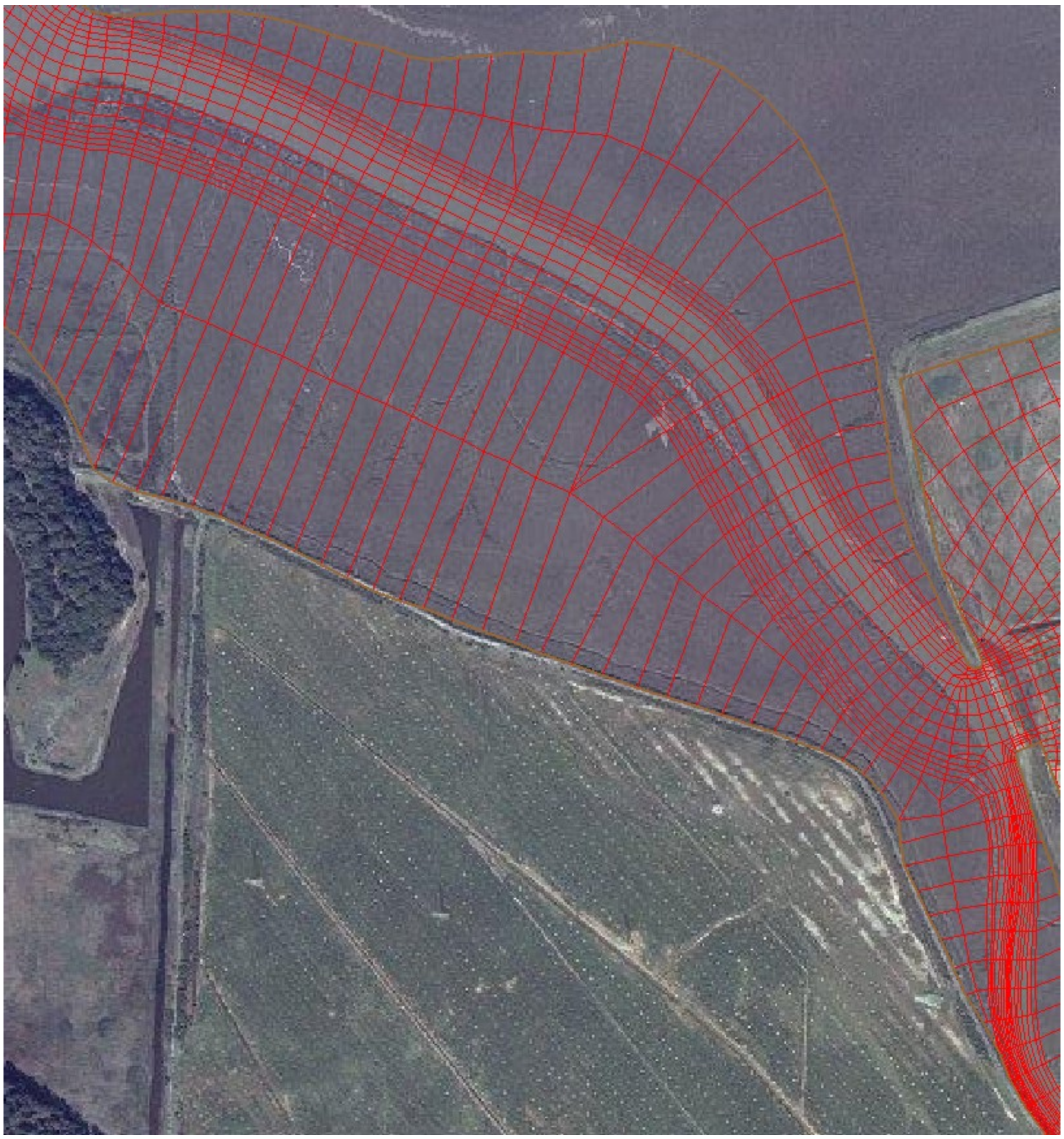


Figure 2-4. Finite Element Mesh (Alt 3, Levee Breach to Creek Mouth)

Figure 2-5. Finite Element Mesh (Alt 3, North Lock to Levee Breach)

Figure 2-6. Modeled Bathymetry (Alt 3, Levee Breach to Creek Mouth)

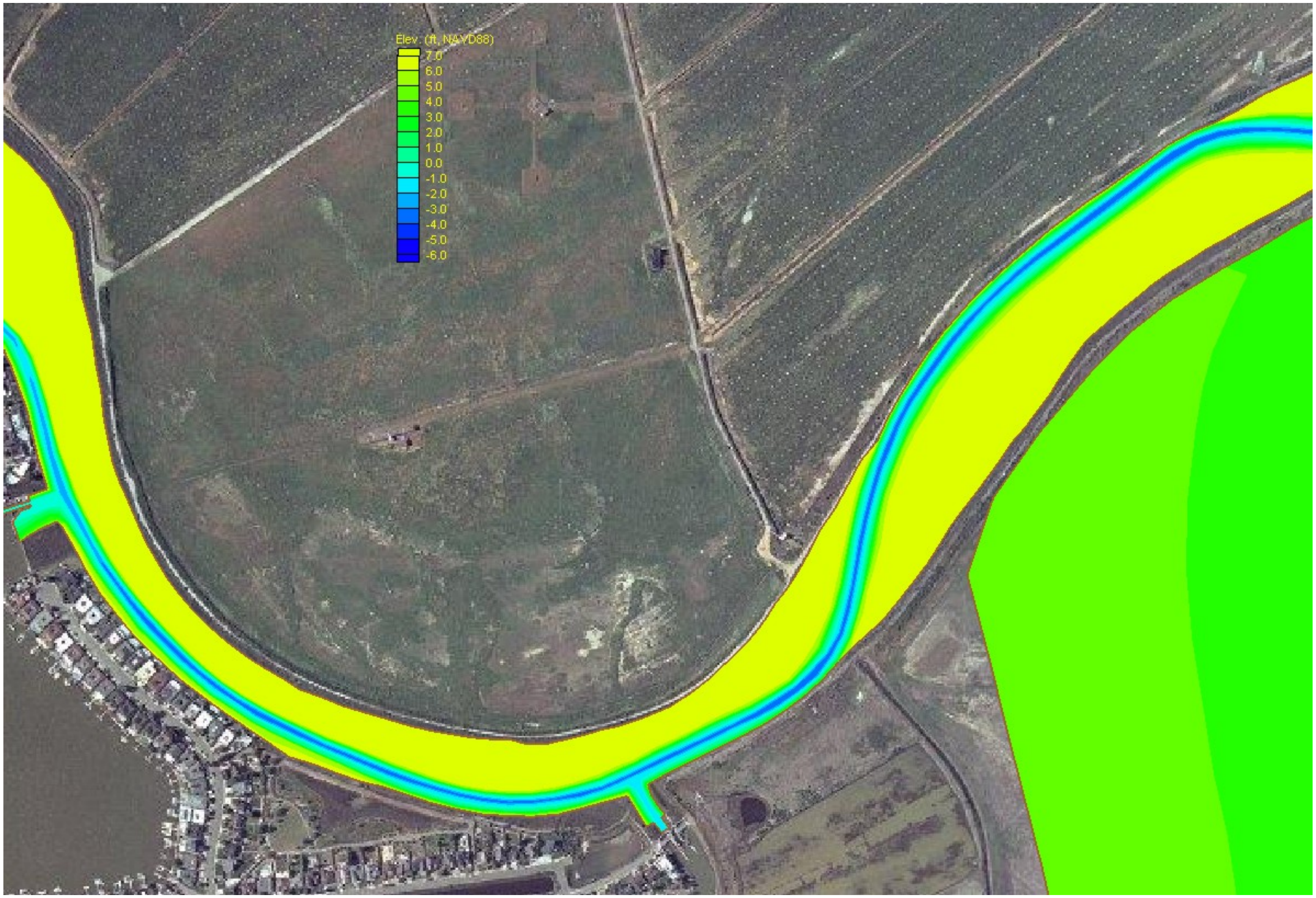


Figure 2-7. Modeled Bathymetry (Alt 3, North Lock to Levee Breach)

All the boundary conditions and the model parameters that were applied in the RMA2 and SED2D simulations for Alternative 3 are identical to those used in the previous modeling study for Alternatives 1 and 2. Therefore, the differences in predicted hydrodynamic and sedimentation parameters among the alternatives would solely result from the differences in the geometric conditions associated with individual alternatives. By comparing the model results under the existing, originally proposed and modified project conditions, the potential impacts of the project alternatives can be evaluated.

2.2 Predicted Water Level within Novato Creek

Based on the simulated 15-day time series of water levels, the Mean High Water (MHW), Mean Low Water (MLW), Mean Water Level (MWL), and mean tidal range, were calculated for various representative locations along the centerline of the creek. The tides during the 15 day period from April 18 to May 2, 2005 roughly cover a complete tidal cycle of the spring and neap tides. The 42 representative locations within Novato Creek were chosen along the centerline of the creek at every 10 stations (i.e. 1,000 feet) and at the control structures such as South Lock, North Lock, Highway 101, etc., as shown in Figure 1-2. The derived MHW and MLW along the creek for the selected optimal project alternative (Alternative 3), as compared to those for the existing conditions (Alternative 1) and for the originally proposed project conditions (Alternative 2), are shown in **Figure 2-8** and tabulated in **Table 2-3**. The MWL and mean tidal range are shown in **Figure 2-9** and listed in **Table 2-4**. The predicted time series of water levels for each of the 42 representative locations are respectively shown in **Figures A-1** to **A-13** of Appendix A.

The model results indicate that while the originally proposed project alternative (Alternative 2) will induce noticeable impacts to the water levels along the Novato Creek, the modified optimal project alternative (Alternative 3) will only result in limited changes to the water levels. Alternative 2 is expected to elevate the MLW by as much as 1.6 feet and lower the MHW by as much as 0.9 feet, while Alternative 3 will lower the MLW by less than a half foot and elevate the MHW by less than 0.1 feet. As a result, the MWL along the creek will be elevated by as much as a half foot for Alternative 2, but merely lowered down by less than 0.1 feet for Alternative 3. The mean tidal range under Alternative 3 is expected to be 1 to 3 feet greater than Alternative 2, but merely 0.5 feet

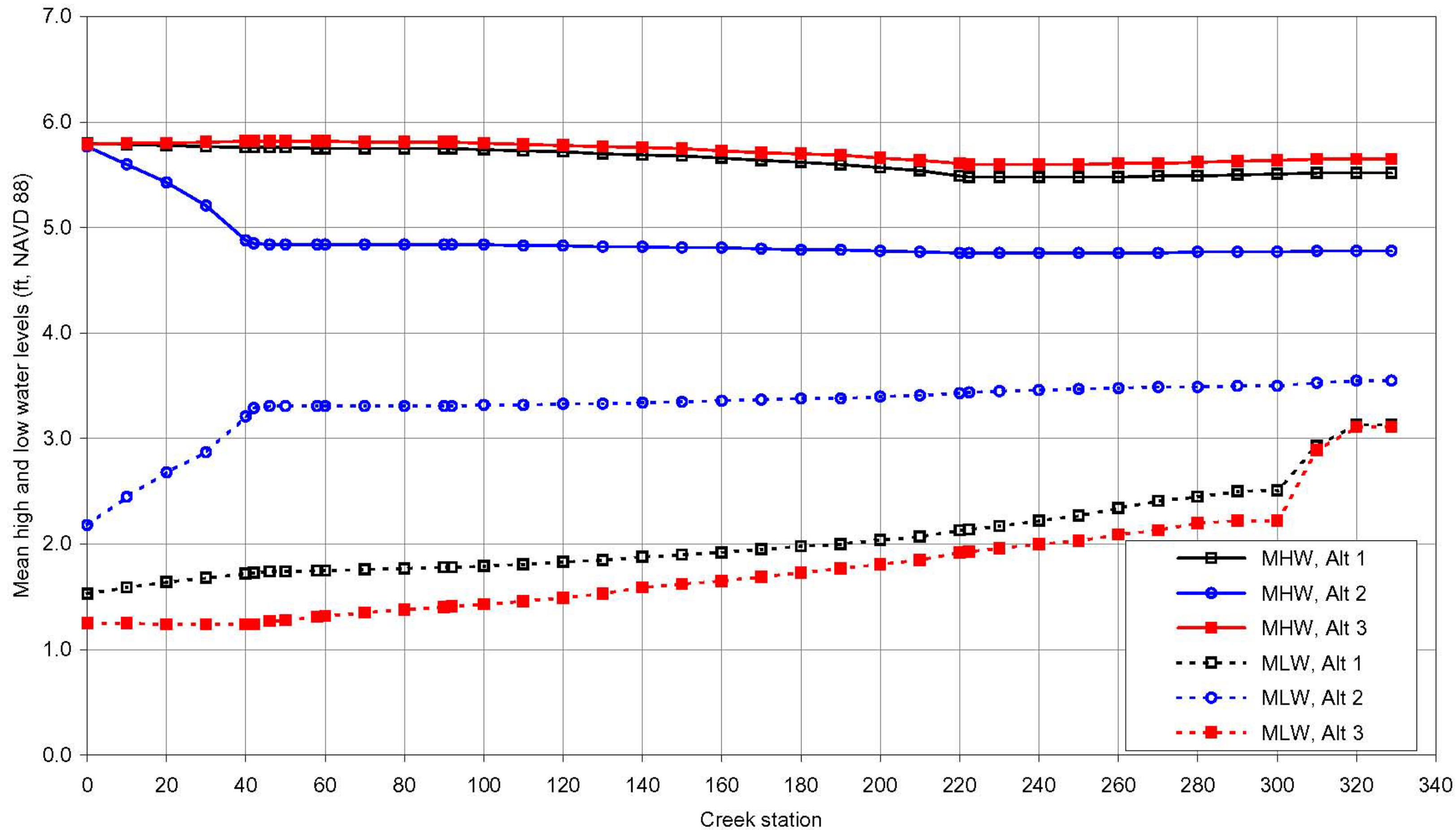


Figure 2-8. Comparison of MHW and MLW along Creek Centerline

Table 2-3. Comparison of MHW and MLW along Creek Centerline

Creek station	Mean High Water, MHW (ft, NAVD 88)			Mean Low Water, MLW (ft, NAVD 88)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
+00 (Creek mouth)	5.8	5.8	5.8	1.5	2.2	1.3
10+00	5.8	5.6	5.8	1.6	2.5	1.3
20+00	5.8	5.4	5.8	1.6	2.7	1.2
30+00	5.8	5.2	5.8	1.7	2.9	1.2
40+00	5.8	4.9	5.8	1.7	3.2	1.2
42+00 (Levee breach)	5.8	4.9	5.8	1.7	3.3	1.2
46+00	5.8	4.8	5.8	1.7	3.3	1.3
50+00	5.8	4.8	5.8	1.7	3.3	1.3
58+00 (Pilecluster)	5.8	4.8	5.8	1.8	3.3	1.3
60+00	5.8	4.8	5.8	1.8	3.3	1.3
70+00	5.8	4.8	5.8	1.8	3.3	1.4
80+00	5.8	4.8	5.8	1.8	3.3	1.4
90+00	5.8	4.8	5.8	1.8	3.3	1.4
92+00 (South Lock)	5.8	4.8	5.8	1.8	3.3	1.4
100+00	5.7	4.8	5.8	1.8	3.3	1.4
110+00	5.7	4.8	5.8	1.8	3.3	1.5
120+00 (North Lock)	5.7	4.8	5.8	1.8	3.3	1.5
130+00	5.7	4.8	5.8	1.9	3.3	1.5
140+00	5.7	4.8	5.8	1.9	3.3	1.6
150+00	5.7	4.8	5.8	1.9	3.4	1.6
160+00	5.7	4.8	5.7	1.9	3.4	1.7
170+00	5.6	4.8	5.7	2.0	3.4	1.7

Table 2-3. Comparison of Water Levels along Creek Centerline (continued)

Creek station	Mean High Water, MHW (ft, NAVD 88)			Mean Low Water, MLW (ft, NAVD 88)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
180+00	5.6	4.8	5.7	2.0	3.4	1.7
190+00	5.6	4.8	5.7	2.0	3.4	1.8
200+00	5.6	4.8	5.7	2.0	3.4	1.8
210+00	5.5	4.8	5.6	2.1	3.4	1.9
220+00	5.5	4.8	5.6	2.1	3.4	1.9
222+40 (HWY 37)	5.5	4.8	5.6	2.1	3.4	1.9
230+00	5.5	4.8	5.6	2.2	3.5	2.0
240+00	5.5	4.8	5.6	2.2	3.5	2.0
250+00	5.5	4.8	5.6	2.3	3.5	2.0
260+00	5.5	4.8	5.6	2.3	3.5	2.1
270+00	5.5	4.8	5.6	2.4	3.5	2.1
280+00	5.5	4.8	5.6	2.5	3.5	2.2
290+00	5.5	4.8	5.6	2.5	3.5	2.2
300+00	5.5	4.8	5.6	2.5	3.5	2.2
310+00	5.5	4.8	5.7	Dry during low tides		
320+00	5.5	4.8	5.7	Dry during low tides		
328+82 (HWY 101)	5.5	4.8	5.7	Dry during low tides		

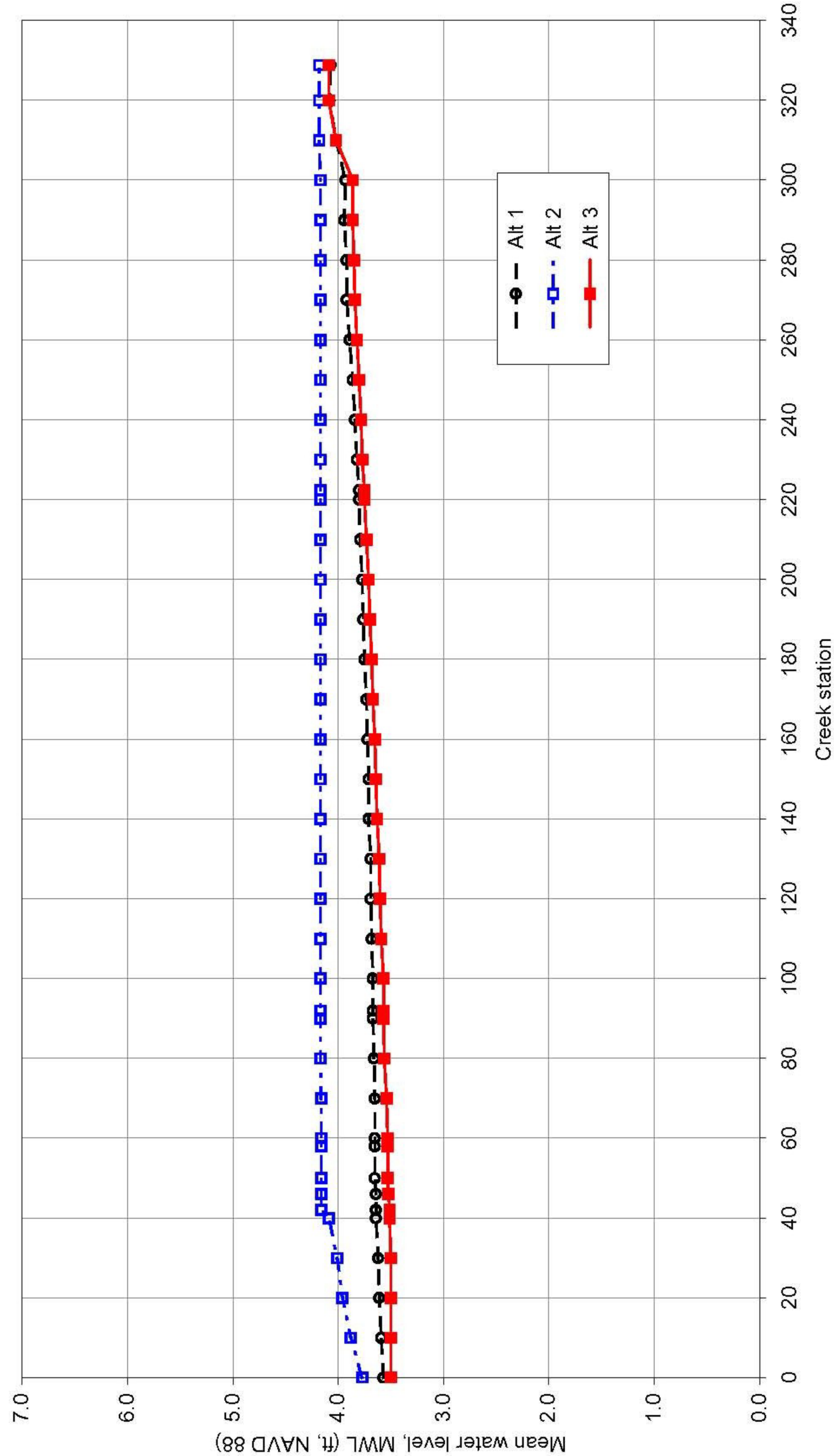


Figure 2-9. Comparison of MWL along Creek Centerline

Table 2-4. Comparison of MWL and Tidal Range along Creek Centerline

Creek station	Mean Water Level, MWL (ft, NAVD 88)			Mean Tidal Range (ft)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
0+00 (Creek mouth)	3.6	3.8	3.5	4.3	3.6	4.5
10+00	3.6	3.9	3.5	4.2	3.1	4.5
20+00	3.6	4.0	3.5	4.2	2.7	4.6
30+00	3.6	4.0	3.5	4.1	2.3	4.6
40+00	3.6	4.1	3.5	4.1	1.7	4.6
42+00 (Levee breach)	3.6	4.2	3.5	4.1	1.6	4.6
46+00	3.6	4.2	3.5	4.1	1.5	4.5
50+00	3.7	4.2	3.5	4.1	1.5	4.5
58+00 (Pilecluster)	3.7	4.2	3.5	4.0	1.5	4.5
60+00	3.7	4.2	3.5	4.0	1.5	4.5
70+00	3.7	4.2	3.5	4.0	1.5	4.4
80+00	3.7	4.2	3.6	4.0	1.5	4.4
90+00	3.7	4.2	3.6	4.0	1.5	4.4
92+00 (South Lock)	3.7	4.2	3.6	4.0	1.5	4.4
100+00	3.7	4.2	3.6	3.9	1.5	4.4
110+00	3.7	4.2	3.6	3.9	1.5	4.3
120+00 (North Lock)	3.7	4.2	3.6	3.9	1.5	4.3
130+00	3.7	4.2	3.6	3.8	1.5	4.3
140+00	3.7	4.2	3.6	3.8	1.5	4.2
150+00	3.7	4.2	3.6	3.8	1.4	4.2
160+00	3.7	4.2	3.7	3.8	1.4	4.0
170+00	3.7	4.2	3.7	3.6	1.4	4.0

Table 2-4. Comparison of MWL and Tidal Range along Creek Centerline (continued)

Creek station	Mean Water Level, MWL (ft, NAVD 88)			Mean Tidal Range (ft)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
180+00	3.8	4.2	3.7	3.6	1.4	4.0
190+00	3.8	4.2	3.7	3.6	1.4	3.9
200+00	3.8	4.2	3.7	3.6	1.4	3.9
210+00	3.8	4.2	3.7	3.4	1.4	3.7
220+00	3.8	4.2	3.8	3.4	1.4	3.7
222+40 (HWY 37)	3.8	4.2	3.8	3.4	1.4	3.7
230+00	3.8	4.2	3.8	3.3	1.3	3.6
240+00	3.8	4.2	3.8	3.3	1.3	3.6
250+00	3.9	4.2	3.8	3.2	1.3	3.6
260+00	3.9	4.2	3.8	3.2	1.3	3.5
270+00	3.9	4.2	3.8	3.1	1.3	3.5
280+00	3.9	4.2	3.9	3.0	1.3	3.4
290+00	3.9	4.2	3.9	3.0	1.3	3.4
300+00	3.9	4.2	3.9	3.0	1.3	3.4
310+00	4.0	4.2	4.0	Dry during low tides		
320+00	4.1	4.2	4.1	Dry during low tides		
328+82 (HWY 101)	4.1	4.2	4.1	Dry during low tides		

larger than the existing conditions. The greater tidal range will increase the tidal currents and thus alleviate the sedimentation, if any, within Novato Creek.

It is noted that Alternative 3 is expected to lower the MLW by less than one half foot. Also, under Alternative 3, the channel will be deepened to the elevation at -6.0 feet, NAVD 88 (two to four feet deeper than the existing conditions) for the reach that is downstream of the levee breach, and will be dredged approximately one foot deeper between the North Lock and the levee breach. Therefore, Alternative 3 will in fact increase the existing water depth in the navigation channel of the Novato Creek and consequently improve the boat traffic condition in the creek.

2.3 Predicted Tidal Current within Novato Creek

As indicators of the tidal current conditions, the Mean Peak Ebb Current (MPEC), Mean Peak Flood Current (MPFC), Mean Ebb Current (MEC) and Mean Flood Current (MFC) were calculated along the centerline of the creek based on the predicted instantaneous current velocities under for modified project conditions. The MPEC and MPFC derived along the centerline of the creek are shown in Error! Reference source not found. and tabulated in **Table 2-5,** and the MEC and MFC are listed in **Table 2-6**. Positive flow velocities denote ebb currents (i.e. from the creek out to San Pablo Bay), and negative velocities indicate flood currents (i.e. from San Pablo Bay into the creek). The results that were predicted for Alternatives 1 and 2 in the previous Phase II study are also shown in **Error! Reference source not found.** and listed in Tables 2-5 and 2-6 for comparison. The predicted instantaneous current velocities at the representative locations are shown in **Figures A-14** to **A-26** of Appendix A.

Compared to the existing flow conditions in Novato Creek, the modified project alternative (Alternative 3) will still increase the tidal currents in the reach that is downstream of the levee breach, but will only slightly alter the current conditions in the reach upstream of the levee breach. Under the Alternative 3 scenario, the increases to the currents in the reach downstream of the levee breach were predicted to be less than one foot per second (fps) for the MPEC, approximately 0.5 to 0.6 fps for MPFC, 0.1 to 0.3 fps for MEC and 0.2 to 0.4 fps for MFC, respectively. The limited increase to tidal currents will not likely induce any noticeable scouring in this downstream reach. Instead, it would alleviate the sedimentation that occurs in this reach under the existing conditions, as discussed in Section 2.5. The tidal circulation in the reach upstream of the levee breach will be slightly stronger under Alternative 3. The ebb currents will be increased by 0.1 to 0.2 feet per second, while the increase to flood currents will be negligible. The slightly stronger tidal circulation in the upstream reach will also reduce the sedimentation that was predicted for the existing conditions.

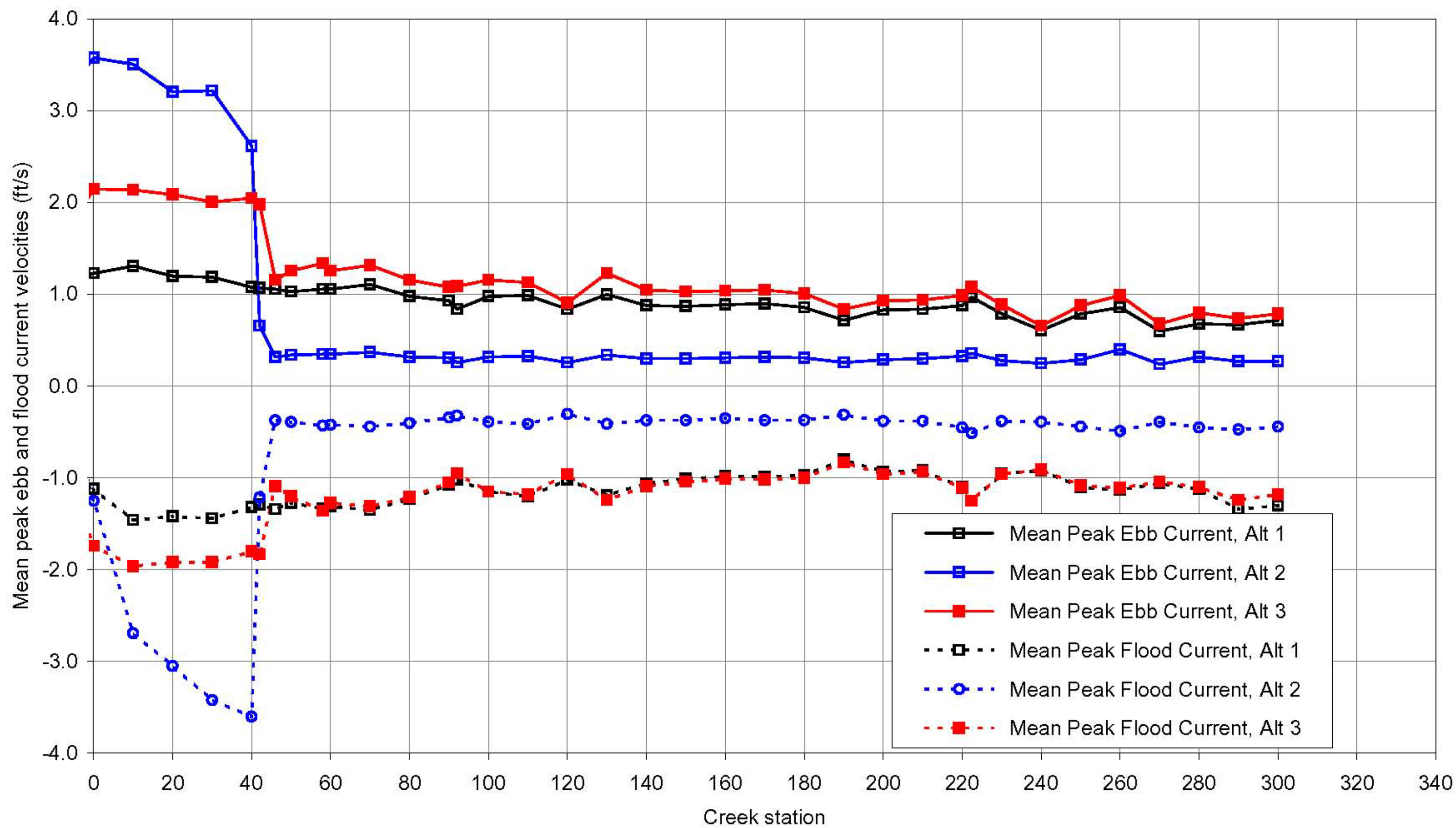


Figure 2-10. Comparison of Mean Peak Currents along Creek Centerline

Table 2-5. Comparison of MPEC and MPFC along Creek Centerline

Creek station	Mean Peak Ebb Current MPEC (ft/s)			Mean Peak Flood Current MPFC (ft/s)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
0+00 (Creek mouth)	1.2	3.6	2.2	-1.1	-1.3	-1.7
10+00	1.3	3.5	2.1	-1.5	-2.7	-2.0
20+00	1.2	3.2	2.1	-1.4	-3.1	-1.9
30+00	1.2	3.2	2.0	-1.4	-3.4	-1.9
40+00	1.1	2.6	2.1	-1.3	-3.6	-1.8
42+00 (Levee breach)	1.1	0.7	2.0	-1.3	-1.2	-1.8
46+00	1.1	0.3	1.2	-1.3	-0.4	-1.1
50+00	1.0	0.3	1.3	-1.3	-0.4	-1.2
58+00 (Pilecluster)	1.1	0.4	1.3	-1.3	-0.4	-1.4
60+00	1.1	0.4	1.3	-1.3	-0.4	-1.3
70+00	1.1	0.4	1.3	-1.4	-0.4	-1.3
80+00	1.0	0.3	1.2	-1.2	-0.4	-1.2
90+00	0.9	0.3	1.1	-1.1	-0.3	-1.1
92+00 (South Lock)	0.8	0.3	1.1	-1.0	-0.3	-1.0
100+00	1.0	0.3	1.2	-1.2	-0.4	-1.2
110+00	1.0	0.3	1.1	-1.2	-0.4	-1.2
120+00 (North Lock)	0.8	0.3	0.9	-1.0	-0.3	-1.0
130+00	1.0	0.3	1.2	-1.2	-0.4	-1.2
140+00	0.9	0.3	1.1	-1.1	-0.4	-1.1
150+00	0.9	0.3	1.0	-1.0	-0.4	-1.0
160+00	0.9	0.3	1.0	-1.0	-0.4	-1.0
170+00	0.9	0.3	1.1	-1.0	-0.4	-1.0

Table 2-5. Comparison of MPEC and MPFC along Creek Centerline (continued)

Creek station	Mean Peak Ebb Current MPEC (ft/s)			Mean Peak Flood Current MPFC (ft/s)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
180+00	0.9	0.3	1.0	-1.0	-0.4	-1.0
190+00	0.7	0.3	0.8	-0.8	-0.3	-0.8
200+00	0.8	0.3	0.9	-0.9	-0.4	-1.0
210+00	0.8	0.3	0.9	-0.9	-0.4	-0.9
220+00	0.9	0.3	1.0	-1.1	-0.5	-1.1
222+40 (HWY 37)	1.0	0.4	1.1	-1.3	-0.5	-1.3
230+00	0.8	0.3	0.9	-1.0	-0.4	-1.0
240+00	0.6	0.3	0.7	-0.9	-0.4	-0.9
250+00	0.8	0.3	0.9	-1.1	-0.4	-1.1
260+00	0.9	0.4	1.0	-1.1	-0.5	-1.1
270+00	0.6	0.2	0.7	-1.1	-0.4	-1.0
280+00	0.7	0.3	0.8	-1.1	-0.5	-1.1
290+00	0.7	0.3	0.7	-1.3	-0.5	-1.2
300+00	0.7	0.3	0.8	-1.3	-0.4	-1.2
310+00	Dry during low tides					
320+00	Dry during low tides					
328+82 (HWY 101)	Dry during low tides					

Table 2-6. Comparison of MEC and MFC along Creek Centerline

Creek station	Mean Ebb Current MEC (ft/s)			Mean Flood Current MFC (ft/s)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
0+00 (Creek mouth)	0.9	2.7	1.1	-0.6	-1.0	-1.0
10+00	1.0	2.7	1.1	-0.8	-1.9	-1.1
20+00	0.9	2.5	1.1	-0.8	-2.2	-1.0
30+00	0.9	2.5	1.0	-0.8	-2.4	-1.0
40+00	0.8	2.1	1.0	-0.8	-2.5	-1.0
42+00 (Levee breach)	0.8	0.5	1.0	-0.7	-0.8	-1.0
46+00	0.8	0.2	0.8	-0.8	-0.3	-0.6
50+00	0.8	0.2	0.9	-0.7	-0.3	-0.7
58+00 (Pilecluster)	0.8	0.3	1.0	-0.8	-0.3	-0.8
60+00	0.8	0.3	0.9	-0.8	-0.3	-0.7
70+00	0.8	0.3	1.0	-0.8	-0.3	-0.8
80+00	0.7	0.2	0.9	-0.7	-0.3	-0.7
90+00	0.7	0.2	0.8	-0.6	-0.2	-0.6
92+00 (South Lock)	0.6	0.2	0.8	-0.6	-0.2	-0.6
100+00	0.7	0.2	0.9	-0.7	-0.3	-0.7
110+00	0.7	0.2	0.8	-0.7	-0.3	-0.7
120+00 (North Lock)	0.6	0.2	0.7	-0.6	-0.2	-0.6
130+00	0.7	0.3	0.9	-0.7	-0.3	-0.8
140+00	0.6	0.2	0.8	-0.7	-0.3	-0.7
150+00	0.6	0.2	0.8	-0.6	-0.3	-0.7
160+00	0.6	0.2	0.8	-0.6	-0.3	-0.7
170+00	0.7	0.2	0.8	-0.6	-0.3	-0.7

Table 2-6. Comparison of MEC and MFC along Creek Centerline (continued)

Creek station	Mean Ebb Current MEC (ft/s)			Mean Flood Current MFC (ft/s)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
180+00	0.6	0.2	0.8	-0.6	-0.3	-0.7
190+00	0.5	0.2	0.6	-0.5	-0.2	-0.6
200+00	0.6	0.2	0.7	-0.6	-0.3	-0.7
210+00	0.6	0.2	0.7	-0.6	-0.3	-0.7
220+00	0.7	0.3	0.7	-0.8	-0.3	-0.8
222+40 (HWY 37)	0.7	0.3	0.8	-0.8	-0.4	-0.9
230+00	0.6	0.2	0.7	-0.6	-0.3	-0.7
240+00	0.5	0.2	0.5	-0.6	-0.3	-0.6
250+00	0.5	0.2	0.6	-0.7	-0.3	-0.7
260+00	0.7	0.3	0.8	-0.7	-0.4	-0.7
270+00	0.4	0.2	0.5	-0.7	-0.3	-0.7
280+00	0.6	0.2	0.6	-0.7	-0.3	-0.7
290+00	0.5	0.2	0.5	-0.8	-0.3	-0.8
300+00	0.4	0.2	0.5	-0.7	-0.3	-0.7
310+00	Dry during low tides					
320+00	Dry during low tides					
328+82 (HWY 101)	Dry during low tides					

Compared to the originally proposed project alternative (Alternative 2), under which the tidal currents will be significantly increased in the reach downstream of the levee breach and be significantly decreased in the reach upstream of the levee breach, Alternative 3 will result in much less alteration to the tidal circulation in Novato Creek. In fact, the slightly stronger tidal currents under Alternative 3, particularly for the reach upstream of the levee breach, will be beneficial to the channel stability. As discussed in Section 2.5, Alternative 3 will not only alleviate the existing channel sedimentation in Novato Creek, but also avoid significant creek scouring or sedimentation associated with Alternative 2

2.4 Predicted Bottom Shear Stress within Novato Creek

The derived mean peak shear stresses along the creek centerline are shown in **Figure 2-11** and listed **Table 2-7**. The shear stresses respectively predicted for the existing conditions (Alternative 1) and originally proposed project conditions (Alternative 2) are also plotted in these figures for comparison. The predicted time series of bottom shear stresses induced by tidal currents for Alternative 3 are respectively shown in **Figures A-27** to **A-39** of Appendix A for the representative locations.

Compared to the existing conditions, the modified project alternative (Alternative 3) will increase the bottom shear stress by 60 to 80 percent in the reach downstream of the levee breach and by 10 to 20 percent in the reach upstream of the levee breach. However, the originally proposed project alternative (Alternative 2) will result in four to five times increase in the bottom shear stress in the reach downstream of the levee breach and 80 to 90 percent decrease in the reach upstream of the levee breach. As a consequence, Alternative 3 will cause much less changes to the bottom shear stress in Novato Creek, as compared to Alternative 2.

It is noted that the limited increase in the bottom shear stress associated with Alternative 3 will alleviate the existing sedimentation in Novato Creek, and will also avoid the significant erosion or sedimentation associated with Alternative 2. The bottom shear stress associated with Alternative 3 will allow sediment to deposit when tidal currents are weak. This newly deposited material will, however, be partially or totally re-suspended by the following peak tidal currents. On the other hand, the bottom shear stress resulting from the peak tidal currents for Alternative 3 will not be strong enough to significantly erode away the consolidated clay bed underneath the newly deposited layer.

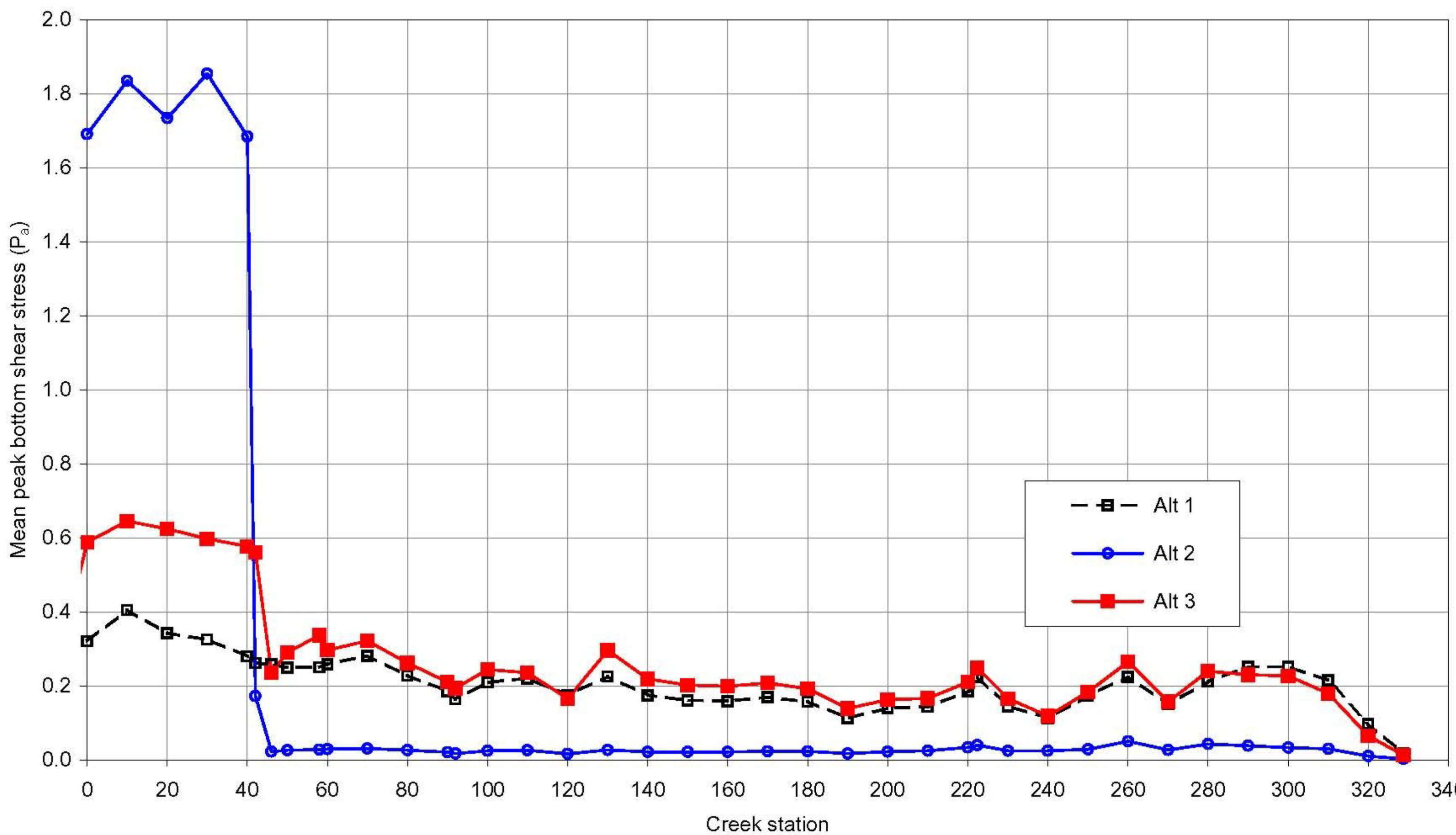


Figure 2-11. Comparison of Mean Peak Bed Shear Stress along Creek Centerline

Table 2-7. Comparison of Mean Peak Bed Shear Stress along Creek Centerline

Creek Station	Mean Peak Bed Shear Stress (Pa)			Creek Station	Mean Peak Bed Shear Stress (Pa)		
	Alt 1	Alt 2	Alt 3		Alt 1	Alt 2	Alt 3
0+00 (Creek mouth)	0.32	1.69	0.59	160+00	0.16	0.02	0.20
10+00	0.40	1.84	0.65	170+00	0.17	0.02	0.21
20+00	0.34	1.73	0.62	180+00	0.16	0.02	0.19
30+00	0.33	1.86	0.60	190+00	0.11	0.02	0.14
40+00	0.28	1.69	0.58	200+00	0.14	0.02	0.16
42+00 (Levee breach)	0.26	0.17	0.56	210+00	0.14	0.02	0.17
46+00	0.26	0.02	0.24	220+00	0.19	0.03	0.21
50+00	0.25	0.03	0.29	222+40 (HWY 37)	0.22	0.04	0.25
58+00 (Pilecluster)	0.25	0.03	0.34	230+00	0.14	0.02	0.17
60+00	0.26	0.03	0.30	240+00	0.11	0.02	0.12
70+00	0.28	0.03	0.32	250+00	0.17	0.03	0.18
80+00	0.23	0.03	0.26	260+00	0.22	0.05	0.26
90+00	0.19	0.02	0.21	270+00	0.15	0.03	0.16
92+00 (South Lock)	0.16	0.02	0.19	280+00	0.21	0.04	0.24
100+00	0.21	0.02	0.24	290+00	0.25	0.04	0.23
110+00	0.22	0.03	0.24	300+00	0.25	0.03	0.23
120+00 (North Lock)	0.17	0.02	0.17	310+00	Dry during low tides		
130+00	0.23	0.03	0.30	320+00	Dry during low tides		
140+00	0.17	0.02	0.22	328+82 (HWY 101)	Dry during low tides		
150+00	0.16	0.02	0.20				

2.5 Predicted Morphological Adjustment within Novato Creek

Since the simulation period of 15 days selected in this analysis covers a typical spring-ebb tidal cycle, the simulated bed change in this period was then used to forecast the annual bed change by linearly extrapolating the results from 15 days to 365 days. The projected annual bed changes along the centerline of the creek for Alternative 3 as well as the other two alternatives are presented **Figure 2-12** and in **Table 2-8.** The spatial variations of the annual bed change within the reach from the North Lock to the creek mouth are respectively shown in **Figure 2-13** and **Figure 2-14** for this optimal project alternative. A positive value of bed change indicates deposition, and a negative value denotes erosion. The predicted sedimentation or erosion processes at the representative locations are illustrated in **Figures A-40** to **A-52** of Appendix A.

