Imhoff Creek Bank Stabilization
FEMA CLOMR Application

Norman, Oklahoma
August 2025

Prepared For:
City of Norman, Oklahoma

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INTRODUCTION

On behalf of the City of Norman, Oklahoma, the Design Consultant (Meshek & Associates, LLC and WSP, USA, formerly Wood/Amec Foster Wheeler) performed a detailed flood impact study for the proposed Imhoff Creek Bank Stabilization Project between Imhoff Road and State Highway 9. The purpose of this project is to address severe erosion along Imhoff Creek that has resulted in down cutting and bank widening, which threatens both the infrastructure and residences located along the stream. The project site is currently located within the floodway and floodplain fringe of Imhoff Creek as shown on the Cleveland County, OK Flood Insurance Rate Maps (FIRMs) 40027C0290H dated September 26, 2008, and 40027C0280J dated January 15, 2021. Local, state, and federal regulations require a floodplain impact study showing that the 1% annual chance water surface elevations are not impacted and that the proposed changes meet a “No-Rise” condition.

The baseline for this project comes from the FEMA Effective model for Imhoff Creek, a HEC-2 model created in 1997. As part of the study phase of this project completed by the Design Consultant in 2017, new hydrology and hydraulics were developed to create a preliminary Corrected Effective model using HEC-HMS Version 4.0 and HEC-RAS Version 4.1.0. The terrain data consist of 1-foot 2007 contours with 2015 survey data incorporated in the project area. For the detailed methodology used to develop the preliminary Corrected Effective, see Attachment 1: Lower Imhoff Creek Hydraulic & Hydrologic Study Project Report. In the present phase of the project, the 2017 preliminary Corrected Effective model has been updated to HEC-RAS Version 6.5, and the terrain was updated with 2-foot 1978 contours in the project area to create a Corrected Effective model that has a channel profile closer to that of the time when the Effective modeling was done, compared to the 2015 survey data that has eroded considerably since the Effective date. To create the preliminary Pre-Project (Existing) Conditions model, the terrain was updated in the project area with 2021 survey data. There was an emergency repair to the Imhoff Road bridge during the project, which was included in the modeling as the final Pre-Project (Existing) Conditions model.

The Post-Project (Proposed) Conditions model scenario represents a post-construction analysis which assumes the improvements are constructed per the plans. The Proposed Conditions model was developed by modifying a copy of the Existing Conditions model with the recommended improvements. It is then used to compute the changes to the water surface elevations which would result from the proposed stream embankment improvements. The following section details the methods used to perform this floodplain impact study. Below, Figure 1 shows the area of the project, along Imhoff Creek between Imhoff Road and Highway 9.

Figure 1: Imhoff Creek Project Reach

EFFECTIVE MODELING

To determine the impacts of the proposed streambank stabilization improvements along Imhoff Creek, the Design Consultant referenced the March 2024 Effective Cleveland County FEMA FIS report and the associated models. The current FEMA Effective floodplains were developed using a steady-state HEC-2 model for Imhoff Creek completed in 1997. Peak discharges from a HEC-1 model developed in 1996 were input into the HEC-2 model and used to compute the 1% annual chance water surface elevations (WSE). A digital version of the Effective HEC-2 model for Imhoff Creek was not available, and the HEC-2 results were provided in PDF format, therefore a Duplicate Effective model was not necessary. Below, Figure 2 shows the Effective regulatory floodplain and floodway for Imhoff Creek (FEMA, 2024).

