

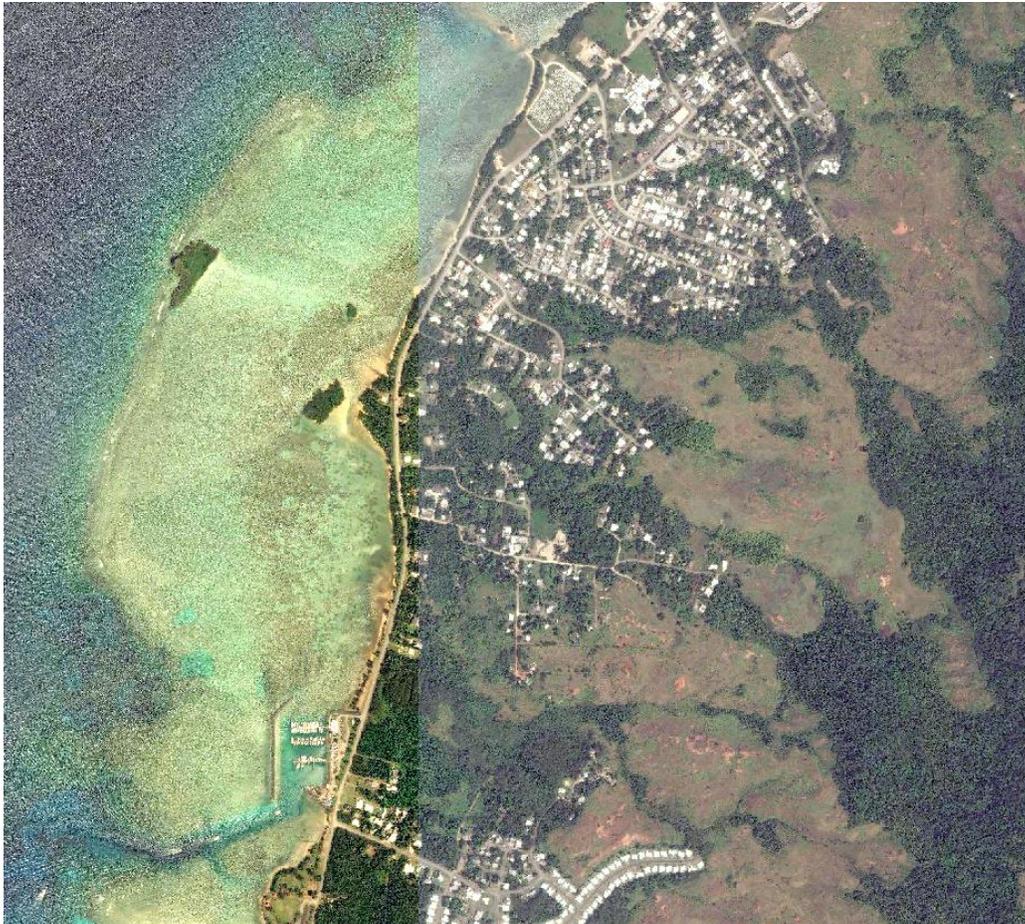


**US Army Corps  
of Engineers**®  
Honolulu District

**Finile Creek  
Agat Village  
Territory of Guam**

# **Finile Creek Flood Hazard Study**

## **Hydrologic and Hydraulic Analysis of Finile Creek and Agat Village**



### **Technical Memorandum**

**Prepared for: Government of Guam  
Prepared by: U.S. Army Corps of Engineers, Honolulu District  
31 October 2025**

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## ACRONYMS

Acronym	Description
%	percent
°C	Celsius
°F	Fahrenheit
1D	one dimensional
2D	two dimensional
A	area; drainage area
AEP	annual exceedance probability
BSP	Bureau of Statistics and Plans
C-CAP	Coastal Change Analysis Program
CN	curve number
D	depth; bank-full depth
DEM	digital elevation model
DPW	Department of Public Works
FCP	flood control project
FHWA	Federal Highway Administration
FPMS	Flood Plain Management Services
FRM	flood risk management
ft	feet
GCMP	Guam Coastal Management Program
GIS	geographical information systems
GUVD04	Guam Vertical Datum of 2004
HEC	Hydrologic Engineering Center
HMS	Hydrologic Modeling Software
IREI	Island Research & Education Initiative
JALBTCX	Joint Airborne LiDAR Bathymetry Technical Center of Expertise
km	kilometer
L	length; length of flow path
LiDAR	Light Detection and Ranging
M	Meter
mi	Miles
MHHW	mean higher high water
MLLW	mean lower low water
MSL	mean sea level
<i>n</i>	Manning's roughness coefficient
NAD83	North American Datum of 1983
NCDC	National Climatic Data Center
NCEI	National Centers for Environmental Information

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NEXRAD	Next-Generation Radar
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
NSE	Nash-Sutcliffe model efficiency
OCD	Office of Civil Defense
OHS	Office of Homeland Security
PFDS	Precipitation Frequency Data Server
R	storage coefficient
RAS	River Analysis System
$S_0$	mean channel slope
SSP	Statistical Software Package
$T_c$	Time of concentration
TR-55	Technical Release 55
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WERI	Water and Environmental Research Institute of the Pacific
yr	year

## **SECTION 1 - INTRODUCTION**

### **1.1 PURPOSE AND SCOPE**

This technical memorandum was written to support the Finile Creek Flood Hazard Study (Flood Risk Management). The purpose of this study is to evaluate the flood hazard in Finile Creek and Agat Village in Guam and make preliminary recommendations for flood mitigation. This study will include Finile Creek, Salinas River, Gaan River, and Auau Creek.

### **1.2 AUTHORITY**

This study is being funded by through the Interagency and International Services (IIS) program. It is fully funded by the Federal Emergency Management Agency's Building Resilient Infrastructure And Communities Grant.

### **1.3 PROJECT SPONSOR**

The project sponsor and partner agency for this project is the Government of Guam.

#### **1.3.1 Guam Bureau of Statistics and Plans**

The Government of Guam, Bureau of Statistics and Plans (BSP) is designated as the proponent of the study because of their broad coordination authorities and comprehensive planning mandates under their Guam Coastal Management Program (GCMP). Responsible for land and natural resource planning, BSP is often involved with issues concerning natural hazards that impact the daily lives of Guam's communities. A common issue faced by Guam residents and Government agencies is flooding. This project will be a comprehensive feasibility study to develop concept alternatives for flood mitigation in Finile Creek and its sub-watershed

### **1.4 LOCATION**

The study area is located on the western coast of Guam in the village of Agat, see Figure 1.