As compared to Alternative 2, under which significant erosion will occur in the reach downstream of the levee breach and substantial sedimentation will occur in the reach upstream, Alternative 3 will result in a quasi-stable channel along Novato Creek. A negligible deposition will occur downstream of the South Lock, with a sedimentation rate of less than 0.1 feet per year along the centerline of the creek. It is noted that the overall sedimentation rate associated with Alternative 3 will be much less than the existing conditions (see Figure 2-12), indicating that the existing channel deposition within the Novato Creek will be alleviated under the optimal project alternative.

Similar to Alternatives 1 and 2, the sedimentation pattern for Alternative 3 also shows spatial variation throughout the cross-section of the creek. The sedimentation along the edges of the main channel will be generally greater than in the central channel area as a result of the cross-sectional distribution of the current-induced bottom shear stress. In addition, the sedimentation on the floodplain will be negligible as it will be infrequently inundated.

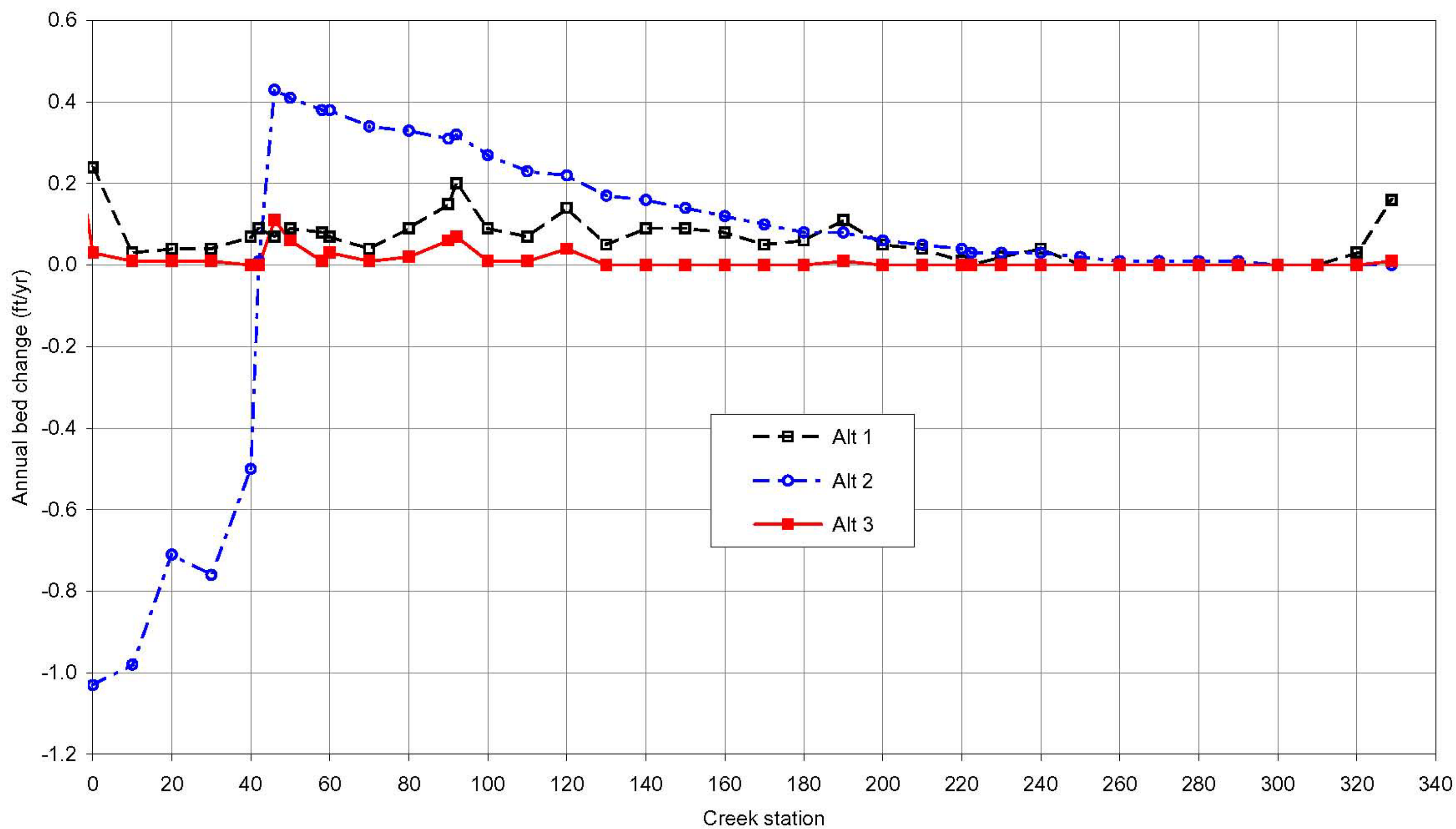


Figure 2-12. Comparison of Bed Change along Creek Centerline

Table 2-8. Comparison of Bed Change along Creek Centerline

Creek Station	Annual bed Change (ft/yr)			Creek Station	Annual bed Change (ft/yr)		
	Alt 1	Alt 2	Alt 3		Alt 1	Alt 2	Alt 3
0+00 (Creek mouth)	0.2	-1.0	~0.0	160+00	0.1	0.1	~0.0
10+00	~0.0	-1.0	~0.0	170+00	0.1	0.1	~0.0
20+00	~0.0	-0.7	~0.0	180+00	0.1	0.1	~0.0
30+00	~0.0	-0.8	~0.0	190+00	0.1	0.1	~0.0
40+00	0.1	-0.5	~0.0	200+00	0.1	0.1	~0.0
42+00 (Levee breach)	0.1	~0.0	~0.0	210+00	~0.0	0.1	~0.0
46+00	0.1	0.4	0.1	220+00	~0.0	~0.0	~0.0
50+00	0.1	0.4	0.1	222+40 (HWY 37)	~0.0	~0.0	~0.0
58+00 (Pilecluster)	0.1	0.4	~0.0	230+00	~0.0	~0.0	~0.0
60+00	0.1	0.4	~0.0	240+00	~0.0	~0.0	~0.0
70+00	~0.0	0.3	~0.0	250+00	~0.0	~0.0	~0.0
80+00	0.1	0.3	~0.0	260+00	~0.0	~0.0	~0.0
90+00	0.2	0.3	0.1	270+00	~0.0	~0.0	~0.0
92+00 (South Lock)	0.2	0.3	0.1	280+00	~0.0	~0.0	~0.0
100+00	0.1	0.3	~0.0	290+00	~0.0	~0.0	~0.0
110+00	0.1	0.2	~0.0	300+00	~0.0	~0.0	~0.0
120+00 (North Lock)	0.1	0.2	~0.0	310+00	~0.0	~0.0	~0.0
130+00	0.1	0.2	~0.0	320+00	~0.0	~0.0	~0.0
140+00	0.1	0.2	~0.0	328+82 (HWY 101)	0.2	~0.0	~0.0
150+00	0.1	0.1	~0.0				

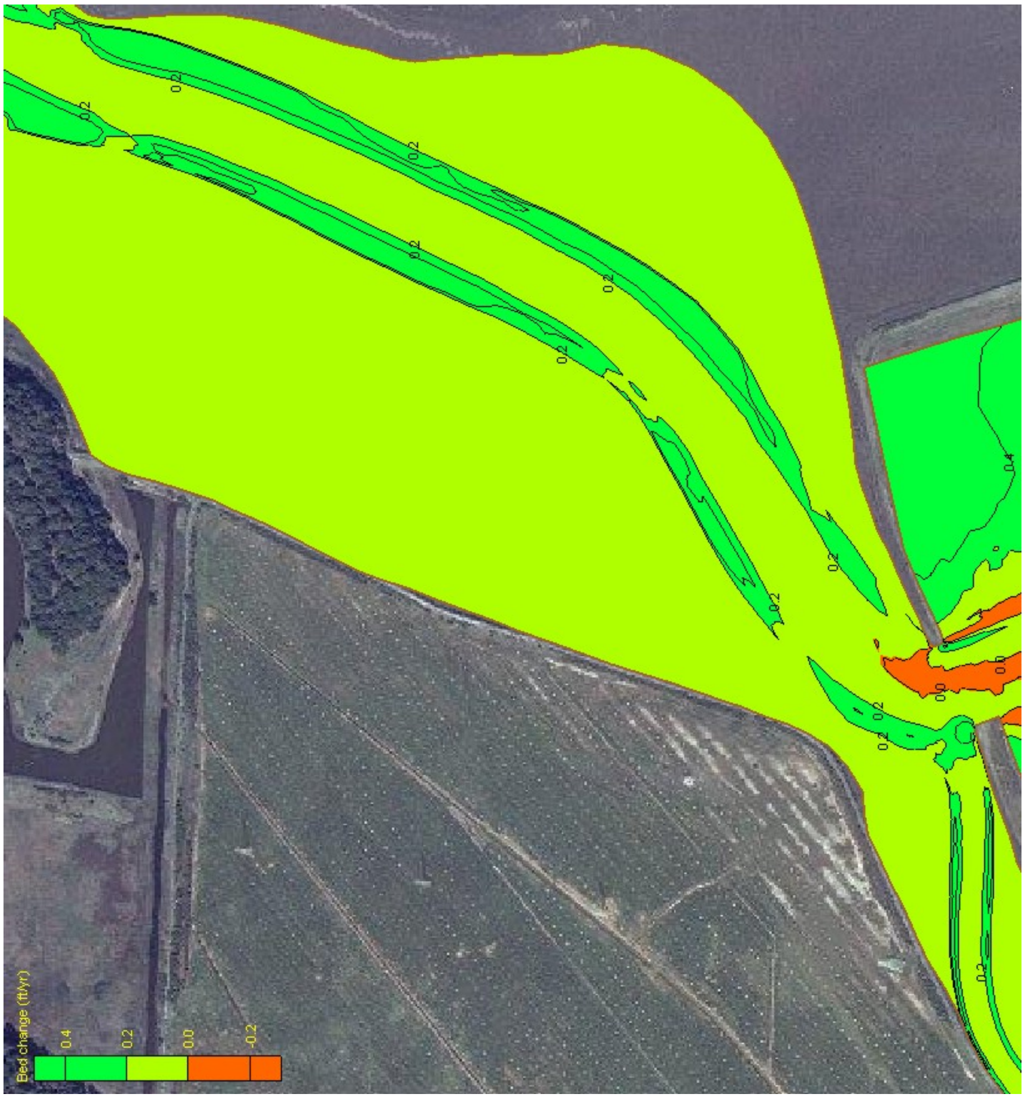


Figure 2-13. Predicted Bed Change (Alt 3, Levee Breach to Creek Mouth)

Figure 2-14. Predicted Bed Change (Alt 3, North Lock to Levee Breach)

2.6 Flow Conditions and Sedimentation in Northern Wetland Basin

The representative water levels and current velocities within the Northern wetland Basin are summarized in **Table 2-9** and **Table 2-10**. The predicted temporal variations of hydrodynamic characteristics at the representative locations in the wetland basin are illustrated in **Figures A-53** to **A-55** of Appendix A for water levels, in **Figures A-56** to **A-58** flow velocities, and in **Figures A-59** to **A-61** for the bottom shear stresses.

Compared to the originally proposed project alternative (Alternative 2), the tidal muting in the wetland basin will be insignificant under the optimal project alternative (Alternative 3) as a result of increased flow conveyance capacity of the Novato Creek downstream of the breach location. Compared to Alternative 2, the MHW within the wetland for Alternative 3 will be elevated by approximately one foot, and the MLW decreased by more than 2 feet, resulting in a tidal range that will be two to three times larger than the muted tidal range for Alternative 2. Consequently, the tidal circulation and tidal induced bottom shear stress within the wetland basin will be much stronger than Alternative 2. For the most portion of the wetland basin, the tidal currents for Alternative 3 will be two to four times stronger than Alternative 2. Stronger tidal circulation and the resulting increase in bottom shear stress will lessen the sedimentation within the wetland basin.

The projected annual bed change at the nine representative locations (see Figure 1-2) for Alternative 3 is shown in **Figure 2-15**, as compared to that estimated for Alternative 2. The sedimentation/erosion processes predicted for these locations during the 15-day simulation period are shown in **Figures A-62** to **A-64**. The spatial variation of the sedimentation in the wetland basin for Alternative 3 is shown in **Figure 2-16**. The sedimentation rate within the wetland basin predicted for Alternative 3 is expected to be much less than Alternative 2. The deposition rate for Alternative 3 will be less than 0.1 feet per year for the most part of the wetland basin, and will range from 0.1 feet per year to 0.3 feet per year for the northeast and northwest areas of the wetland basin that are located in the shadow zones of the wetland entrance. It is also noticed that the pilot channel at the wetland entrance will be relatively stable, with negligible sedimentation or erosion being predicted.

Table 2-9. Comparison of Water Levels along BMK-V Northern Wetland Centerline

BMK-V Station	MHW (ft, NAVD 88)		MLW (ft, NAVD 88)		MWL (ft, NAVD 88)		Mean Tidal Range (ft)	
	Alt 2	Alt 3	Alt 2	Alt 3	Alt 2	Alt 3	Alt 2	Alt 3
0+00	4.9	5.8	3.3	1.2	4.2	3.5	1.6	4.6
1+40	4.9	5.8	3.3	1.2	4.2	3.5	1.6	4.6
3+90	4.9	5.8	3.3	1.2	4.2	3.5	1.6	4.6
8+00	4.9	5.8	3.3	1.2	4.2	3.5	1.6	4.6
12+60	4.9	5.8	Dry when tides lower than +2.5’					
29+90	4.9	5.8	Dry when tides lower than +3.0’					
44+90	4.9	5.8	Dry when tides lower than +3.5’					
53+10	4.9	5.8	Dry when tides lower than +4.0’					
60+80	Dry when tides lower than +4.5’							

Table 2-10. Comparison of Currents along BMK-V Northern Wetland Centerline

BMK-V Station	MPEC (ft/s)		MPFC (ft/s)		MEC (ft/s)		MFC (ft/s)	
0+00	0.5	2.1	-1.0	-1.9	0.4	0.9	-0.7	-1.0
1+40	0.5	2.0	-0.8	-1.9	0.4	0.9	-0.5	-0.9
3+90	0.4	1.7	-0.6	-1.5	0.3	0.7	-0.4	-0.8
8+00	0.3	1.3	-0.5	-1.1	0.2	0.6	-0.3	-0.6
12+60	0.3	1.5	-0.5	-1.2	0.3	0.9	-0.4	-0.8
29+90	0.2	0.7	-0.3	-0.7	0.2	0.5	-0.2	-0.5
44+90	0.1	0.4	-0.2	-0.4	0.1	0.2	-0.1	-0.3
53+10	0.1	0.3	-0.1	-0.3	0.1	0.2	-0.1	-0.2
60+80	~0.0	0.2	-0.1	-0.2	~0.0	0.1	-0.1	-0.1

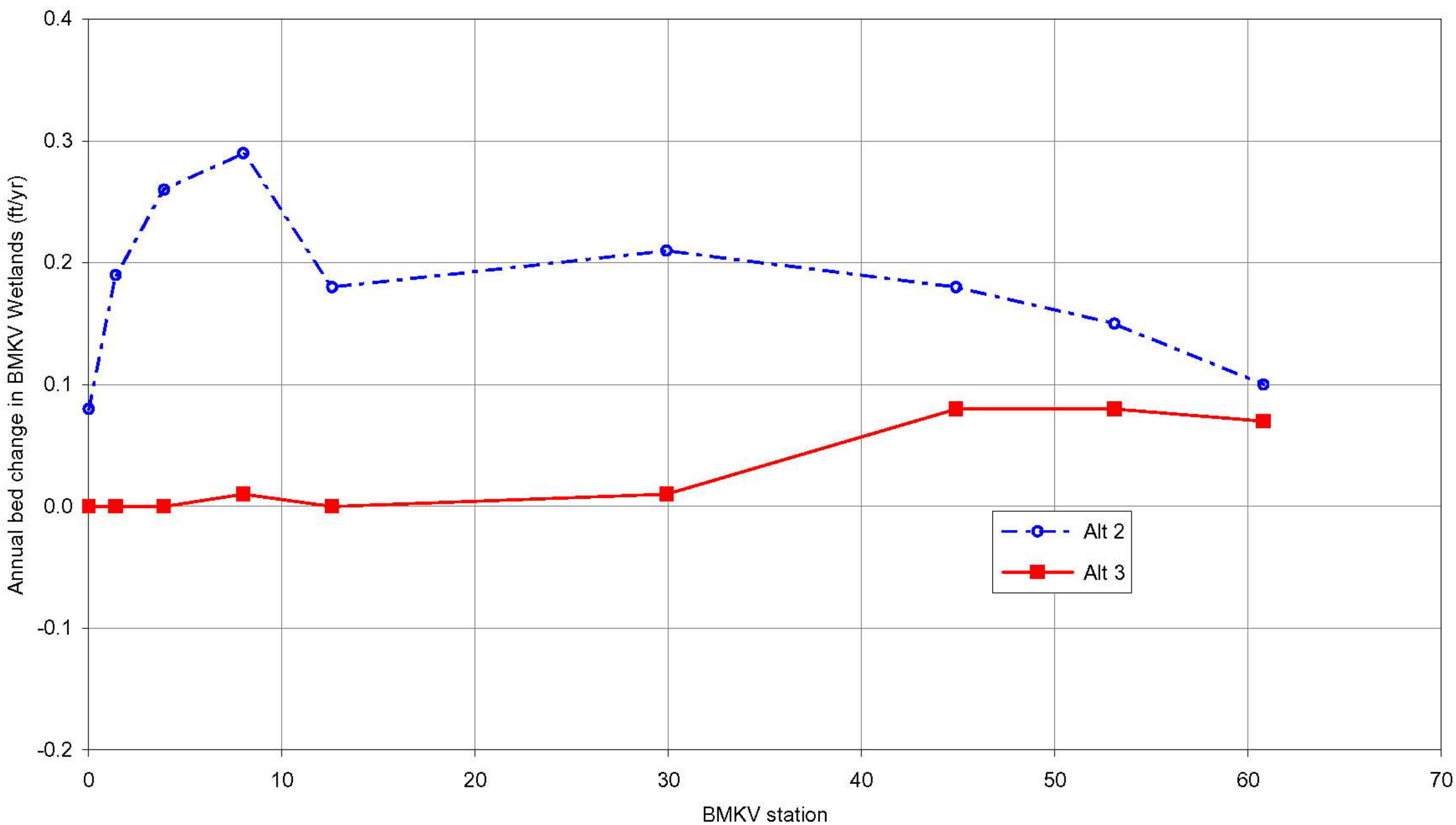


Figure 2-15. Comparison of Bed Change along Centerline of Wetland

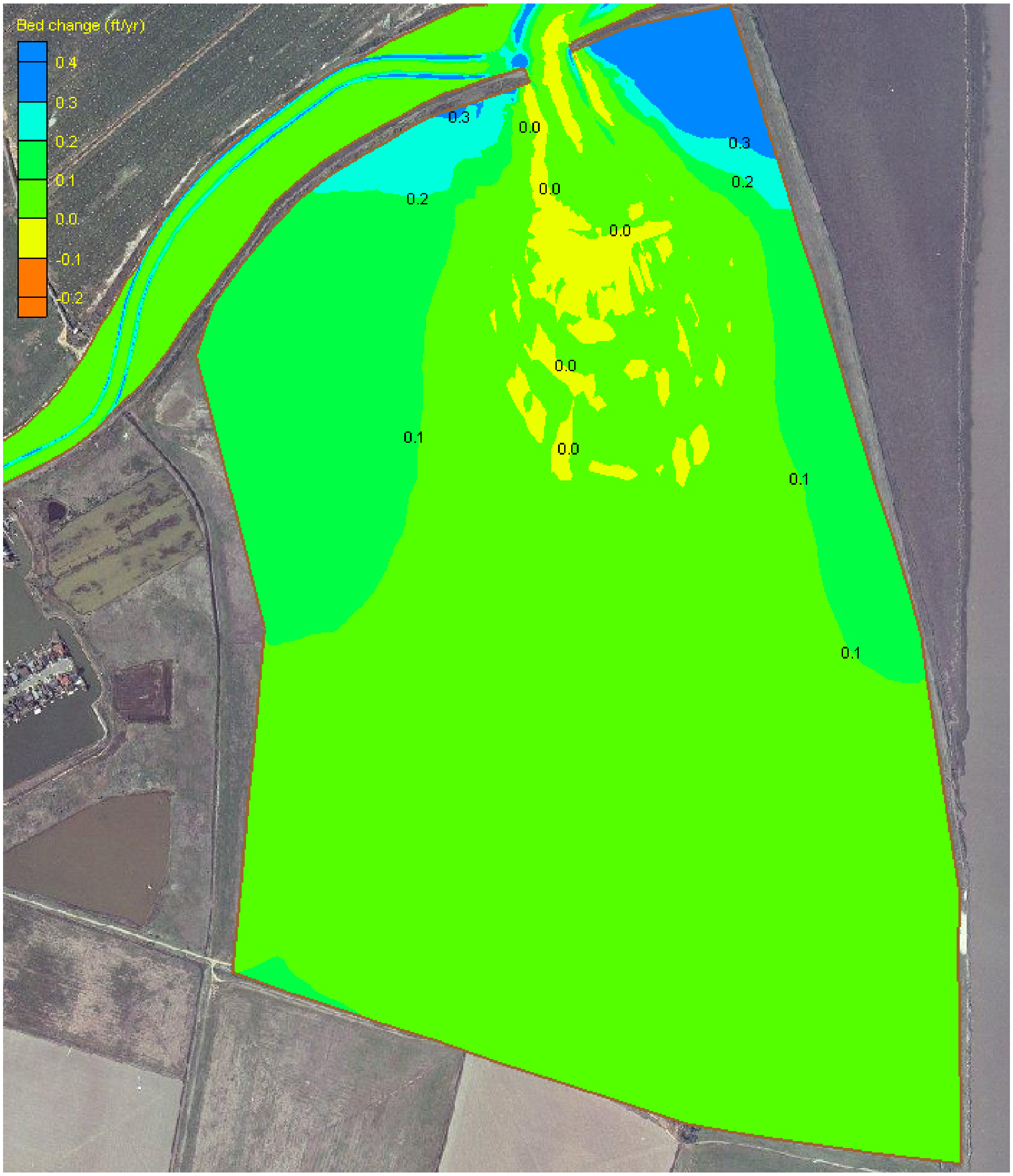


Figure 2-16. Predicted Bed Change (Alt 3, BMK-V Northern Wetland)

3.0 HYDRAULIC MODELING OF FLOOD POTENTIAL SCENARIOS

Hydraulic modeling of 19 flood potential scenarios was previously performed and documented in the Phase II study (NCI & **nhc**, 2006). These 19 scenarios were composed of two basic geometries representing the existing and originally proposed project conditions for three extreme flooding events. These events are representative of concurrent occurrence of 100-year flood with a 10-year tide, 10-year flood with a 100-year tide, and a 100-year flood with a 100-year tide.

This supplemental hydraulic analysis included the same application of the one-dimensional unsteady HEC-RAS modeling effort for three above-mentioned flood potential scenarios to evaluate the flood dynamics under the modified project conditions, as described in Section 2.0. The initial conceptual design for the restoration of tidal wetlands for the Bel Marin Keys V (BMK-V) parcel consisted of breaching the south levee of Novato Creek to serve as one of the entry points for San Pablo Bay tide water flowing into the proposed wetland via Novato Creek without any changes to the creek channel. The modified project conditions that were simulated in this study included the same initial design of wetland basins, levee system, pond expansion, etc. with the widening and deepening of the creek channel from the creek mouth upstream to the North Lock of the BMK Lagoon. It is noted that the initial design study did include additional geometric conditions to evaluate the effects of the removal of the Highway 37 and Northwest Pacific Railroad (NWPRR) bridges. In this analysis, the removal of these two bridges was not included in the model simulations.

The scenarios that were modeled in the 2006 study (NCI & **nhc**, 2006) and referenced in this report are Scenario 1 (existing conditions under 100-year flood, 10-year tide), Scenario 5 (project conditions under 100-year flood and 10-year tide), Scenario 9 (existing conditions under 10-year flood, 100-year tide), Scenario 13 (project conditions under 10-year flood and 100-year tide), Scenario 18 (existing conditions under 100-year flood, 100-year tide), and Scenario 19 (project conditions under 100-year flood and 100-year tide). Herein the term *Existing Conditions* shall refer to the pre-project existing conditions (Scenarios 1, 9, and 18); the term *Originally Proposed Project Conditions* shall refer to the initial project conditions reported in the 2006 study

(Scenarios 5, 13 and 19), and the term *Modified Project Conditions* shall refer to the project conditions incorporating changes to the Novato Creek geometry.

3.1 Model Description of HEC-RAS

The conceptual HEC-RAS model applied in the Phase II study (NCI & **nhc**, 2006) is shown in **Figure 3-1** and was used as the baseline model for this study. In the baseline model, 69 cross-sections extend over 5.2 miles of Novato Creek from RS 31+79 to RS 339+68 with a pilot channel connecting the BMK-V wetland between RS 44+90 and RS 41+59. Channel cross-sections are based on the San Francisco Bay Light Detection and Ranging (LiDAR) data (Merrick, 2004) and extended wide enough to include the low flow channel and floodplain areas.

These floodplain storage areas possess the elevation-volume relationships representative of the existing low-laying floodplain areas and water reservoirs adjacent to Novato Creek and can be flooded by the overtopping of levees. Model calibration performed in the Phase II study (NCI & **nhc,** 2006) provided Manning's n values of 0.02 for the channel and 0.04 for the floodplain. For the project conditions, a dummy channel representing San Pablo Bay having a dimension of 10,000 feet in length and 50,000 feet wide was artificially included in the model. It was connected to the proposed wetlands via lateral structures and was used to simulate the exchange of tidal waters between the wetlands. A pilot channel connects the Northern Wetland Basin to Novato Creek through the breached levee.

The identical unsteady flow hydrograph representative of the modeled 10- and 100- year flood flows through Novato Creek that was used in the Phase II study (see **Error! Reference source not found.**, NCI & **nhc,** 2006) was applied in the present HEC-RAS modeling as the upstream boundary condition. The hydrographs are representative of 72 hour flood events and have peak discharges of 3,420 cubic feet per second (cfs) for the 10-year event and 8,000 cfs for the 100-year event. Base flows of 55 cfs in the San Jose Arroyo and 20 cfs in Pancheco Creek were incorporated into the model as a lateral inflow into Pancheco Pond. Similarly, an unsteady tide stage hydrograph that is identical to the one used in the Phase II study (see **Error! Reference source not found.**, NCI & **nhc**, 2006) was applied as the downstream boundary condition. Modified tidal stage time series, which were derived from tidal data measured in Novato Creek (NCI et al., 2005) and corresponding to the estimated 100- and 10-year tides, were used as the downstream boundary conditions in the HEC-RAS model. A more detailed description of the boundary conditions is available in the 2006 Phase II report (NCI & **nhc**, 2006).

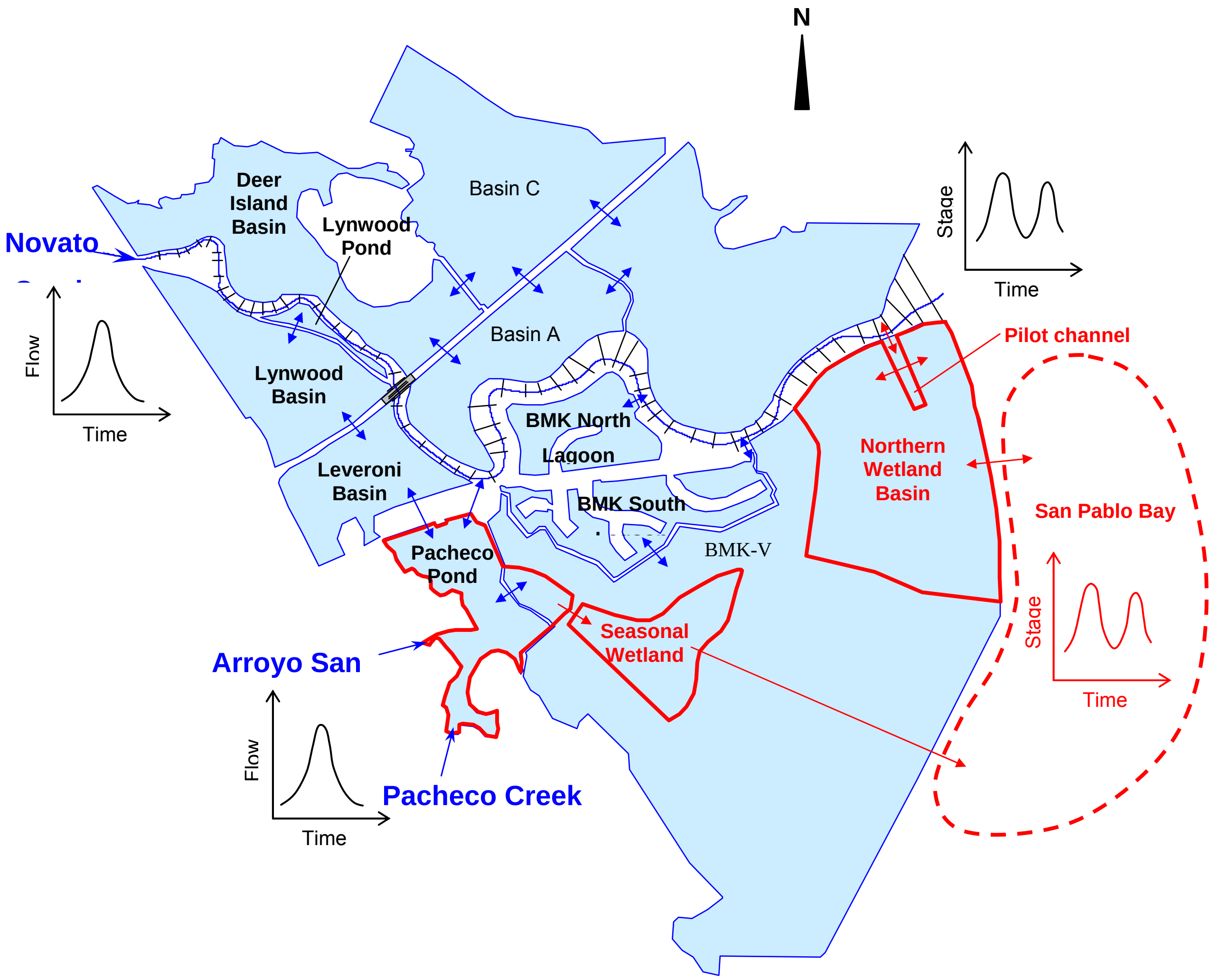


Figure 3-1. Conceptual HEC-RAS Layout Used for Study. (NCI & nhc, 2006)

The existing HEC-RAS model was updated to include the proposed alternative channel adjustments, as described in Section 2.0. This data was used to create a Triangulated Irregular Network (TIN) in AutoCAD Civil 3D 2008. Cross-sections were derived from the TIN and uploaded into the HEC-RAS model. These cross-sections replaced the existing cross-sections extending from the Novato Creek mouth to RS 125+37 (upstream of North Lock) as well as the pilot channel cross-sections. Changes in the channel geometry (see Figure 2-1) include lowering the invert elevation from -1.5 feet NAVD 88 to -6 feet NAVD 88 from the levee breach downstream to the mouth, as well as increasing the bottom width and decreasing the bank slope. Modification of channel geometry also applied to the reach between the levee breach upstream to the North Lock (see Figure 2-2 and Figure 2-3).

HEC-RAS simulations were run for the modified design conditions using equivalent upstream and downstream boundary conditions as used in the 2006 study and described above. Manning's n values and stability coefficients were also kept consistent to allow a close comparison between the results. These HEC-RAS input coefficients used for the simulations are listed in **Table 3-1**.

Table 3-1. Input Parameters Used for HEC-RAS Simulations

Parameter	Value
Manning's Roughness Coefficient (channel/floodplain)	0.02/0.04
Computational Interval	10 s
Hydrograph Output Interval	10 min
Profile Output Interval	10 min
Mixed Flow Regime Option	Yes
Implicit Weighting Factor	1.0
Water Surface Calculation Tolerance	0.02 feet
Storage Area Elevation Tolerance	0.05 feet
Maximum Number of Iterations	40
Weir Flow Stability Factor	3.0
Weir Flow Submergence Decay Exponent	3.0

3.2 Modeled Scenarios

Nine modeling scenarios were considered in the present analysis. Three basic geometries were used with each being representative of either the existing conditions, originally proposed project conditions, or the modified project conditions. As in the 2006 study (NCI & **nhc**, 2006), each geometry was run for three separate extreme flow and high tide conditions. The scenarios were numbered to maintain consistency with the 2006 Phase II study and are summarized below.

100-year Flood and 10-year Tide

Scenario 1 (Existing Conditions) – Hydrologic boundary conditions are 100-year inflow flood hydrographs; 10-year tide. Results were also presented in the 2006 Phase II study (NCI & **nhc,** 2006).

Scenario 5 (Originally Proposed Project Conditions) – Hydrologic boundary conditions are 100-year inflow flood hydrographs; 10-year tide. Results were also presented in the 2006 Phase II study (NCI & **nhc,** 2006).

Scenario 20 (Modified Project Conditions) – Hydrologic boundary conditions are 100-year inflow flood hydrograph, 10-year tide.

10-year Flood and 100-year Tide

Scenario 9 (Existing Conditions) – Hydrologic boundary conditions are 10-year inflow flood hydrographs; 100-year tide. Results were also presented in the 2006 Phase II study (NCI & **nhc,** 2006).

Scenario 13 (Originally Proposed Project Conditions) – Hydrologic boundary conditions are 10-year inflow flood hydrographs; 100-year tide. Results were also presented in the 2006 Phase II study (NCI & **nhc,** 2006).

Scenario 21 (Modified Project Conditions) – Hydrologic boundary conditions are 10-year inflow flood hydrograph, 100-year tide.

100-year Flood and 100-year Tide

Scenario 18 (Existing Conditions) – Hydrologic boundary conditions are 100-year inflow flood hydrographs; 100-year tide. Results were also presented in the 2006 Phase II study (NCI & **nhc,** 2006).

Scenario 19 (Originally Proposed Project Conditions) – Hydrologic boundary conditions are 100-year inflow flood hydrographs; 100-year tide. Results were also presented in the 2006 Phase II study (NCI & **nhc,** 2006).

Scenario 22 (Modified Project Conditions) – Hydrologic boundary conditions are 100-year inflow flood hydrograph, 100-year tide.

3.3 Model Results

The hydrologic parameters of stage/flow hydrographs and peak stages were used to evaluate the relative change in water level resulting from the modified project conditions. Evaluation of these peak stages was made for various selected locations along Novato Creek and for all the storage areas specified in the model. To remain consistent with the 2006 Phase II study (NCI & **nhc**, 2006), the selected control sections in the creek were: (1) at the model upstream boundary (RS 302+24 feet); (2) at the upstream end of Lynwood Pond (RS 253+37 feet); (3) immediately upstream of Highway 37 (RS 224+74 feet); (4) upstream of the existing confluence with Pacheco Pond (RS 192+89 feet); (5) upstream of park (RS 167+31 feet); (6) upstream of the north lock (RS 121+51 feet); (7) downstream of the south lock (RS 89+41 feet); and (8) upstream of the proposed levee breach location (RS 44+90 feet). Discussion of the main modeling results is provided in the following section. All differences in computed stages of less than 0.1 feet are considered to be insignificant as they are within the computational tolerances and errors specified in the model.

Table 3-2 provides the peak water surfaces modeled at the control locations in the creek. The modified project conditions will result in an increase in the peak water surface elevations near the North Lock. This increase may be the consequence of

Table 3-2. Peak Stages Simulated for Novato Creek

Geometry	Location in Novato Creek							
	At Model Upstream Boundary (RS 302+24 feet)	At Lynwood Pond (RS 253+37 feet)	Upstream of Highway 37 (RS 224+74 feet)	Upstream of Pacheco Pond (RS 192+89 feet)	Upstream of Park (RS 167+31 feet)	Upstream of North Lock (RS 121+51 feet)	Downstream of South Lock (RS 89+41 feet)	Upstream of Proposed Breach (RS 44+90 feet)
100-Yr Flood and 10-Yr Tide								
Existing	+14.94	+12.57	+11.17	+10.11	+9.70	+8.99	+8.73	+8.64
Originally Proposed Project	+14.94	+12.57	+11.14	+9.85	+9.55	+8.93	+8.72	+8.64
Modified Project	+14.94	+12.57	+11.14	+9.88	+9.59	+9.07	+8.78	+8.65
10-Yr Flood and 100-Yr Tide								
Existing	+12.47	+11.11	+10.22	+9.59	+9.43	+9.16	+9.10	+9.11
Originally Proposed Project	+12.47	+11.11	+10.22	+9.60	+9.46	+9.21	+9.15	+9.14
Modified Project	+12.47	+11.11	+10.22	+9.62	+9.48	+9.26	+9.19	+9.15
100-Yr Flood and 100-Yr Tide								
Existing	+14.94	+12.57	+11.17	+10.14	+9.78	+9.25	+9.10	+9.12
Originally Proposed Project	+14.94	+12.57	+11.14	+9.97	+9.70	+9.29	+9.18	+9.14
Modified Project	+14.94	+12.57	+11.14	+9.98	+9.72	+9.37	+9.22	+9.14

the reduced tidal muting in the channel, as the increased channel size better conveys the tidal influences upstream. This is apparent in the stage/flow hydrograph at a location (RS 65+00) upstream of the proposed breach, as shown in **Table 3-2**, where the temporal changes in the hydrograph are much more dynamic and representative of the tidal fluctuation.

Figure 3-3, **Figure 3-4** and **Figure 3-5** provide a more illustrative comparison of the peak water surface elevations that were simulated under individual conditions. No appreciable difference in water surface was predicted in the creek located upstream of RS 170+00 or downstream of 90+00, as shown in these plots. Although the modified project conditions do result in slightly higher peak water surface elevations, the simulated overall water surfaces occurring over time appear to be less than those for the originally proposed project conditions. The stage/ flow hydrographs of a section located between the North and South Locks (i.e. RS 129+47) shown in **Figure 3-6** illustrates this trend.