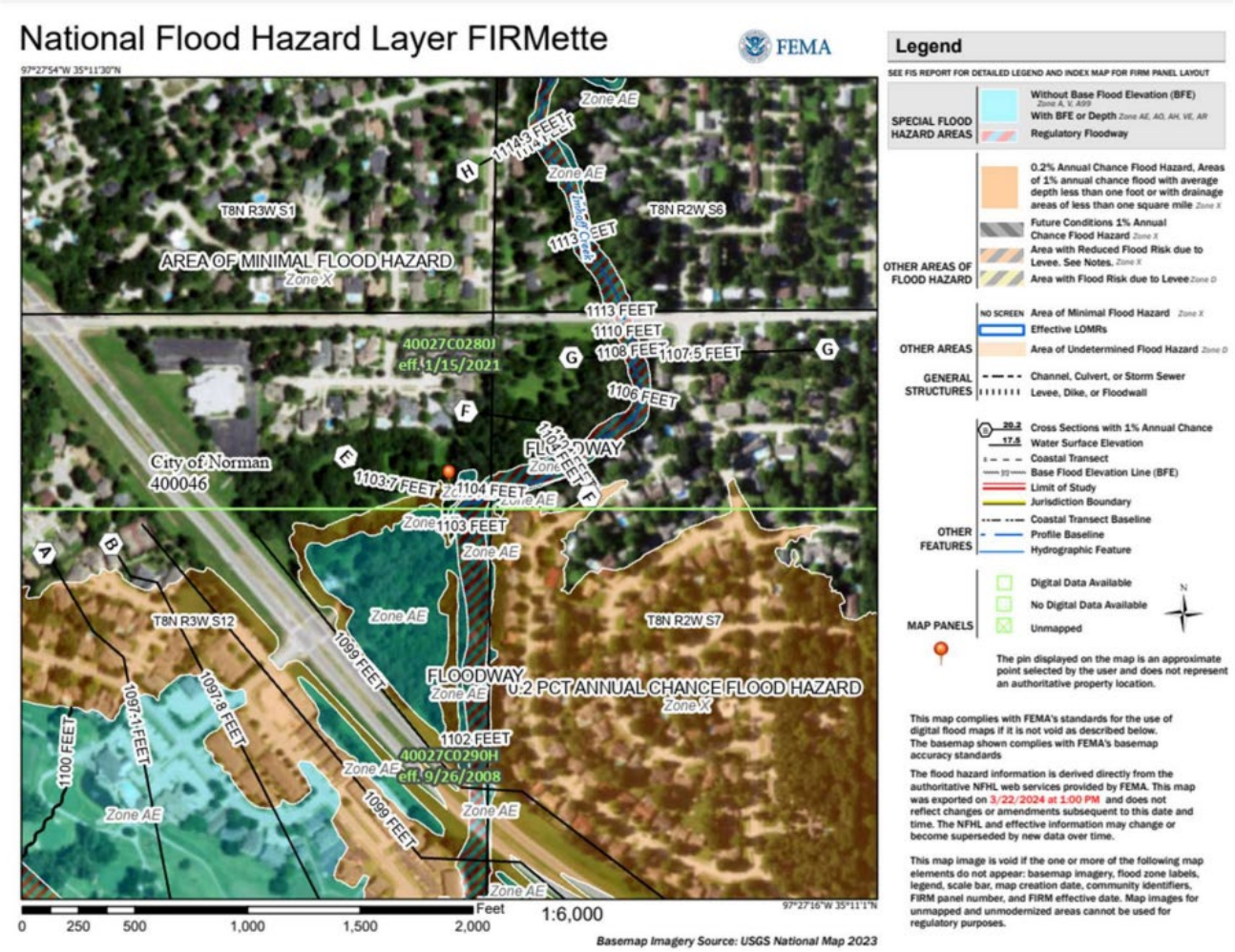

Figure 2: FIRMette for Imhoff Creek

CORRECTED EFFECTIVE AND PRE-PROJECT (EXISTING) CONDITIONS MODELING

HYDROLOGY

The Design Consultant created a rainfall runoff model using HEC-HMS Version 4.0 to generate subbasin runoff hydrographs for the 50%, 20%, 10%, 4%, 2%, 1%, 1%+ and 0.2% chance 24-hr SCS Type II rainfall events. The runoff infiltration was calculated using the NRCS Curve Number methodology based on land use, hydrologic soil group, and Antecedent Moisture Condition Type II. The hydrographs were routed and combined along the studied streams to produce the peak discharges. The resulting hydrographs were used as inflows to Imhoff Creek for the unsteady-state HEC-RAS model, which then routed the flow hydrographs along the channel. For a detailed discussion of the hydrologic methodology, see Attachment 1: Lower Imhoff Creek Hydraulic & Hydrologic Study Project Report.

HYDRAULICS

The Design Consultant created a preliminary Corrected Effective hydraulic model for Imhoff Creek using unsteady-state HEC-RAS Version 4.1.0 during the study phase of this project to compare and evaluate design alternatives. Cross sections were placed using topography and standard guidance for spacing, and structure geometries were taken from past HEC models as well as field measurements, sketches and photographs. The terrain consisted of 2007 1-foot contours with 2015 survey incorporated in the area of interest (shown in Figure 3). Manning's "n" values were assigned based on aerial photography and field investigations and standard contraction and expansion coefficients of 0.1 and 0.3, or 0.3 and 0.5 near structures were used. A normal depth downstream boundary condition was applied.

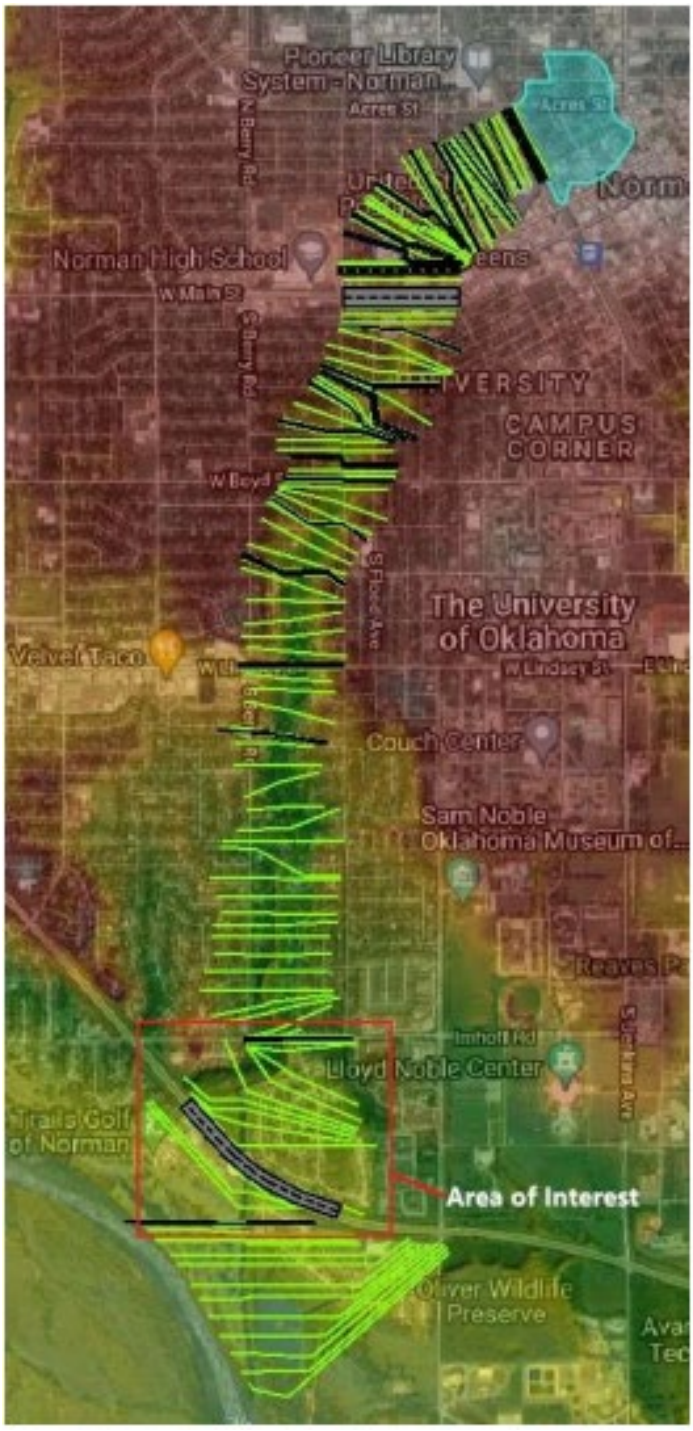

Figure 3: Model Extents and Area of Interest

The preliminary Corrected Effective model was updated to HEC-RAS version 6.5, and 2-foot contours from 1978 were incorporated into the model terrain in the area of interest. It was decided to use older terrain data for the Corrected Effective so that the channel profile would be more similar to that of the Effective modeling than the 2015 survey that was originally in the model. The Design Consultant and the City of Norman agreed to use the Corrected Effective as the basis to evaluate rise against, as it is expected that the project will cause some rise compared to the current Existing Conditions due to the nature of the bank restoration where fill is added to the floodway, and it is expected that there will be rise compared to the Effective BFEs due to the updated modeling techniques. To create the Pre-Project (Existing) Conditions model, LiDAR (Light Detection and Ranging) elevation data including the most recent 2021 survey data was incorporated into the area of interest. Figure 4 shows a comparison of the streambed profile for the 1978 terrain, the 2015 terrain, and the 2021 terrain. Additional cross sections were added near the proposed improvement area to increase the model accuracy at the specific project area to be analyzed.