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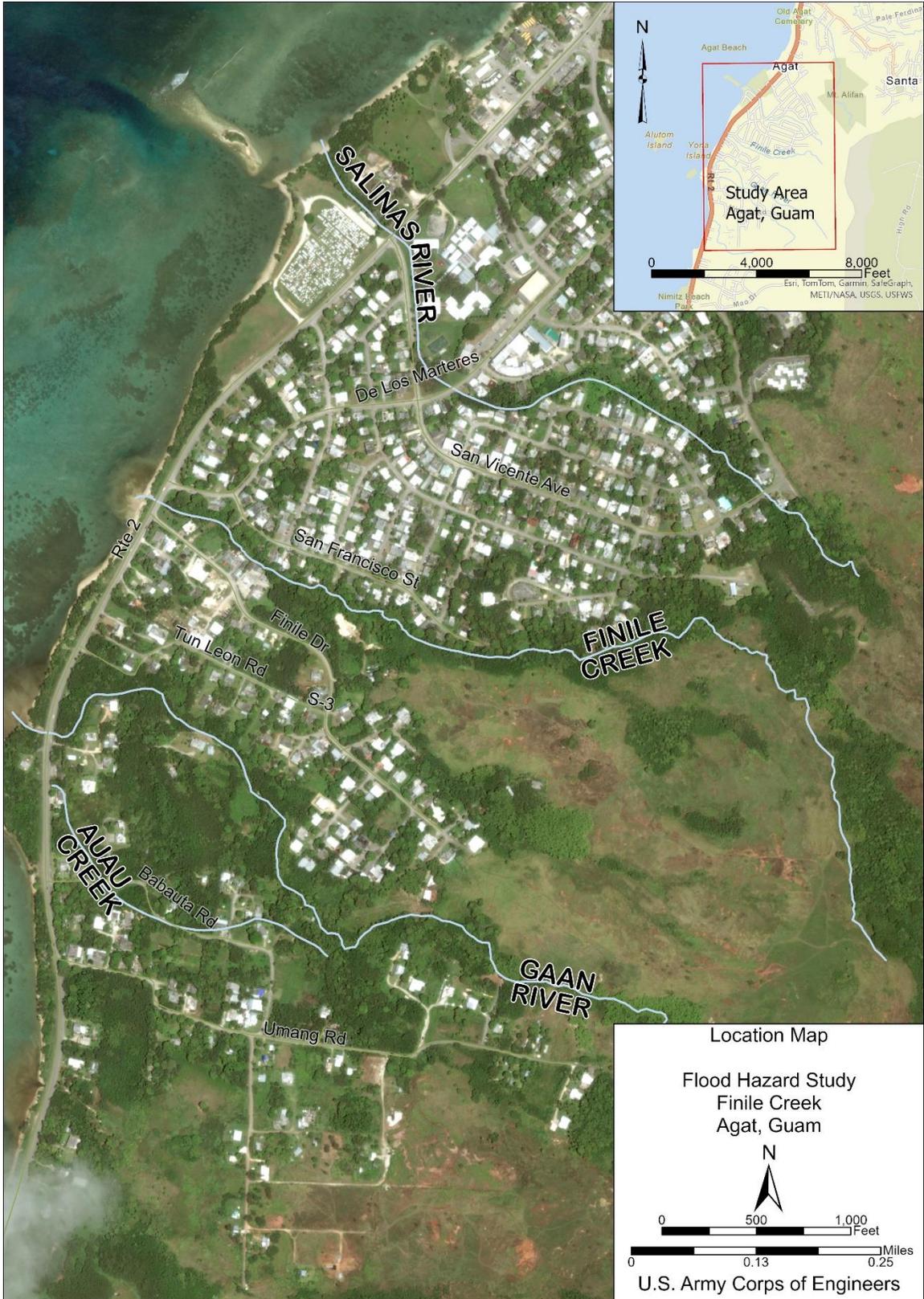


Figure 1 – Project Location Map

## **1.5 FLOOD PROBLEM**

The flooding problem in Finile Creek is systemic in that it is not only limited to the physical landscape, existing conditions/constraints, and development choices, but also impacted due to regulatory and data gaps in the area.

The south tributary of Finile Creek is not mapped in the Flood Insurance Rate Maps (FIRM), see Figure 2. FIRM is implemented by the National Flood Insurance Program (NFIP) managed by Federal Emergency Management Agency (FEMA). Unmapped areas may imply that dwellings in the area are not compliant to any floodplain management requirements and therefore exposes them to flood hazards.

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Figure 2 – FEMA FIRM clipping (Panel no. 0133D), Finile Creek Flood Hazard Study

## **SECTION 2 - BACKGROUND INFORMATION**

### **2.1 TOPOGRAPHY**

The drainage basin for the study area is about 2.6 square (sq) kilometers (km) [1.0 sq miles (mi)], is approximately 1.24 km (0.77 mi) wide, and 2.1 km (1.3 mi) long, extending from Mount Alifan to Agat Bay. With Mount Alifan approximately 169 meters (m) [554 feet (ft)] above sea level, the basin slope is a moderately-steep 15 percent (%). Steep land slopes and soils with a low permeability are often associated with greater stream incision. The longest watercourse in the basin is approximately 2 km (1.24 mi).

### **1.1 GEOLOGY**

The basin of the study is underlain by boninites, breccias, hyaloclastites, sandstones, conglomerates, turbidites, limestone, alluvial clay deposits, beach sand and gravel, and beach rock (Water and Environmental Research Institute at the University of Guam, 2007). Majority of the formations have a low permeability.

### **1.2 SOILS**

The soils within the study area primarily belongs to the Akina series. These soils are classified as silty clay, volcanic in origin. The soils have moderately slow permeability, resulting in rapid runoff. Erosion is a serious concern for Akina soils, which are characteristically dark reddish brown to dark red in color (University of Guam, 2016).

Near the coast and lower elevations, the soil primarily belongs to the Inarajan series, which is also a silty clay of volcanic origins. It has a slow permeability rate, seasonal high water table, and is typically a dark gray color. Erosion is not a problem for this soil type (University of Guam, 2016).

### **1.3 VEGETATION**

In the southern section of Guam, a heavy growth of tropical vegetation borders the inland areas of rivers and represents a plant community known as the ravine forest. Sharp divisions between the non-native savannah grasslands and ravine forest provide particularly aesthetic contrasts in the study area. Fires occur frequently and are often intentionally set by people to draw deer and pigs out when hunting, to clear fields for farming, or as wildfire arson. The spatial extent of the savannah grasslands has increased in size as the fire-adapted grasslands quickly replace the burned forest edge. The southern uplands are some of the island's only expanses of unspoiled terrain.

### **1.4 CLIMATE**

Guam's climate is tropical marine, reflecting the nearness of the equator and the influence of warm surrounding waters. Wind and rainfall are the most variable elements; humidity, temperature and pressure remain fairly constant. The year is divided into a wet (July through December) and a dry (January through June) season with pronounced differences in rainfall.

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Two principal kinds of storms contribute to the climatic character of Guam: small-scale storms, consisting of thunderstorms and squalls, and large systems of tropical storms and typhoons. The small-scale disturbances may dominate an area of only a few square miles. Larger cyclonic storm systems may dominate an area as large as 300,000 square miles and can persist for a week or more.

Major tropical cyclonic disturbances of these kinds occur in all months, but they are prevalent during the rainy season with the greatest probability in the months of October and November. These typhoons are actually tropical storms accompanied by winds of 65 knots (120 kilometers per hour) or greater. Based on the information provided by the Digital Atlas of Southern Guam website, “an average of three tropical storms and one typhoon pass within 180 nautical miles (330 km) of Guam each year” with the most intense typhoon to pass over Guam recently being Super Typhoon Pongsona on December 8, 2002 (WERI and IREI, n.d.). Recently, Guam experienced another intense typhoon in May 25, 2023 – Super Typhoon Mawar.