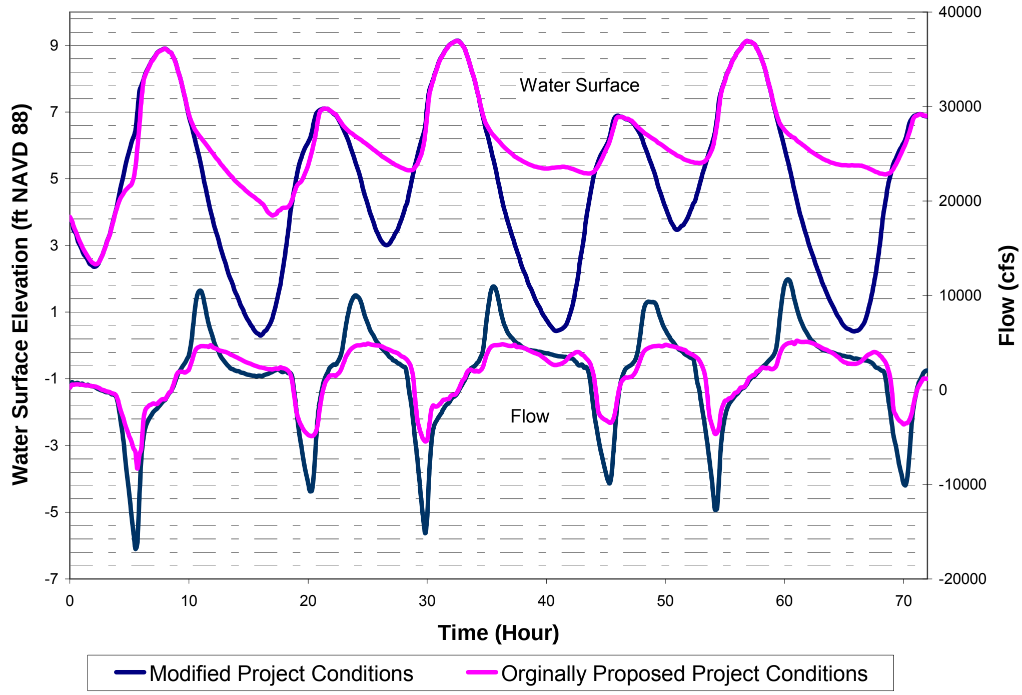


Figure 3-2. Simulated Stage/Flow Hydrograph at RS 65+00 during 100-Year Flood and 100-Year Tide

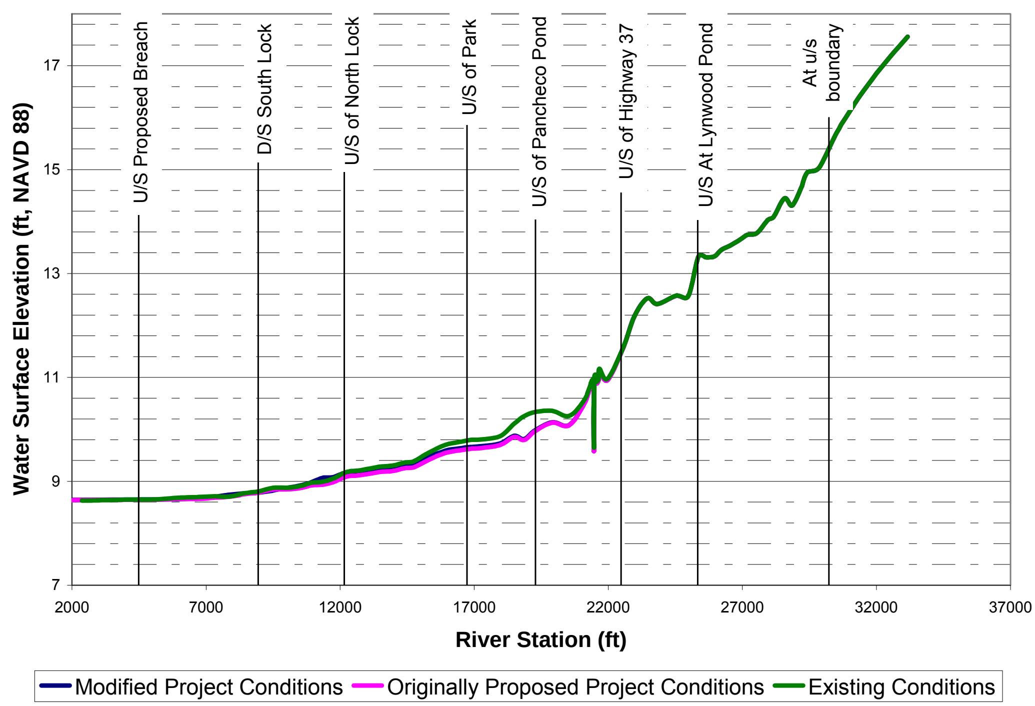


Figure 3-3. Peak Water Surface Elevations in Novato Creek during Concurrent 100-Year Flood and 10-Year Tidal Event

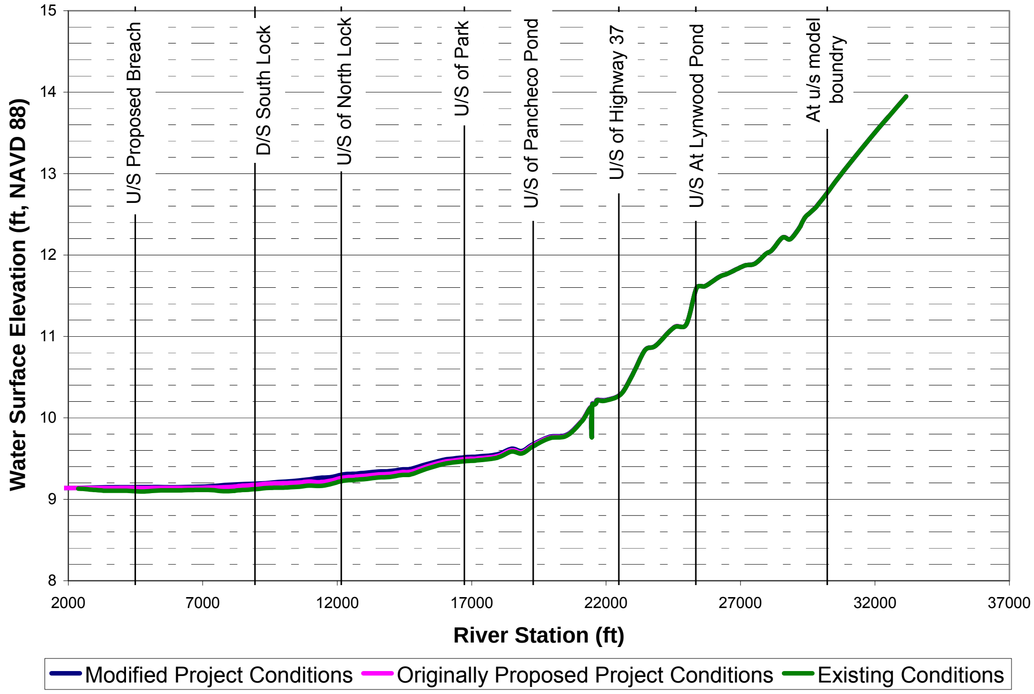


Figure 3-4. Peak Water Surface Elevations in Novato Creek during Concurrent 10-Year Food and 100-Year Tidal Event

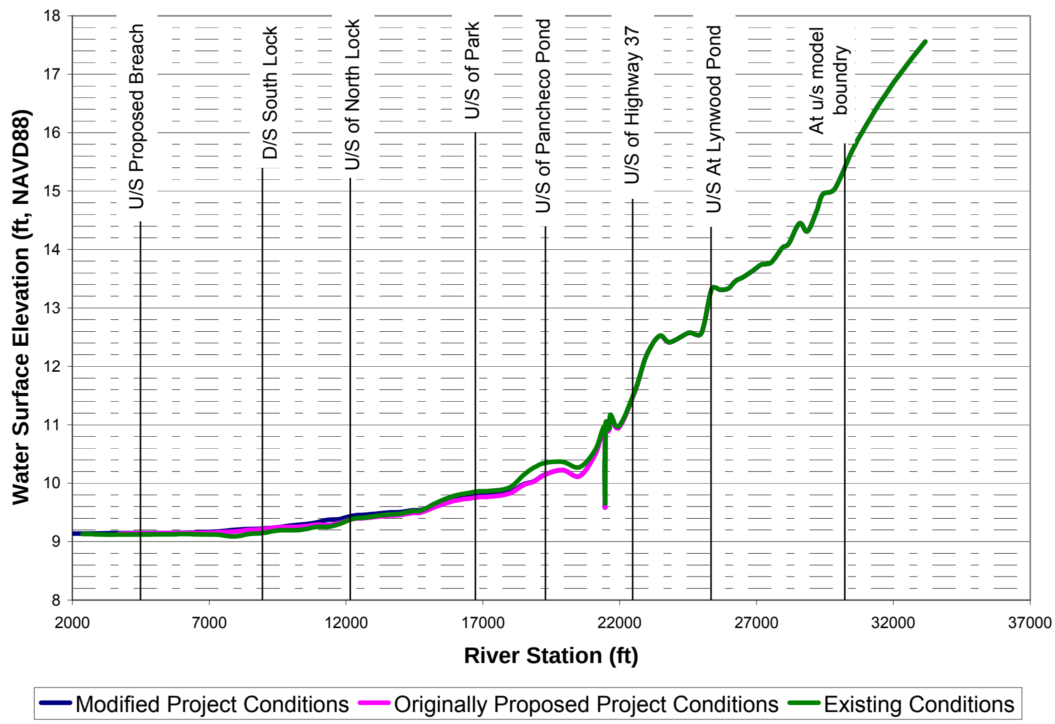


Figure 3-5. Peak Water Surface Elevations in Novato Creek during Concurrent 100-Year Flood and 100-Year Tidal Event

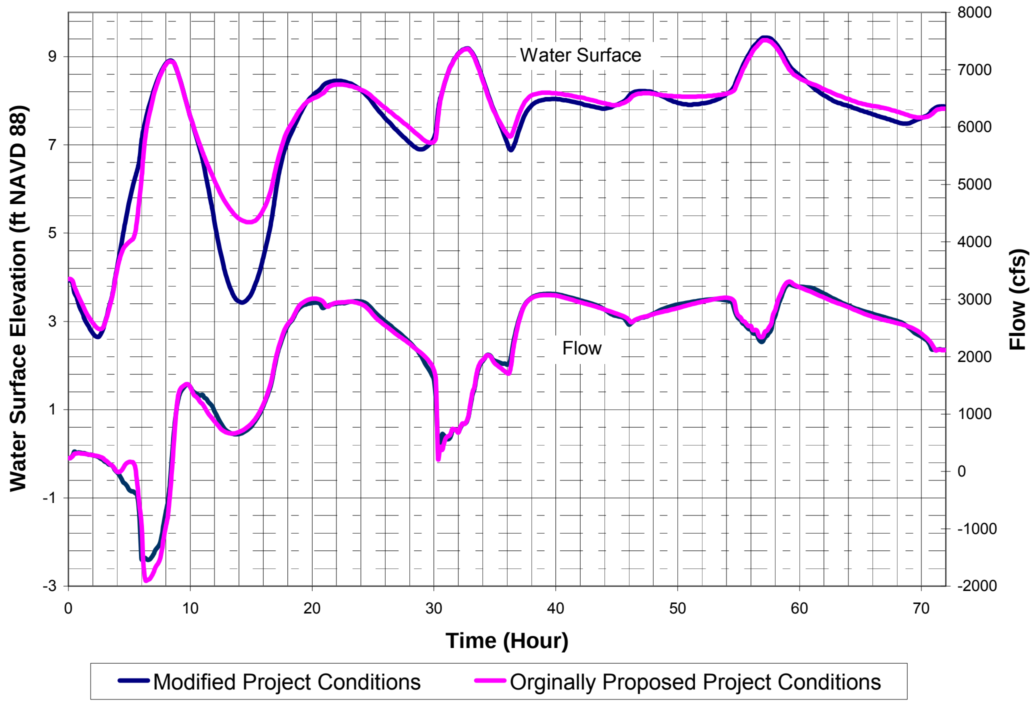


Figure 3-6. Simulated Stage/Flow Hydrograph at RS 129+47 during the 100-Year Flood and 100-Year Tide

Table 3-3 provides the peak water surfaces simulated in various storage areas. The modified project conditions produce some differences of water level only in the Bel Marin Keys North Lagoon. The peak water surface elevation during the 10-year flood with coincident 100-year tidal conditions was predicted to increase 0.13 feet relative to the result from the originally proposed project conditions. However, this water surface elevation is only 0.05 feet higher than the peak elevation simulated for the existing conditions. This difference is well within the tolerances of the model and is therefore deemed to be insignificant. On the contrary, the peak water surface elevation in the Bel Marin Keys North Lagoon under the modified project conditions was predicted to decrease during the 100-year flood with 10-year tidal event, as compared to the originally proposed project conditions. No appreciable difference in water surface elevation is expected in other storage areas.

Figure 3-7, **Figure 3-8** and **Figure 3-9** compare the water surface elevations in the proposed Northern Wetland Basin for the project conditions with and without channel adjustments. The peak stage elevations are not affected by the increase in the channel size. However, the downstream channel expansion allows tidal waters in the wetland to efficiently drain out into the bay, which lowers the water surface elevations in corresponding to the low tide conditions (i.e. the tidal muting effect is lessened).

The results of the simulations show that changes to the channel geometry in the modified project conditions will increase the flow area in the channel, thereby allowing the tidal influences to reach further upstream than for both the existing and originally proposed project conditions. The modified project conditions will provide lower stage heights throughout the majority of the simulated 72 hour storm events, and will increase the peak stage in the channel by not exceeding 0.12 feet at a location downstream of the South Lock (i.e. RS89+41 in Table 3-2) during the 10-year flood and 100-year tidal conditions, as compared to the originally proposed project and existing conditions. Most variations in the peak water surface elevations are well within the model's 0.1-foot tolerance and can be deemed negligible.

Table 3-3. Peak Stages Simulated for Storage Areas

	Storage Areas												
Geometric Conditions	Deer Island Basin	Lynwood Basin	Lynwood Pond	Leveroni Basin	Pacheco Pond	BMK North Lagoon	BMK South Lagoon	BMK-V	Basin A	Basin B	Basin C	Seasonal Wetland	Northern Wetland Basin
100-Yr Flood and 10-Yr Tide													
Existing	+5.68	+10.23	+12.38	+10.21	+10.18	+7.06	+3.64	-0.59	+4.25	-0.25	+1.44	-	-
Originally Proposed Project	+5.67	+9.73	+12.38	+9.72	+9.67	+6.78	+3.64	-	+4.12	-0.56	+1.42	+9.13	+8.63
Modified Project	+5.67	+9.74	+12.38	+9.72	+9.67	+6.69	+3.64	-	+4.12	-0.57	+1.42	+9.14	+8.64
10-Yr Flood and 100-Yr Tide													
Existing	+1.34	-1.55	+9.78	+5.81	+8.53	+6.43	+3.64	-2.18	+1.12	-1.68	-	-	-
Originally Proposed	+1.34	-1.55	+9.80	+4.85	+7.47	+6.35	+3.64	-	+1.13	-1.56	-	+7.45	+9.13

Project													
Modified Project	+1.33	-1.56	+9.77	+4.82	+7.52	+6.48	+3.64	-	+1.12	-1.91	-	+7.43	+9.13
100-Yr Flood and 100-Yr Tide													
Existing	+5.68	+10.25	+12.39	+10.23	+10.19	+7.88	+3.64	-0.11	+4.29	+0.02	+1.45	-	-
Originally Proposed Project	+5.67	+9.99	+12.38	+9.98	+9.93	+7.58	+3.64	-	+4.19	-0.19	+1.43	+9.44	+9.13
Modified Project	+5.67	+9.99	+12.38	+9.98	+9.94	+7.57	+3.64	-	+4.20	-0.25	+1.43	+9.44	+9.13

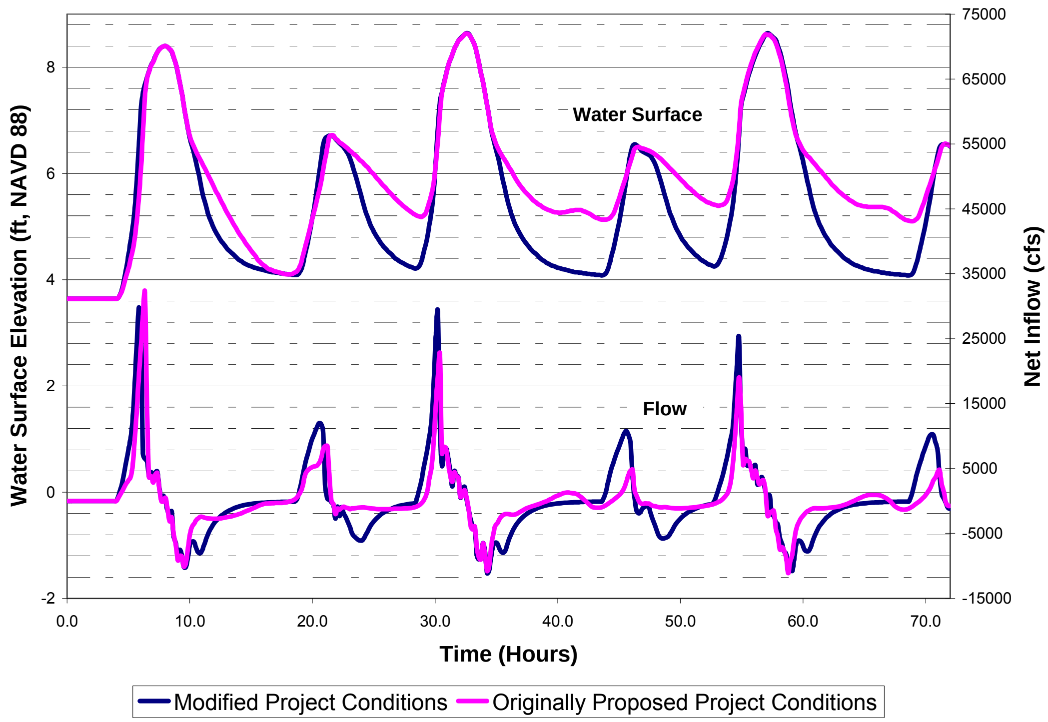


Figure 3-7. Water Surface Elevations in the Wetland over A 72 Hour Period with Concurrent 100-Year Flood and 10-Year Tidal Event

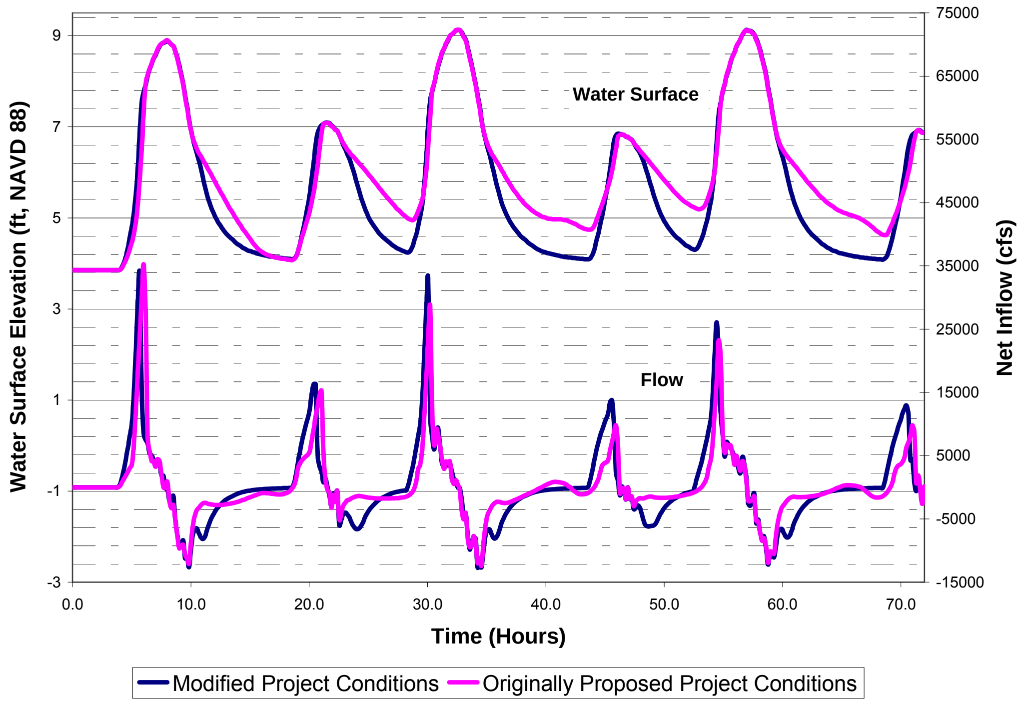


Figure 3-8. Water Surface Elevations in the Wetland over A 72 Hour Period with Concurrent 10-Year Flood and 100-Year Tidal Event

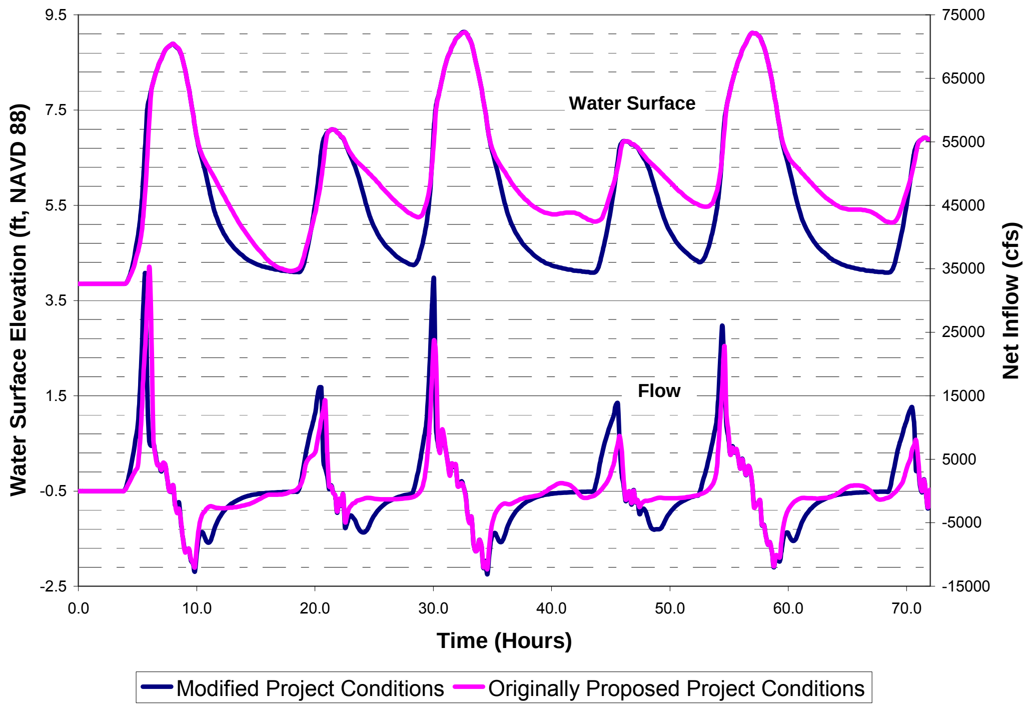


Figure 3-9. Water Surface Elevations in the Wetland over A 72 Hour Period with Concurrent 100-Year Flood and 100-Year Tidal Event

4.0 ASSESMENT AND CONCLUSIONS

Primary concerns for local agencies and stakeholders regarding the proposed BMK-V Wetland Restoration Project are the potential adverse impacts on 1) boat navigability in Novato Creek from the North Lock of the BMK development to San Pablo Bay under the normal tidal conditions; and 2) flooding dynamics in the creek and adjacent flood-control storage basins from Highway 37 downstream to the creek mouth during the extreme rainfall events coinciding with high tides. In order to mitigate the adverse impacts identified for the originally proposed project (NCI & **nhc**, 2006), an iterative process was performed in this analysis to optimize the channel cross-section of Novato Creek, which will be included as one of the project components for this BMK-V wetland restoration project. A detailed description of the optimized design channel geometry is presented in Section 2.0 (see **Error! Reference source not found.** through **Error! Reference source not found.**). The potential project impacts to boat navigability and flooding dynamics in Novato Creek are herein assessed for this optimized project conditions, based on the modeled results of the RMA2, SED2D, and HEC-RAS simulations. Comparisons to the results that were predicted for the existing and the originally proposed project conditions are also included.

4.1 Navigability Impact

Under the modified project alternative, Novato Creek will be deepened by two to four feet and widen by approximately 250 feet at the Mean Sea Level line in the reach downstream of the levee breach, and will be dredged approximately one foot or more in the reach between the North Lock and the levee breach. The tidal range in Novato Creek that was predicted for the modified project alternative (Alternative 3) will be slightly larger than the existing conditions, as summarized in **Table 4-1** at various locations along the creek. This alternative will elevate the existing Mean High Water (MHW) by less than 0.1 feet and will lower the existing Mean Low Water (MLW) by less than 0.5 feet. In addition, the existing channel deposition will also be significantly alleviated. As a result, the water depth of the navigational channel will be deeper than the existing conditions during both low and high tides. In another words, the modified project alternative will improve the navigational conditions in Novato creek.

Compared to the existing conditions, the tidal current in Novato Creek under the modified project alternative will be increased, as summarized in **Table 4-2** for various locations. The mean flood and ebb current velocities will be on the order of two feet per second in the reach downstream of the levee breach and will be slightly faster than one foot per second in the upstream reach. This range of current velocity will not likely worsen the complexity of boat operation under the existing conditions.

Compared to the originally proposed project alternative (Alternative 2), a much larger tidal range (between the mean high and mean low water levels) as well as higher water levels during high tides will occur in Novato Creek under the modified project alternative, and weaker tidal current will take place in the reach downstream of the breach. The increased water depth during high tides and the reduced current velocity in the downstream reach will be beneficial to the navigational conditions in Novato Creek. Although the creek water levels during low tides for Alternative 3 will be lower than those predicted for Alternative 2, the navigable water depths during low tides for Alternative 3 will still be deeper than Alternative 2 after considering the initial channel dredging and a much less deposition rate associated with Alternative 3. In other words, the modified project alternative will significantly improve the channel navigability in Novato Creek, as compared to the originally proposed project alternative.

Table 4-1. Comparison of Predicted Mean Tidal Ranges

Location	Mean Tidal Range (feet)		
	Alternative 1	Alternative 2	Alternative 3
Creek Mouth	4.3	3.6	4.5
Downstream of NWB Entrance*	4.1	1.7	4.6
NWB Entrance*	4.1	1.6	4.6
Upstream of NWB Entrance*	4.1	1.5	4.5
South Lock	4.0	1.5	4.4
North Lock	3.9	1.5	4.3
Highway 37 Crossing	3.4	1.4	3.7
Downstream HWY 101**	3.0	1.3	3.4

Note: * at RS 40+00, RS 42+00 and RS 46+00
** at RS 328+82

Table 4-2. Comparison of Mean Peak Tidal Currents

Location	Mean Peak Flood Current (ft/sec)			Mean Peak Ebb Current (ft/sec)		
	Alt. 1	Alt. 2	Alt. 3	Alt. 1	Alt. 2	Alt. 3
Creek Mouth	1.1	1.3	1.7	1.2	3.6	2.2
Downstream of NWB Entrance*	1.3	3.6	1.8	1.1	2.6	2.1
NWB Entrance *	1.3	1.2	1.8	1.1	0.7	2.0
Upstream of NWB Entrance*	1.3	0.4	1.1	1.1	0.3	1.2
South Lock	1.0	0.3	1.0	0.8	0.3	1.1
North Lock	1.0	0.3	1.0	0.8	0.3	0.9
Highway 37 Crossing	1.3	0.5	1.3	1.0	0.4	1.3
Downstream HWY 101**	1.3	0.4	1.2	0.7	0.3	1.2

Note: * at RS 40+00, RS 42+00 and RS 46+00
** at RS 328+82

4.2 Morphological Impact

The modified project alternative (Alternative 3) is expected to result in little morphological change to Novato Creek, as summarized in **Table 4-3** for various locations along the creek. The existing deposition rate is approximately 0.1 to 0.2 feet per year along the centerline of the creek. The originally proposed project alternative (Alternative 2) will induce a significant morphological change to Novato Creek with an erosion rate of 0.5 to 1.0 feet per year in the reach downstream of the levee breach and a sedimentation rate of as much as 0.4 feet per year in the reach upstream of the breach. On the contrary, Novato Creek will be quasi-stable under Alternative 3 with negligible sedimentation or erosion along the centerline of the channel. Therefore, not only the existing channel sedimentation problem but also the significant morphological impact to Novato Creek associated with the originally proposed project alternative will be significantly mitigated under the modified project alternative. A quasi-stable channel associated with the modified project alternative will also benefit the navigational conditions along Novato Creek.

Table 4-3. Comparison of Predicted Creek Sedimentation

Location	Projected Annual Sedimentation (ft/yr)		
	Alternative 1	Alternative 2	Alternative 3
Creek Mouth	+0.2	-1.0	~0.0
Downstream of NWB Entrance*	+0.1	-0.5	~0.0
NWB Entrance*	+0.1	~0.0	~0.0
Upstream of NWB Entrance*	+0.1	+0.4	+0.1
South Lock	+0.2	+0.3	+0.1
North Lock	+0.1	+0.2	~0.0
Highway 37 Crossing	~ 0.0	~ 0.0	~0.0
Downstream HWY 101**	~ 0.0	~ 0.0	~0.0

Note: * at RS 40+00 & RS 46+00
** at RS 328+82
+ and – denote deposition and scouring, respectively
~ 0.0 denotes negligible sedimentation

4.3 Flood Dynamics Impact

The HEC-RAS model results indicate that the modified project will not significantly alter flooding dynamics in comparison to the originally proposed project. The increased channel size of the modified project will allow the tidal effect to be conveyed further upstream than that under the existing channel cross-sections. The simulated results indicate that the added tidal influence will result in a small increase in the peak stage near the Bel Marin Keys North Lock (see Table 3-2) for a short duration under all three simulated scenarios. However, this increase in peak stage will have a minor effect in the Bel Marin Keys North Lagoon storage area only during the 10-year flood coinciding with 100-year tidal event, as presented in Table 3-3. The peak water surface elevation in this area, which was predicted at +6.48 feet, NAVD88, will increase slightly from the originally proposed project conditions at +6.35 feet, NAVD88. The peak elevation will also be negligibly higher than the existing conditions at +6.43 feet, NAVD88. It is noted that this predicted increase to peak water level is comparable to the accuracy or tolerance of the HEC-RAS model. The modeled peak water surface elevations in other storage areas are either almost identical or slightly lower relative to the predictions for the originally proposed project conditions.

4.4 Conclusions

This modified project alternative involving the major changes to the existing bathymetry of Novato Creek includes 1) expansion (widening and deepening) of the channel that is downstream of the levee breach, and 2) deepening of the channel between the levee breach and the North Lock of the BMK Lagoon. The modified project alternative will slightly increase the existing tidal fluctuation range and tidal circulation, and thus alleviate the existing sedimentation in Novato Creek. Compared to the originally proposed project alternative, the modified project alternative will result in 1) a wider tidal range in both the creek and the Northern Wetland Basin; 2) a reduced current velocity in the reach downstream of the levee breach; 3) a much stronger circulation in the upstream reach; and 4) a negligible morphological change along the creek. The modified project alternative will not only significantly mitigate the adverse impacts to the creek morphology and navigability identified for the originally proposed project alternative, as discussed in the 2006 Phase II study (NCI & **nhc**, 2006), but also improve the existing morphological and navigational conditions in Novato Creek.

Furthermore, the flood potential analysis indicates that the modified project alternative will result in negligible change to the flooding dynamics in both the creek and adjacent storage basins. The peak stages during the flood events will be comparable to the originally proposed project alternative. Thus, no significant alteration of flooding dynamics will occur under the modified project alternative

5.0 REFERENCES

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NCI (Noble Consultants, Inc.), **nhc** (Northwest Hydraulic Consultants, Inc.), and SEI (Sea Engineering, Inc.), 2005. Hydrologic and Hydraulic Study – Phase II, Draft Report Volume 1, Baseline Conditions and Historical Morphology of Novato Creek. Prepared for U.S. Army Corps of Engineers, San Francisco District, June 2005.

APPENDIX A

PREDICTED HYDRODYNAMIC AND SEDIMENTATION PARAMETERS

List of Figures

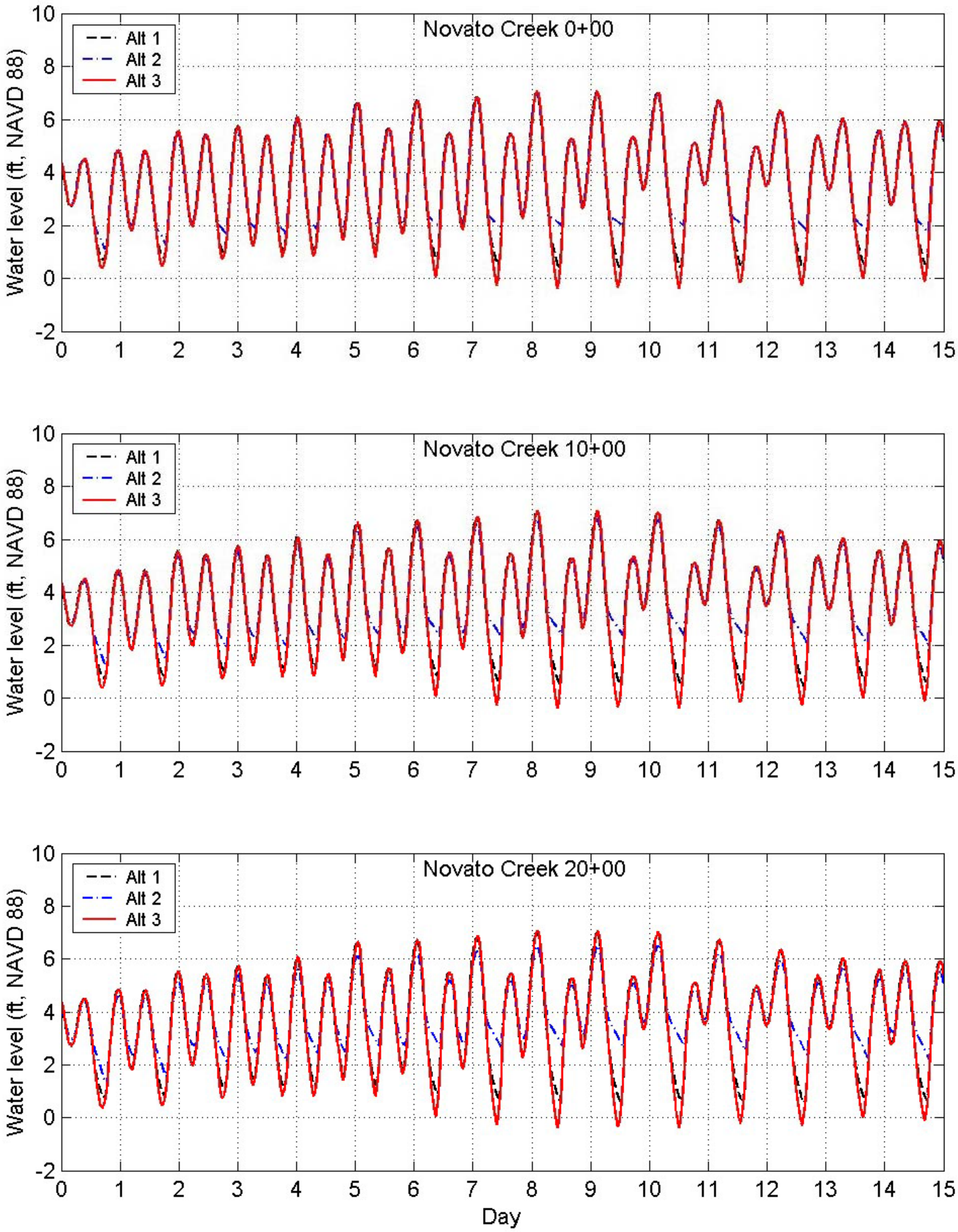


Figure A-1. Predicted Water Levels: CS 0+00 to CS 20+00

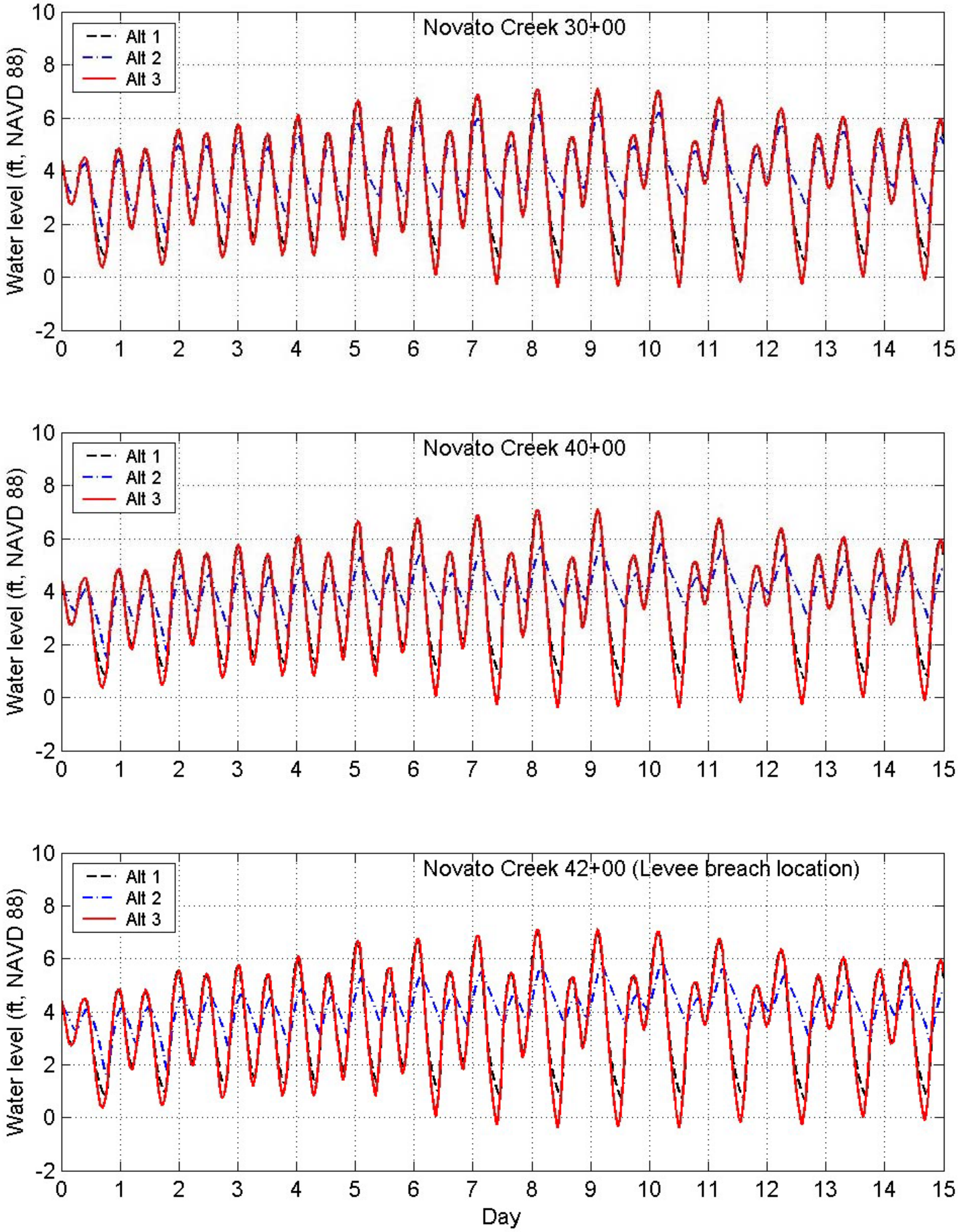


Figure A-2. Predicted Water Levels: CS 30+00 to CS 42+00

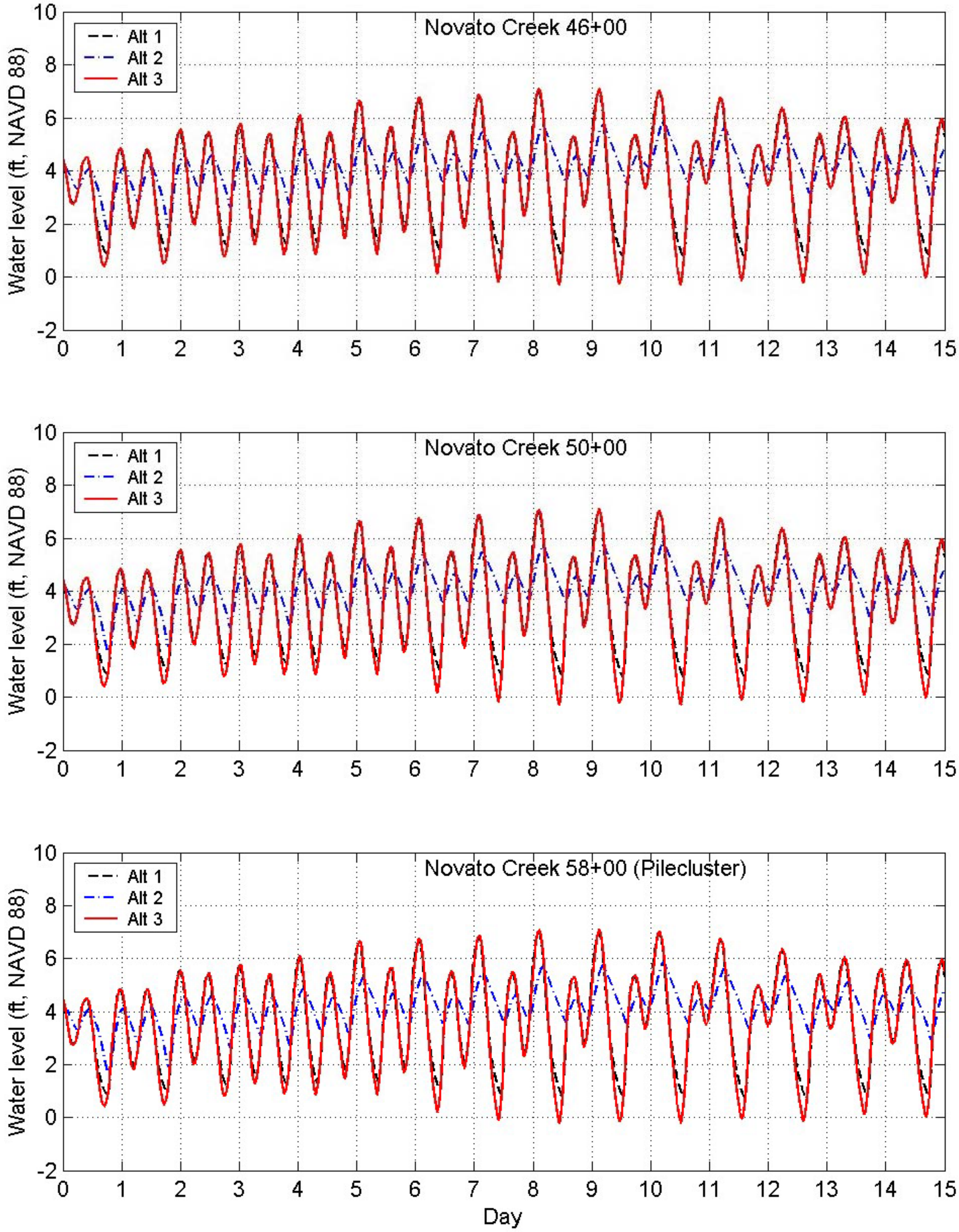


Figure A-3. Predicted Water Levels: CS 46+00 to CS 58+00

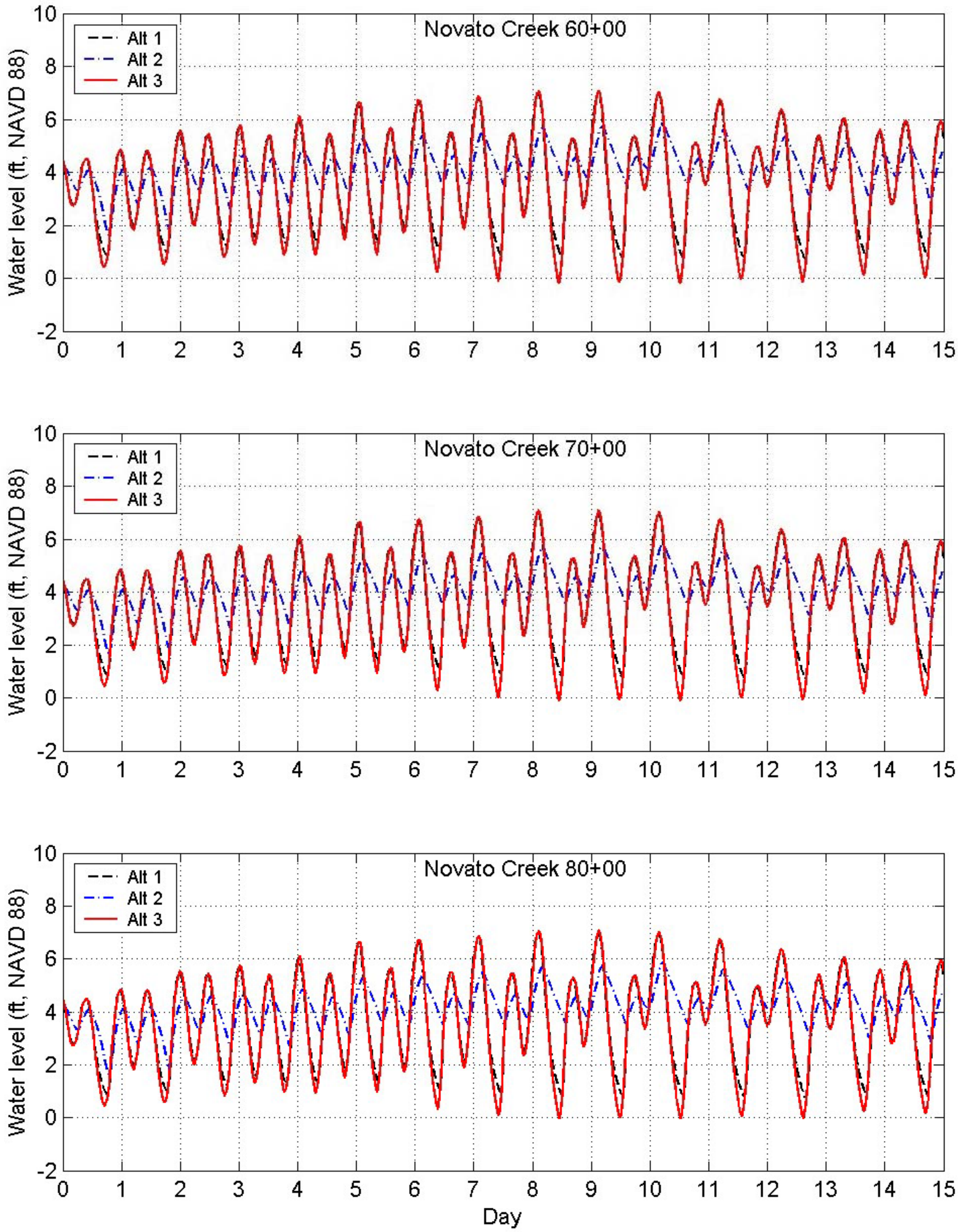
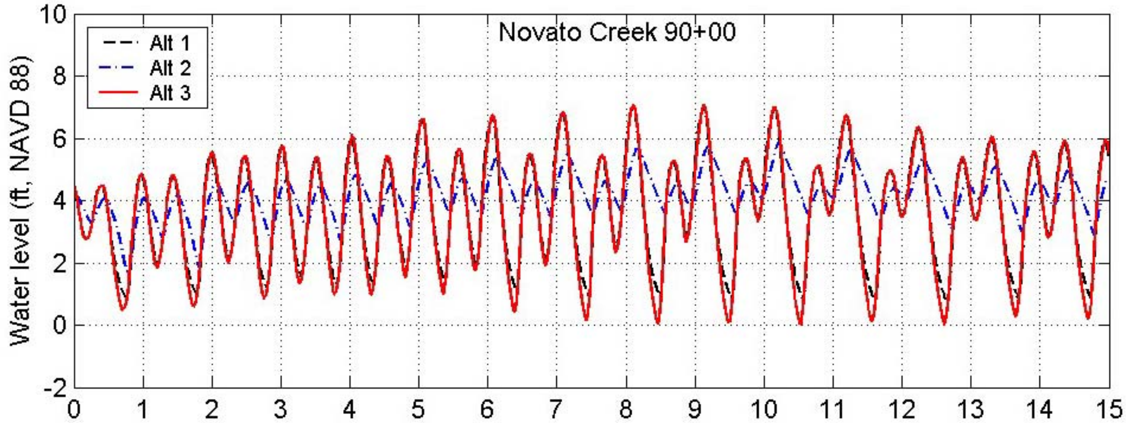
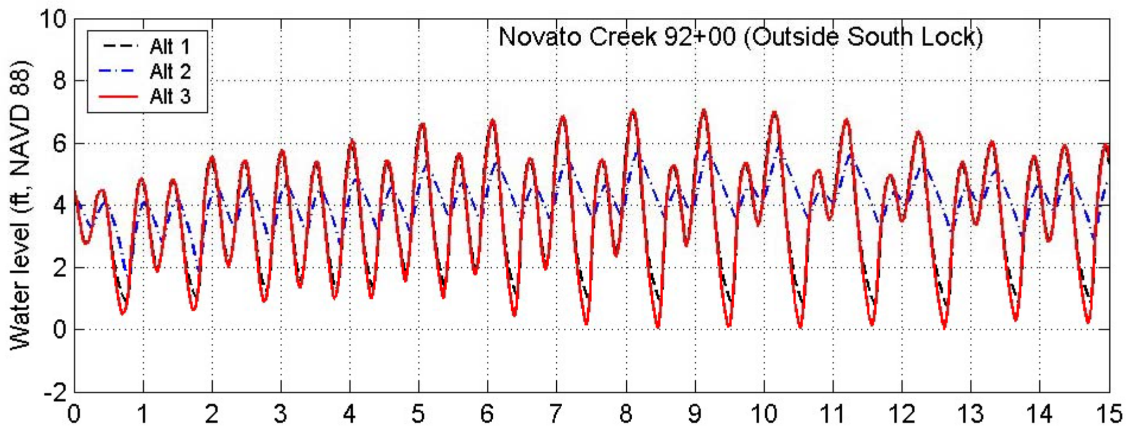