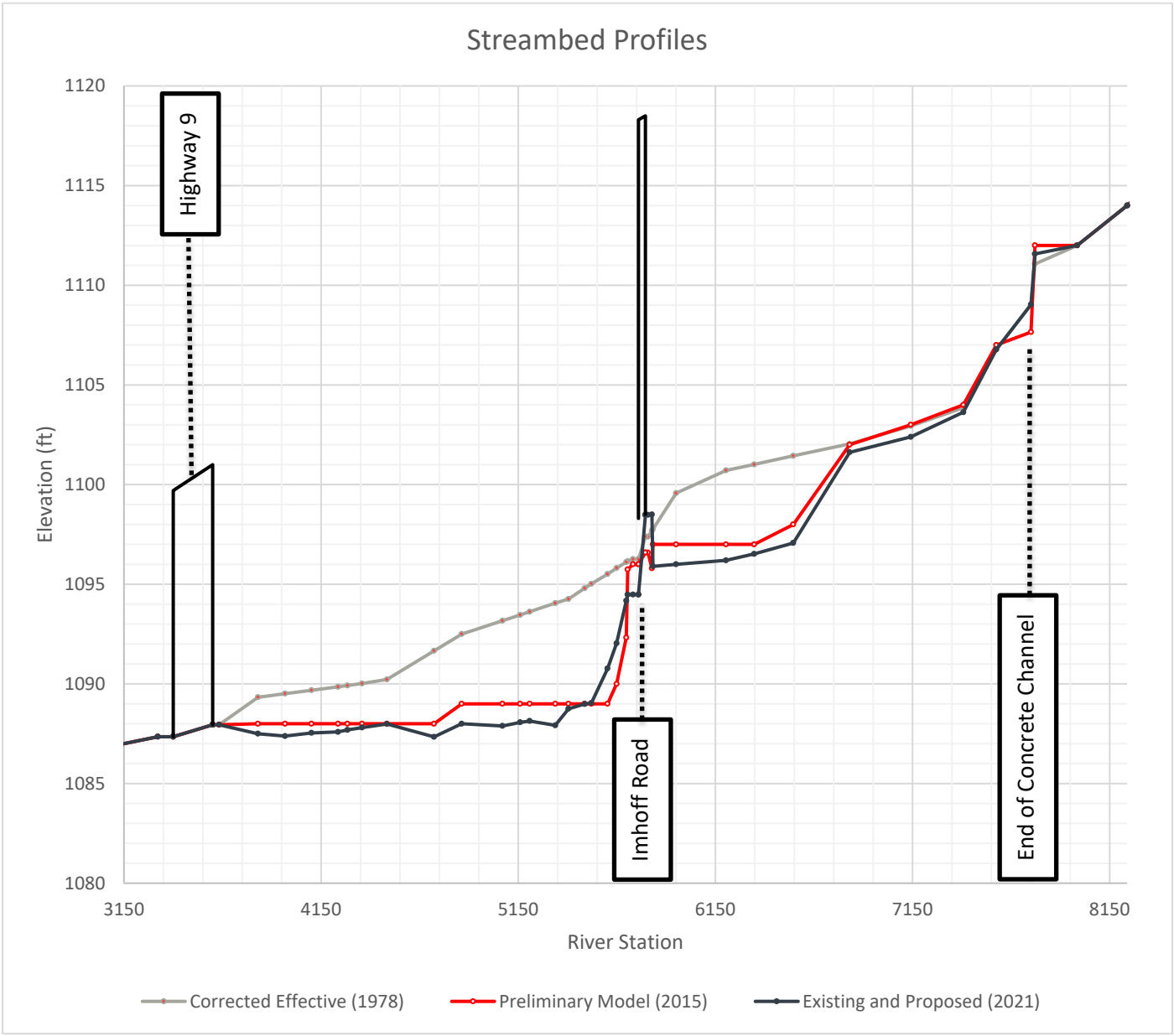

Figure 4: Streambed Profile Comparison

The Imhoff Road bridge located at the upstream end of the area of interest was inspected in October of 2019 by Oklahoma Department of Transportation (ODOT) and rated scour critical. In September of 2021 the southeast wingwall failed as shown in Figure 5 below. An emergency repair was constructed, replacing all four wingwalls and adding new aprons upstream and downstream of the bridge. The structure and its surrounding cross sections were updated to reflect the new construction, creating a new “Emergency Repair” Pre-Project (Existing) Conditions for the design alternatives to be compared to. All comparisons were made for the 1% annual chance storm event.

Figure 5: Failure of Wingwall on Imhoff Rd Bridge

PROPOSED CONDITIONS MODELING

Imhoff Creek is a small urban watershed with approximately 4 square miles of contributing drainage area located within the City of Norman, Oklahoma. Much of the open channel system is concrete or articulated block lined improved channel. During storm events the excess runoff quickly accumulates causing rapid rising and receding flooding events that can be highly turbulent and very erosive to unprotected channel areas. Over the years the channel has developed numerous areas in which exposed vertical banks are created by toe cutting from the channel or from vegetative debris that creates temporary blocks in isolated locations in the channel thus creating erosive tendencies opposite or just downstream of the blockage areas. In some instances, erosion has caused vertical embankments to migrate, impacting existing property owners’ lawns and hazardously approaching existing property structures and other critical infrastructure. If no mitigating action is taken, and the historical rate of lateral erosion of the left bank in the area of interest is maintained, the erosion will threaten two houses and five sewer lines in the next ten years.

The proposed improvements are focused between river station (RS) 5698 and 4284, and include the installation of two sections of stepped reinforced soil slope (RSS) walls on the east bank from RS 5698 to RS 4863, and RS 4358 to RS 4284. The RSS walls consist of a wire formed grid filled with reinforced soil fill, ODOT Type “D” aggregate, and topped with native soil. The walls are designed to allow for a natural vegetated face above the ordinary high water elevation to provide additional stabilization. The proposed improvements also include two sections of rock toe revetment on the west bank the protect the toe and prevent further migration due to washout. In addition to the RSS walls and rock toe revetment, two sheet pile reinforced cross vanes are proposed to be installed downstream of Imhoff Road to reduce flow velocities coming out of the bridge and lessen erosion potential. Figure 6 and Figure 7 show the 3D model and simplified cross section view of the RSS wall, and Figure 8, Figure 9, and Figure 10 show the layout, profile, and cross section view of the cross vanes. For detailed plans of each structure, see Appendix 3 – Proposed Plans.