#### **1.4.1 El Niño Years**

The term El Niño refers to a periodic warming (every two to seven years) of the Pacific Ocean surface waters. These conditions often result in tropical rains shifting eastward across the Pacific and an increased risk of typhoons from March through July and October through December. Rainfall is characteristically greater at the start of El Niño conditions (beginning in May or June), near normal by December, and well below average by the following February. (NOAA Pacific RISA 2015). The duration, strength, and impacts of El Niño events vary, but three periods are universally accepted as having produced very strong conditions: 1982-83, 1997-98, and 2015-16 (NOAA Climate Prediction Center 2018).

### **1.5 2020 GUAM COMPREHENSIVE FLOOD STUDY**

The Guam Comprehensive Flood Study was conducted to serve as a planning framework that can be used toward reducing flood risk for its communities. The study provided estimates of the magnitudes of the 50%, 20%, 10%, 4%, 2%, 1%, and 0.2% Annual Exceedance Probability (AEP) peak stream discharges, inundation maps representing existing conditions in the floodplain for the 1% and 0.2% AEP flood events

### **1.6 TYPHOONS**

A summary of recent notable tropical storms and typhoons that have affected Guam is presented in Table 1.

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**Table 1. Notable historical typhoons affecting Guam in the last 30 years**  
*Recent typhoons and/or typhoons causing >\$1M in total damages*

Date	Typhoon Name	Closest point of approach	Impact
2002 July 4-5	Typhoon Chataan	just north of Guam	\$60M in property damages, 1,996 houses severely damaged or destroyed, island-wide power outage, contamination of Fena Lake
2002 December	Typhoon Pongsona	crossed the northern portion of Guam	\$700M in total damages
2004 June 28	Typhoon Tingting	250 mi northeast of Guam	\$6M in property damages, Record-breaking rainfall, severe flooding, and landslides, 57 homes destroyed, 624 homes damaged, \$500k in crop damage
2005 August 31 – September 1	Typhoon Nabi	north/northeast of Saipan and Guam	\$2.5M in total damages, flooding of roads and a school
2015 May 14-16	Typhoon Dolphin	just north of Guam	\$10M in total damages, 40% of the island lost power, flooding of Guam Memorial Hospital, 9 houses destroyed, 390 houses damaged.
2018 September 11	Typhoon Mangkhut	north of Guam	\$4.3M in infrastructural damage in Guam, 80% of the island lost electricity
2019 February 23-25	Typhoon Wutip	165 mi south of the island	\$1.3M in infrastructural damage, isolated power outages, more significant damages in Inalåhan (Inarajan)
2023 May 22-25	Typhoon Mawar	north of Guam	Overall structural damage was relatively limited
2023 October 10	Typhoon Bolaven	north of Guam	Minor flooding and damage reported in Inalåhan (Inarajan)

### 1.7 STREAM DATA

There are no in-stream gages for Salinas River, Finile Creek, Gaan River, and Auau Creek. The closest USGS stream gage to the study area is Maulap River near Agat, Guam - USGS-16848500. However, this gage is upstream in the mountains. The closest stream gage near the shore, similar to the study location, is La Sa Fua River near Umatac, Guam - USGS-16809600. USGS 16809600 provides continuous flow data for the last 24 years and an annual peak flow record for 37 out of the last 70 years (1953 – 2023). Typhoon Mawar in 2020 is the maximum recorded peak streamflow at 2,300 ft<sup>3</sup>/s. Typhoon Chataan in July 2002 comes second at 2,140 ft<sup>3</sup>/s.

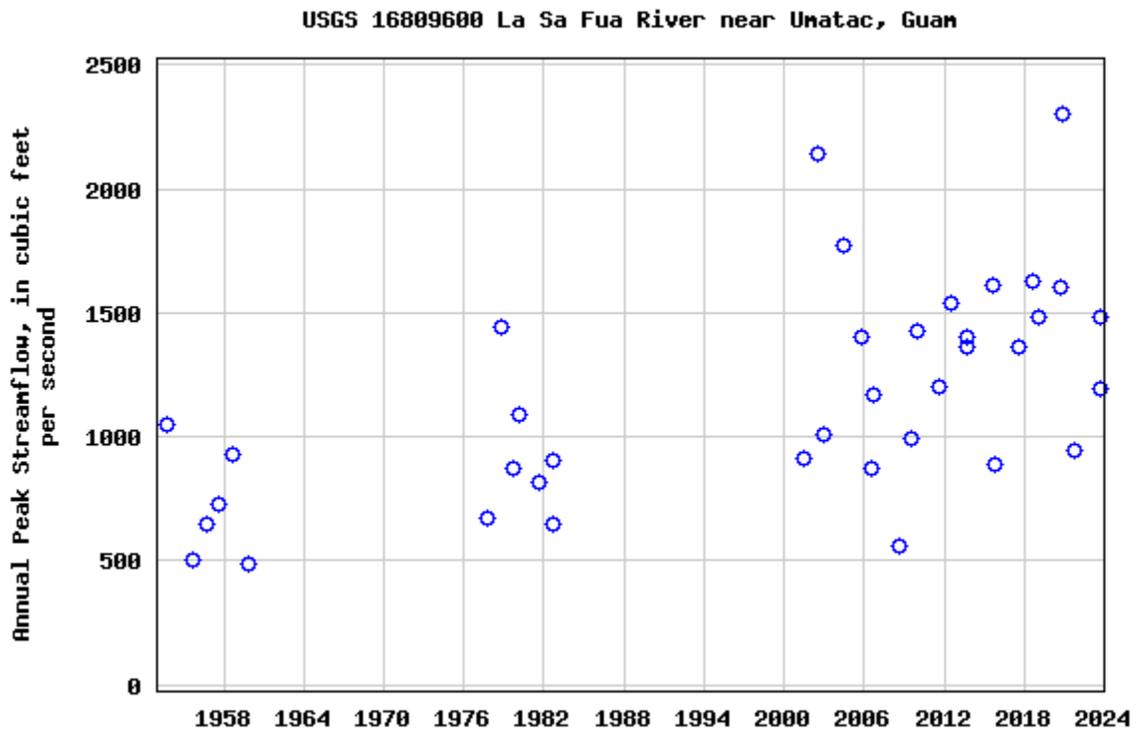


Figure 3 – Annual Peak Streamflow Record for USGS 16809600

## SECTION 3 - HYDROLOGY

### 3.1 HYDROLOGIC MODELING

#### 3.1.1 GIS Data

All Geographic Information System (GIS) processing was performed in ArcGIS Pro version 3.1.0.

#### 3.1.2 HEC-HMS Model

The Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) version 4.11. was used in performing the Hydrologic analysis.

#### 3.1.3 Projection and datum

The projection and datum for this study is as follows:

Horizontal projection: Universal Transverse Mercator (UTM) Zone 55 North (N), Meters

Horizontal datum: North America Datum of 1983 (NAD83) (MA11)

Vertical Datum: Guam Vertical Datum of 2004

Tidal Epoch: 1983-2001

Geoid: 2012B

#### 3.1.4 Elevation

The elevation data used for this study is the *2020 National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS) Topobathy Guam*, downloaded from NOAA Digital Coast. The data downloaded was in meters. The data was converted to US Customary System to be readily available for the Hydrology calculations. This was performed in ArcGIS Pro by setting the projection to feet before running the conversion tool.