Figure A-4. Predicted Water Levels: CS 60+00 to CS 80+00





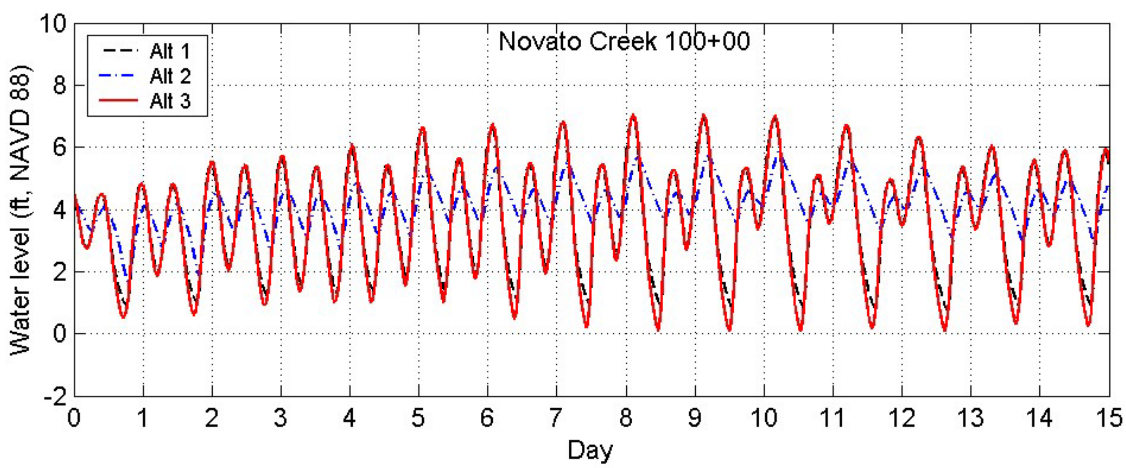


Figure A-5. Predicted Water Levels: CS 90+00 to CS 100+00

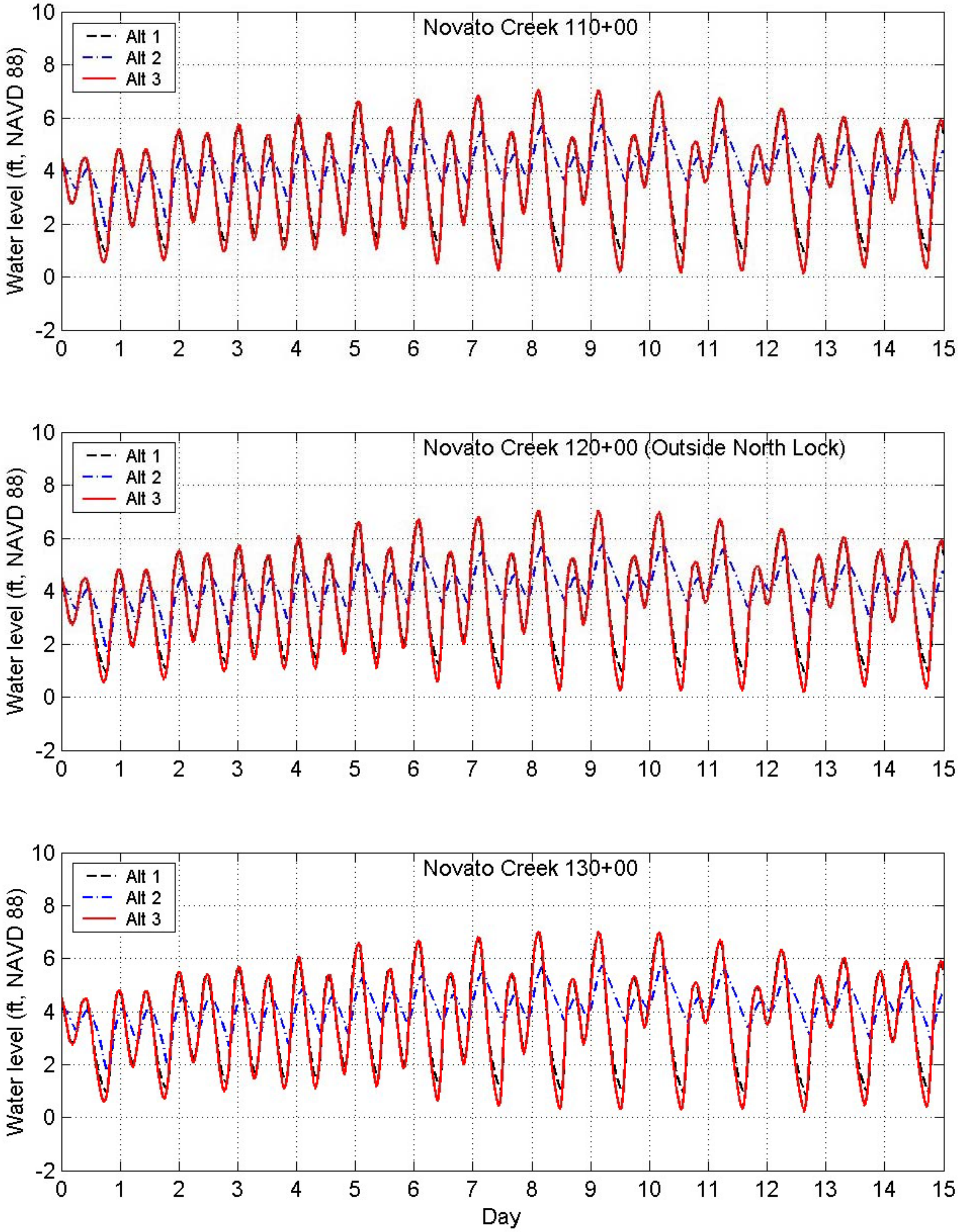


Figure A-6. Predicted Water Levels: CS 110+00 to CS 130+00

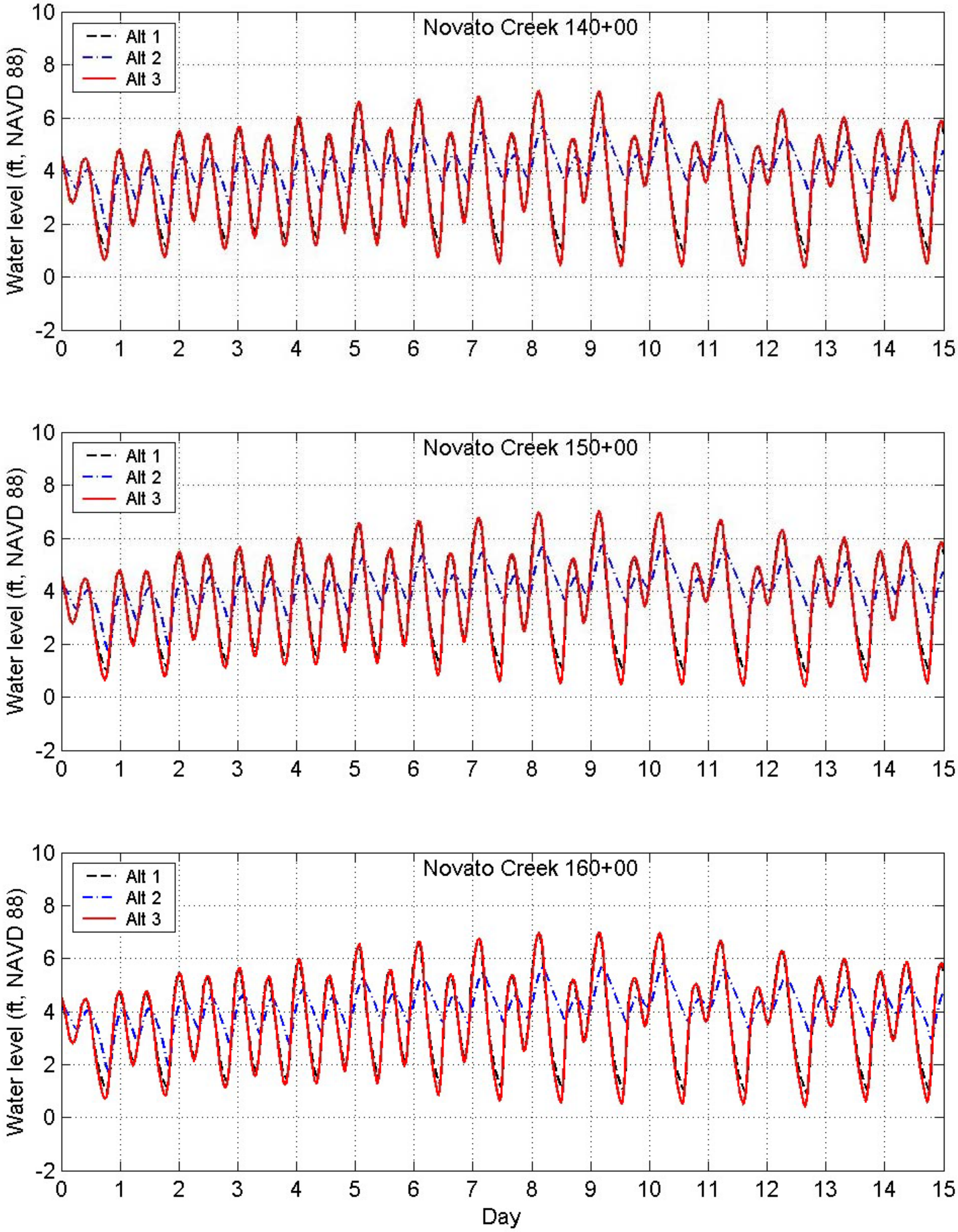


Figure A-7. Predicted Water Levels: CS 140+00 to CS 160+00

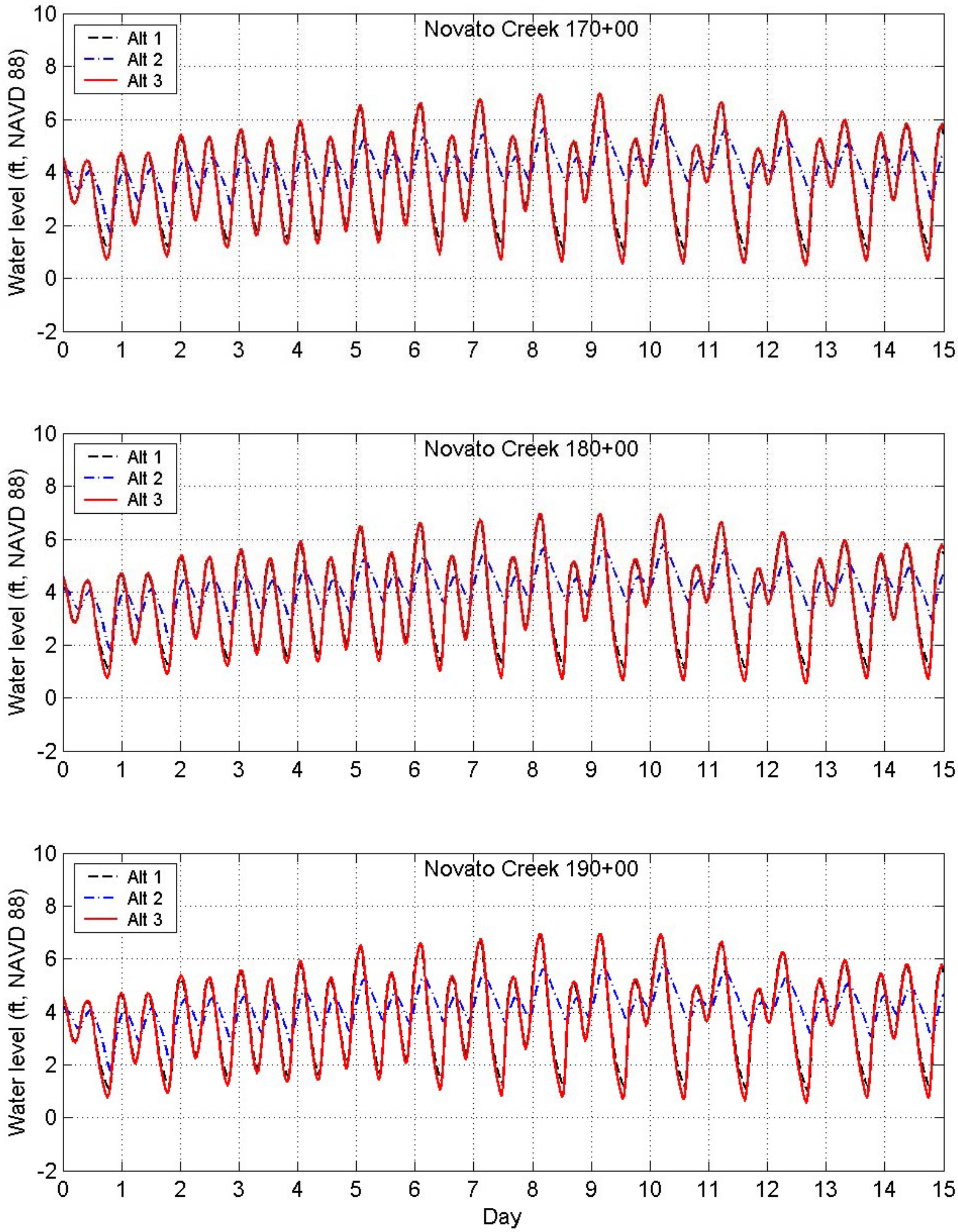


Figure A-8. Predicted Water Levels: CS 170+00 to CS 190+00

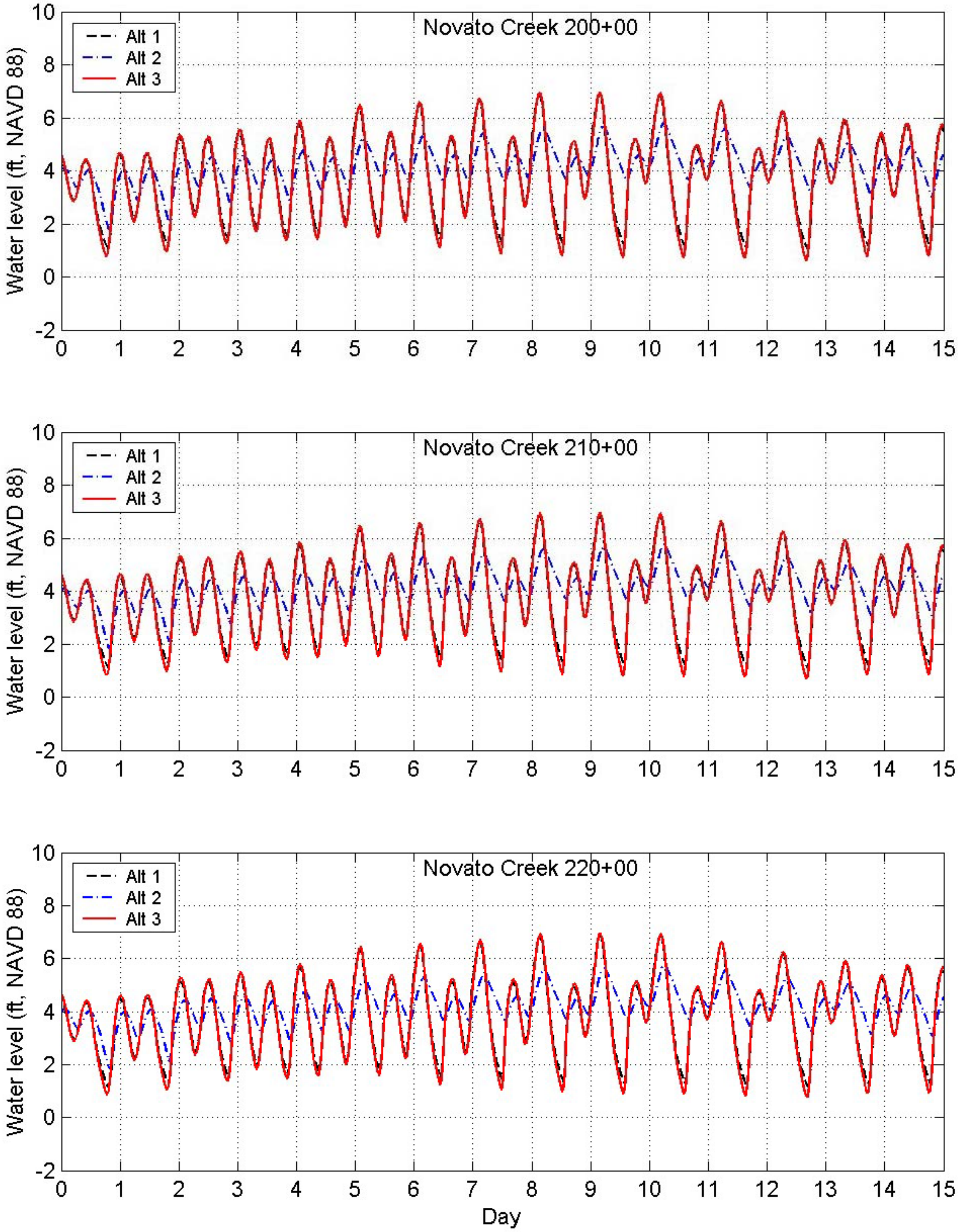


Figure A-9. Predicted Water Levels: CS 200+00 to CS 220+00

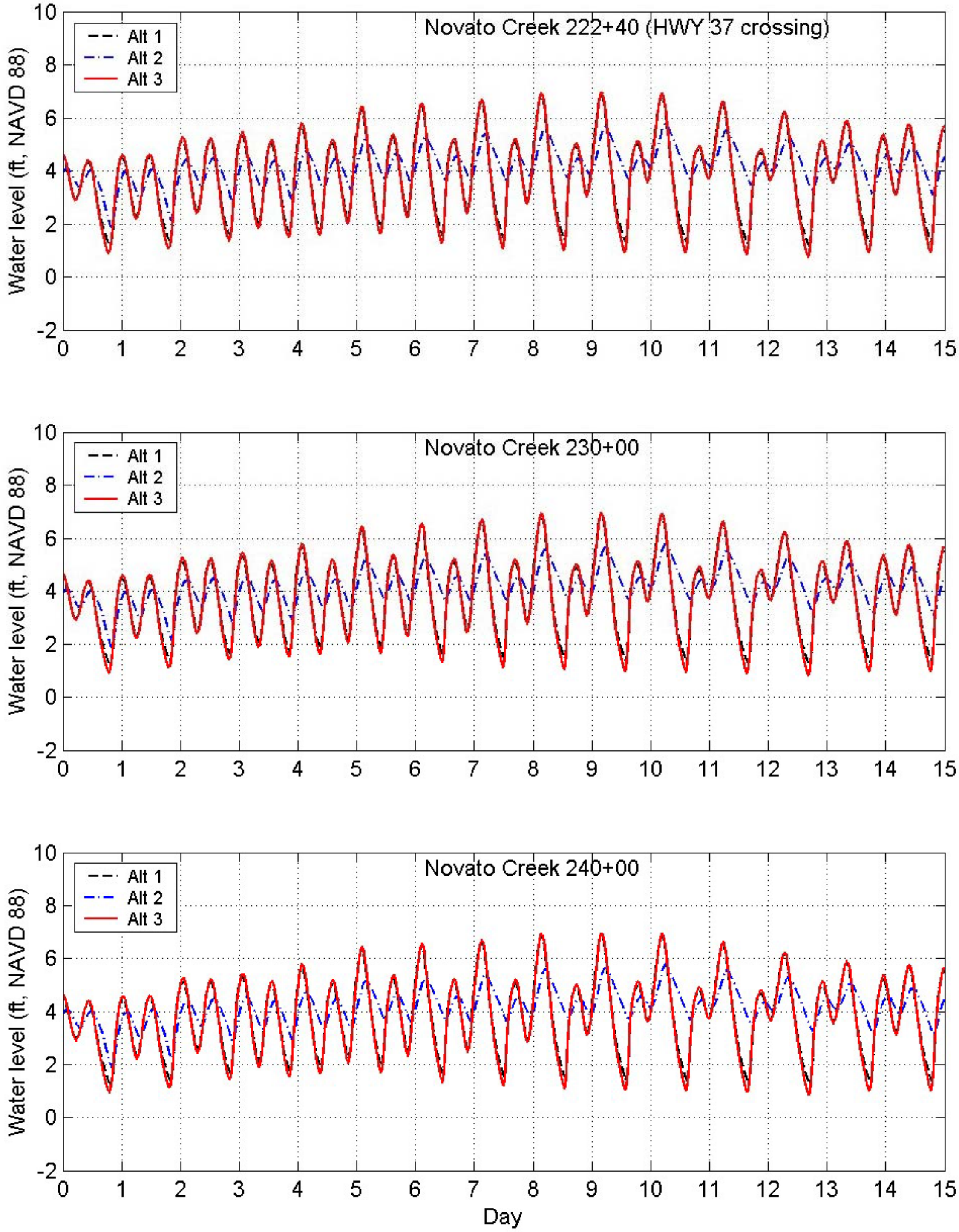


Figure A-10. Predicted Water Levels: HWY 37 to CS 240+00

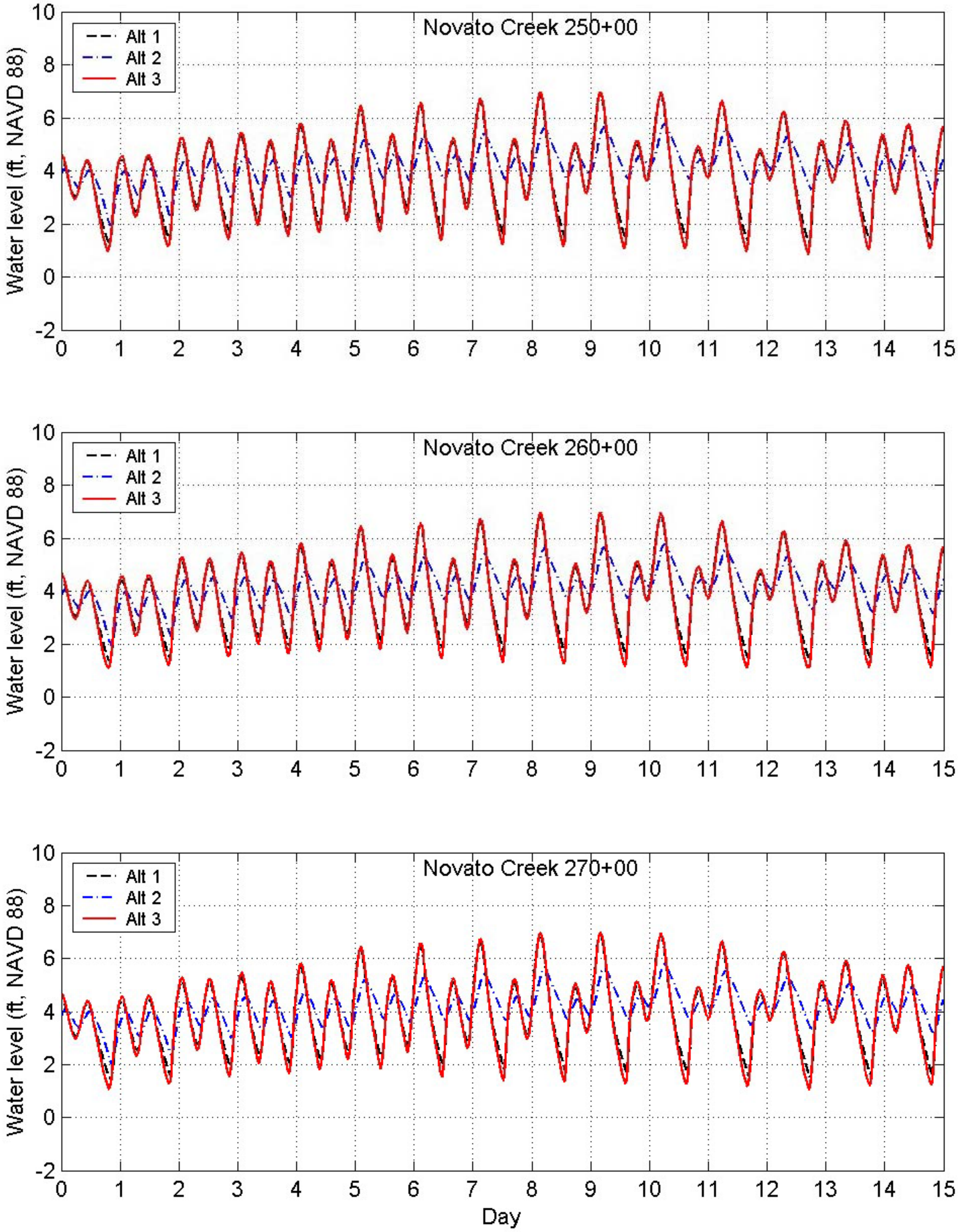


Figure A-11. Predicted Water Levels: CS 250+00 to CS 270+00

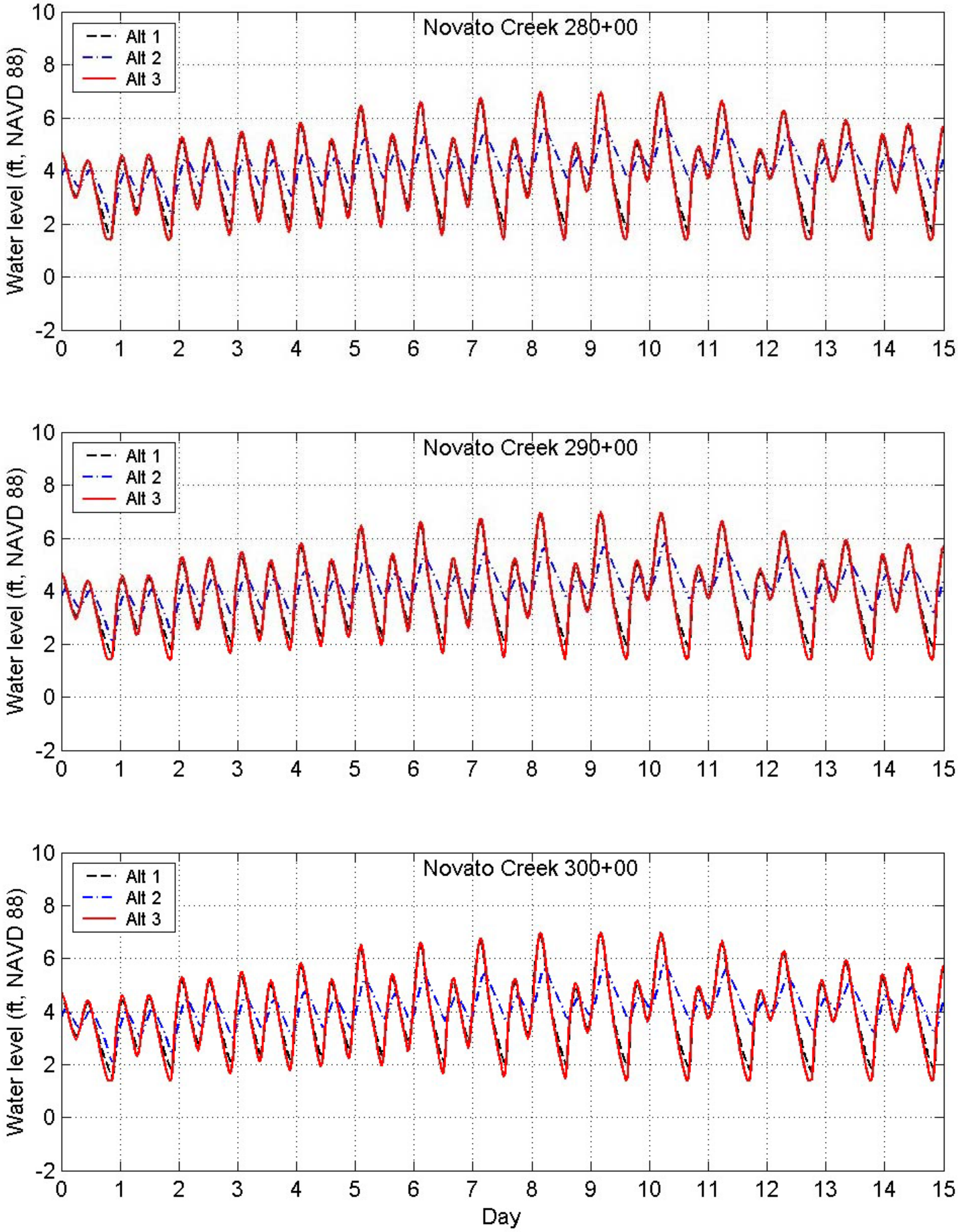


Figure A-12. Predicted Water Levels: CS 280+00 to CS 300+00

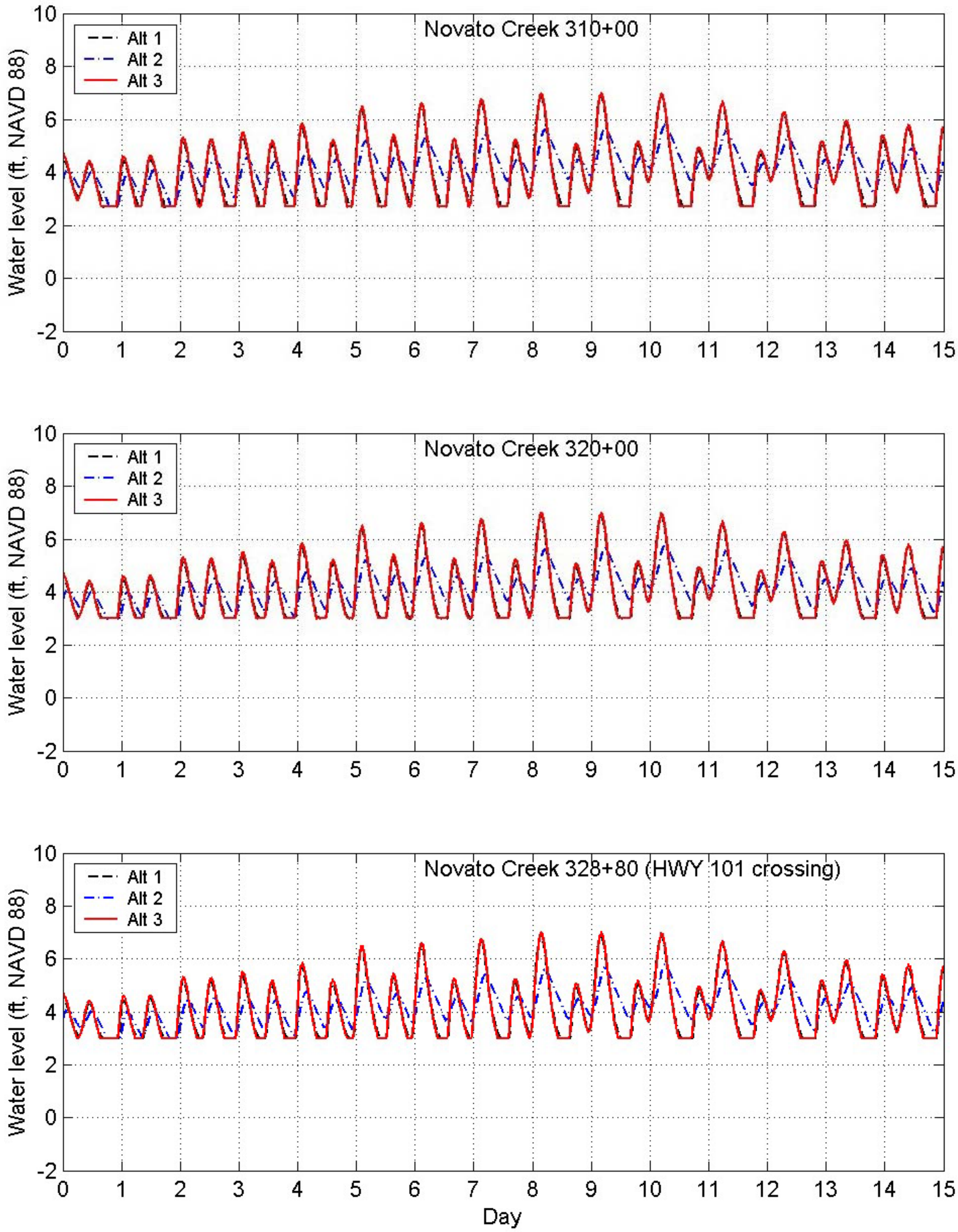


Figure A-13. Predicted Water Levels: CS 310+00 to HWY 101

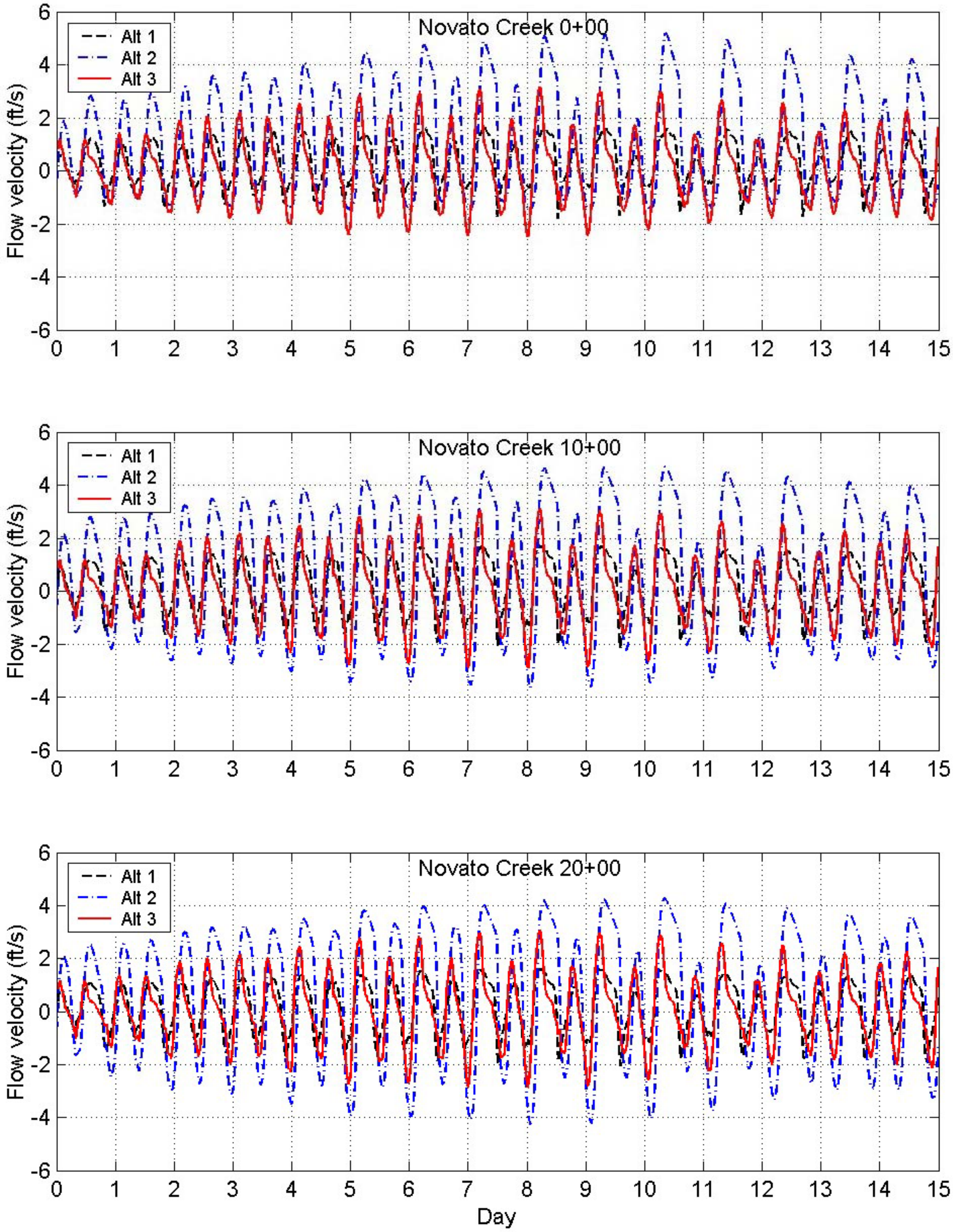


Figure A-14. Predicted Flow Velocities: CS 0+00 to CS 20+00

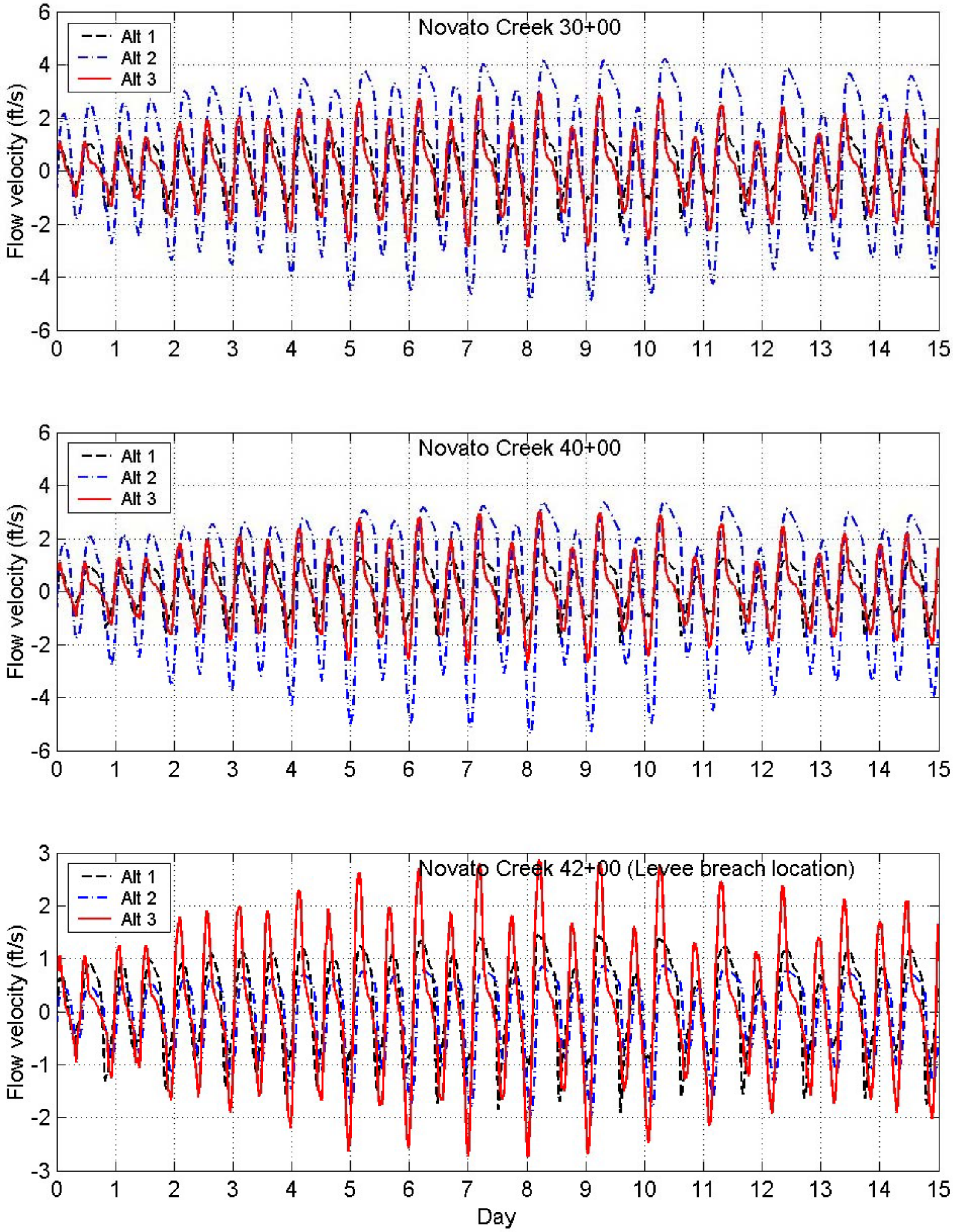


Figure A-15. Predicted Flow Velocities: CS 30+00 to CS 42+00

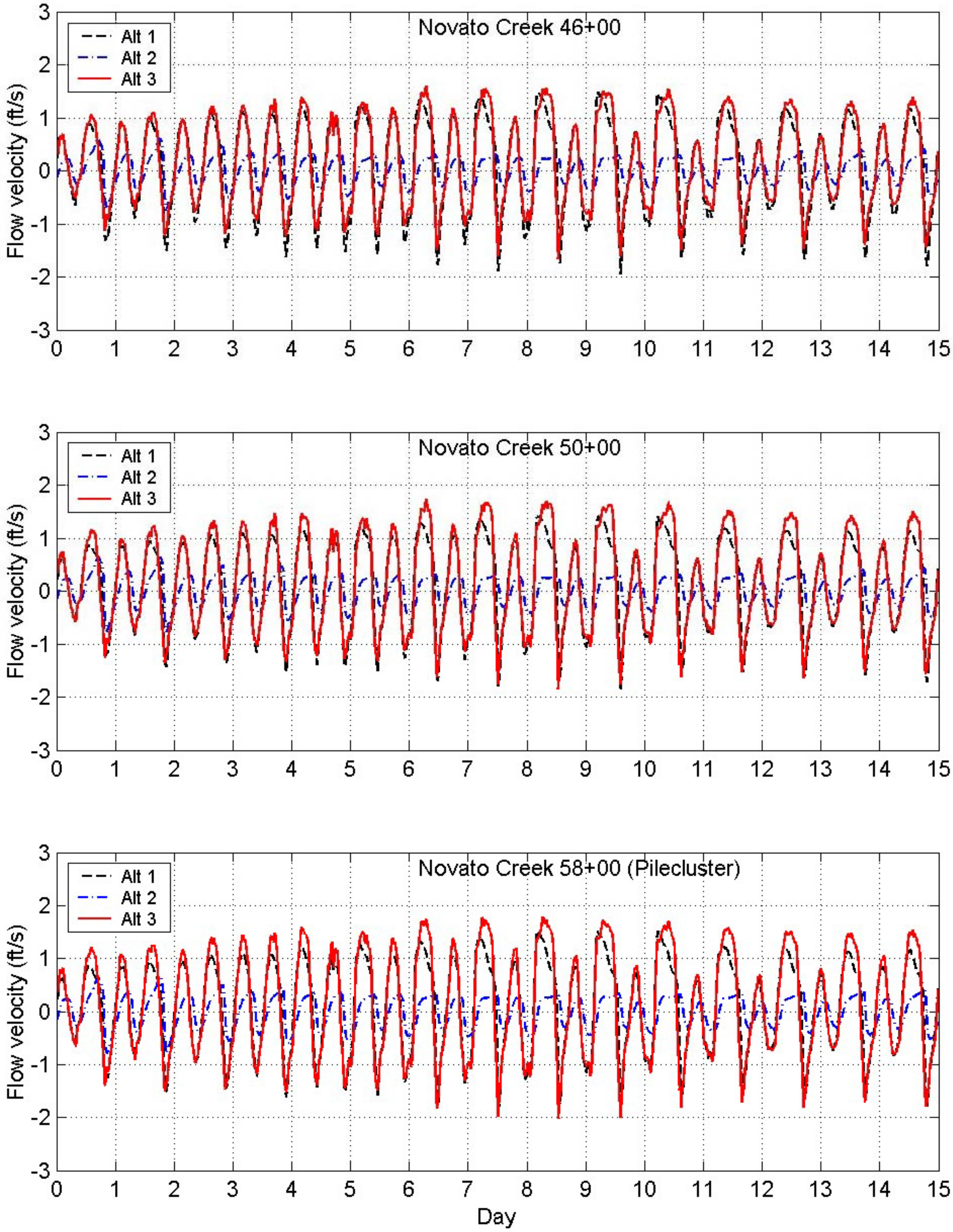