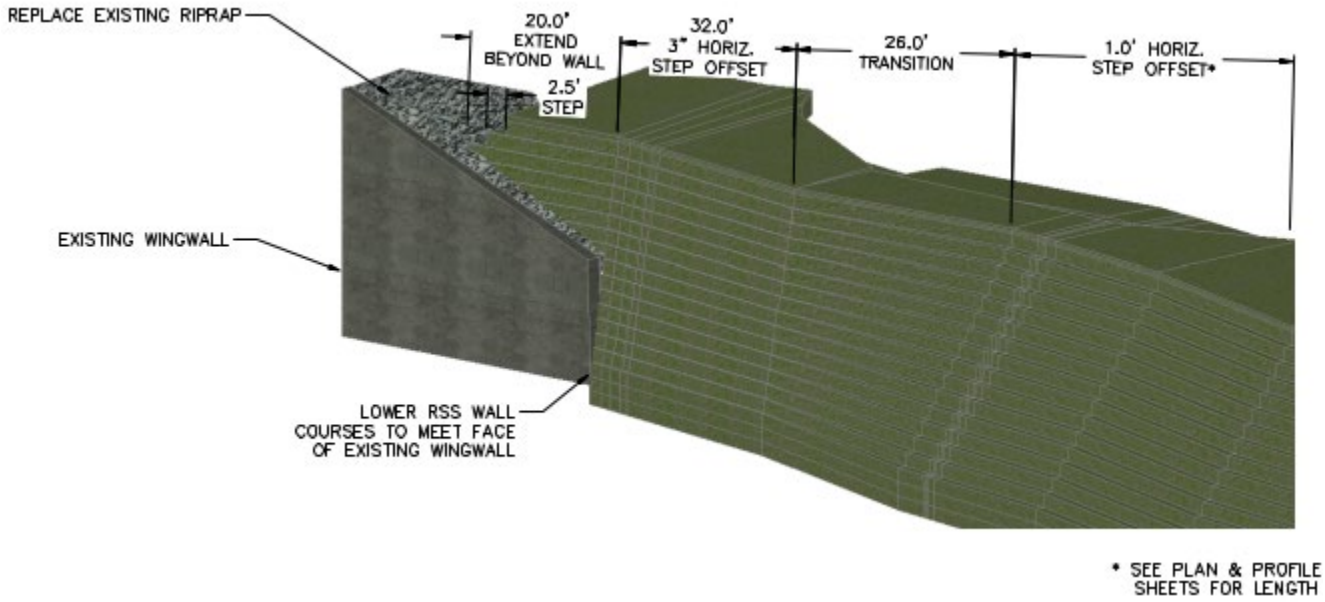

Figure 6: RSS Wall System 3D Model

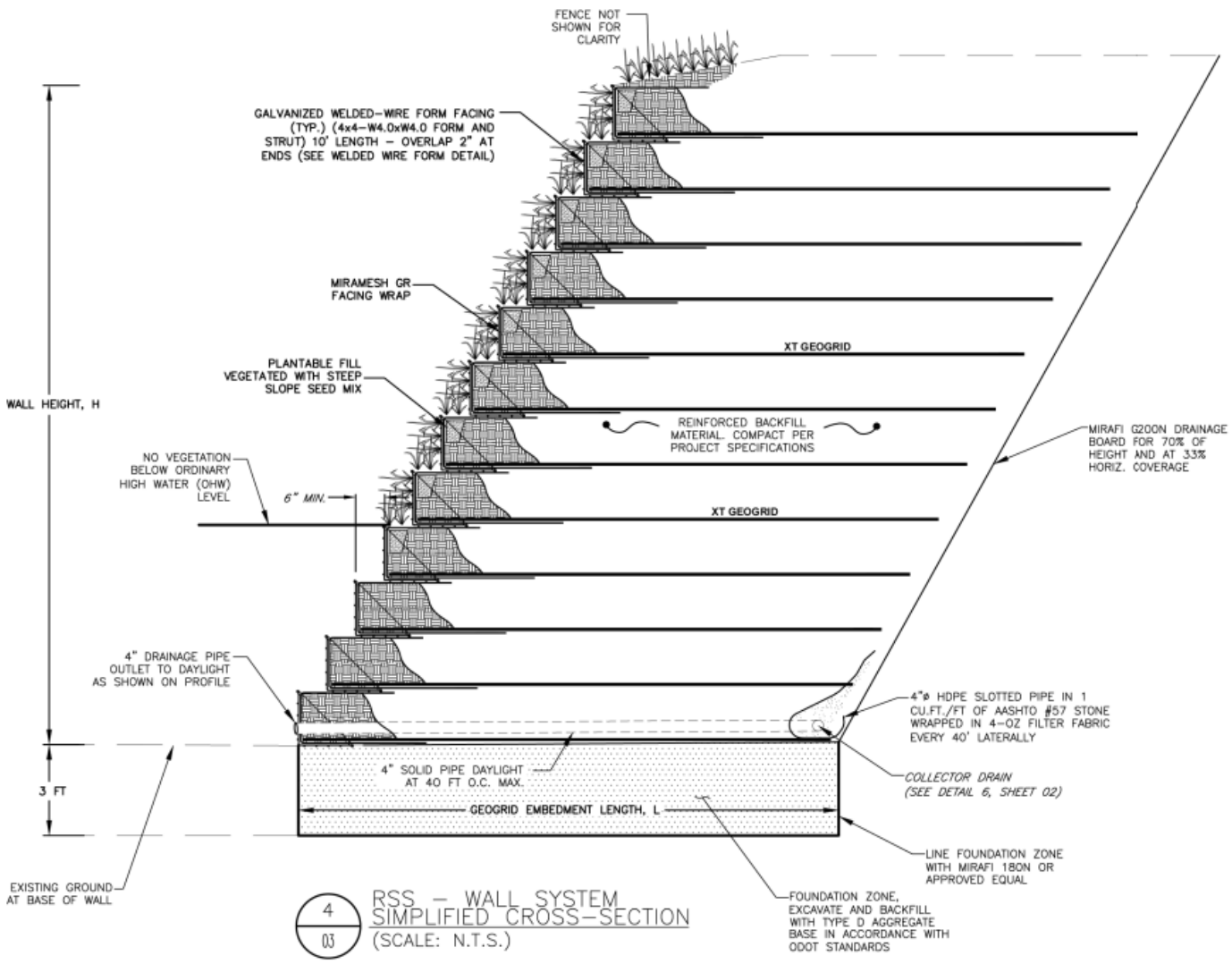

Figure 7: RSS Wall System Simplified Cross Section

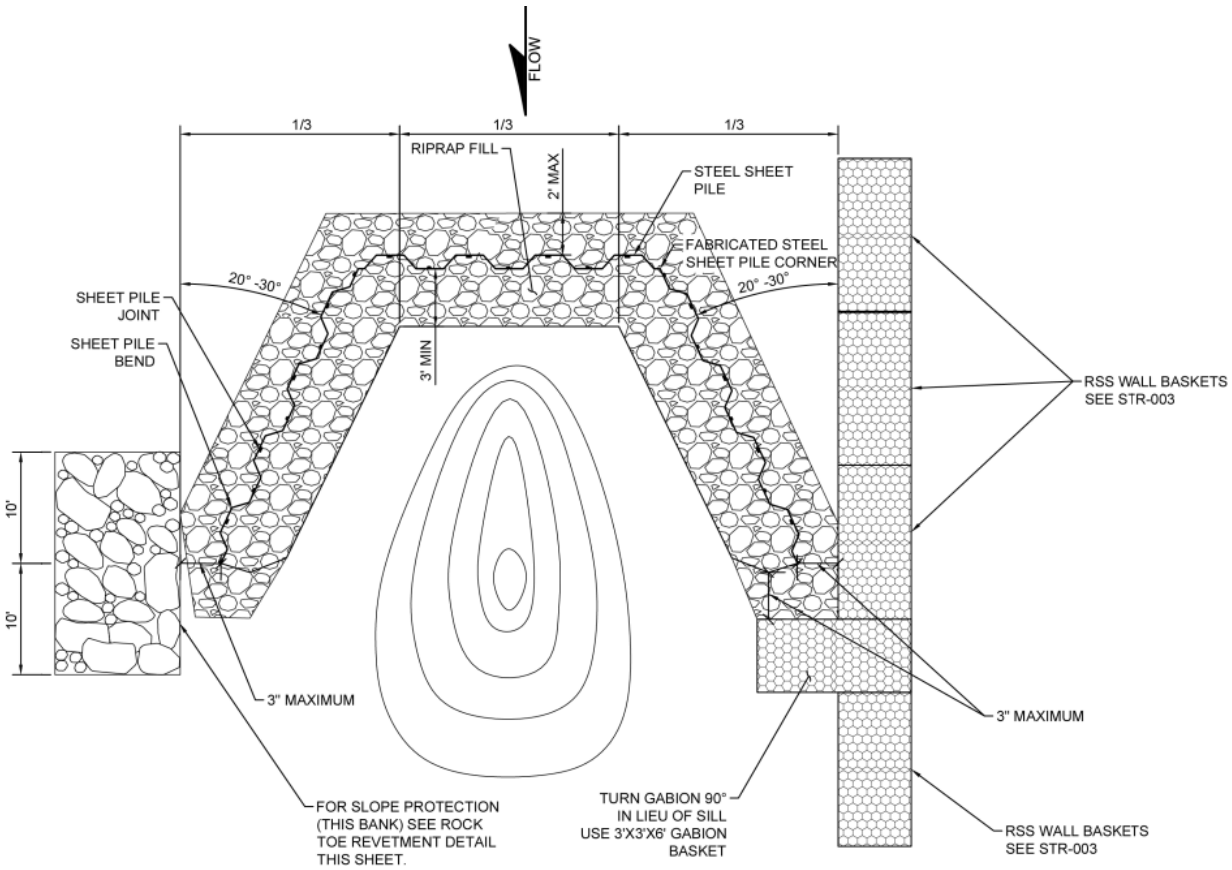

Figure 8: Sheet Pile Cross Vane Layout

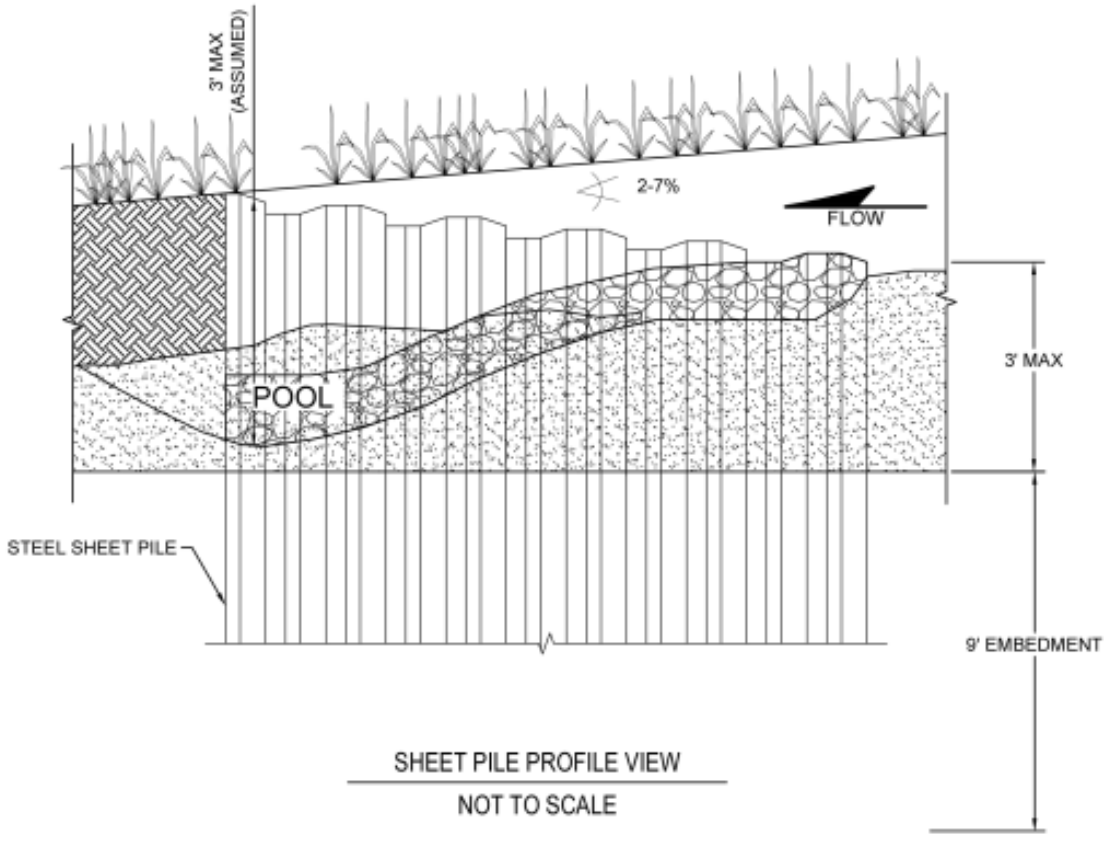

Figure 9: Sheet Pile Cross Vane Profile

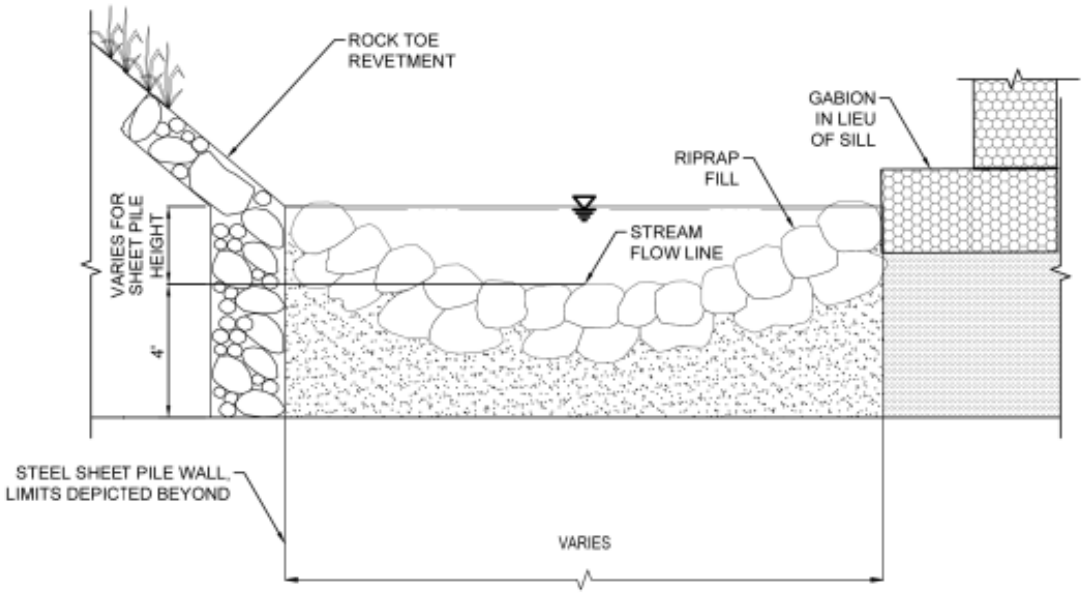

Figure 10: Sheet Pile Cross Vane Cross Section

The proposed RSS walls were represented in the model by altering the station-elevation data on the relevant cross sections according to the plans. The two cross vanes were modeled as inline structures at RS 5390 and 5145. Figure 12 shows the Existing and Proposed cross sections at RS 5405.