#### 3.1.5 Drainage Areas

The drainage areas were delineated for Salinas River (SR), Finile Creek (FC), Gaan River (GR), and Auau Creek (AC) using the elevation data provided above. Initial delineation was performed in HEC-HMS. The initial delineation was then investigated and refined in ArcGIS Pro. The acreage for each stream was validated and found comparable with the drainage acreage of the streams found in FEMA's Flood Insurance Study (FIS) for the Territory of Guam. In finalizing the delineation, the drainage area for Finile Creek and Gaan River was subdivided as flows enter from a tributary/area. See Figure 4 – for visibility purposes, map only shows 20-foot interval contours. The stream centerline shown in the figure was retrieved from FEMA.

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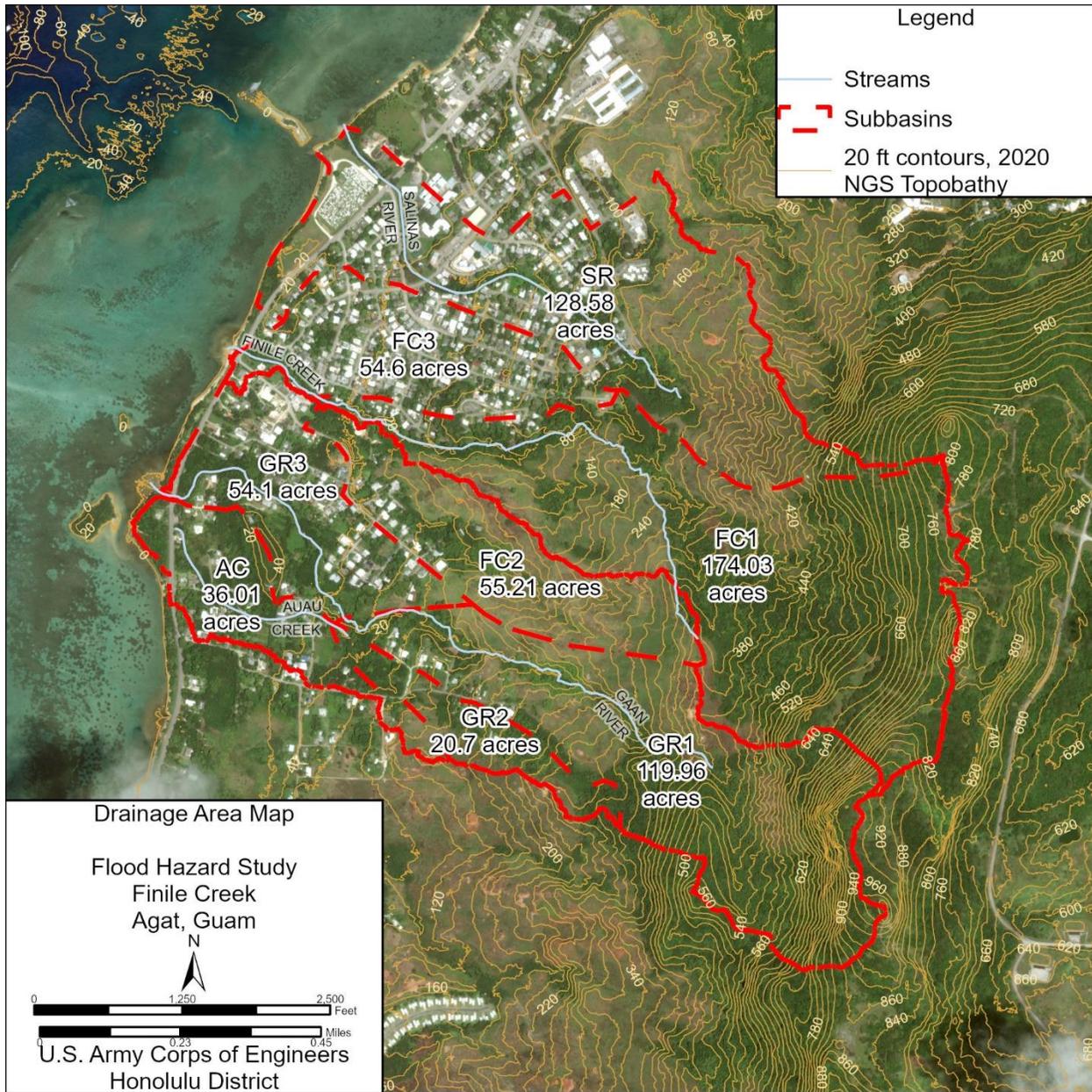


Figure 4 – Drainage Area Map

A basin model was created in HEC-HMS and was setup as shown in Figure 5. No reaches were included in the model as this will be done by the hydraulic model. See Figure 5.

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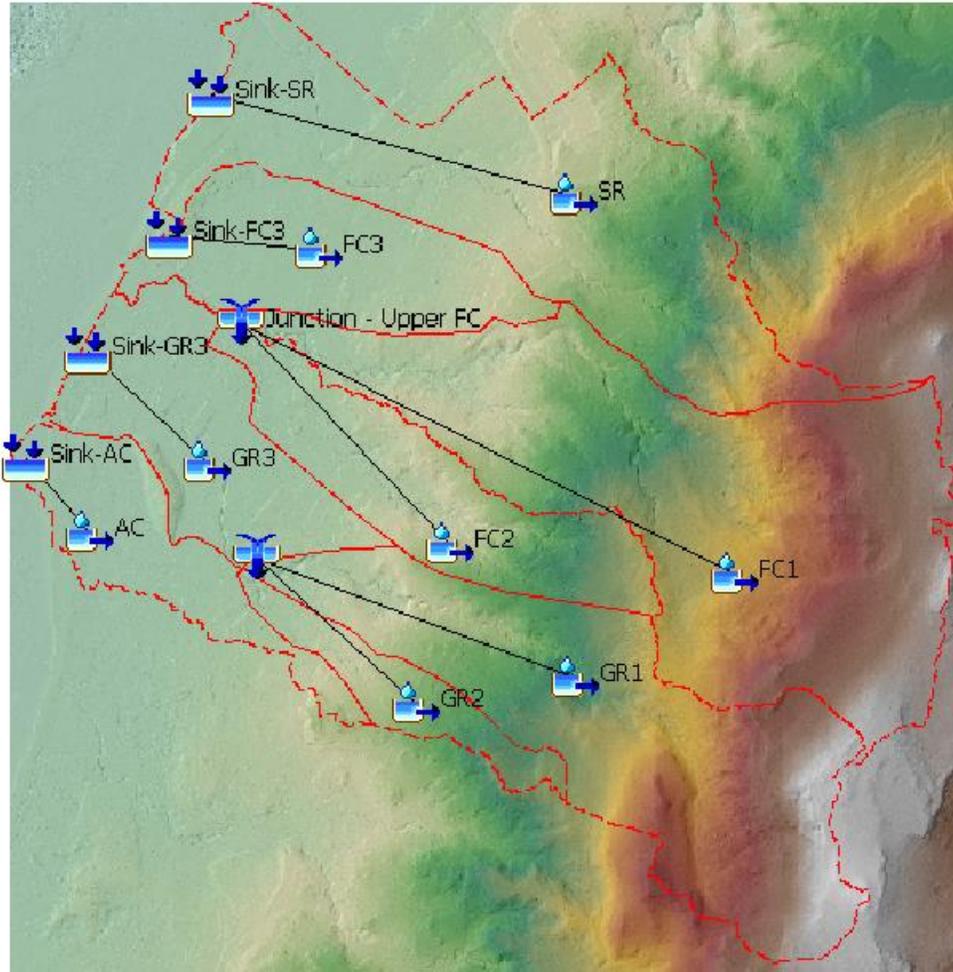


Figure 5 – HEC-HMS Basin model schematic

### 3.1.6 Initial and Constant Loss

#### 3.1.6.1 *Initial Loss*

Initial loss value of 0.1 mm was assigned to all subbasins/drainage areas.