Figure A-16. Predicted Flow Velocities: CS 46+00 to CS 58+00

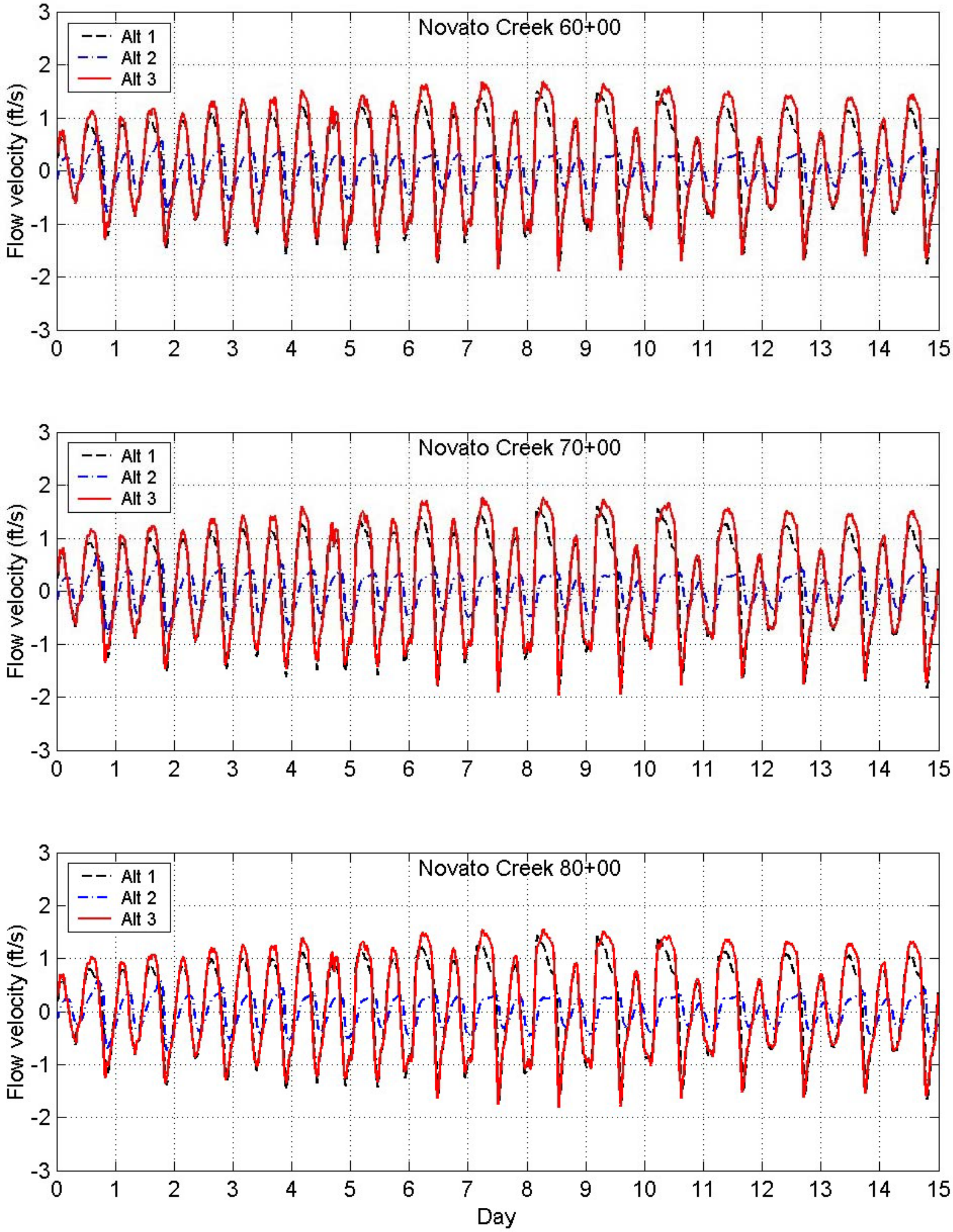


Figure A-17. Predicted Flow Velocities: CS 60+00 to CS 80+00

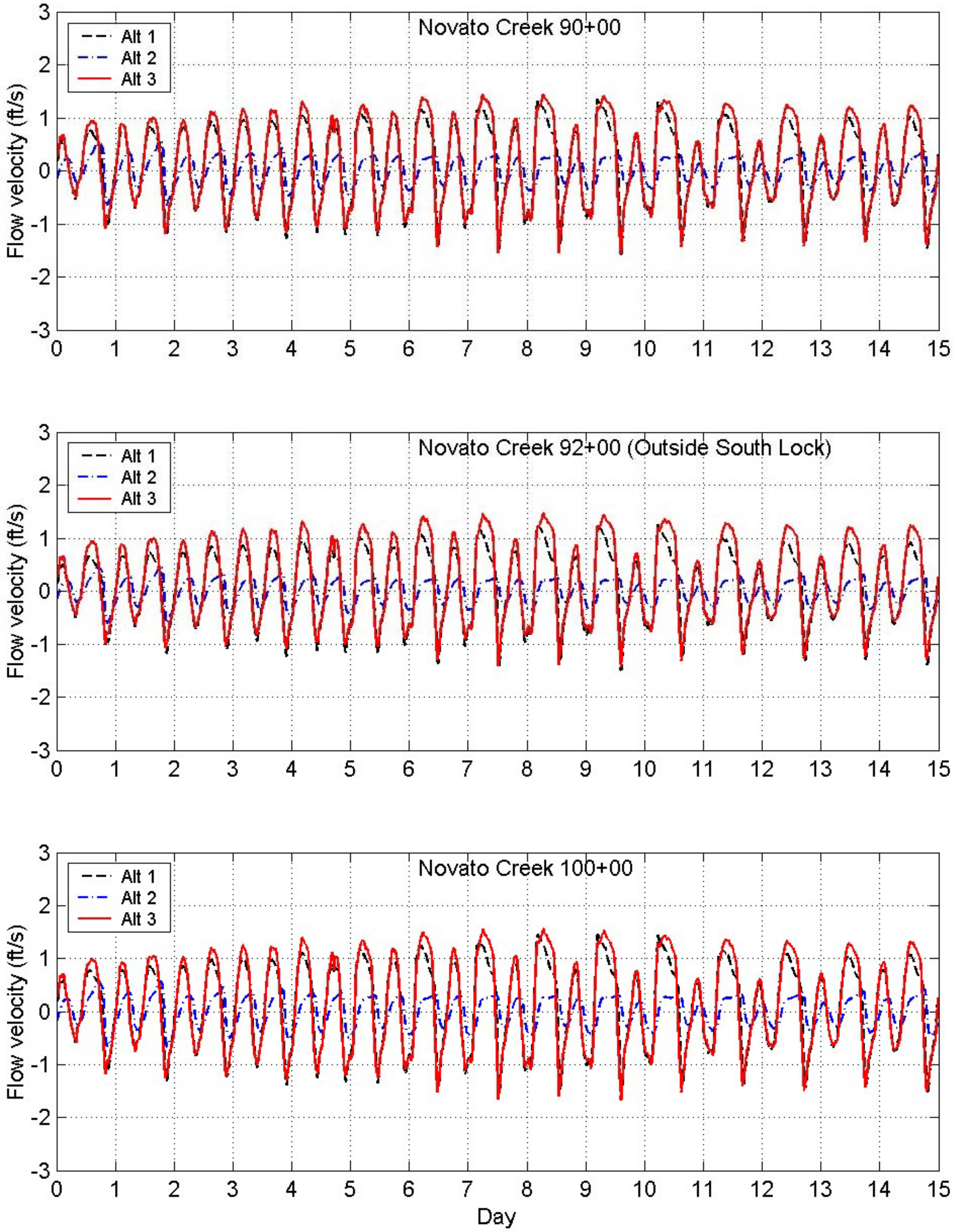


Figure A-18. Predicted Flow Velocities: CS 90+00 to CS 100+00

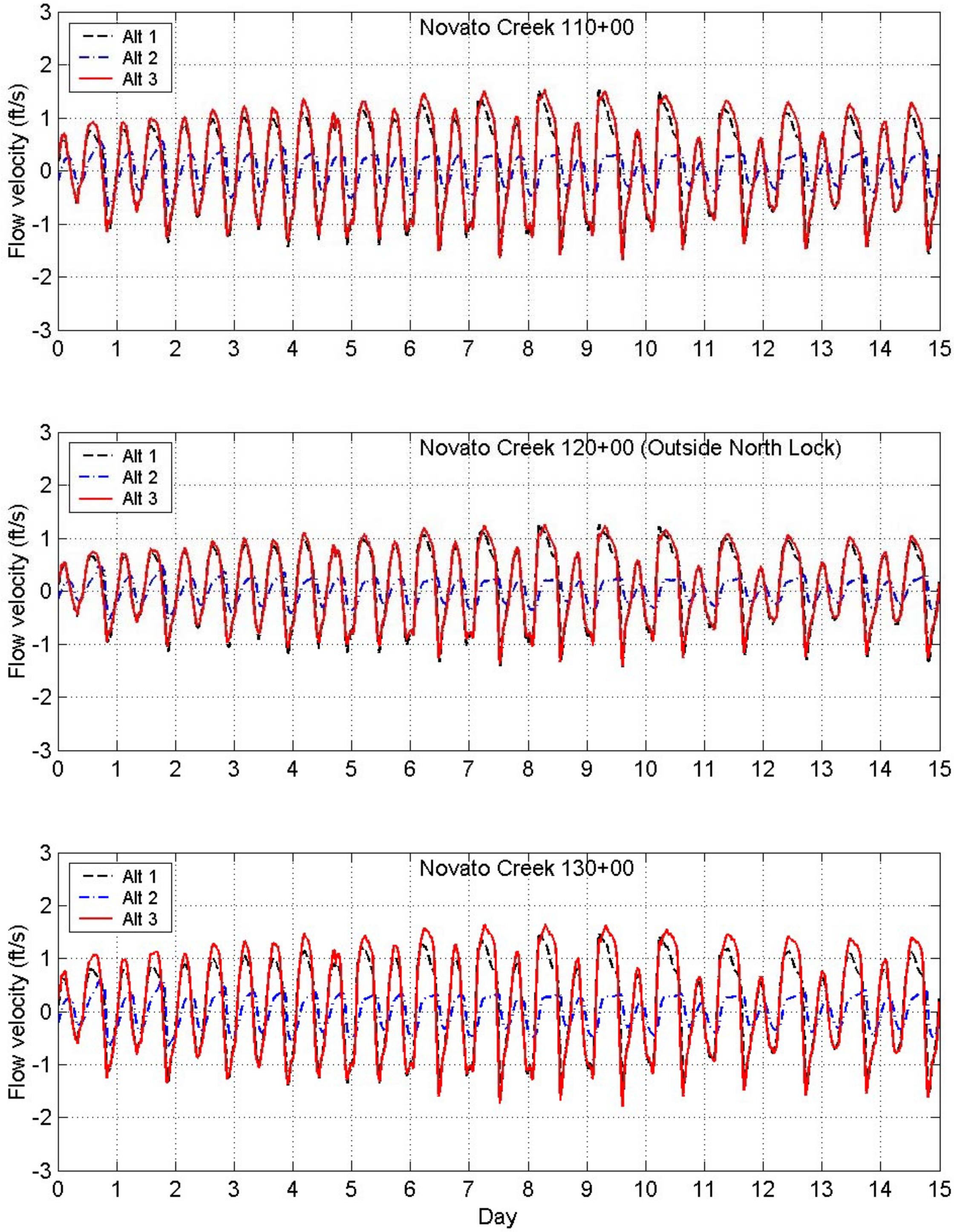


Figure A-19. Predicted Flow Velocities: CS 110+00 to CS 130+00

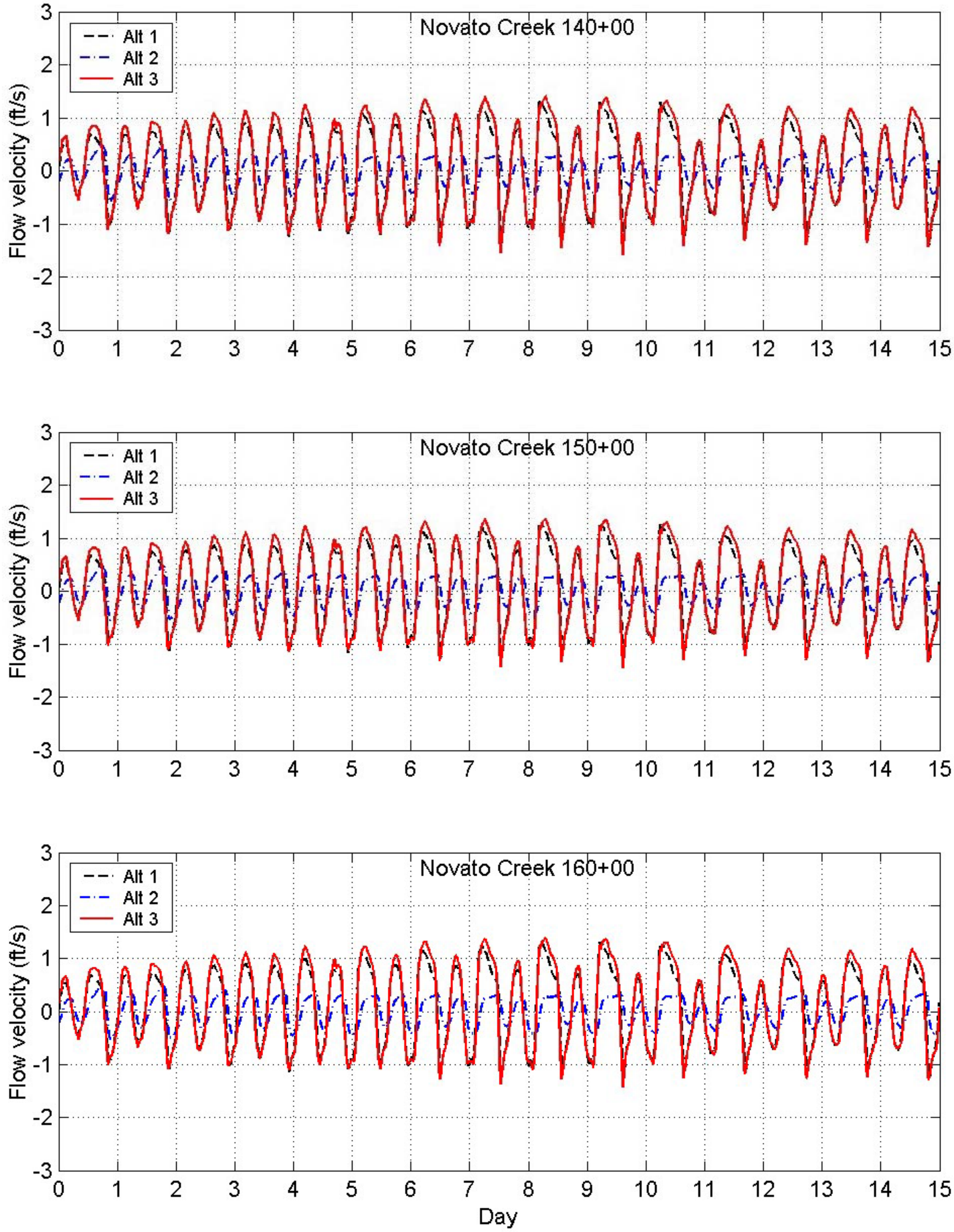


Figure A-20. Predicted Flow Velocities: CS 140+00 to CS 160+00

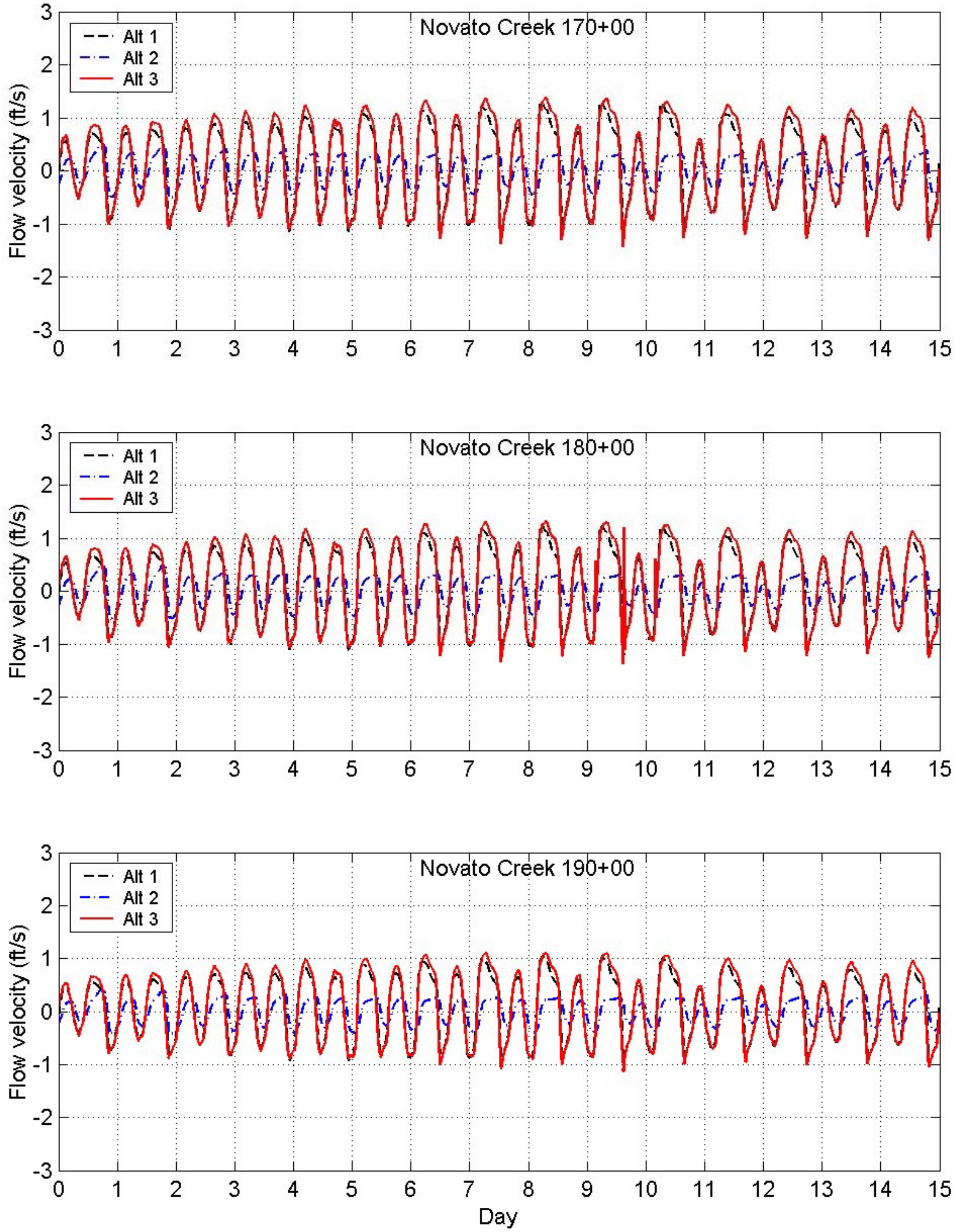


Figure A-21. Predicted Flow Velocities: CS 170+00 to CS 190+00

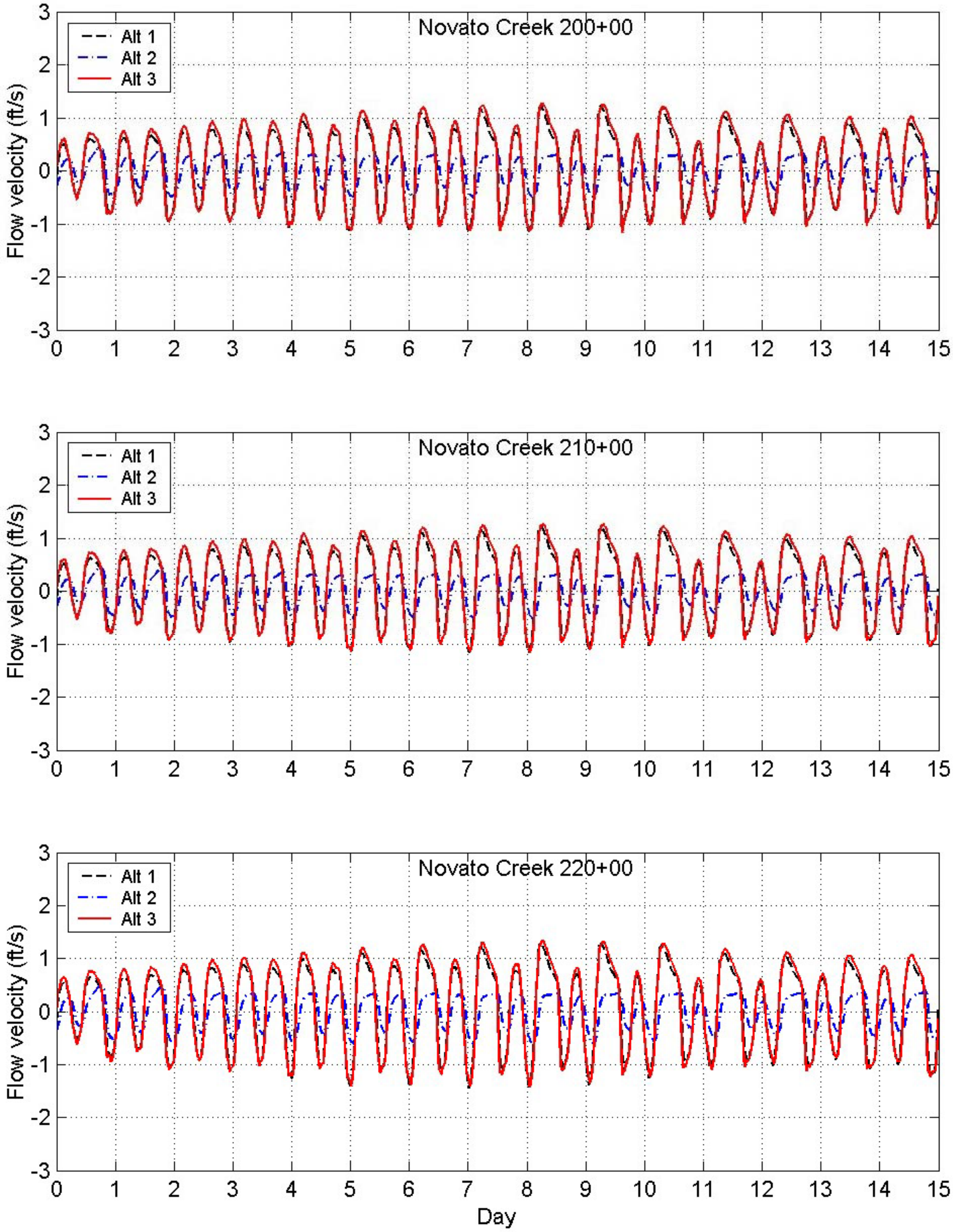


Figure A-22. Predicted Flow Velocities: CS 200+00 to CS 220+00

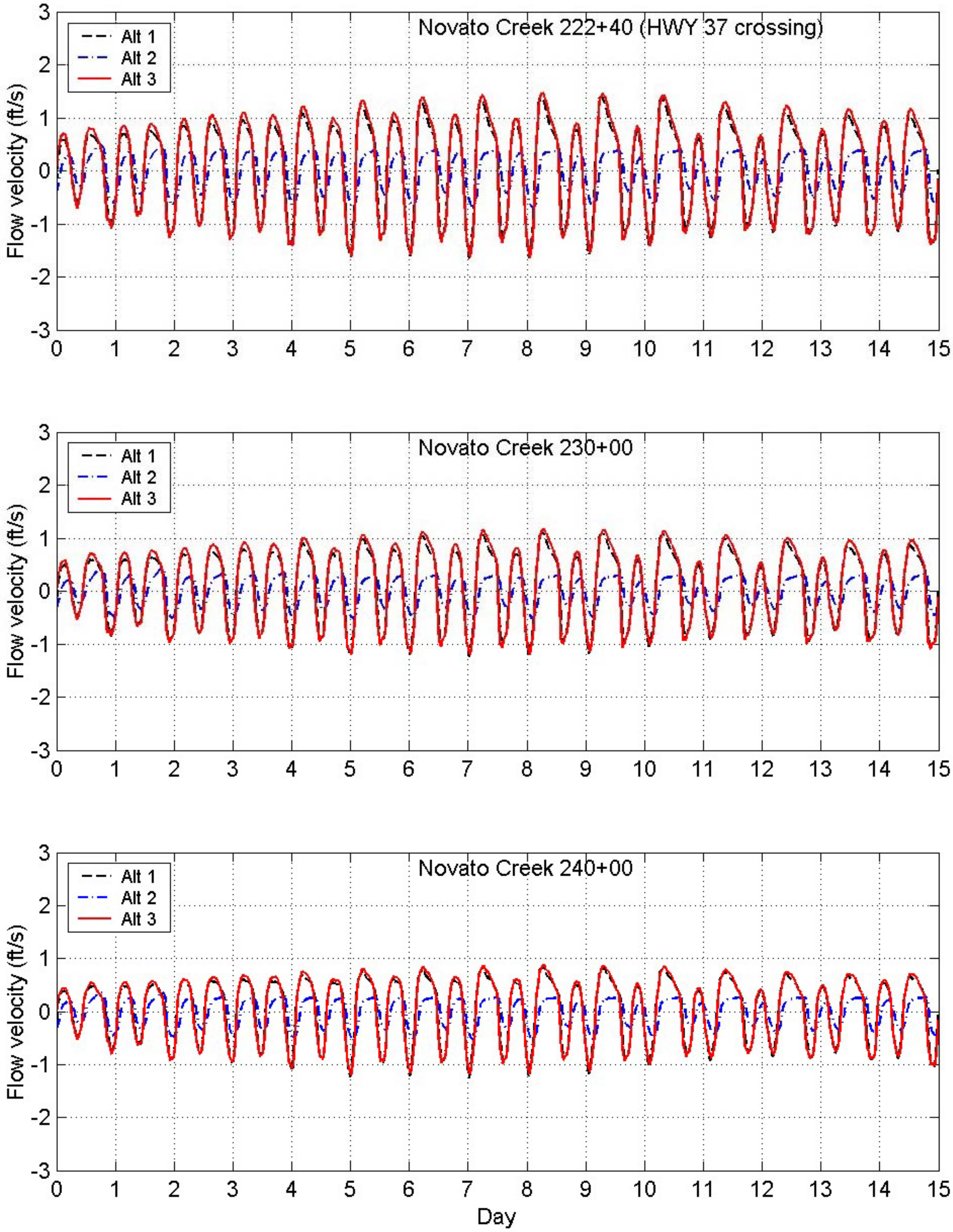


Figure A-23. Predicted Flow Velocities: HWY 37 to CS 240+00

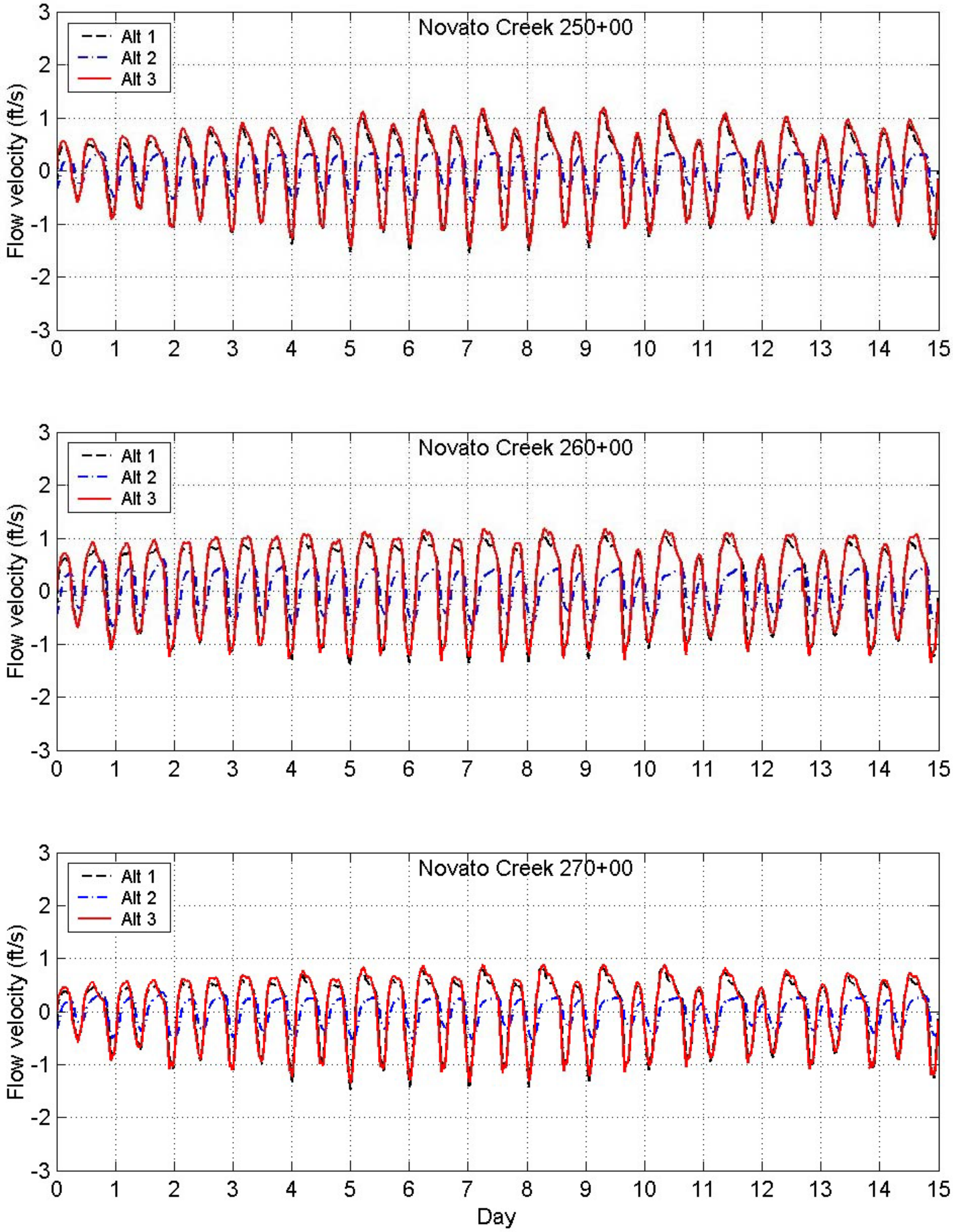


Figure A-24. Predicted Flow Velocities: CS 250+00 to CS 270+00

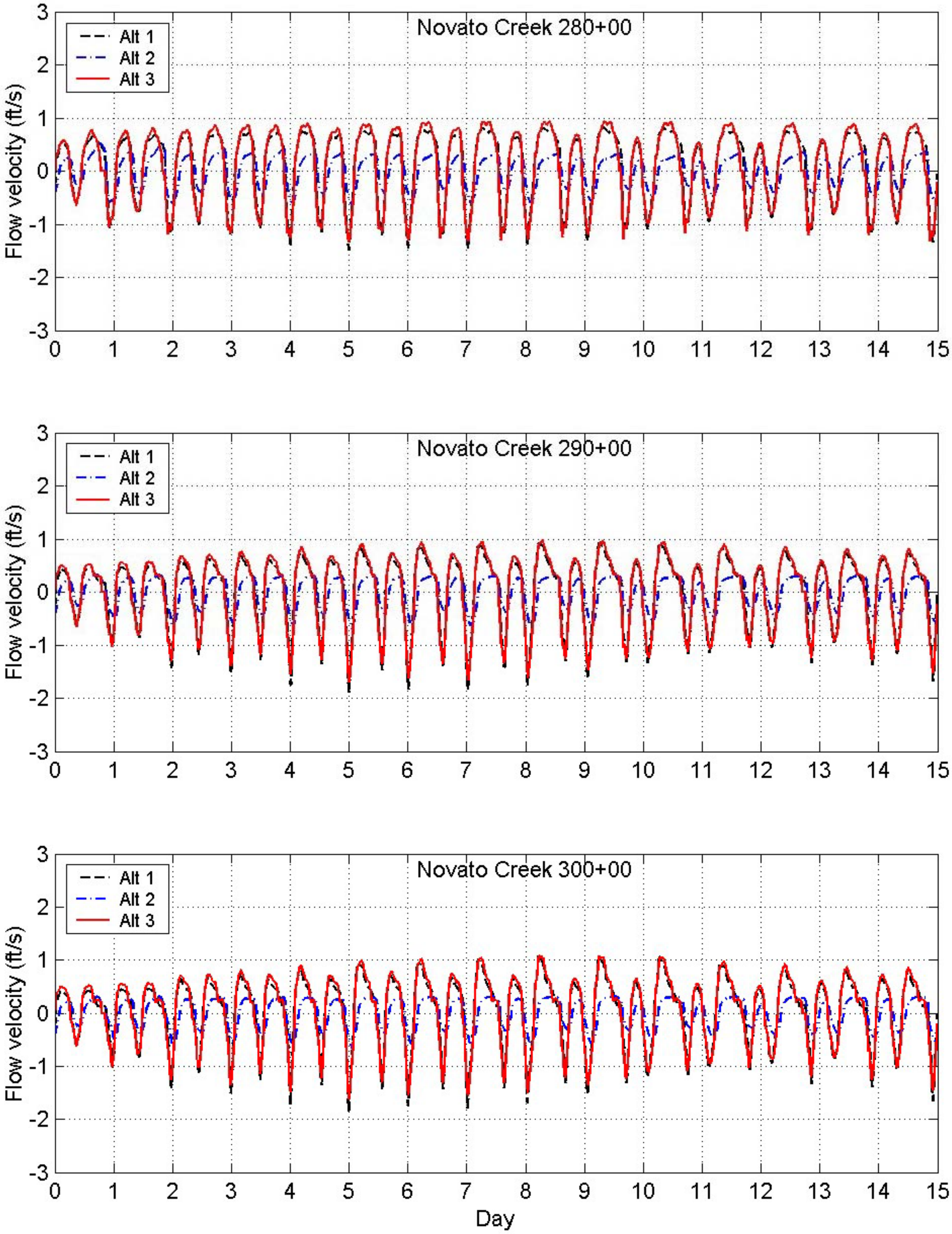


Figure A-25. Predicted Flow Velocities: CS 280+00 to CS 300+00

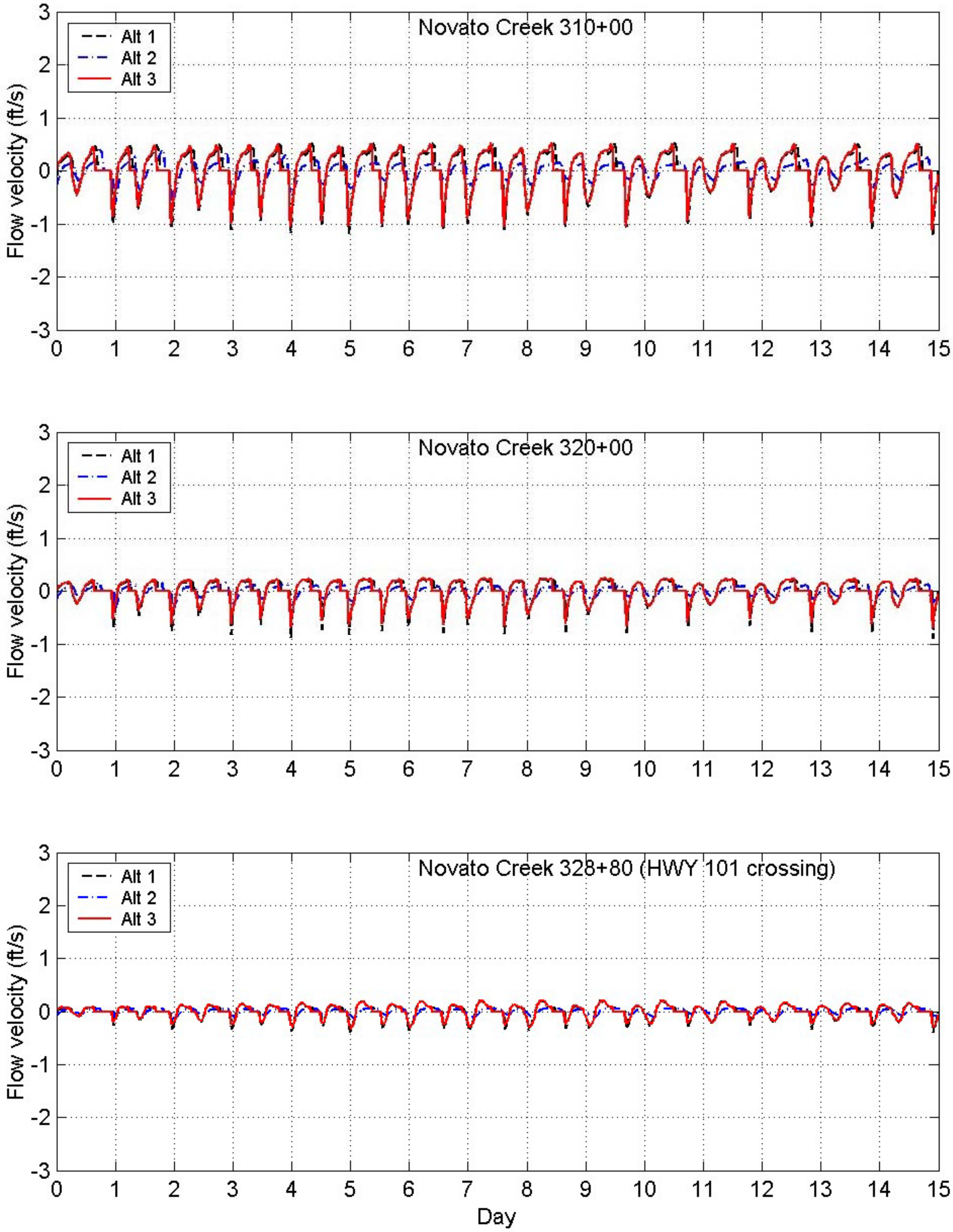


Figure A-26. Predicted Flow Velocities: CS 310+00 to HWY 101

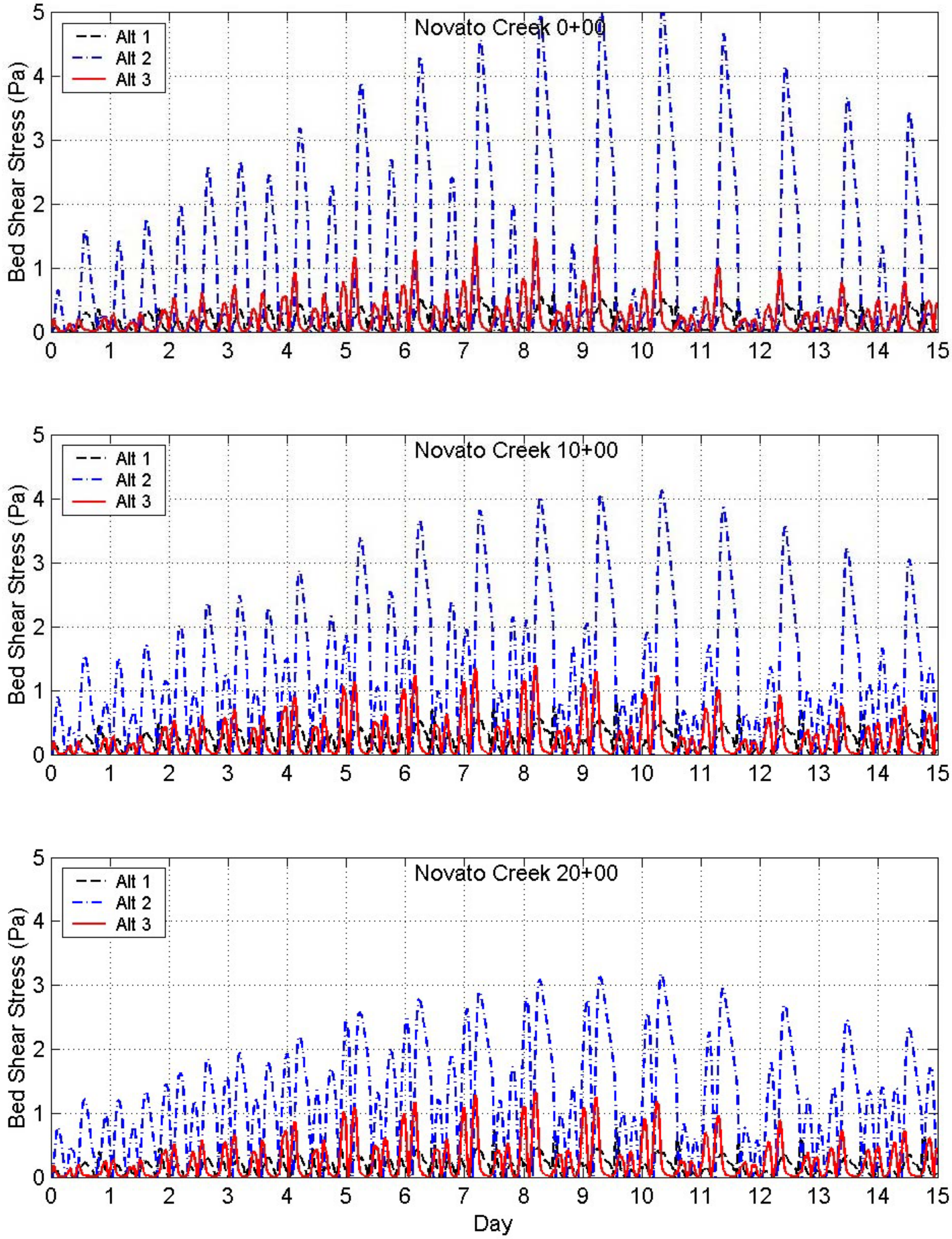


Figure A-27. Predicted Shear Stresses: CS 0+00 to CS 20+00

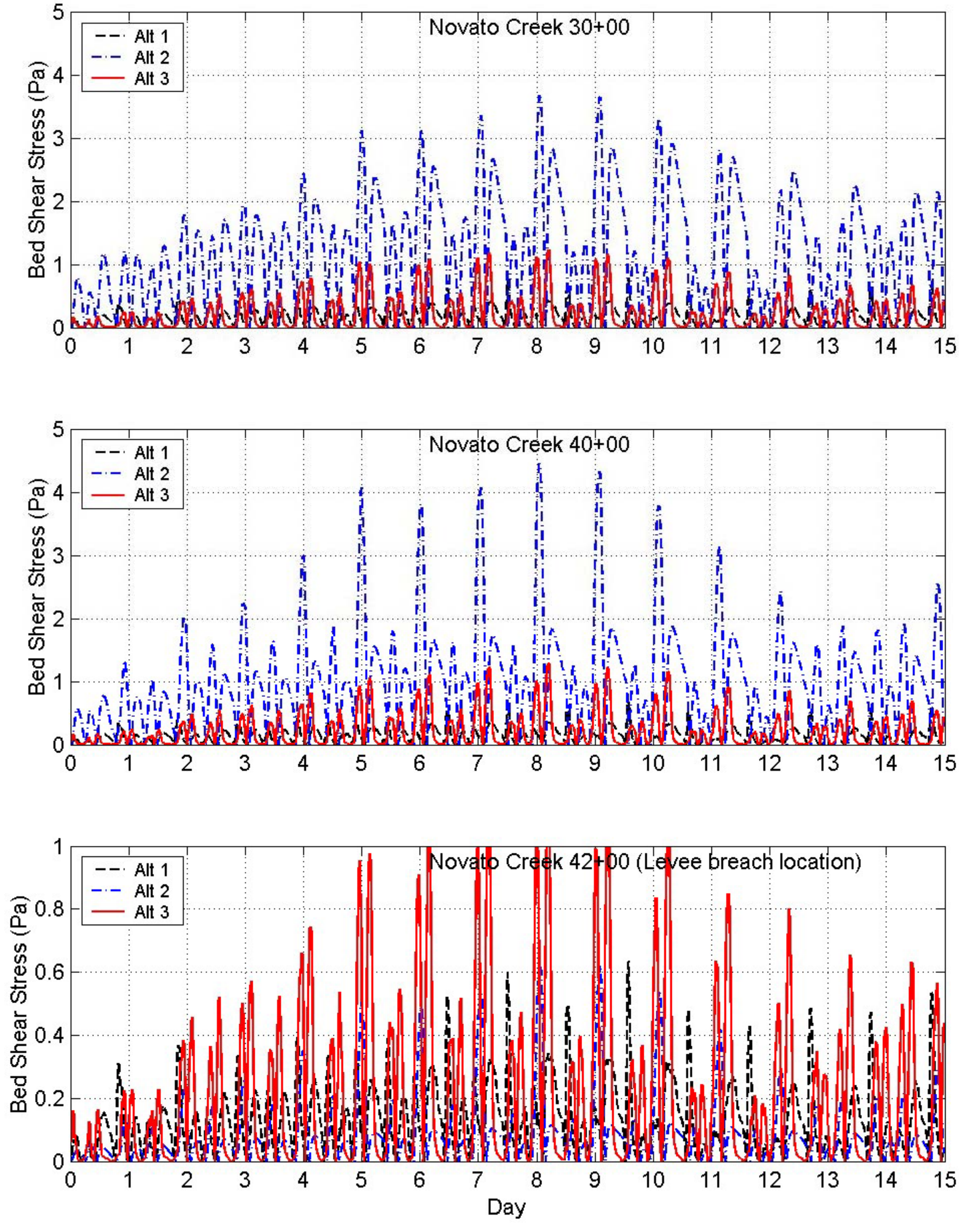