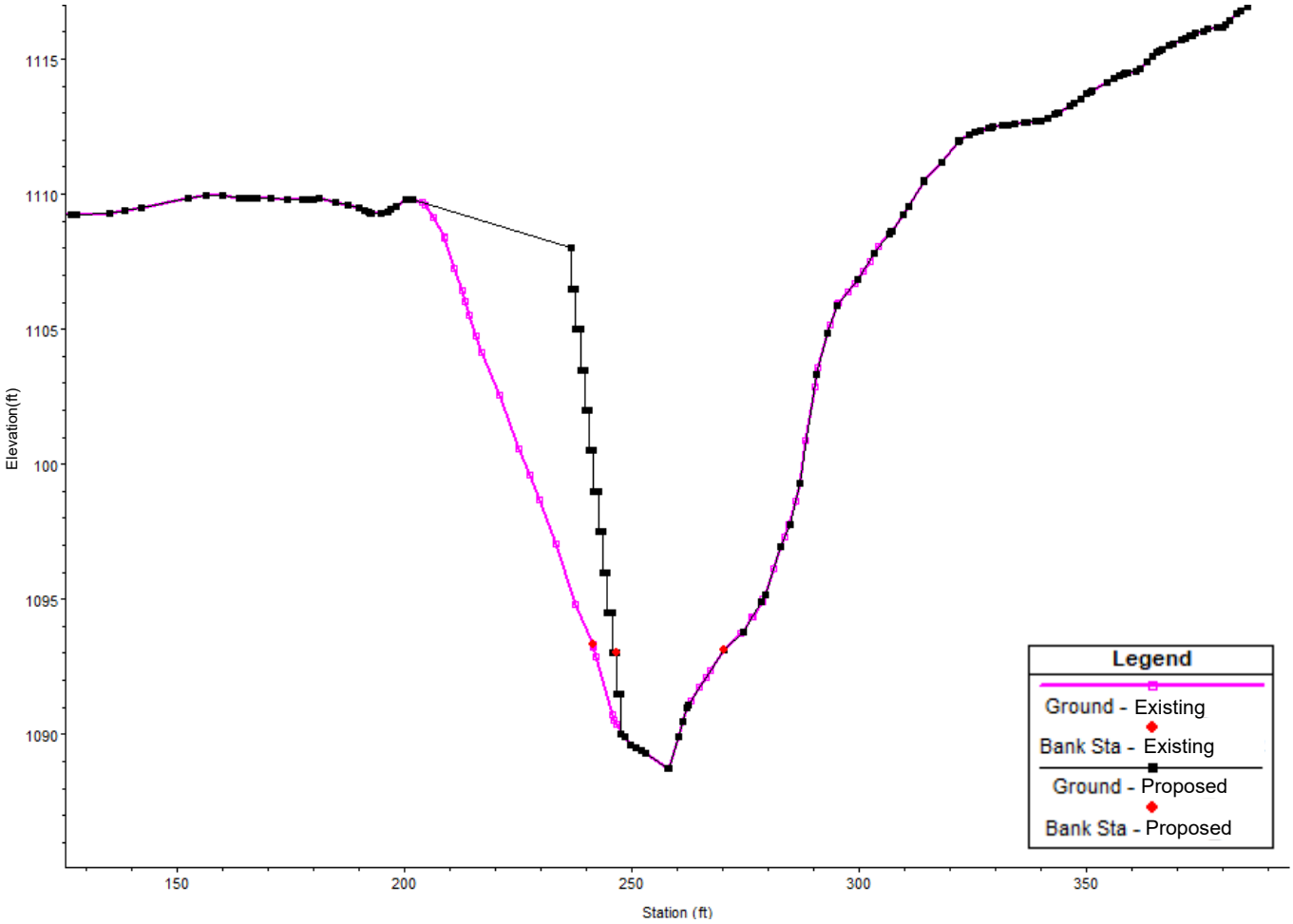

Figure 11: River Station 5405 Existing and Proposed Cross Section

RISE EVALUATION

Table 1 below shows the 1% annual chance water surface elevation comparison between the Effective, Corrected Effective, and Proposed Conditions for Imhoff Creek. The terrain updates between the Corrected Effective and Existing Conditions are between the end of the concrete channel (RS 7771) and Highway 9 (RS 3633), with the proposed improvements between RS 5698 and RS 4284.

The difference between the Proposed Conditions and the Effective shows rise and drop throughout the model, but the difference between the Corrected Effective and the Effective shows rise and drop throughout as well, showing that the rise is due to the updated modeling rather than the proposed project. The rise between the Existing Conditions and Proposed conditions in the project area directly downstream of Imhoff Road is expected due to the placement of fill in the floodway to restore and stabilize the east bank. Rather than comparing the Proposed to the Existing Conditions to evaluate rise, it was decided that due to the erosion between the date of the Effective mapping and today, it is more appropriate to use the Corrected Effective with the higher streambed profile as the basis against which to evaluate rise.