#### 3.1.6.2 *Constant Rate*

The constant rate for each subbasin was determined using the saturated soil hydraulic conductivity (Ksat). The soils data used for this study was retrieved from the United States Department of Agriculture (USDA) Soil Survey Geographic Database (SSURGO). The estimates are expressed in terms of micrometers per second. The data was entered in ArcGIS Pro to calculate the weighted Ksat for each subbasin. Weighted Ksat was converted to millimeters per hour when entered in HEC-HMS. See Figure 6.

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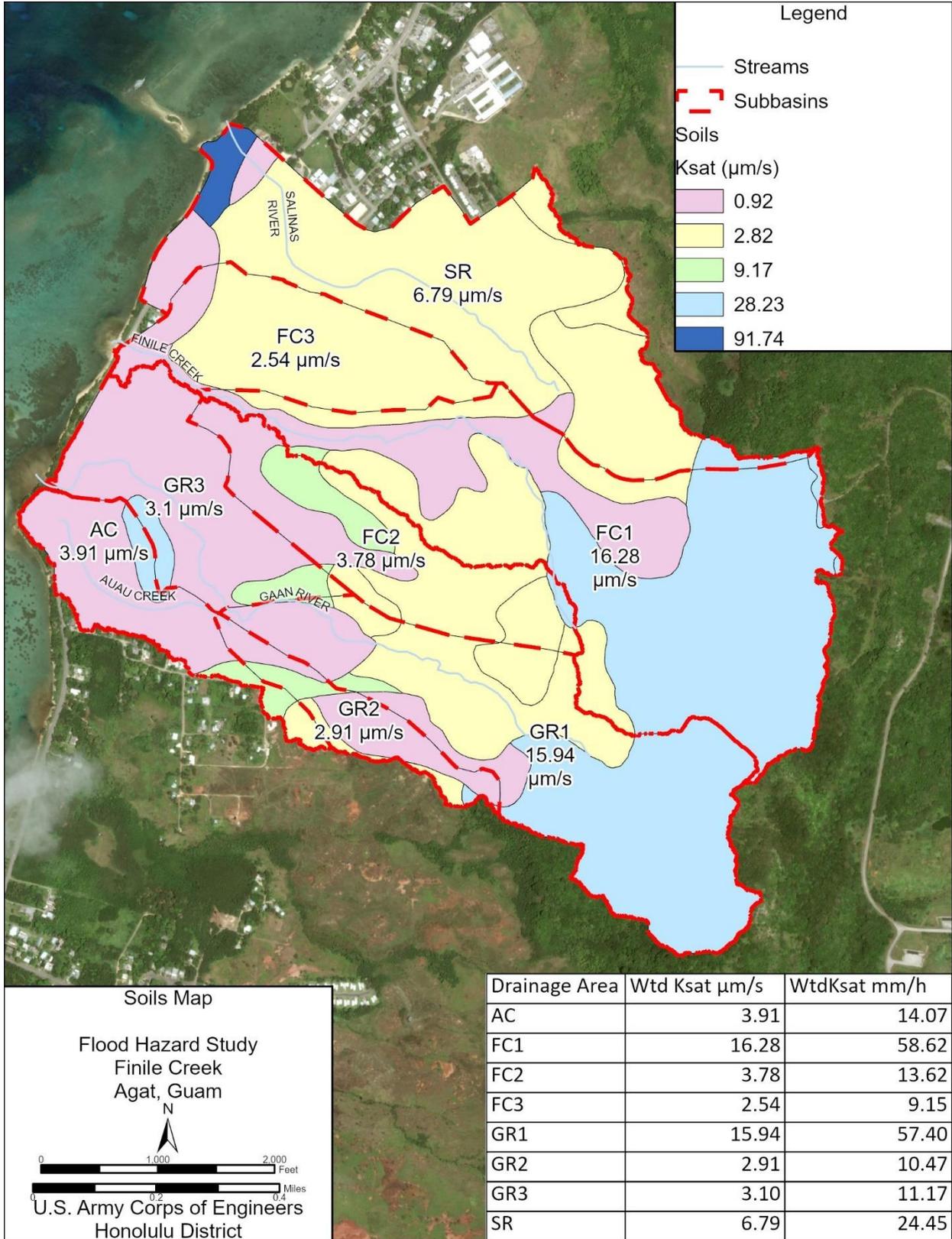
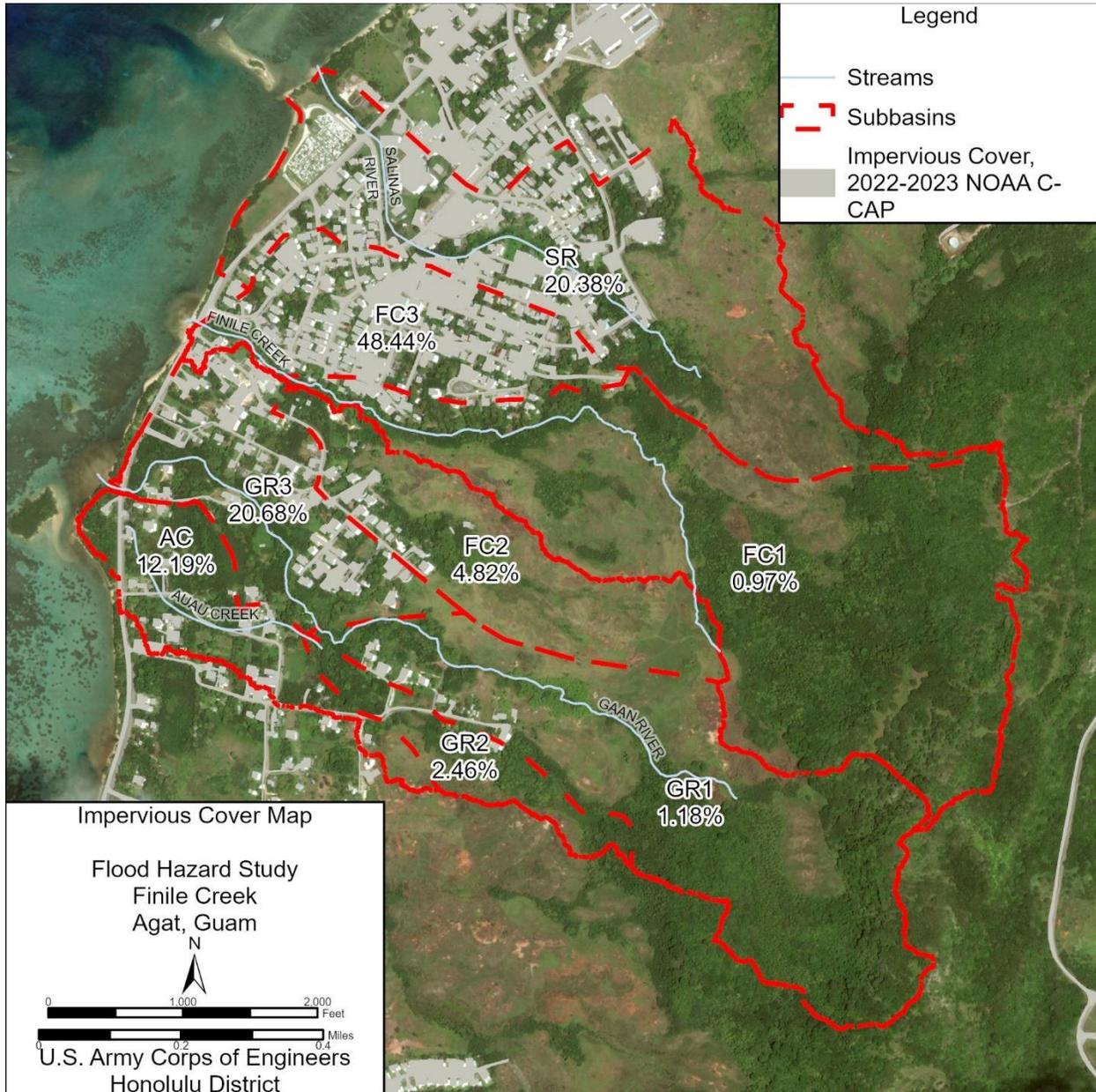