Figure A-28. Predicted Shear Stresses: CS 30+00 to CS 42+00

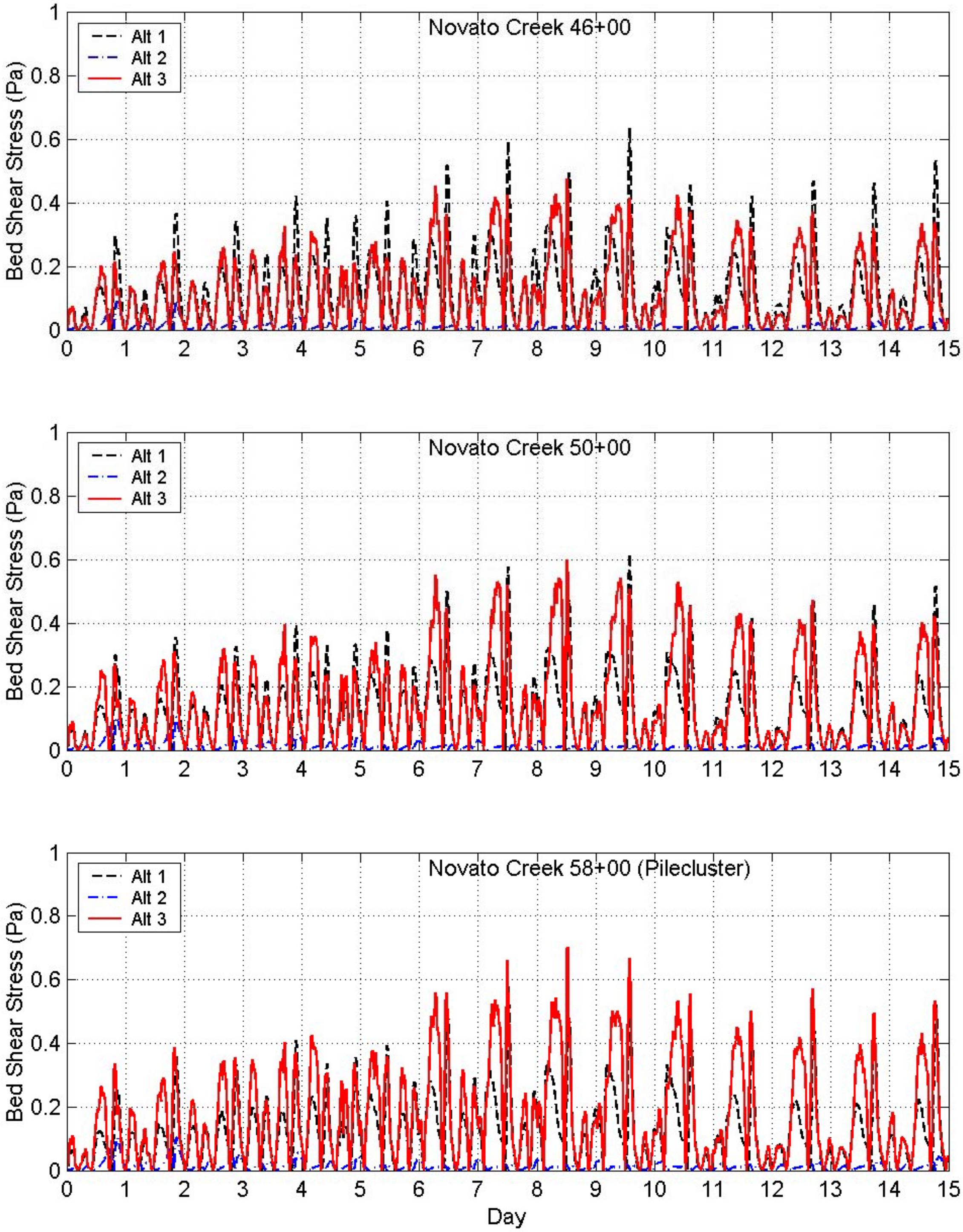


Figure A-29. Predicted Shear Stresses: CS 46+00 to CS 58+00

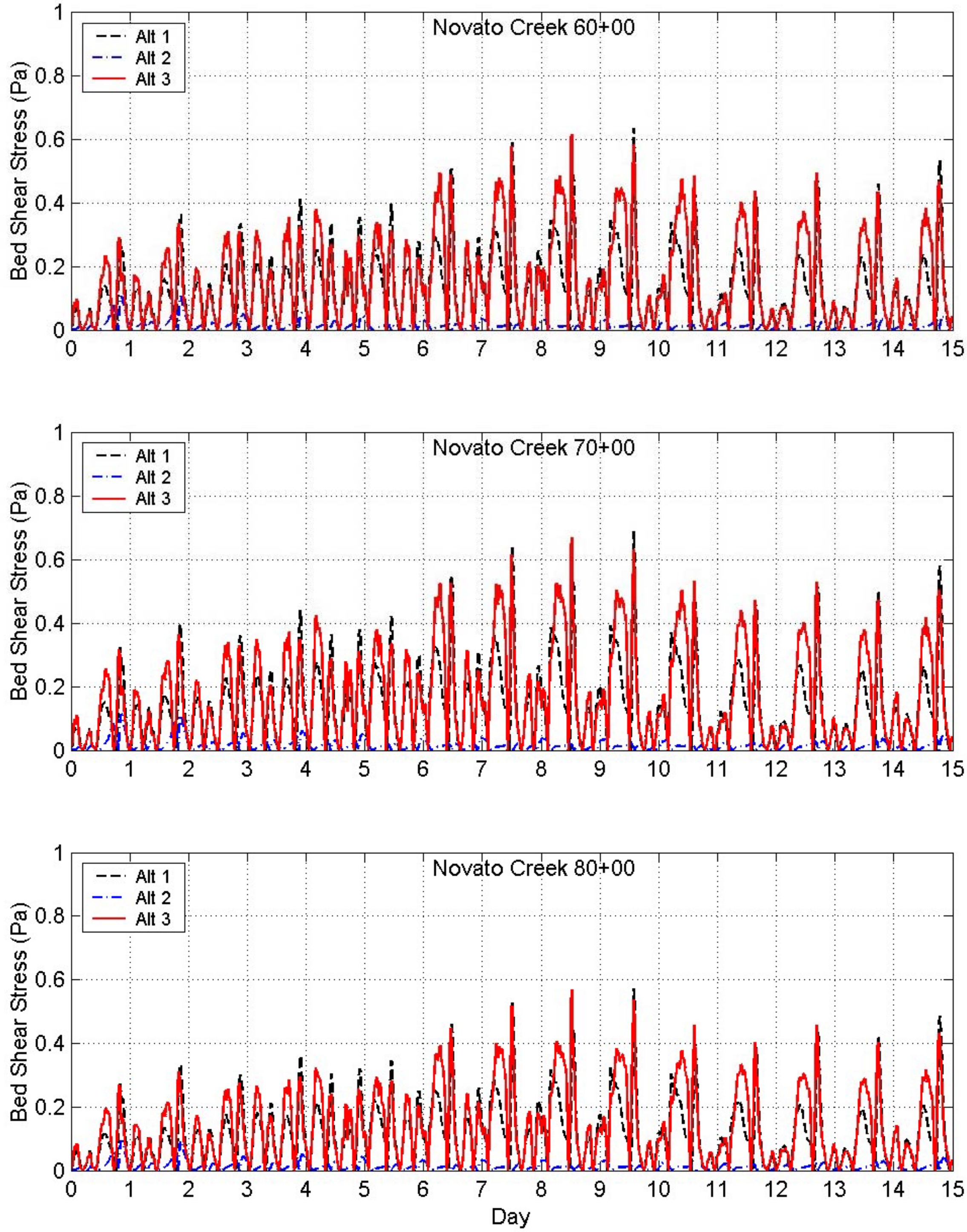


Figure A-30. Predicted Shear Stresses: CS 60+00 to CS 80+00

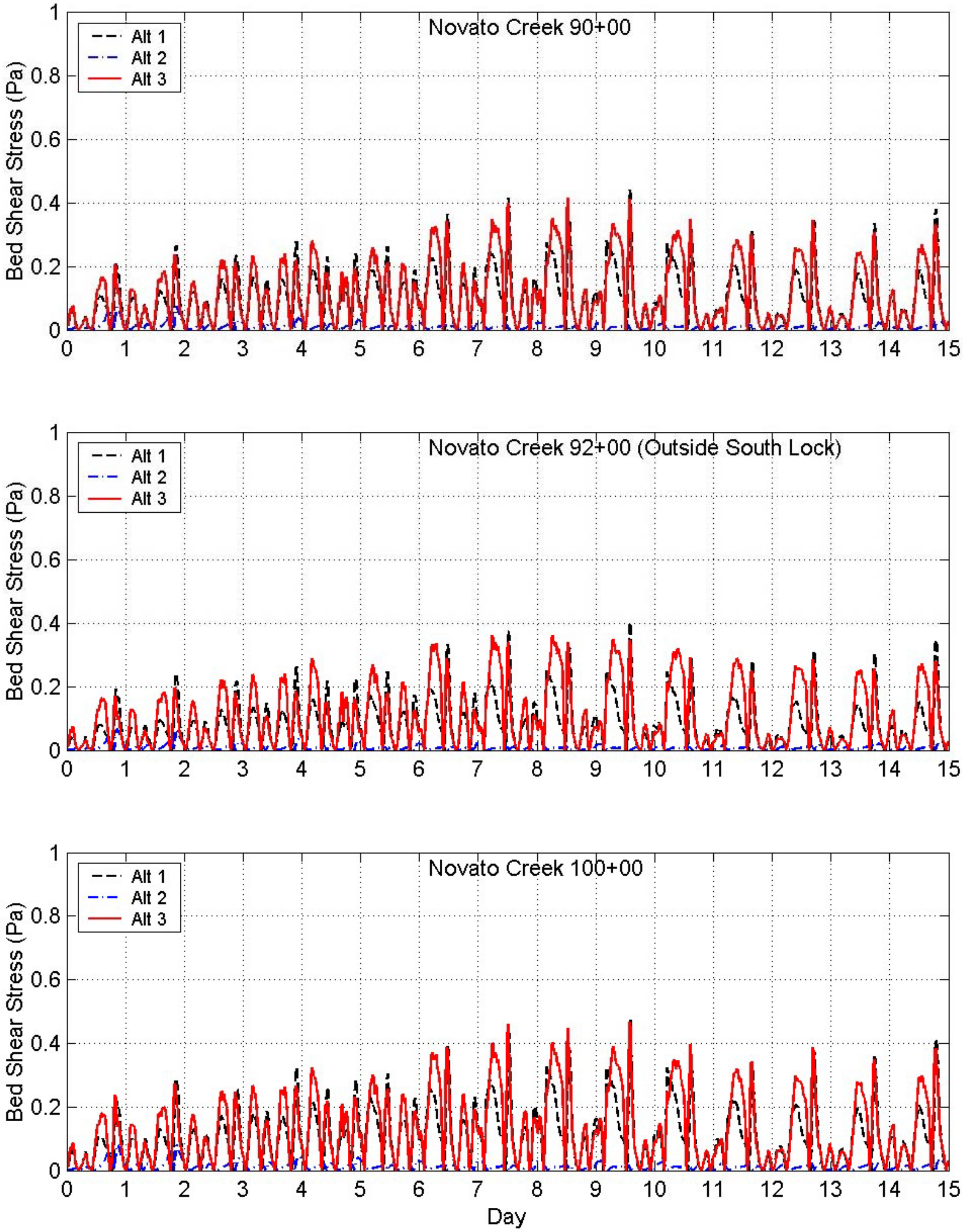


Figure A-31. Predicted Shear Stresses: CS 90+00 to CS 100+00

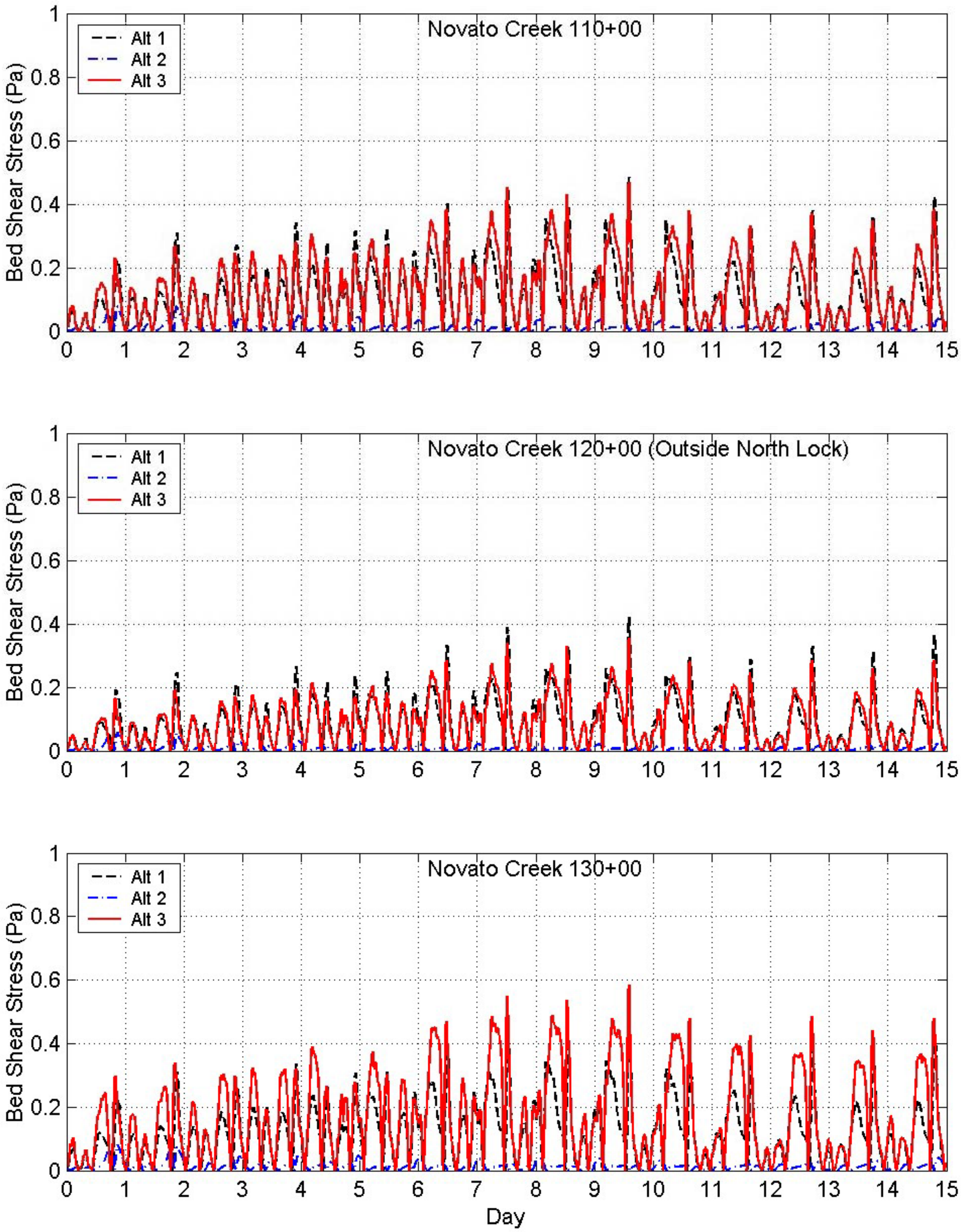


Figure A-32. Predicted Shear Stresses: CS 110+00 to CS 130+00

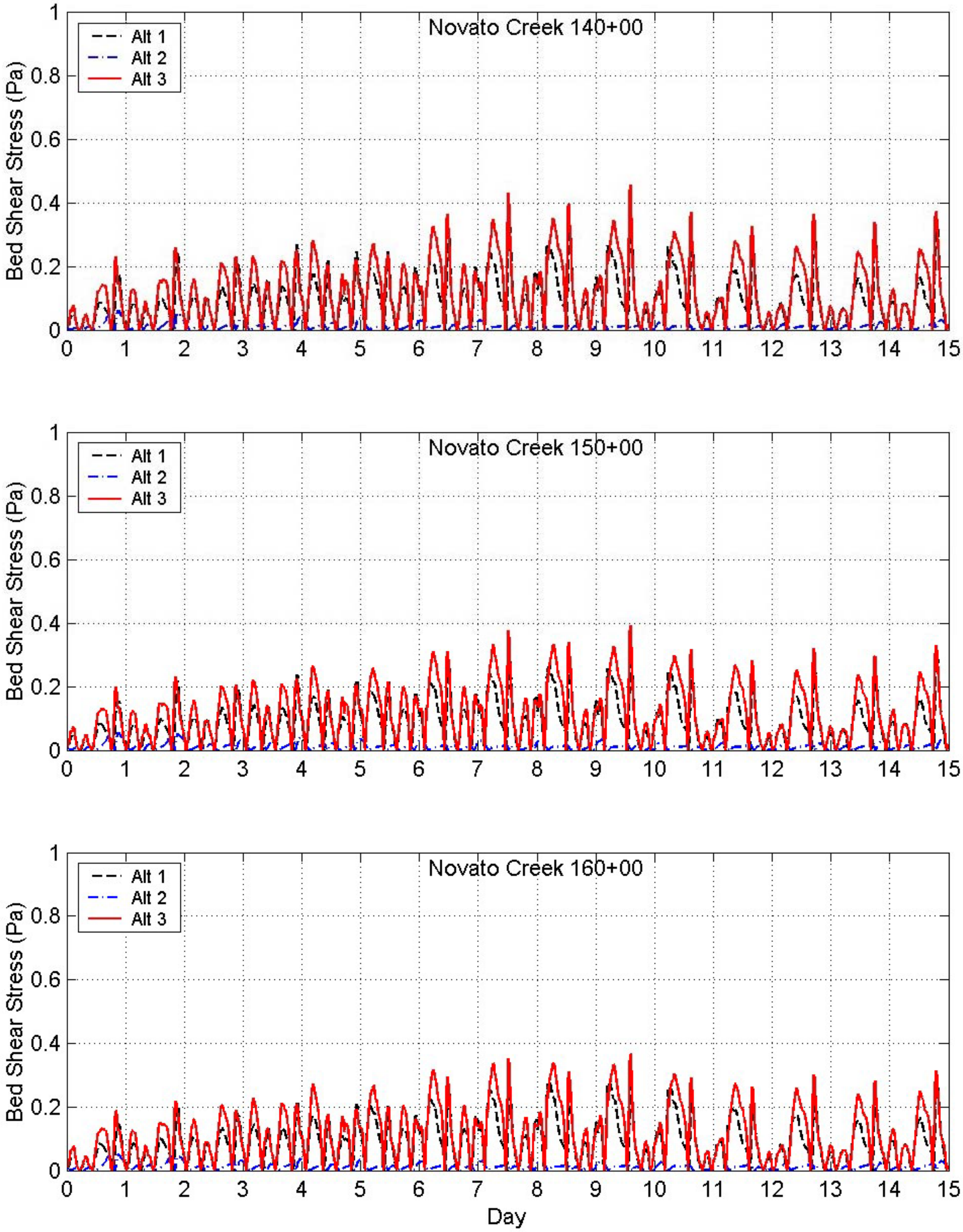


Figure A-33. Predicted Shear Stresses: CS 140+00 to CS 160+00

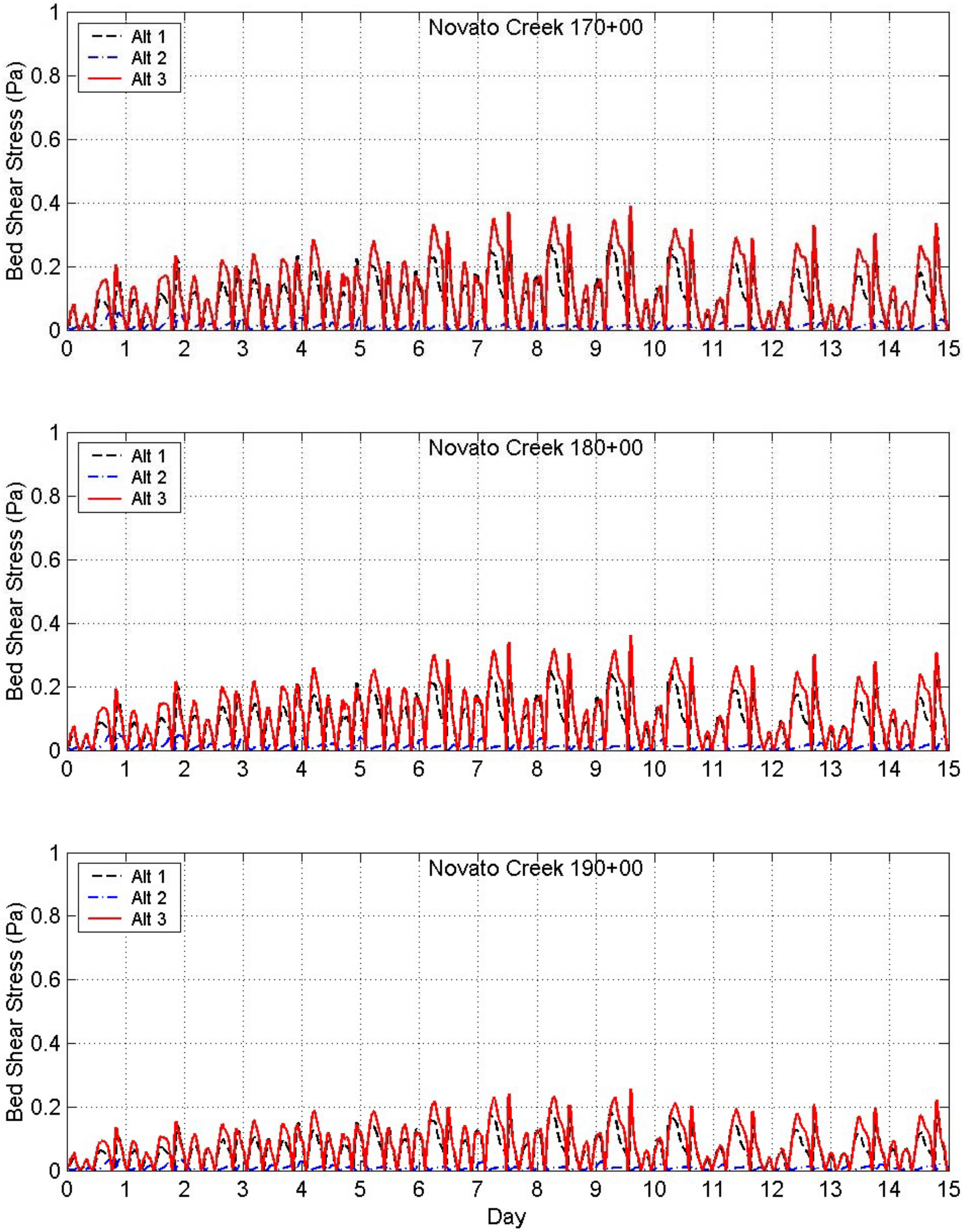


Figure A-34. Predicted Shear Stresses: CS 170+00 to CS 190+00

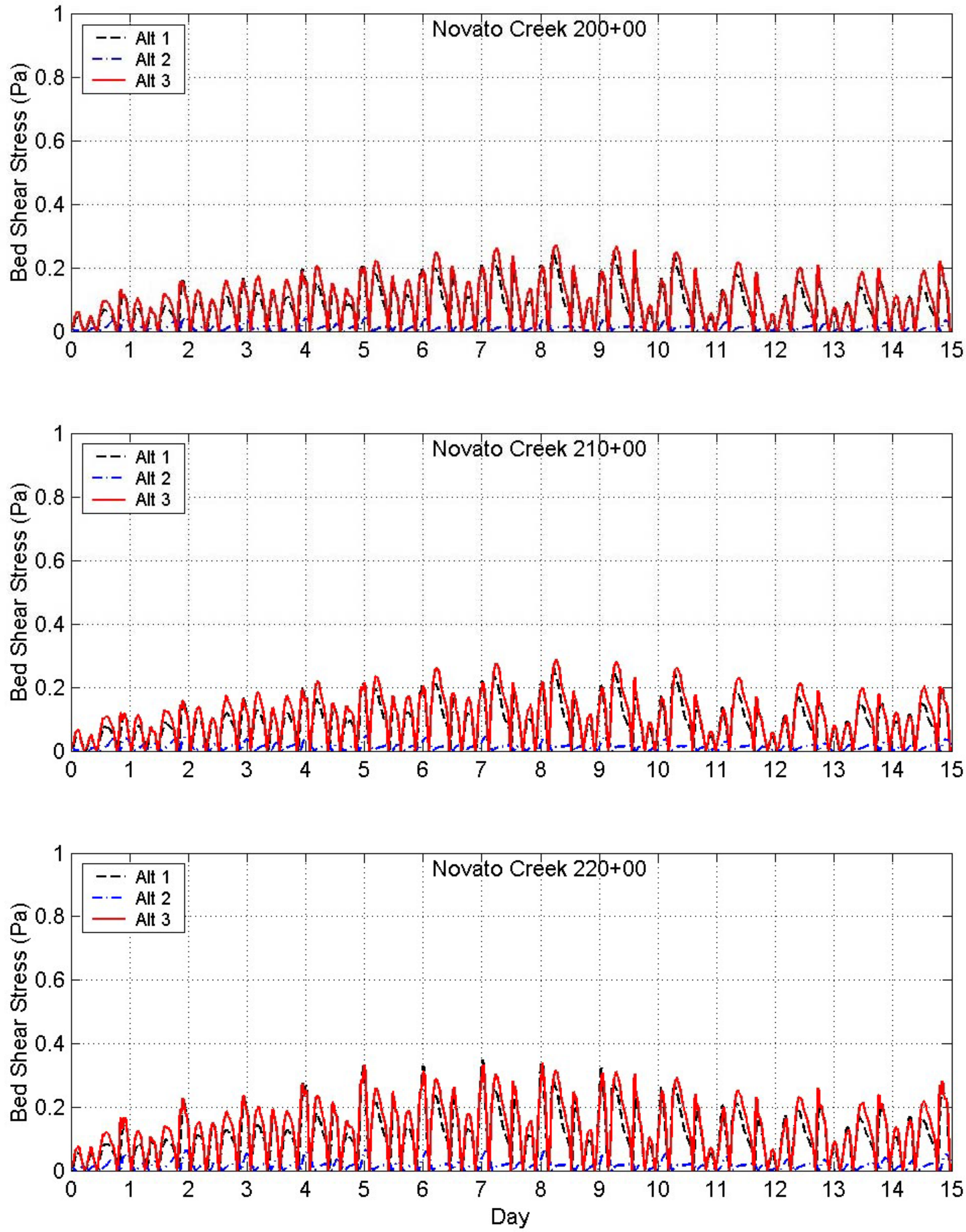


Figure A-35. Predicted Shear Stresses: CS 200+00 to CS 220+00

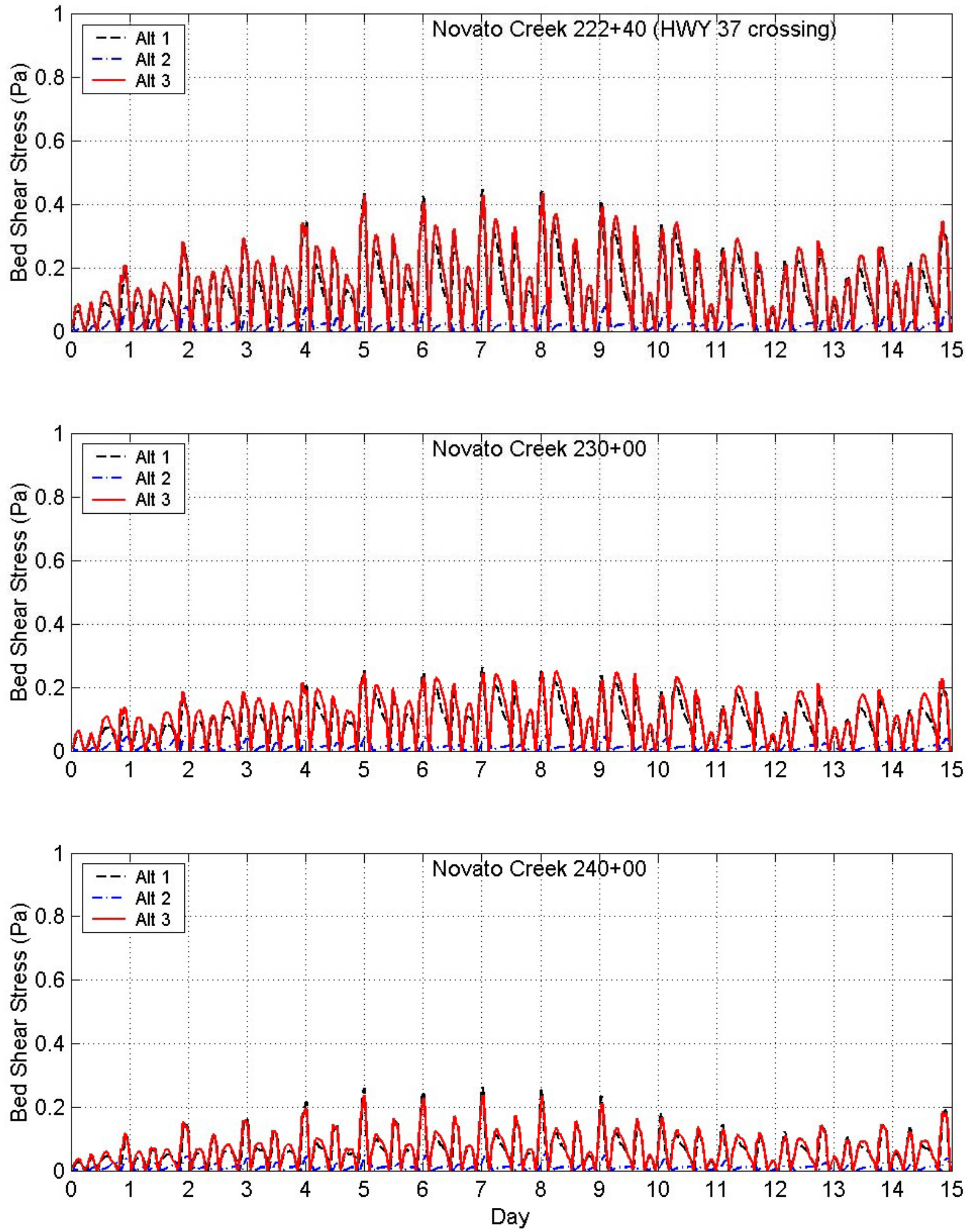


Figure A-36. Predicted Shear Stresses: HWY 37 to CS 240+00

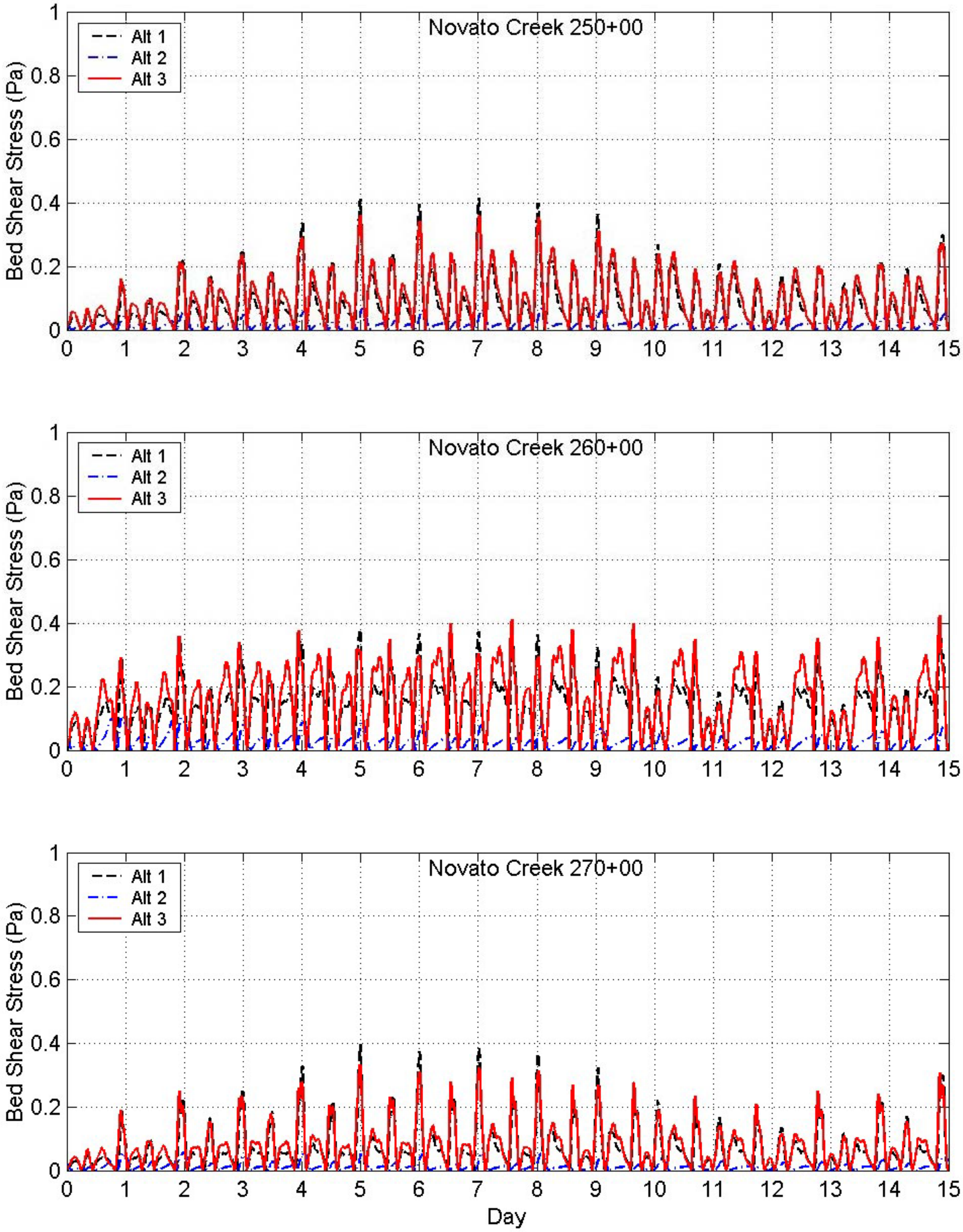


Figure A-37. Predicted Shear Stresses: CS 250+00 to CS 270+00

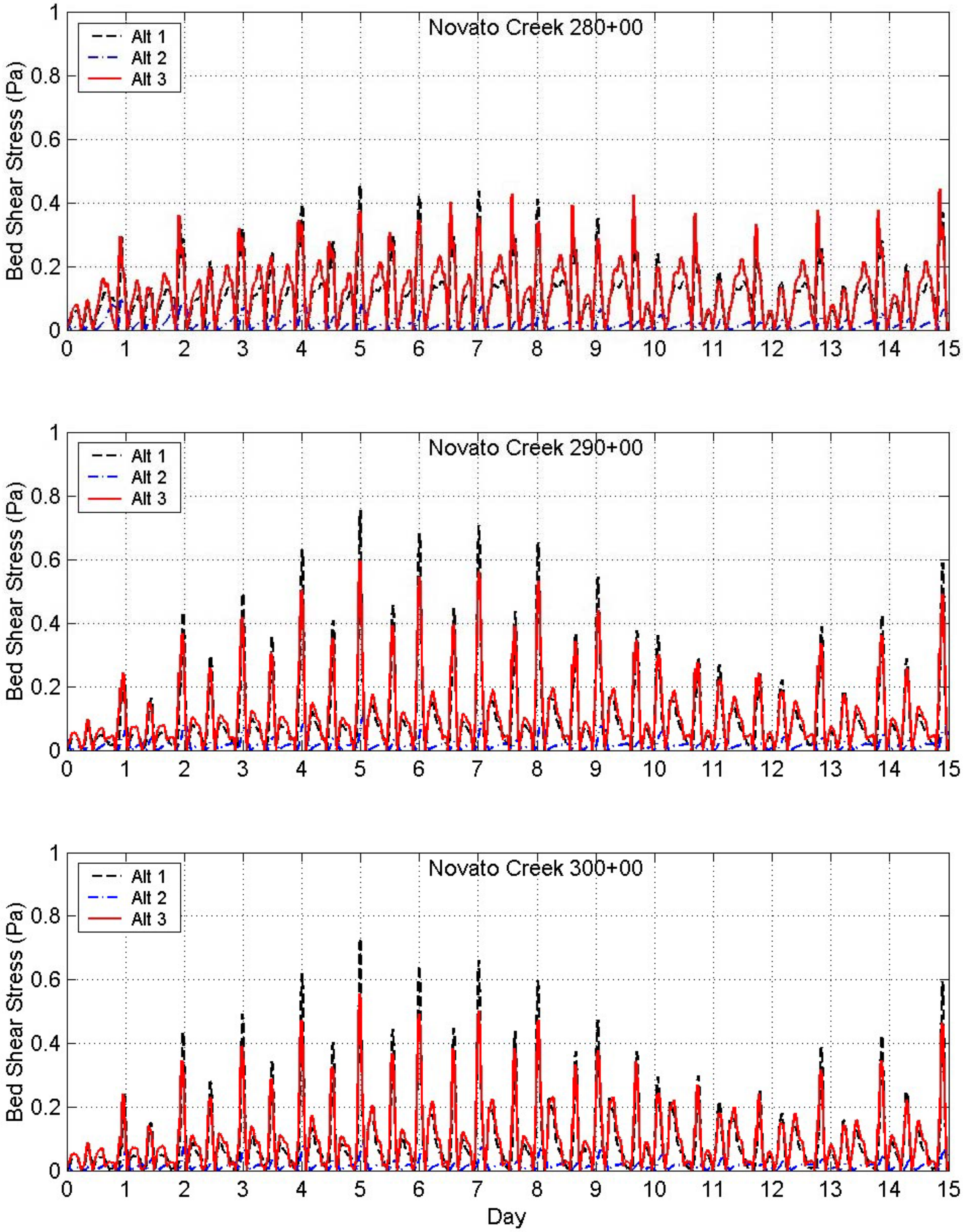


Figure A-38. Predicted Shear Stresses: CS 280+00 to CS 300+00

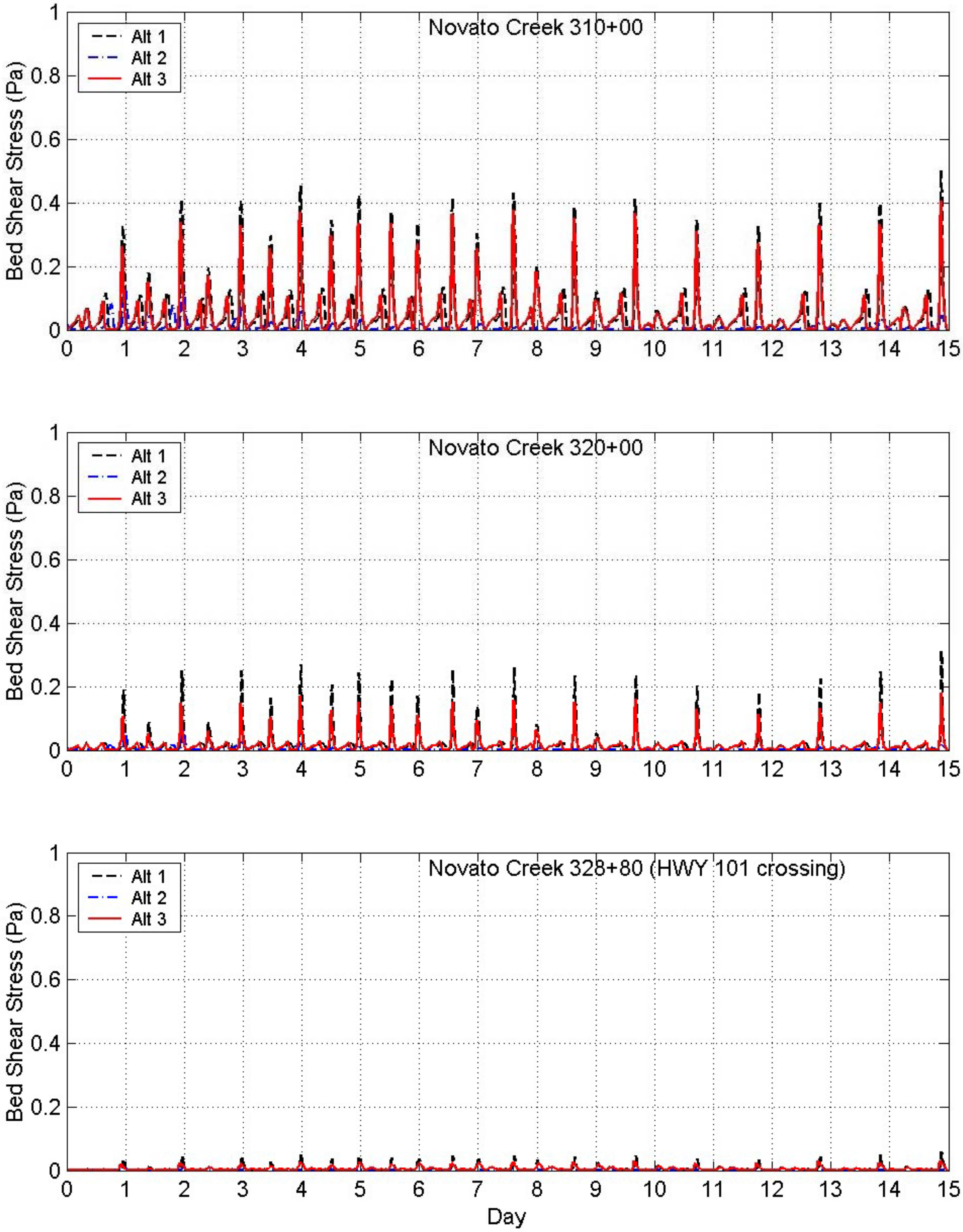


Figure A-39. Predicted Shear Stresses: CS 310+00 to HWY 101

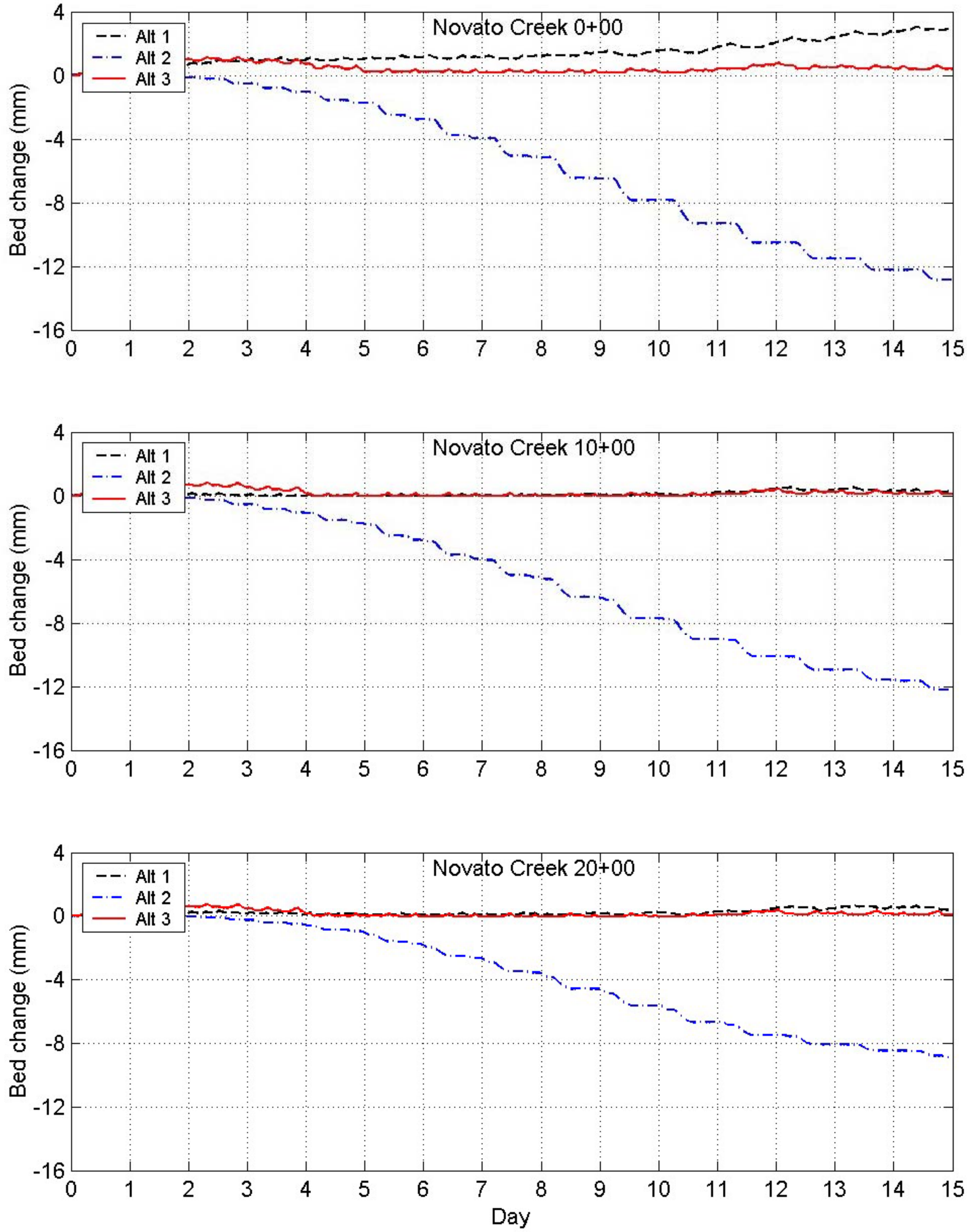