Table 1 - 1% Annual Chance Water Surface Elevation Comparison for Imhoff Creek

Cross Section River Station	Effective BFE*	Corrected Effective	Proposed	Difference Between Corrected Effective and Effective	Difference Between Proposed and Corrected Effective	Difference Between Proposed and Effective
20354 AG	-	1173.18	1173.17		-0.01	
20331	-	1173.13	1173.13		0	
20271	1171	1172.5	1172.5	1.5	0	1.5
20263	-	1172.46	1172.46		0	
20188	-	1167.64	1167.66		0.02	
20088 AF	-	1167.46	1167.46		0	
20001	1169	1167.3	1167.3	-1.7	0	-1.7
19932	-	1167.13	1167.13		0	
19909	-	1166.08	1166.08		0	
19827 AE	1167	1165.9	1165.9	-1.1	0	-1.1
19736	1166	1165.78	1165.78	-0.22	0	-0.22
19700	-	1165.63	1165.63		0	
19662 AD	-	1165.65	1165.65		0	
19628	-	1165.52	1165.52		0	
19608	-	1164.98	1164.98		0	
19574 AC	-	1164.9	1164.9		0	
19550	-	1164.9	1164.9		0	
19532	-	1164.75	1164.75		0	
19483 AB	1165	1164.77	1164.77	-0.23	0	-0.23
19442	-	1164.76	1164.76		0	
19415	-	1164.42	1164.42		0	
19354 AA	-	1164.12	1164.12		0	
19275	1164	1163.95	1163.95	-0.05	0	-0.05
19227	-	1163.46	1163.46		0	
19175 Z	-	1163.4	1163.4		0	
19033	-	1163.07	1163.07		0	
18984	-	1162.72	1162.72		0	
18901 Y	-	1162.59	1162.58		-0.01	
18825	-	1162.31	1162.31		0	
18757	1163	1161.86	1161.86	-1.14	0	-1.14
18688 X	-	1161.89	1161.89		0	
18606	-	1161.63	1161.63		0	
18530	-	1160.38	1160.39		0.01	
18467	-	1160.59	1160.6		0.01	

Cross Section River Station	Effective BFE*	Corrected Effective	Proposed	Difference Between Corrected Effective and Effective	Difference Between Proposed and Corrected Effective	Difference Between Proposed and Effective
18364	1160	1160.2	1160.2	0.2	0	0.2
18309 W	-	1160.05	1160.05		0	
18250	-	1159.67	1159.67		0	
18133	-	1159.46	1159.46		0	
18097	1159	1159.43	1159.43	0.43	0	0.43
18030	-	1158.47	1158.47		0	
18000 V	-	1158.65	1158.65		0	
17909	-	1158.72	1158.72		0	
17846	1158	1158.74	1158.74	0.74	0	0.74
17772 U	1158	1158.73	1158.73	0.73	0	0.73
17719	-	1158.73	1158.73		0	
17608	-	1158.36	1158.36		0	
17525 T	-	1158.39	1158.39		0	
17419	1157	1158.2	1158.2	1.2	0	1.2
17131	1156	1153.83	1153.83	-2.17	0	-2.17
17029 S	1155	1153.47	1153.47	-1.53	0	-1.53
16922	-	1153.19	1153.19		0	
16837	1153	1153.04	1153.04	0.04	0	0.04
16803	-	1153.03	1153.03		0	
16600	-	1153.06	1153.05		-0.01	
16380 R	1153	1152.89	1152.89	-0.11	0	-0.11
16173	-	1151.69	1151.69		0	
16022	1152	1151.32	1151.32	-0.68	0	-0.68
15954	1151	1150.96	1150.96	-0.04	0	-0.04
15806 Q	-	1150.96	1150.97		0.01	
15579	-	1150.34	1150.41		0.07	
15490	1151	1150.61	1150.61	-0.39	0	-0.39
15363 P	-	1150.53	1150.54		0.01	
15284	-	1150.51	1150.52		0.01	
15261	-	1150.49	1150.5		0.01	
15173 O	-	1150.39	1150.4		0.01	
15082	-	1150.38	1150.38		0	
15031	1151	1150.18	1150.18	-0.82	0	-0.82
14870	-	1150.06	1150.06		0	
14737 N	-	1149.95	1149.95		0	
14580	1150	1149.81	1149.81	-0.19	0	-0.19
14535	-	1149.34	1149.35		0.01	
14421	-	1148.98	1148.98		0	
14351 M	-	1148.92	1148.92		0	
14322	1149	1148.78	1148.79	-0.22	0.01	-0.21
14273	-	1147.62	1147.62		0	
14171	1148	1147.65	1147.65	-0.35	0	-0.35
13976 L	1148	1147.18	1147.18	-0.82	0	-0.82
13745	1147	1146.87	1146.87	-0.13	0	-0.13
13645	1146	1146.8	1146.81	0.8	0.01	0.81
13615	-	1146.26	1146.26		0	
13470	-	1146.19	1146.19		0	
13254 K	-	1146.02	1146.02		0	
13023	-	1145.79	1145.79		0	
12899	1146	1145.68	1145.68	-0.32	0	-0.32
12830	-	1142.85	1142.85		0	
12676	1143	1142.84	1142.84	-0.16	0	-0.16
12414	-	1142.37	1142.37		0	

Cross Section River Station	Effective BFE*	Corrected Effective	Proposed	Difference Between Corrected Effective and Effective	Difference Between Proposed and Corrected Effective	Difference Between Proposed and Effective
12140 J	1142	1141.66	1141.66	-0.34	0	-0.34
11903	-	1141.28	1141.28		0	
11671	-	1141.48	1141.48		0	
11495	1141	1141.25	1141.25	0.25	0	0.25
11419	1139	1141.37	1141.37	2.37	0	2.37
11280	1139	1141.25	1141.25	2.25	0	2.25
11119 I	1137	1141.26	1141.26	4.26	0	4.26
10821	1137	1140.78	1140.78	3.78	0	3.78
10462	1136	1140.53	1140.53	4.53	0	4.53
10428	-	1135.84	1135.84		0	
10312 H	1136	1135.04	1135.04	-0.96	0	-0.96
9995	1135	1133.7	1133.7	-1.3	0	-1.3
9742	-	1132.77	1132.77		0	
9391	1134	1131.43	1131.43	-2.57	0	-2.57
9081	1133	1130.34	1130.34	-2.66	0	-2.66
8864 G	-	1129.17	1129.17		0	
8472	1129	1126.12	1126.12		0	
8239	1126	1124.44	1124.44		0	
7985	1125	1122.7	1122.7	-2.3	0	-2.3
7751	1123	1121.72	1121.71		-0.01	
7771	-	1119.3	1119.08		-0.22	
7575 F	1115	1118.31	1117.97	3.31	-0.34	2.97
7408	-	1117.53	1116.78		-0.75	
7141	1114	1116.79	1115.31	2.79	-1.48	1.31
6831	-	1115.41	1113.81		-1.6	
6545	1114	1114.91	1113.74	0.91	-1.17	-0.26
6347 E	-	1114.12	1112.94		-1.18	
6204	1113	1113.28	1112.59	0.28	-0.69	-0.41
5951	-	1112.27	1112.36		0.09	
5833	-	1112.26	1112.22		-0.04	
5828	-	1112.23	1111.83		-0.4	
5808	1113	1112.07	1112.36	-0.93	0.29	-0.64
5721	1110	1106.86	1106.28	-3.14	-0.58	-3.72
5705	-	1106.84	1106.2		-0.64	
5698	-	1106.81	1106.11		-0.7	
5649	1108	1106.44	1105.59	-1.56	-0.85	-2.41
5603 D	-	1106.4	1106.22		-0.18	
5521	-	1106.25	1105.76		-0.49	
5487	1106	1106.17	1104.98	0.17	-1.19	-1.02
5405	-	1105.66	1104.74		-0.92	
5338	-	1105.44	1104.74		-0.7	
5208	-	1105.21	1103.9		-1.31	
5160	1104	1105	1104.14	1	-0.86	0.14
5070	-	1104.67	1103.44		-1.23	
4863	1104	1103.61	1102.55	-0.39	-1.06	-1.45
4723	1103	1103.17	1102.68	0.17	-0.49	-0.32
4484	-	1103.26	1102.79		-0.47	
4358	-	1103	1102.74		-0.26	
4284	-	1102.72	1102.45		-0.27	
4236	-	1102.7	1102.16		-0.54	
4101	-	1102.54	1102.23		-0.31	
3967	-	1102.31	1102.09		-0.22	
3830	-	1102	1101.97		-0.03	