Figure 6 – Soils Map

**3.1.6.3 Impervious cover**

The impervious cover data used for this study is the 2022-2023 NOAA Coastal Change Analysis Program (C-CAP) Version 2 Impervious Cover: Guam, downloaded from NOAA Digital Coast, see Figure 7. The data was used in determining the percent impervious for the Hydrology model.



**Figure 7 – Impervious Cover Map**

### 3.1.7 Clark Unit Hydrograph

#### 3.1.7.1 Storage coefficient

Storage coefficient was estimated using the equation shown in Figure 8.

$$R = \frac{13}{7} * T_c$$

Figure 8 – Estimated storage coefficient

#### 3.1.7.2 Time of concentration

The time of concentration ( $T_c$ ) was calculated using the USDA Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) Urban Hydrology for Small Watersheds. See Figure 10.

The maximum length for the sheet flow is 300 feet. The Manning's roughness coefficient used for the sheet flow on grass areas are 0.24. The time for the sheet flow was determined using the NOAA Atlas 14 Point Precipitation Frequency (PF) Estimates for each subbasin.

The time for the shallow concentrated flow was calculated by determining average velocity using equation in Figure 9 which is from HEC's guide to *Clark Unit Hydrograph Model*.

$$V_{\text{shallow}} = \begin{cases} 16.1345 * \sqrt{S}, & \text{for unpaved surfaces} \\ 20.3282 * \sqrt{S}, & \text{for paved surfaces} \end{cases}$$

Figure 9 – Estimated average velocity for shallow concentrated flow

The time for channel flow was calculated by using cross section dimensions along the flow to determine Hydraulic radius and the Manning's roughness coefficient for open channel flow.

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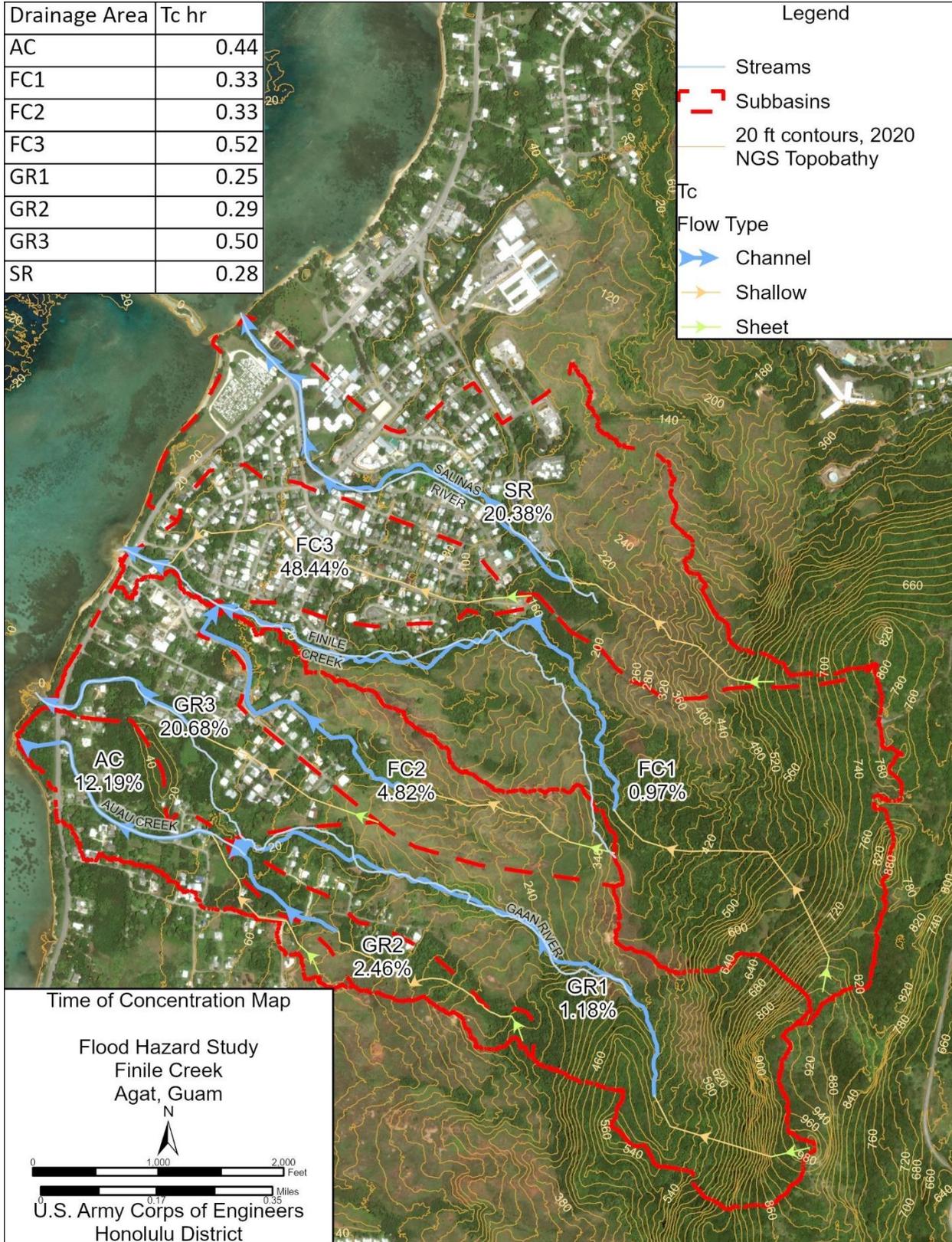


Figure 10 – Time of Concentration Map

### 3.1.8 Meteorologic Models

The NOAA Atlas 14 Precipitation Frequencies for the study area was used in the simulation runs.

The NOAA Atlas 14 frequencies is comprised of annual maximum flows without regard for the type of flood that caused each individual annual maximum. In Guam, there are two types of flood-causing mechanisms that can generate large flows in any given year: 1) those caused by tropical cyclones (typhoons), tropical storms, and tropical depressions and 2) those that are not.