Figure A-40. Predicted Bed Changes: CS 0+00 to CS 20+00

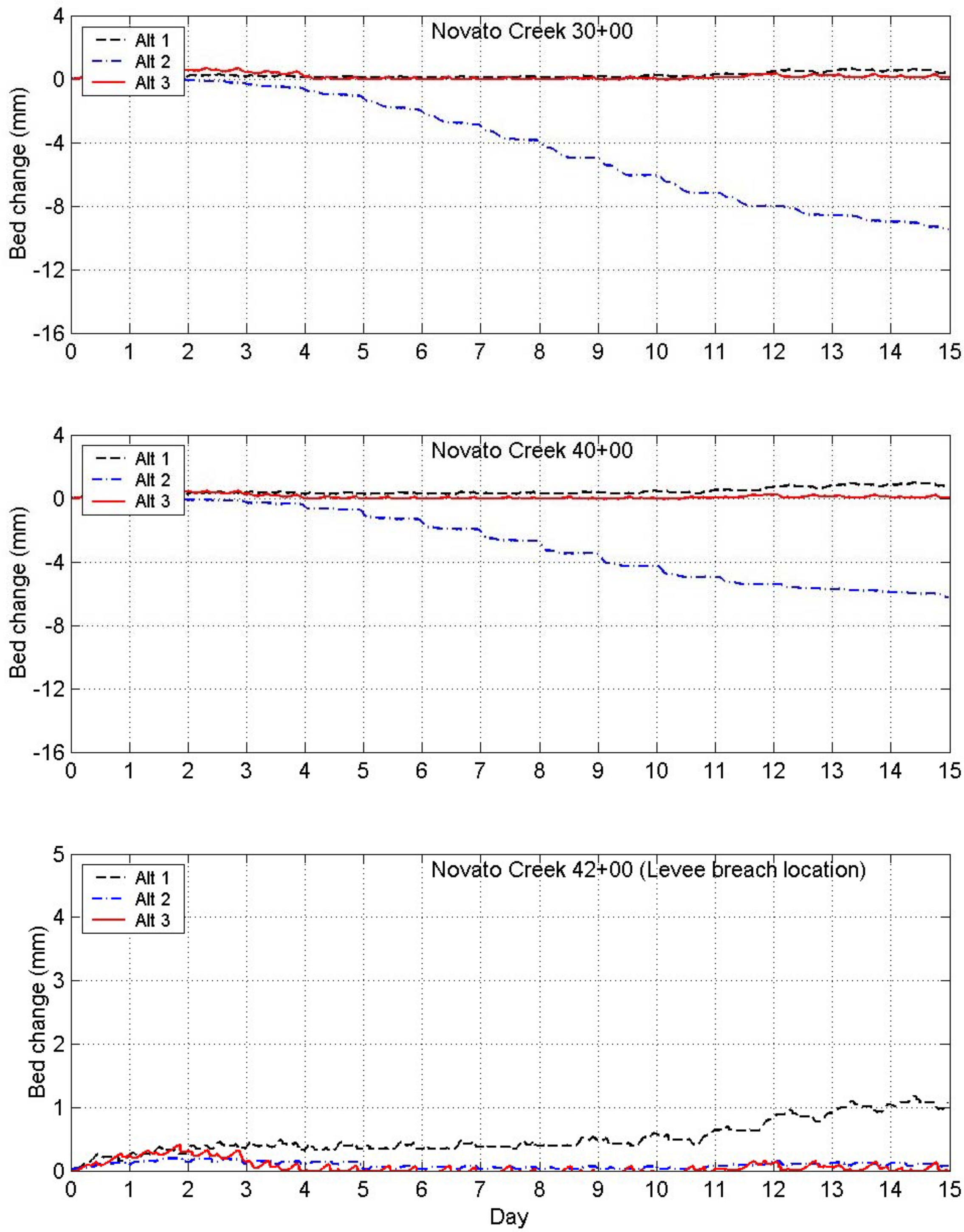


Figure A-41. Predicted Bed Changes: CS 30+00 to CS 42+00

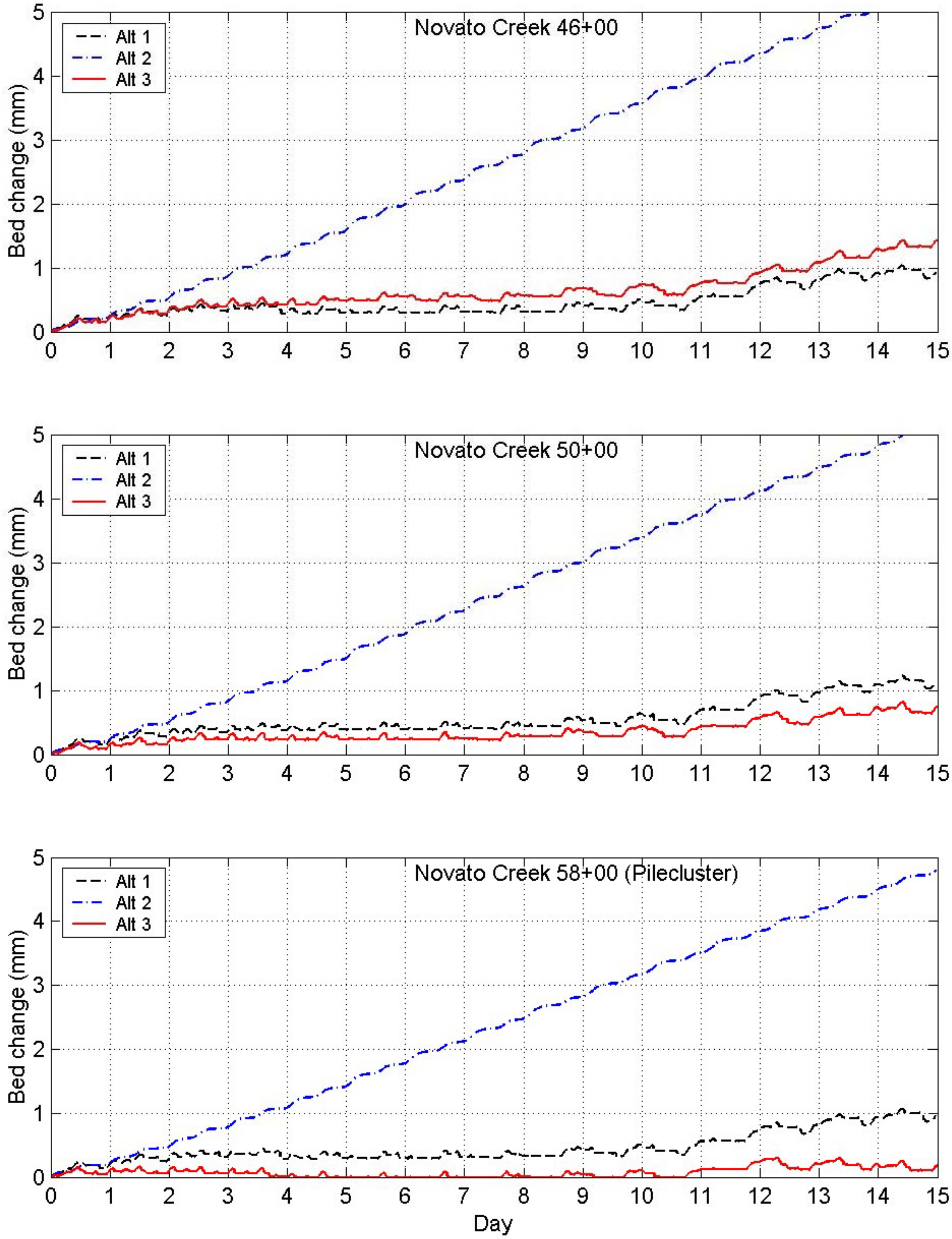


Figure A-42. Predicted Bed Changes: CS 46+00 to CS 58+00

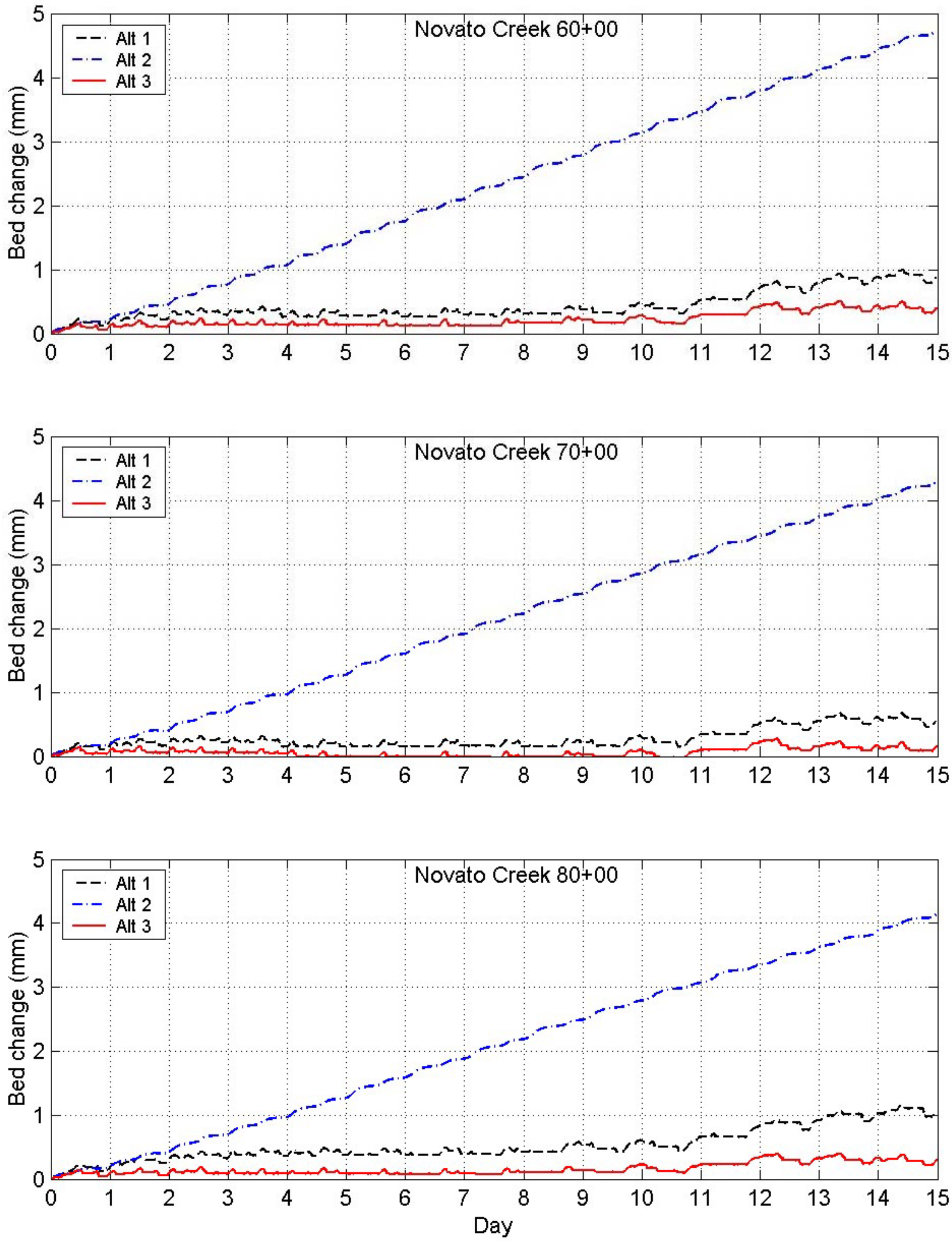


Figure A-43. Predicted Bed Changes: CS 60+00 to CS 80+00

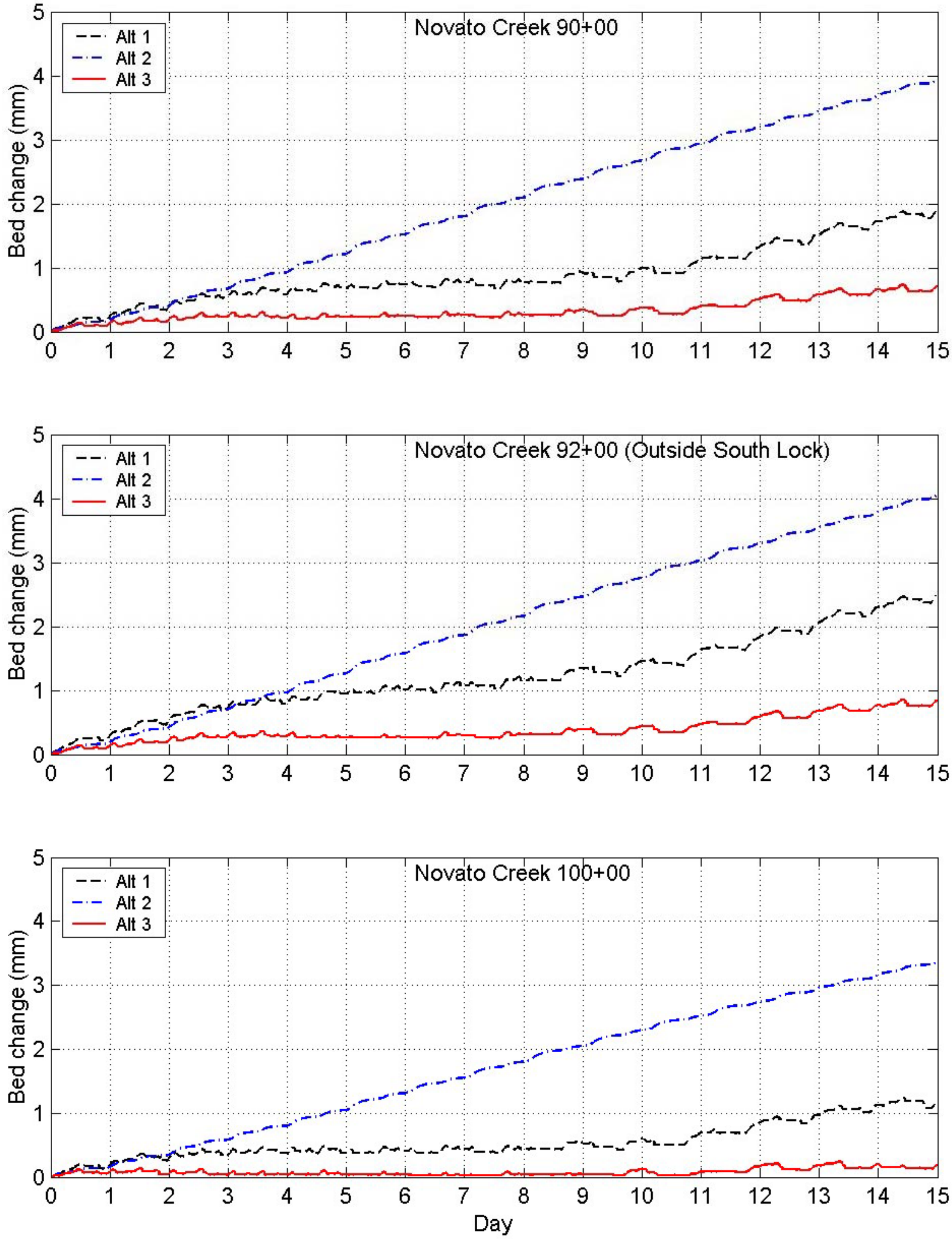


Figure A-44. Predicted Bed Changes: CS 90+00 to CS 100+00

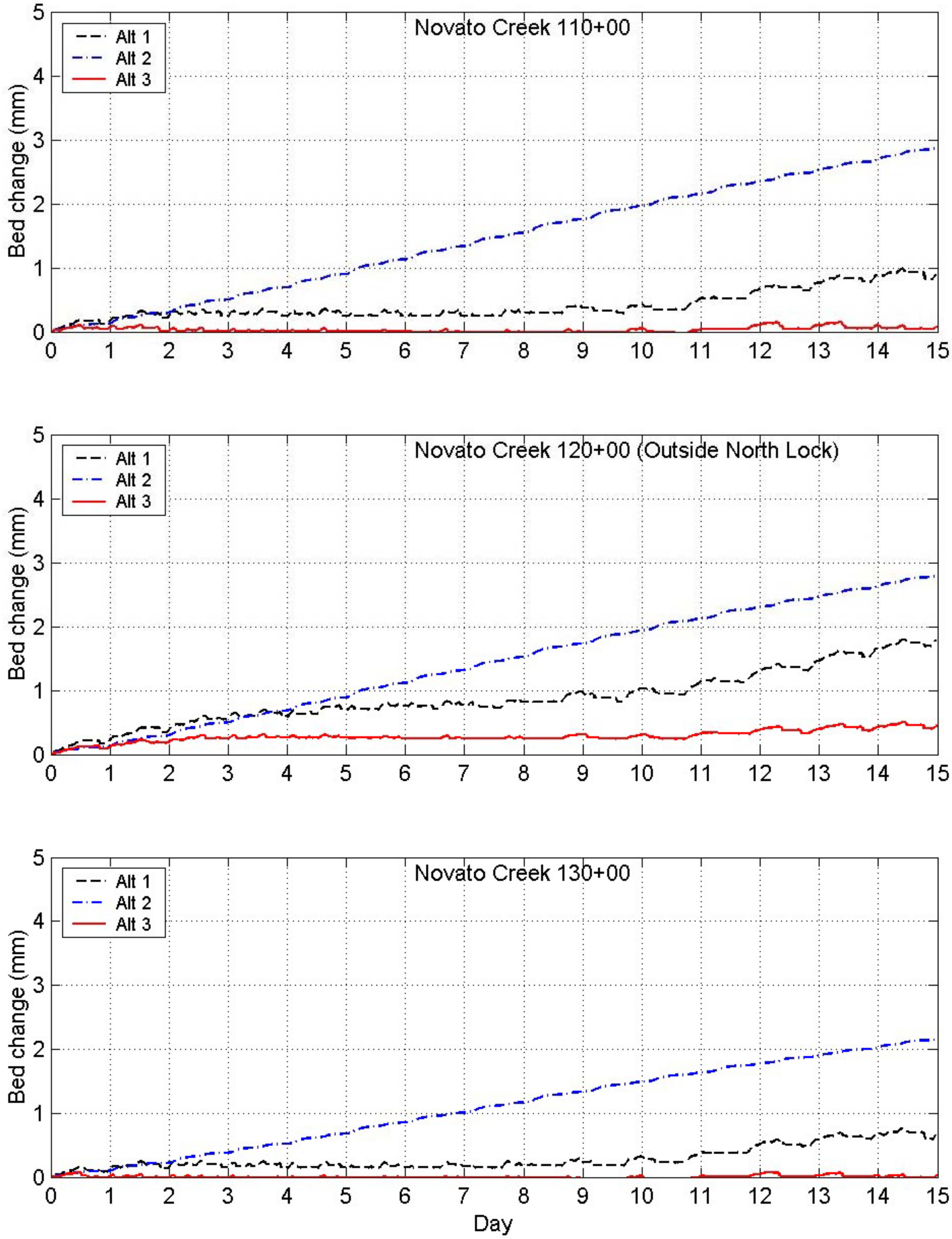


Figure A-45. Predicted Bed Changes: CS 110+00 to CS 130+00

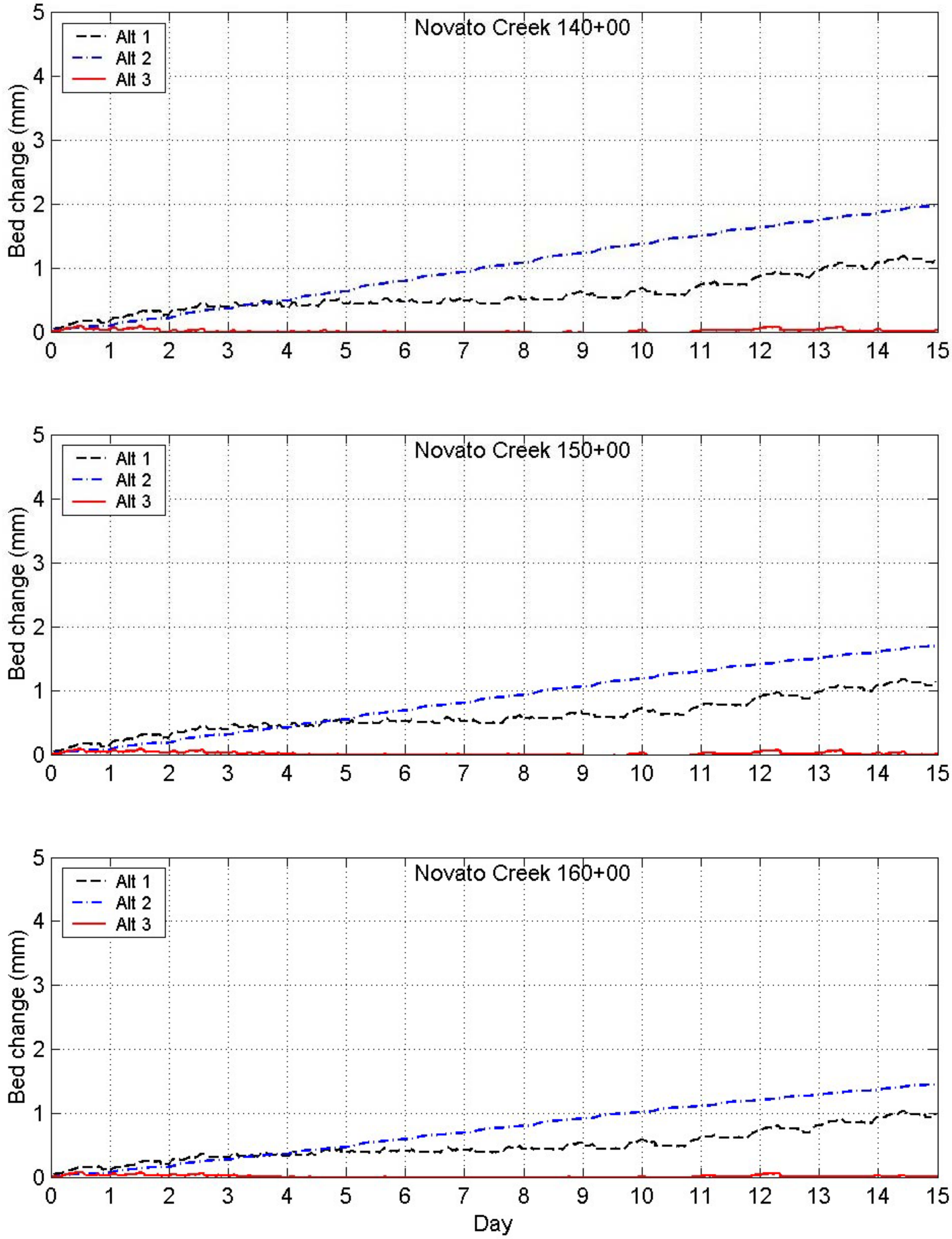


Figure A-46. Predicted Bed Changes: CS 140+00 to CS 160+00

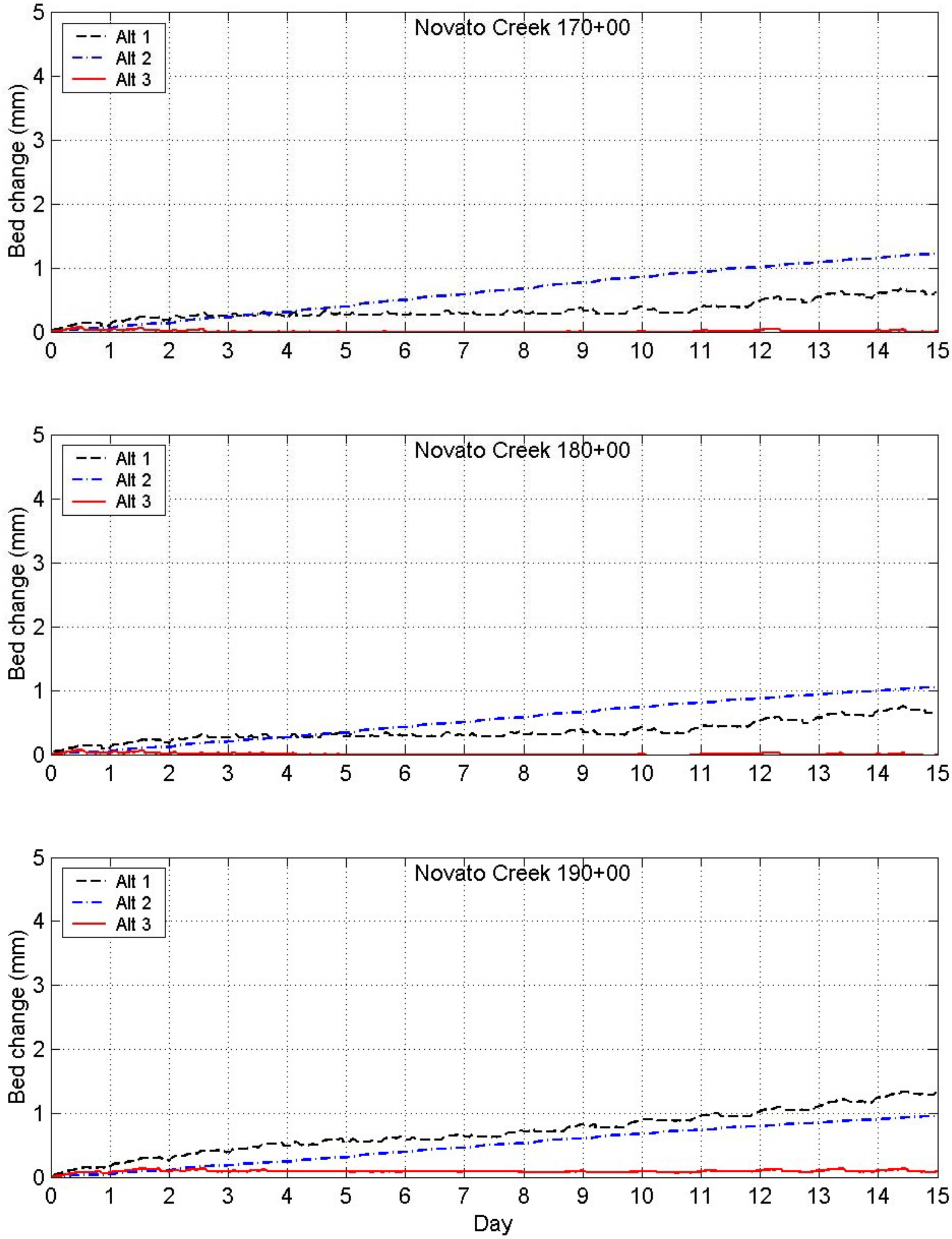


Figure A-47. Predicted Bed Changes: CS 170+00 to CS 190+00

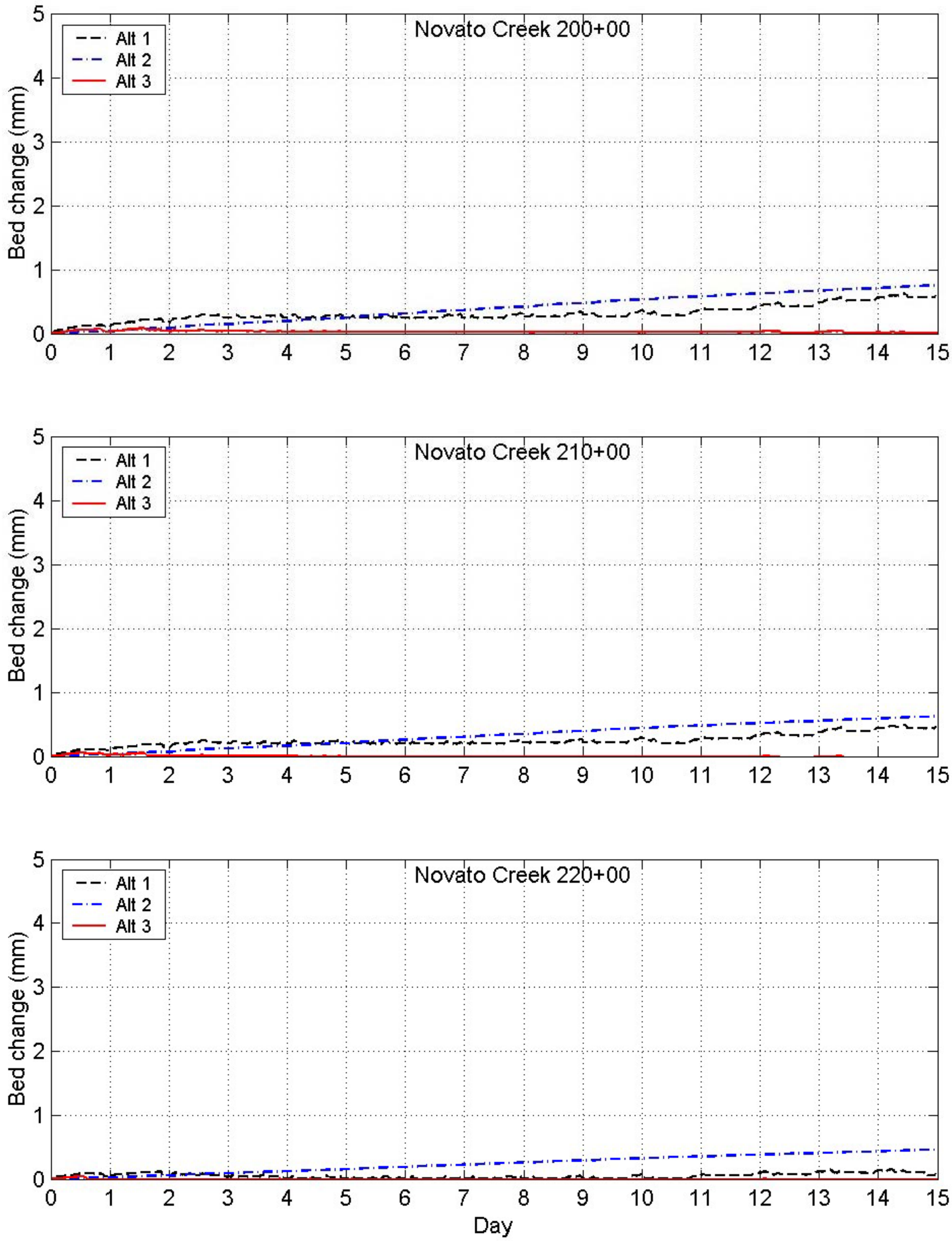


Figure A-48. Predicted Bed Changes: CS 200+00 to CS 220+00

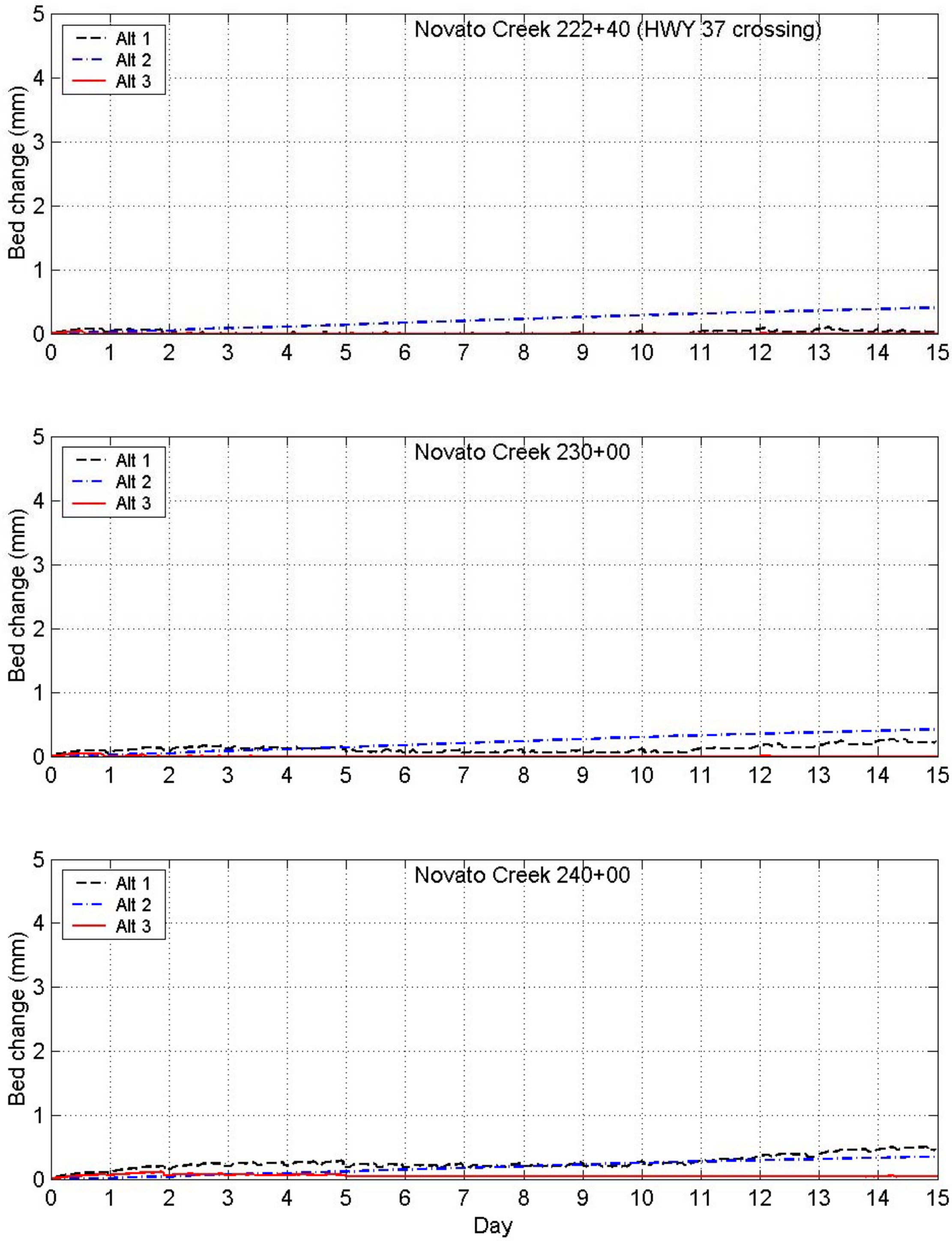


Figure A-49. Predicted Bed Changes: HWY 37 to CS 240+00

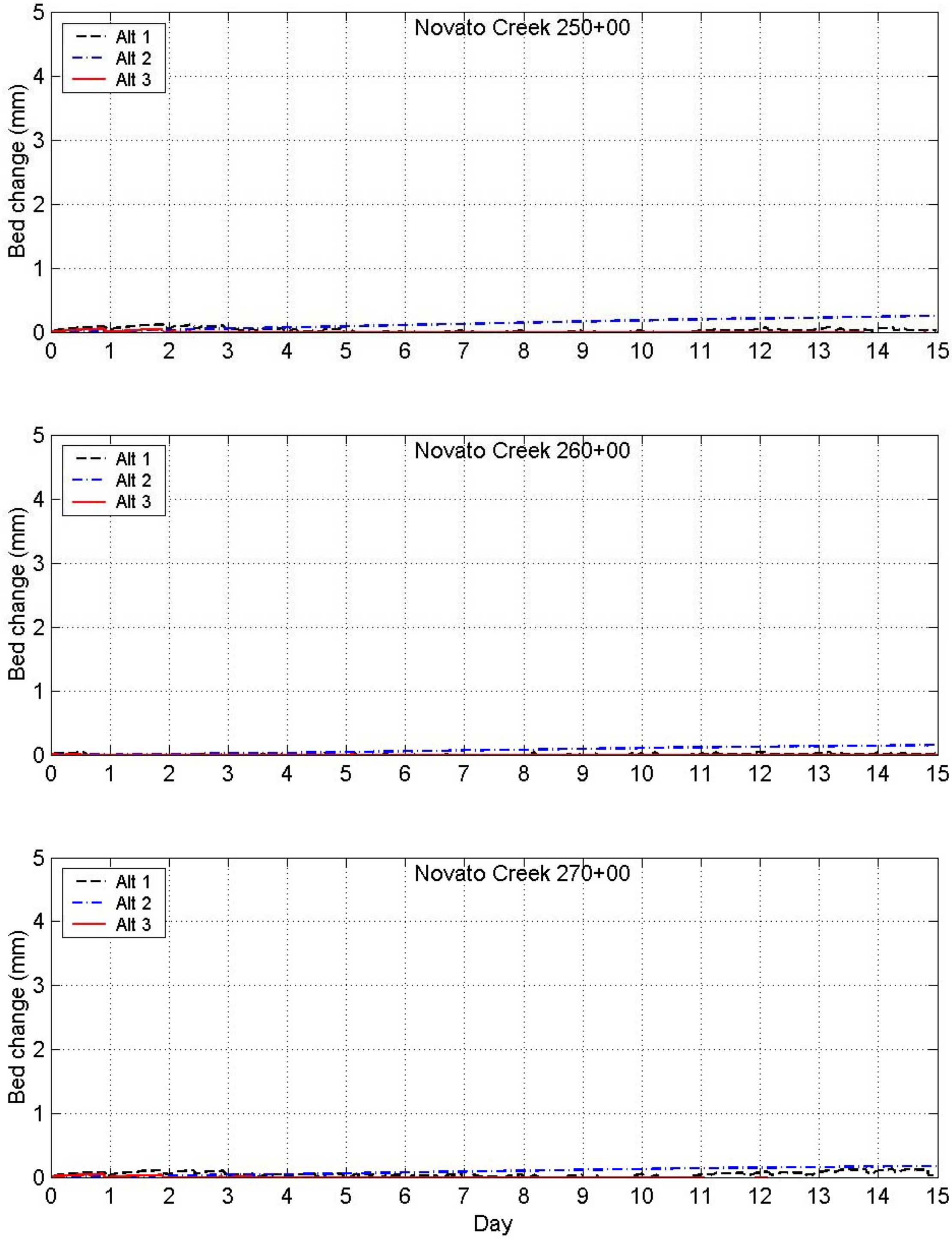


Figure A-50. Predicted Bed Changes: CS 250+00 to CS 270+00

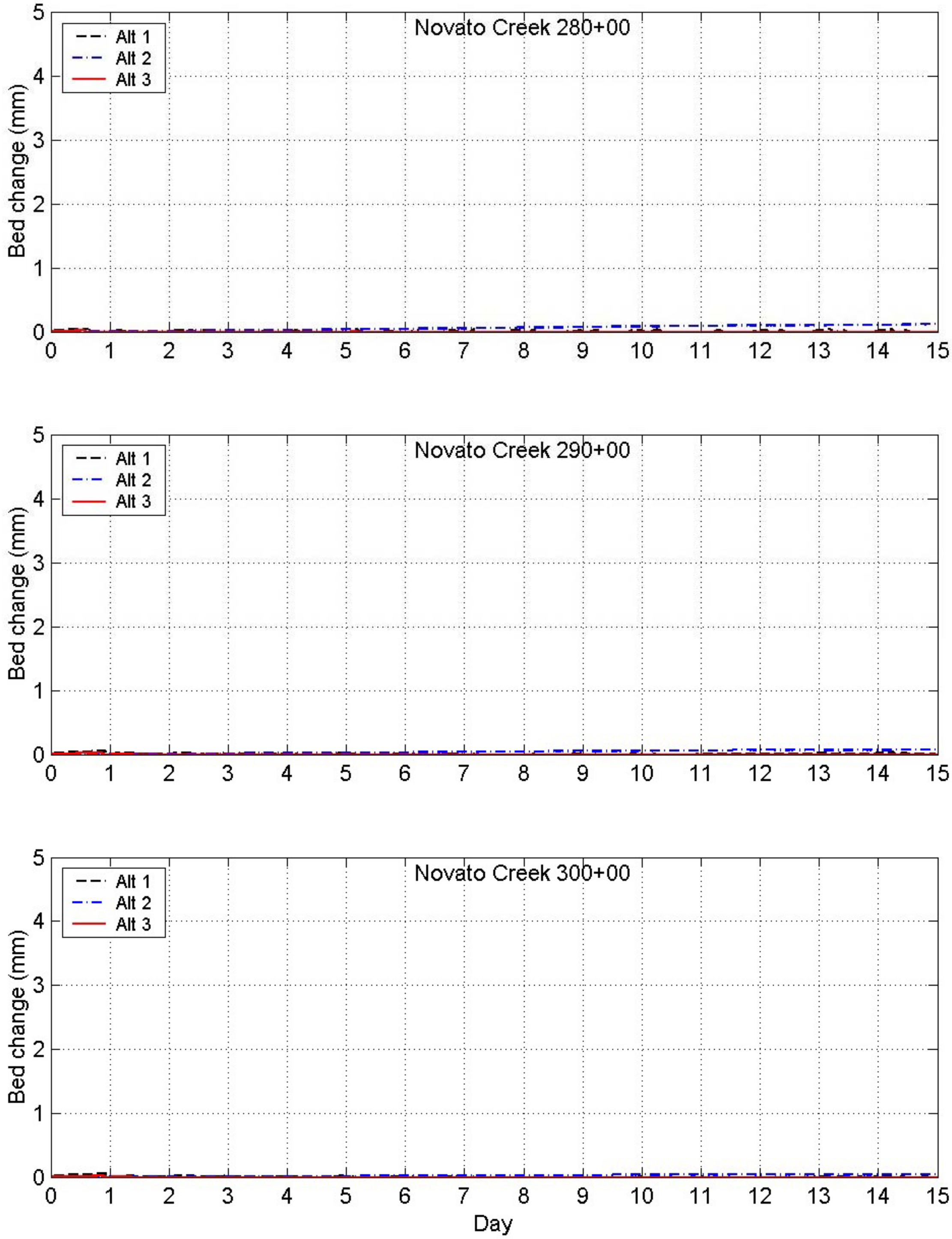


Figure A-51. Predicted Bed Changes: CS 280+00 to CS 300+00

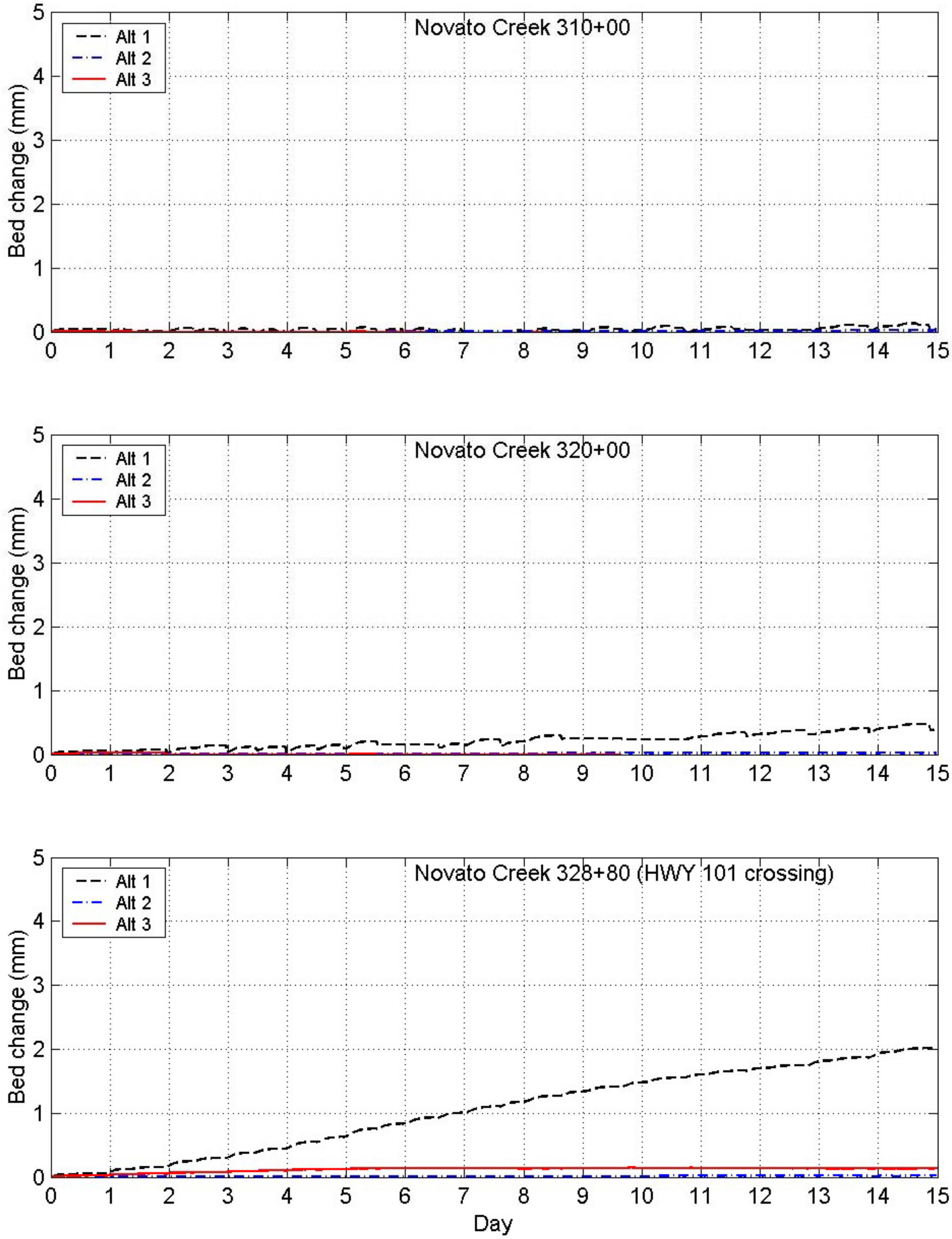


Figure A-52. Predicted Bed Changes: CS 310+00 to HWY 101