Cross Section River Station	Effective BFE*	Corrected Effective	Proposed	Difference Between Corrected Effective and Effective	Difference Between Proposed and Corrected Effective	Difference Between Proposed and Effective
3633	1102	1102.08	1101.88	0.08	-0.2	-0.12
3322	-	1099.73	1099.57		-0.16	
3149 B	1100	1098.97	1099.29	-1.03	0.32	-0.71
2927	1099	1098.54	1098.45	-0.46	-0.09	-0.55
2706	1098	1098	1097.69	0	-0.31	-0.31
2672	-	1096.97	1097.01		0.04	
2544	-	1096.26	1096.31		0.05	
2446 A	-	1095.92	1095.95		0.03	
2410	-	1095.89	1095.93		0.04	
2325	-	1095.84	1095.87		0.03	
2245	-	1095.76	1095.75		-0.01	
2094	-	1095.61	1095.61		0	
1798	-	1095.44	1095.44		0	
1611	-	1095.36	1095.34		-0.02	
1336	-	1095.15	1095.14		-0.01	
1048	-	1094.61	1094.6		-0.01	
815	-	1094.54	1094.53		-0.01	
548	-	1094.31	1094.25		-0.06	
300	-	1094.15	1094.09		-0.06	

*Effective BFEs were reported at the closest cross section available

The cross sections with slight rise between the Proposed and the Corrected Effective were determined to be due to model instabilities rather than project effects. The model has many cross sections and structures and is sensitive to instabilities. The rise in the upper reaches is clearly due to instabilities as there are no differences between any modeling parameters upstream of river station 7771. The rise just upstream of Imhoff Road (RS 5951 and 5808) is due to an unstable jump in the proposed conditions, as well as the emergency repair which restored the original apron at a higher elevation than the Corrected Effective streambed elevation at that location. The rise between river stations 3149 and 2325 is also attributed to instability, as the structures at RS 3498 and RS 2688 are highly sensitive with complex ineffective areas through the reach. The flow hydrograph for the structure at RS 2688 shows the instabilities in the area through the peak.

CLOMR RISE EXEMPTION

FEMA guidance for a CLOMR request requires determination of whether the following situations occur:

- Projects that will have construction within the regulatory floodway that causes the BFEs to increase (more than 0.00 feet), or
- Projects that will have construction within the floodplain of streams that have a detailed effective study, but for which a regulatory floodway has not been established, which causes the BFEs to increase more than 1.0 foot (or any other more stringent requirement set by the community or State).

If either of these two situations occurs, then the conditions in the NFIP regulations at 44 CFR §65.12 must be met. The conditions of 44 CFR §65.12 include:

- An evaluation of alternatives that would not result in a BFE increase above that permitted, demonstrating why these alternatives are not feasible;
- Documentation of individual legal notice to all affected property owners within and outside of the community, explaining the impact of the proposed action on their property;
- Concurrence of the Chief Executive Officers of any communities affected by the proposed actions; and
- Certification that no structures are in areas that would be affected by the increased BFE.

Fill is proposed to be placed in the floodway due to the nature of bank restoration. Multiple designs were evaluated in the 2017 study to determine impact, rise and other factors. The final design was chosen to as a balance between protecting the bank and channel from further erosion and minimizing impact on the adjacent properties. It is the Design Consultant's conclusion that the reported results represent the best possible outcome for this proposed bank stabilization.

The map revision would add one structure to the floodplain due to the increased BFE and the updated terrain, but it would not be due to the project effects. The structure would be included in the Corrected Effective remap as well. The BFE of the Corrected Effective and Proposed Conditions is slightly higher than the Effective at the property location. The house was constructed between 1995 and 2003, so it is likely that the house was not present in the Effective mapping and the property had not yet been graded. In the 2007 contours, the property is flat graded at 1099 ft with the BFE also being 1099 towards the upstream end of the property. A remap of the Effective BFEs on updated terrain would likely also include the structure. The Corrected Effective and Proposed show an elevation of 1099.3 ft in the middle of the property. If allowed, the house could be removed from the remap manually due to shallow flooding, or the remap could possibly tie in within the Highway 9 structure and not include any of the area between Highway 9 and the confluence with the Canadian River.

The concurrence of the Chief Executive Officer is noted on Form 1 in Appendix 4 – Imhoff Creek CLOMR Application Forms, and the property owner notification letter is provided in Appendix 6 – Property Owner Notification.

FLOODPLAIN PLOTTING

For conventional 1D modeling, flood elevations are computed along a flooding source and the floodplains are linearly interpolated from cross-section to cross-section. The flood elevations for the small ditches, creeks and ponding areas beyond the 1-square-mile stream extents are not computed nor plotted, except as backwater, as they are considered to be localized flooding concerns.

The proposed 1% annual chance, 0.2% annual chance and floodway flood hazard areas are shown in Appendix 1 – Topographic Maps and Appendix 2 – Annotated FIRMS. The spatial data for the proposed floodplains, cross sections, and BFEs was provided in GIS format as an ArcGIS Pro map and associated shapefiles.

CONCLUSION

The proposed project improvement plans show a slight adverse impact to the water surface elevations or volume in the Proposed Conditions models compared to the Existing Conditions. This is a necessary result of constricting the channel to stabilize and protect the surrounding properties. There is no adverse impact compared to the Corrected Effective with an older streambed profile. It is the Design Consultant's conclusion that the proposed embankment stabilization will add zero additional structures to the 1% annual chance floodplain, though one would be added due to the remap and updated terrain data. Floodway data tables and profiles will be created for Imhoff Creek upon CLOMR approval. Documentation of ESA compliance can be found in Appendix 5 – ESA Compliance.

APPENDIX 1 – TOPOGRAPHIC MAPS

APPENDIX 2 – ANNOTATED FIRMS

APPENDIX 3 – PROPOSED PLANS

APPENDIX 4 – IMHOFF CREEK CLOMR APPLICATION FORMS

APPENDIX 5 – ESA COMPLIANCE

APPENDIX 6 – PROPERTY OWNER NOTIFICATION