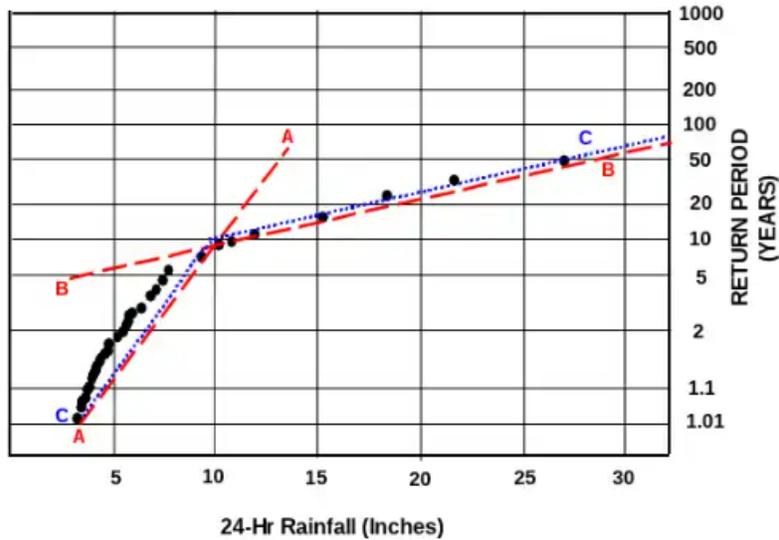
This notion that a different rainfall distribution should be considered in hydrologic studies is discussed in Technical Report No. 103, *Rainfall Climatology for Saipan: Distribution, Return-periods, El Nino, Tropical Cyclones, and Long-term Variations* (Lander, 2004). Figure 11 demonstrates the variation in precipitation frequency between rainfall events (line “A-A”) and typhoons (line “B-B”), with all rainfall totals in excess of 10 inches on this chart caused by the direct passage of typhoons over the island. The different resulting precipitation frequency estimates are presented in Table 2.

**Table 2 – Comparison of Different Precipitation Frequency Estimates**

Recurrence Interval		2	5	10	25	50	100	200	500
Average Rain (in/24 hours)	NOAA Atlas 14	5.17	7.78	9.59	12.0	13.8	15.7	17.6	20.2
	Lander, 2004	7	--	10	20	27	34	41	51
% increase		35.4	--	4.28	66.7	95.7	117	133	152

\*extrapolated for the 100-, 200-, and 500-year recurrence intervals

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**Figure 11 – Return period for 24-hour rainfall totals computed for Guam**  
Source: Technical Report No. 103, Figure 13 (Lander, 2004)

In this study, the greater precipitation frequency estimates presented by Lander in Technical Report No. 103 were used in the HMS model to establish the flow frequency estimates and inflow hydrographs for all frequency events greater than the 10% AEP event. This was done by scaling the NOAA Atlas 14 precipitation frequency estimates by the same percentage increases presented in Table 2.

### 3.1.9 Calibration

Calibration methods of the Finile Creek Flood Hazard Study was based on the calibration methods of Manell River on the 2020 Guam Comprehensive Flood Study. The calibration used the rainfall and stream flow data from the USGS Gage 16809600, La Sa Fua River near Umatac, Guam, located approximately 6.8 km south of the study area. The La Sa Fua River Basin was calibrated to 8 different events, ranging from Typhoon Chata'an in July 2002 to Typhoon Mangkhut in September 2018. The initial and final parameters for the La Sa Fua River Basin are presented in Table 3.

**Table 3 – Initial and Calibrated Parameters for the La Sa Fua River Basin**

Calibration Status	Initial Loss (mm)	Constant Loss Rate (mm/hr)	Time of Concentration (hr)	Storage Coefficient (hr)
Initial	0.1	10.20	0.673	0.545
Calibrated	26	5.81	0.419	0.508
% Change	25900	-43.04	-37.74	-6.79

The initial value for Constant Loss Rate shown in Table 3 is a corrected value. Its value of 0.15 mm/hr from the 2020 Guam Comprehensive Flood Study was investigated because it is unusually low. This value yielded to a high percent change of 3,773.33%. Consequently, the initial value for Constant Loss Rate was corrected to 10.20 mm/hr

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which yields to a percent change of -43.04%. The corrected value was derived from the Ksat soil properties (surface values) on the USGS SSURGO Database. The percent change is based on the initial value and the weighted average of the same events that were used in the 2020 study. A comparison table is shown below.

**Table 4 – Corrected Constant Loss Rate, Comparison table**

Calibration Scenario	Constant Loss Rate (mm/hr), 2020 Guam Comprehensive Flood Study	Corrected Constant Loss Rate (mm/hr)
<b>Initial</b>	<b>0.15</b>	<b>10.20</b>
Jul-02	3	3
Dec-02	5	5
Aug-09	15	15
Dec-09	13	13
Jul-12	0.1	0.1
Sep-15	3	3
Aug-18	3	3
Sep-18	1	1
Wtd avg	5.81	5.81
<b>Percent change</b>	<b>3773.33%</b>	<b>-43.04%</b>

The initial parameters computed for the Finile Creek Flood Hazard Study were similarly calibrated using the percent changes shown on Table 3. No calibration was applied to the drainage area. The final calibrated parameters for the Finile Creek Flood Hazard Study are shown in Table 5 and Table 6.

**Table 5 – Initial and Calibrated Transform Parameters for Finile Creek Flood Hazard Study**

Drainage Area	Initial Values		Calibrated Values	
	Time of Concentration (hr)	Storage Coefficient (hr)	Time of Concentration (hr)	Storage Coefficient (hr)
AC	0.44	0.82	0.27	0.76
FC1	0.33	0.62	0.21	0.58
FC2	0.33	0.61	0.20	0.56
FC3	0.52	0.96	0.32	0.90
GR1	0.25	0.46	0.15	0.43
GR2	0.29	0.54	0.18	0.51
GR3	0.50	0.93	0.31	0.87
SR	0.28	0.52	0.17	0.48

**Table 6 – Initial and Calibrated Loss Parameters for Finile Creek Flood Hazard Study**

Drainage Area	Initial Values		Calibrated Values	
	Initial Loss (mm)	Constant Loss Rate (mm/hr)	Initial Loss (mm)	Constant Loss Rate (mm/hr)
AC	0.1	14.07	26	8.02
FC1	0.1	58.62	26	33.39

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FC2	0.1	13.62	26	7.76
FC3	0.1	9.15	26	5.21
GR1	0.1	57.40	26	32.69
GR2	0.1	10.47	26	5.96
GR3	0.1	11.17	26	6.36
SR	0.1	24.45	26	13.93

Resulting peak flows simulations are summarized in Table 7 and Table 8. Its hydrographs will be used in the hydraulic analysis. A summary of its methodologies can be found on Table 9.