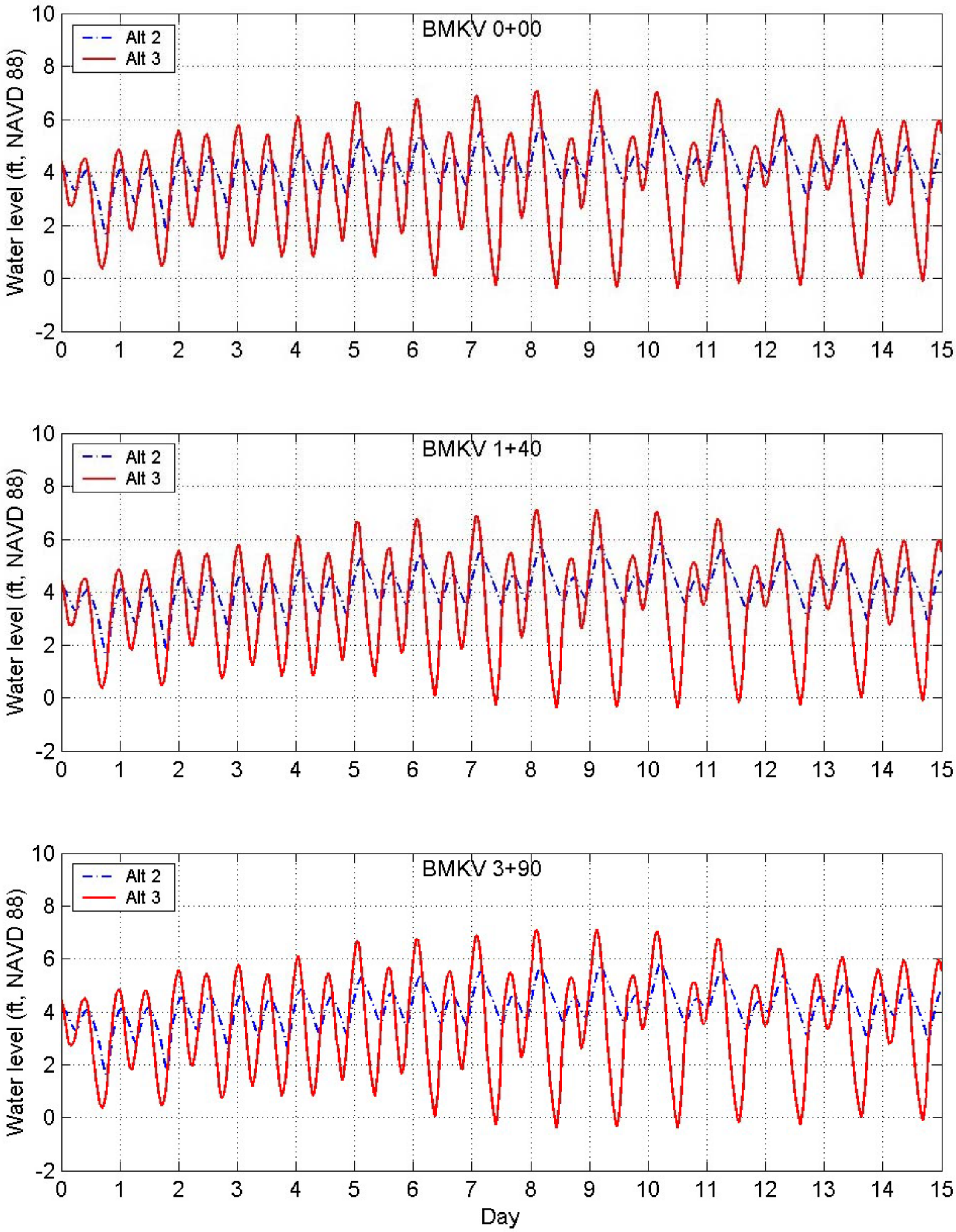


Figure A-53. Predicted Water Levels: BMK-V 0+00 to 3+90

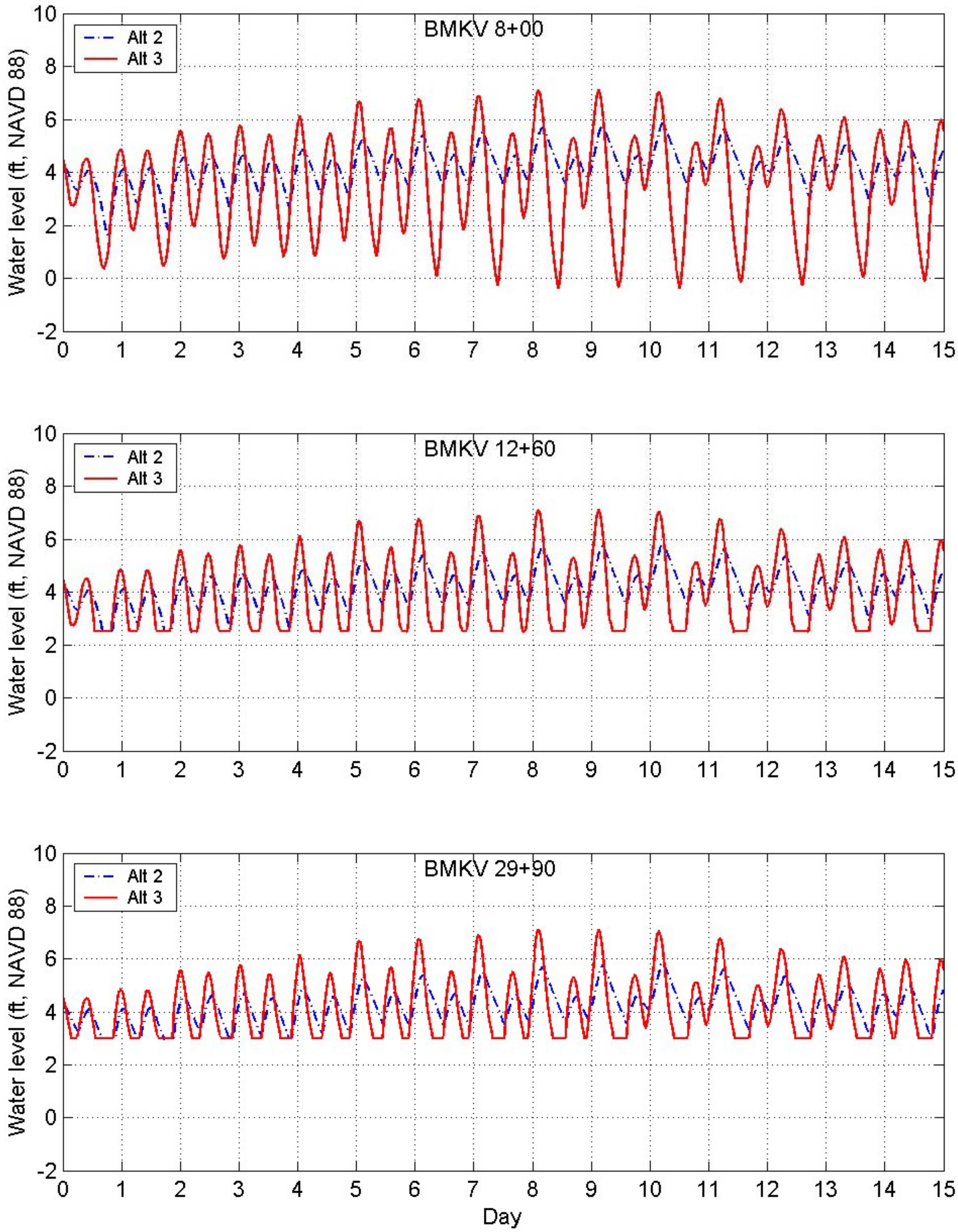


Figure A-54. Predicted Water Levels: BMK-V 8+00 to 29+90

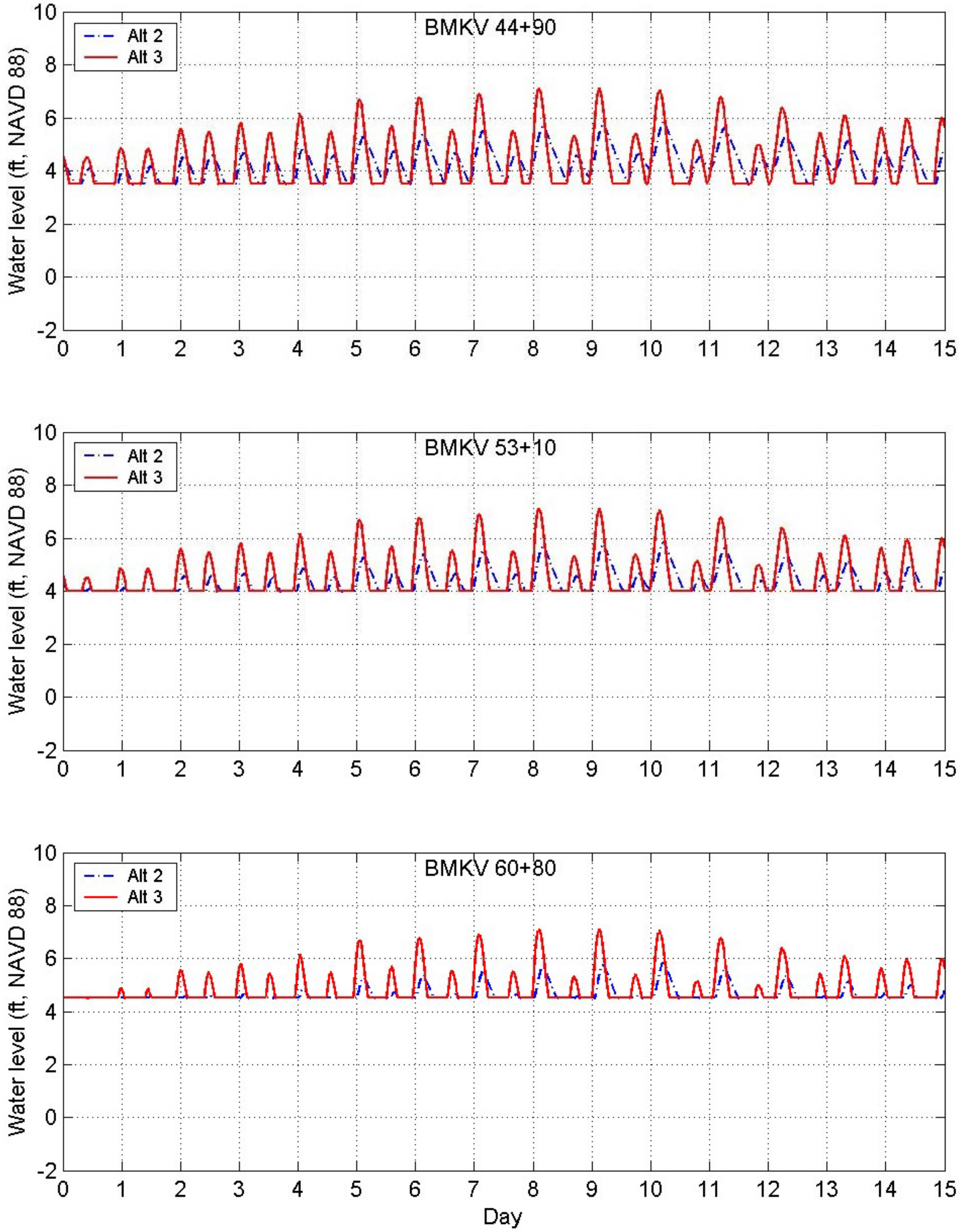


Figure A-55. Predicted Water Levels: BMK-V 44+00 to 60+80

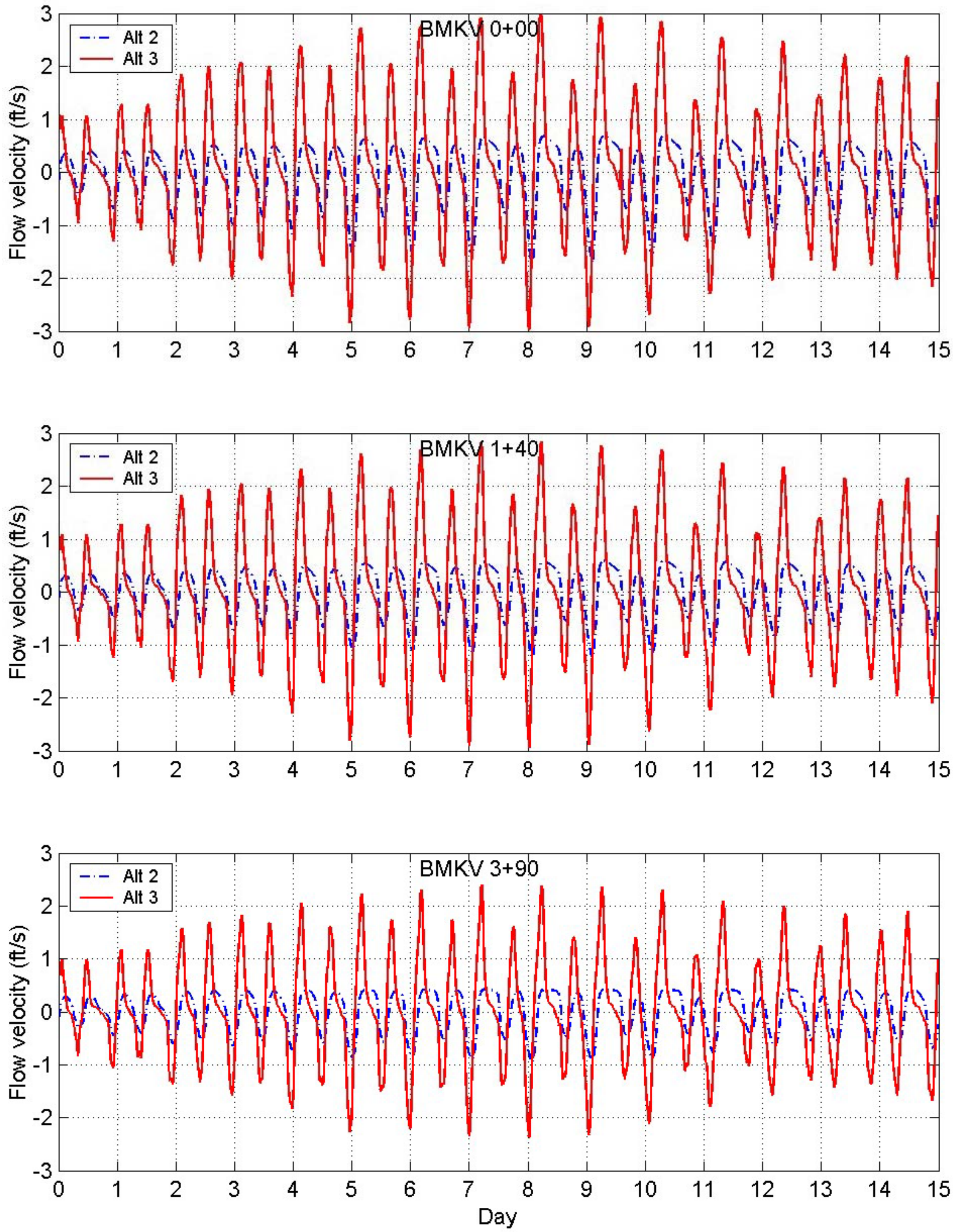


Figure A-56. Predicted Flow Velocities: BMK-V 0+00 to 3+90

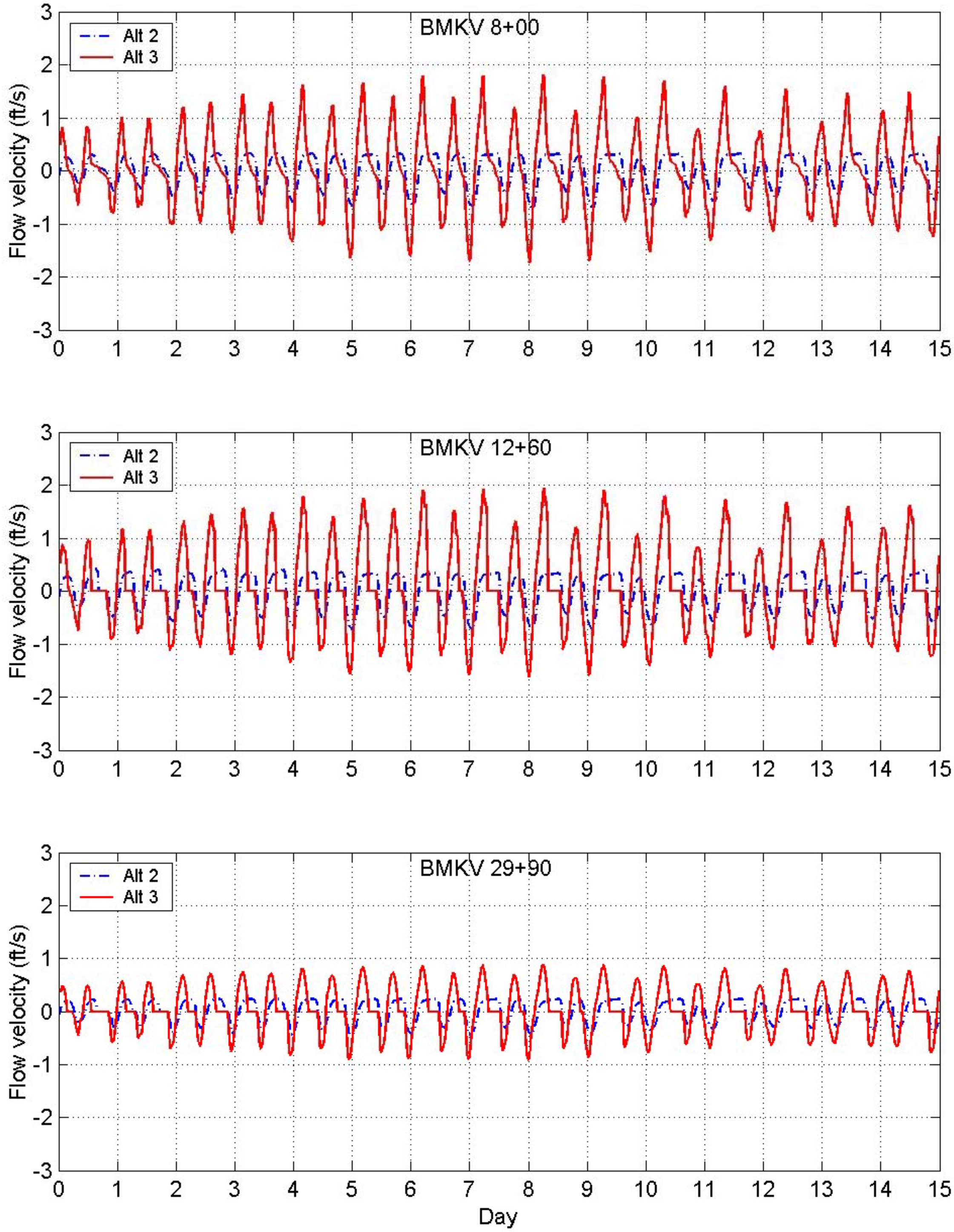


Figure A-57.   Predicted Flow Velocities: BMK-V 8+00 to 29+90

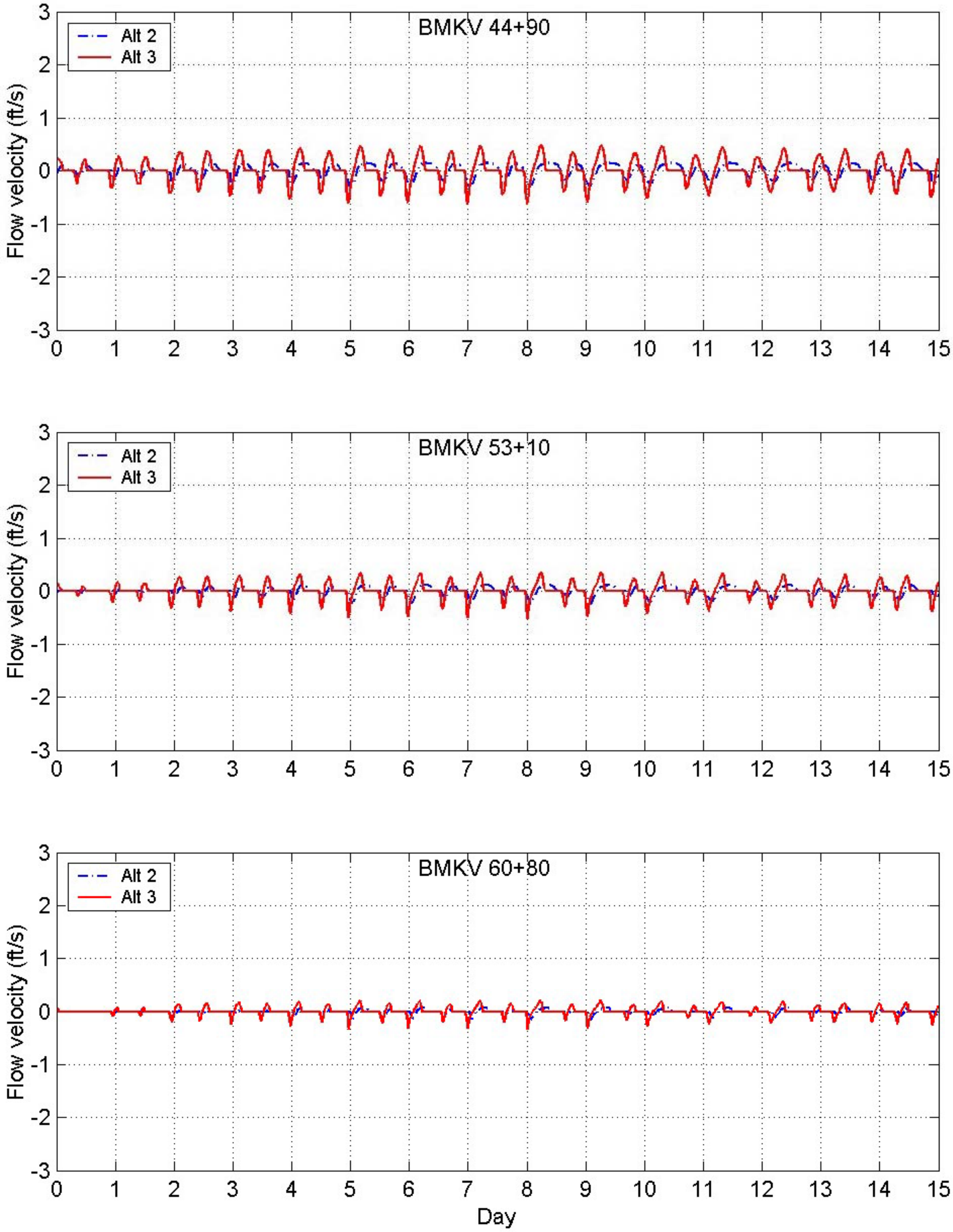


Figure A-58. Predicted Flow Velocities: BMK-V 44+00 to 60+80

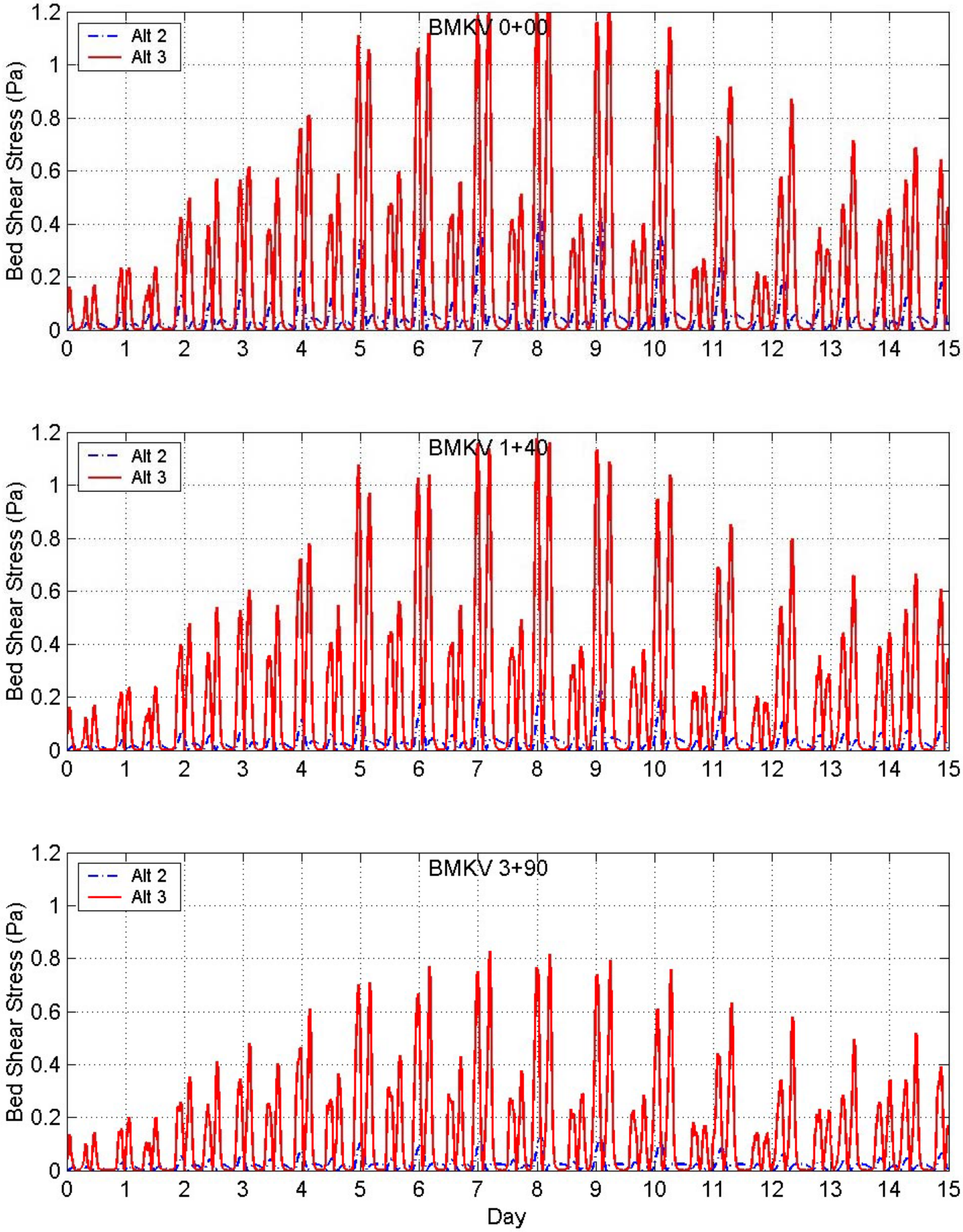


Figure A-59. Predicted Bottom Shear Stresses: BMK-V 0+00 to 3+90

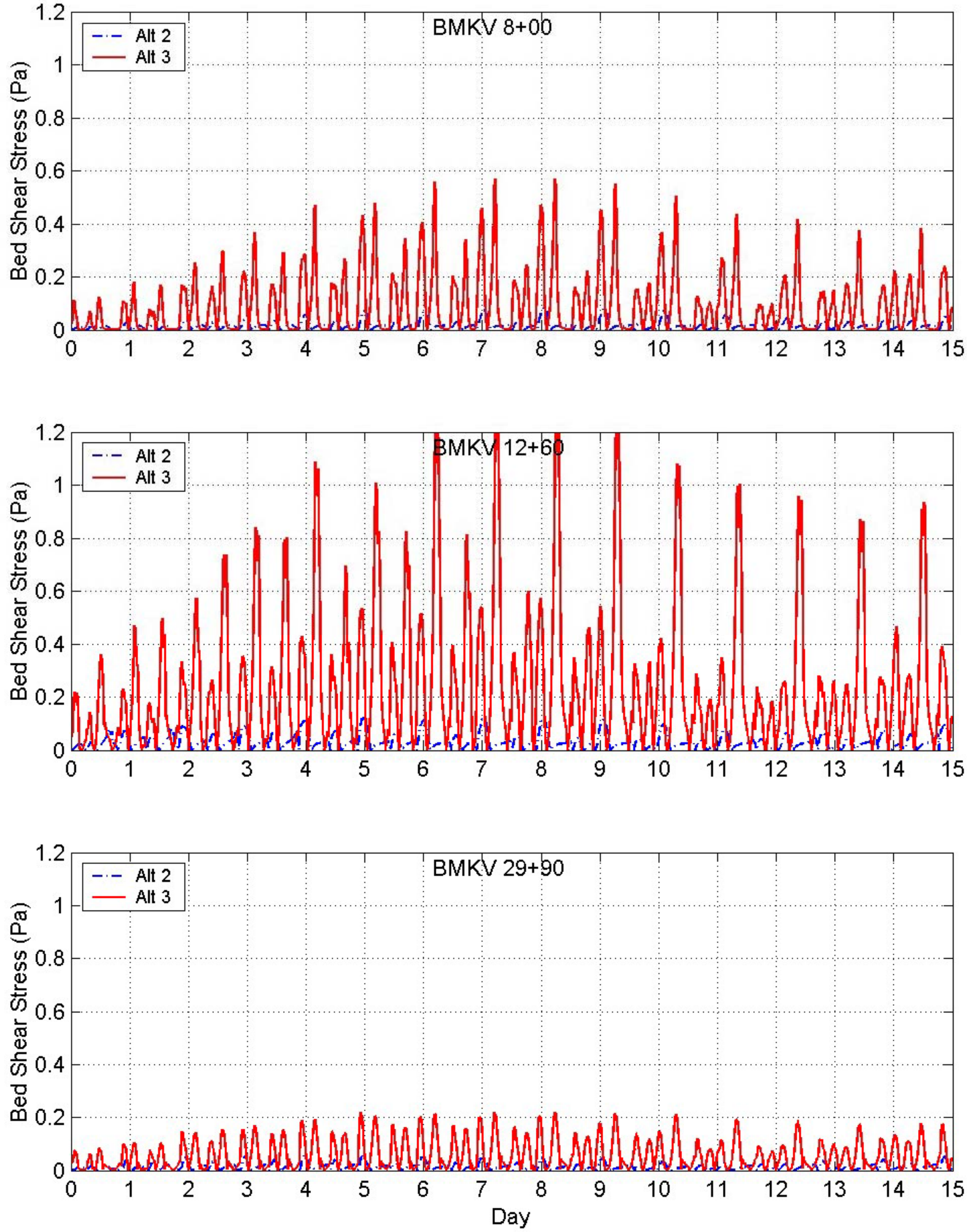


Figure A-60. Predicted Bottom Shear Stresses: BMK-V 8+00 to 29+90

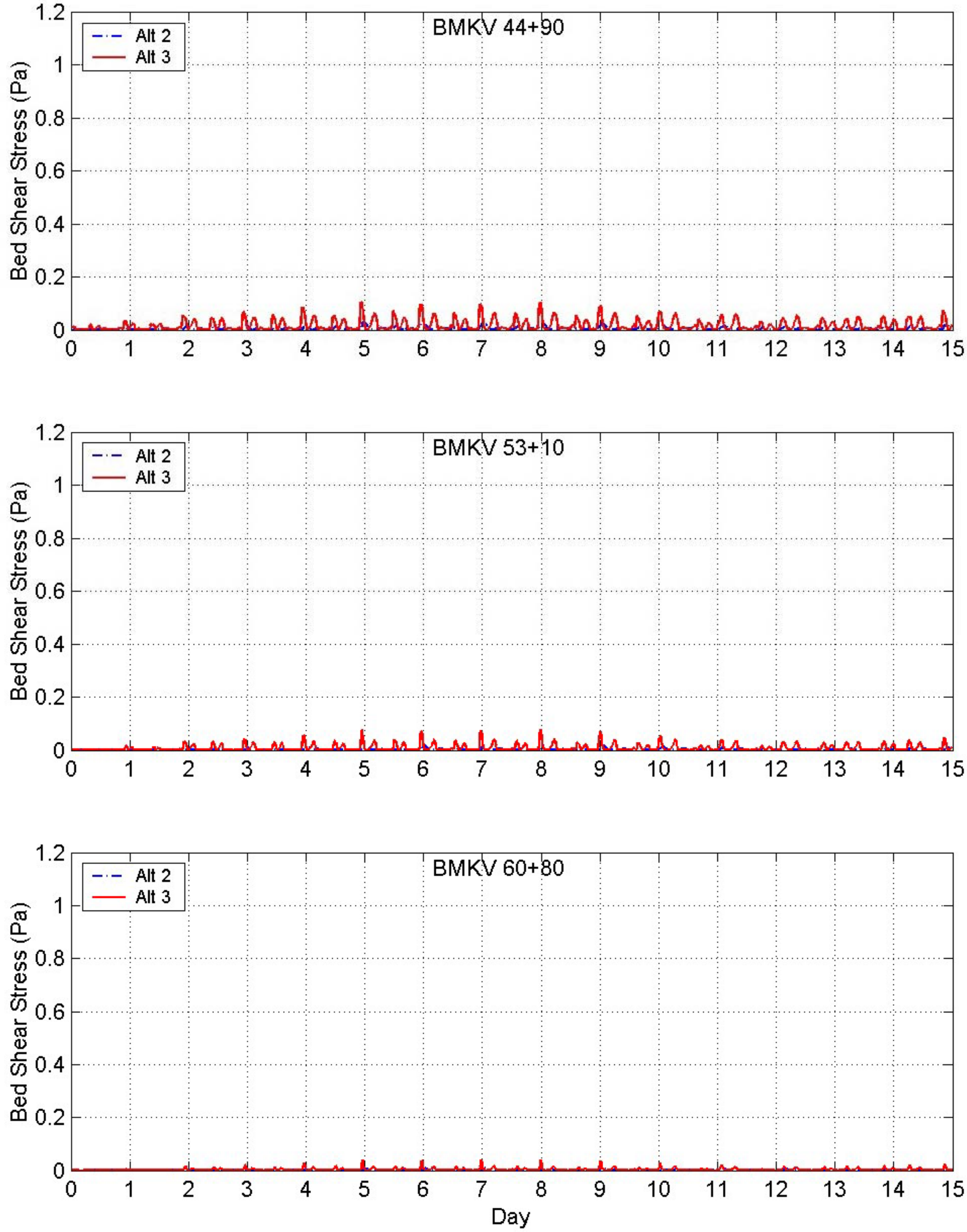


Figure A-61.   Predicted Bottom Shear Stresses: BMK-V 44+00 to 60+80

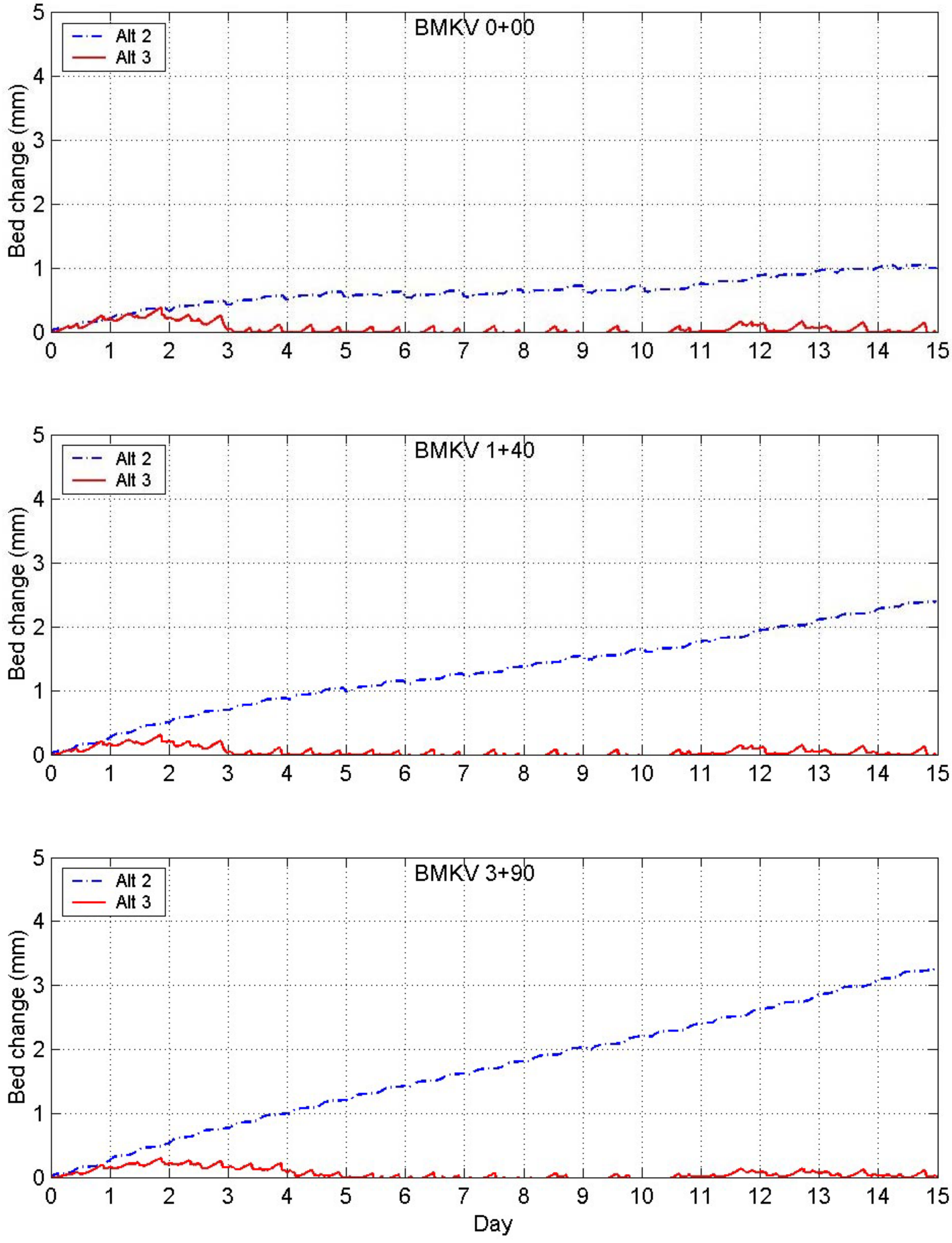


Figure A-62. Predicted Bed Changes: BMK-V 0+00 to 3+90

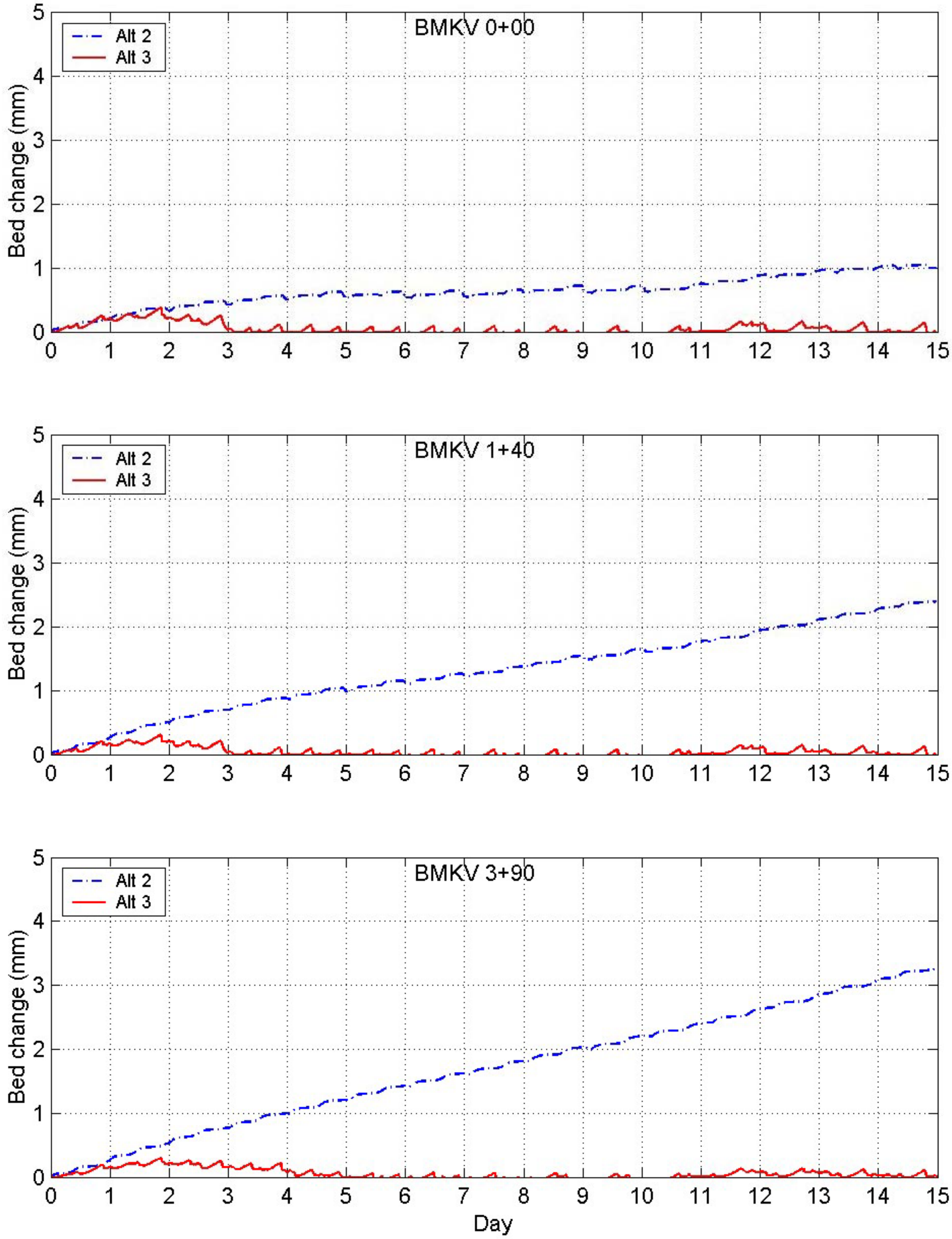


Figure A-63. Predicted Bed Changes: BMK-V 8+00 to 29+90

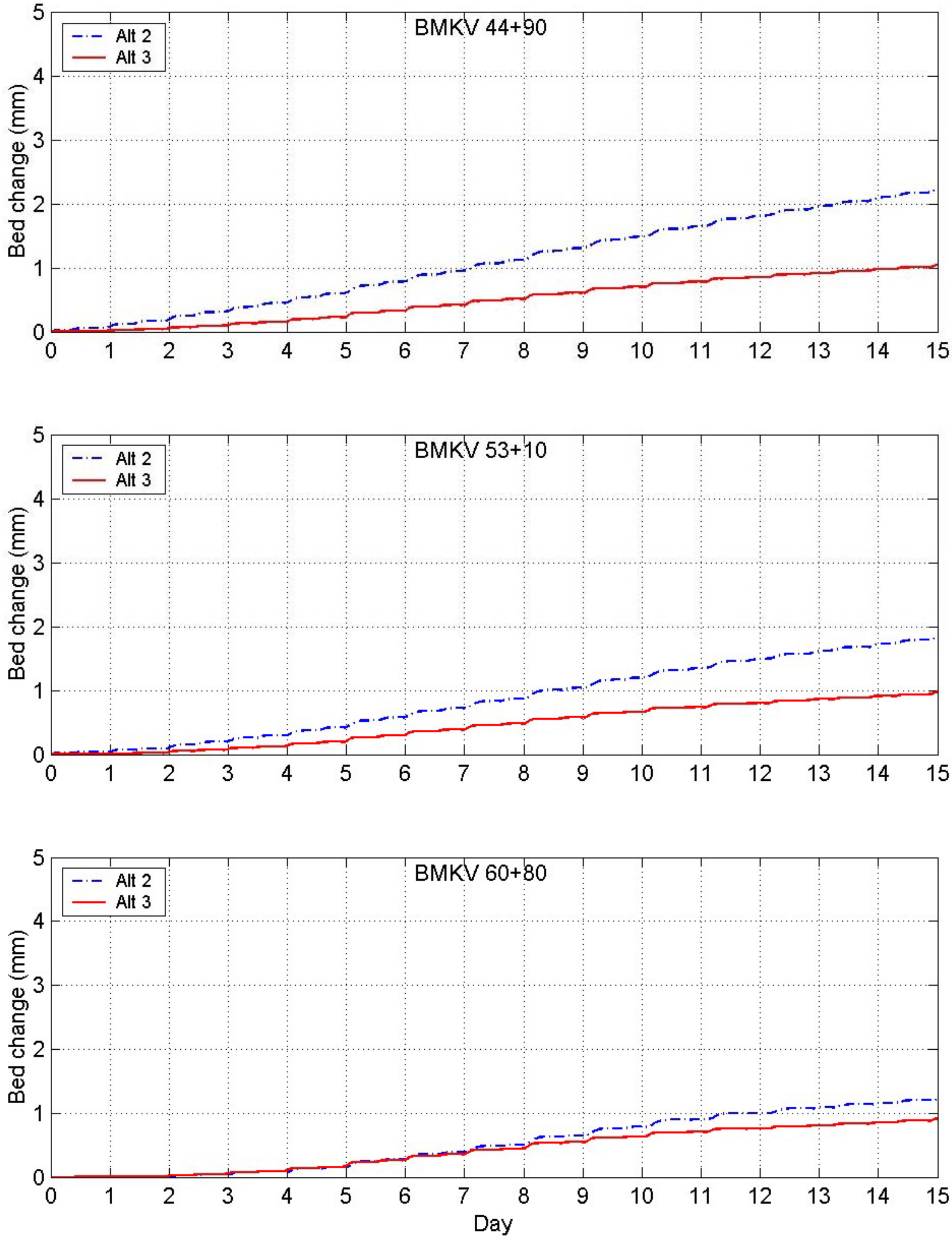


Figure A-64. Predicted Bed Changes: BMK-V 44+00 to 60+80