**Table 7 – Final peak flow estimates in cubic meters per second from HEC-HMS**

HEC-HMS Element Name	Drainage Area (km <sup>2</sup> )	Flows m <sup>3</sup> /s, Annual Exceedance Probability (AEP)							
		50% (1/2)	20% (1/5)	10% (1/10)	4% (1/25)	2% (1/50)	1% (1/100)	0.5% (1/200)	0.2% (1/500)
AC	0.1	1.3	1.9	2.3	5.1	6.8	8.5	10.1	12.3
FC1	0.7	3.8	6.3	8.2	23.2	32.7	41.6	50.3	62.7
FC2	0.2	2.4	3.4	4	9.1	12.1	15	17.7	21.7
FC3	0.2	2	2.8	3.3	7.2	9.6	11.8	14	17.1
GR1	0.5	3.1	5.2	6.7	18.5	25.9	32.8	39.4	48.9
GR2	0.1	1	1.4	1.6	3.6	4.8	5.9	7	8.5
GR3	0.2	1.9	2.7	3.2	7.2	9.5	11.8	14	17.1
Junction - Upper FC	0.9	6.2	9.7	12.3	32.3	44.7	56.6	68.1	84.4
Junction - Upper GR	0.6	4.1	6.5	8.4	22.1	30.6	38.7	46.4	57.5
SR	0.5	5.5	7.8	9.5	21.9	29.4	36.5	43.4	53.1

**Table 8 – Final peak flow estimates in cubic feet per second from HEC-HMS**

HEC-HMS Element Name	Drainage Area (mi <sup>2</sup> )	Flows ft <sup>3</sup> /s, Annual Exceedance Probability (AEP)							
		50% (1/2)	20% (1/5)	10% (1/10)	4% (1/25)	2% (1/50)	1% (1/100)	0.5% (1/200)	0.2% (1/500)
AC	0.04	45.91	67.10	81.22	180.10	240.14	300.17	356.68	434.37
FC1	0.27	134.20	222.48	289.58	819.30	1154.79	1469.09	1776.33	2214.23

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FC2	0.08	84.76	120.07	141.26	321.36	427.31	529.72	625.07	766.33
FC3	0.08	70.63	98.88	116.54	254.27	339.02	416.71	494.41	603.88
GR1	0.19	109.48	183.64	236.61	653.32	914.65	1158.32	1391.40	1726.89
GR2	0.04	35.31	49.44	56.50	127.13	169.51	208.36	247.20	300.17
GR3	0.08	67.10	95.35	113.01	254.27	335.49	416.71	494.41	603.88
Juncti on - Upper FC	0.35	218.95	342.55	434.37	1140.6 6	1578.5 7	1998.81	2404.93	2980.56
Juncti on - Upper GR	0.23	144.79	229.55	296.64	780.45	1080.6 3	1366.68	1638.60	2030.60
SR	0.19	194.23	275.45	335.49	773.39	1038.2 5	1288.99	1532.66	1875.21

**Table 9 – Methodology summary**

Methods	Description
Initial Loss	Initial values calibrated to USGS Gage 16809600 La Sa Fua River using methodology from 2020 Guam Comprehensive Flood Study
Constant Rate	Initial values calibrated to USGS Gage 16809600 La Sa Fua River using methodology from 2020 Guam Comprehensive Flood Study. The initial value on the 2020 Guam Comprehensive Flood Study was corrected. The correction was derived from the Ksat surface values from USGS SSURGO Database.
Impervious Cover	Calculated based on the 2022-2023 NOAA C-CAP Version 2 Impervious Cover: Guam
Storage coefficient	Calculated initial values and calibrated to USGS Gage 16809600 La Sa Fua River using methodology from 2020 Guam Comprehensive Flood Study
Time of concentration	Calculated initial values and calibrated to USGS Gage 16809600 La Sa Fua River using methodology from 2020 Guam Comprehensive Flood Study
Meteorologic model	0.2% (500yr AEP): TR103 0.5% (200yr AEP): TR103 1% (100yr AEP): TR103 2% (50yr AEP): TR103 4% (25yr AEP): TR103 10% (10yr AEP): NOAA Atlas 14 20% (5yr AEP): NOAA Atlas 14 50% (2yr AEP): NOAA Atlas 14

### 3.2 REGIONAL REGRESSION EQUATIONS

Regression Equations is an alternative to HEC-HMS modeling. Regional regression equations were formulated in the 2020 Guam Comprehensive Flood Study. The equations are conditional based on two explanatory variables: the drainage area and the rainfall intensity for the 2-year flood event. The range of explanatory variable for the drainage area is from 0.681 to 18.2 km<sup>2</sup>. Only subbasin FC1 (0.7 km<sup>2</sup>) falls within this

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range. However, combining all the subdivided subbasins for Finile Creek and Gaan River will result to a drainage area within the variable conditions. On contrary, subbasins AC (0.10 km<sup>2</sup>) and SR (0.50 km<sup>2</sup>) in the Finile Creek Flood Study still does not fall within the drainage area criteria. Therefore, these regional regression equations cannot be applied to AC and SR. The explanatory variable rainfall intensity of Finile Creek and Gaan River fall within the its limits of 139 to 187 mm. So, only Finile Creek (FC), which is a combination of FC1, FC2, and FC3, and Gaan River (GR), which is a combination of GR1, GR2, and G3, is qualified for the regional regression equations. See summary of calculations in Table 10 and Table 11.

**Table 10 – Frequency flows using Regional Regression Equations in metric units**

D A	Area (km <sup>2</sup> )	I24H2Y (mm)	Q <sub>2</sub> (m <sup>3</sup> /s)	Q <sub>5</sub> (m <sup>3</sup> /s)	Q <sub>10</sub> (m <sup>3</sup> /s)	Q <sub>25</sub> (m <sup>3</sup> /s)	Q <sub>50</sub> (m <sup>3</sup> /s)	Q <sub>100</sub> (m <sup>3</sup> /s)	Q <sub>250</sub> (m <sup>3</sup> /s)	Q <sub>500</sub> (m <sup>3</sup> /s)
F C	1.1	184	15.71	23.20	32.96	40.93	53.90	62.07	69.85	82.86
G R	0.8	186	13.19	19.39	27.36	33.82	44.29	50.81	56.95	67.21

**Table 11 – Frequency flows using Regional Regression Equations in SI units**

DA	Q <sub>2</sub> (ft <sup>3</sup> /s)	Q <sub>5</sub> (ft <sup>3</sup> /s)	Q <sub>10</sub> (ft <sup>3</sup> /s)	Q <sub>25</sub> (ft <sup>3</sup> /s)	Q <sub>50</sub> (ft <sup>3</sup> /s)	Q <sub>100</sub> (ft <sup>3</sup> /s)	Q <sub>250</sub> (ft <sup>3</sup> /s)	Q <sub>500</sub> (ft <sup>3</sup> /s)
FC	554.82123 7	819.469 6	1164.07 8	1445.45 7	1903.55 6	2191.89 8	2466.807 4	2926.030 4
GR	465.82705 4	684.925 7	966.126	1194.44 4	1564.13 5	1794.39 4	2011.212	2373.465 8

## SECTION 4 - HYDRAULICS

The 2D Hydraulic analysis was performed in Hydrologic Engineering Center River Analysis System (HEC-RAS) version 6.6. The model was setup and ran in metric system.

### 4.1 EXISTING CONDITIONS

#### 4.1.1 Terrain

The terrain associated with the existing conditions geometry and simulation is named Existing (based on Existing\_2020\_LiDAR.Clone). It is based on the best available LiDAR data, the *2020 National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS) Topobathy Guam*. Terrain was modified to allow the runoff to continue flowing at the following existing culvert crossings and existing drainage ditch/channels highlighted in pink in Figure 12.

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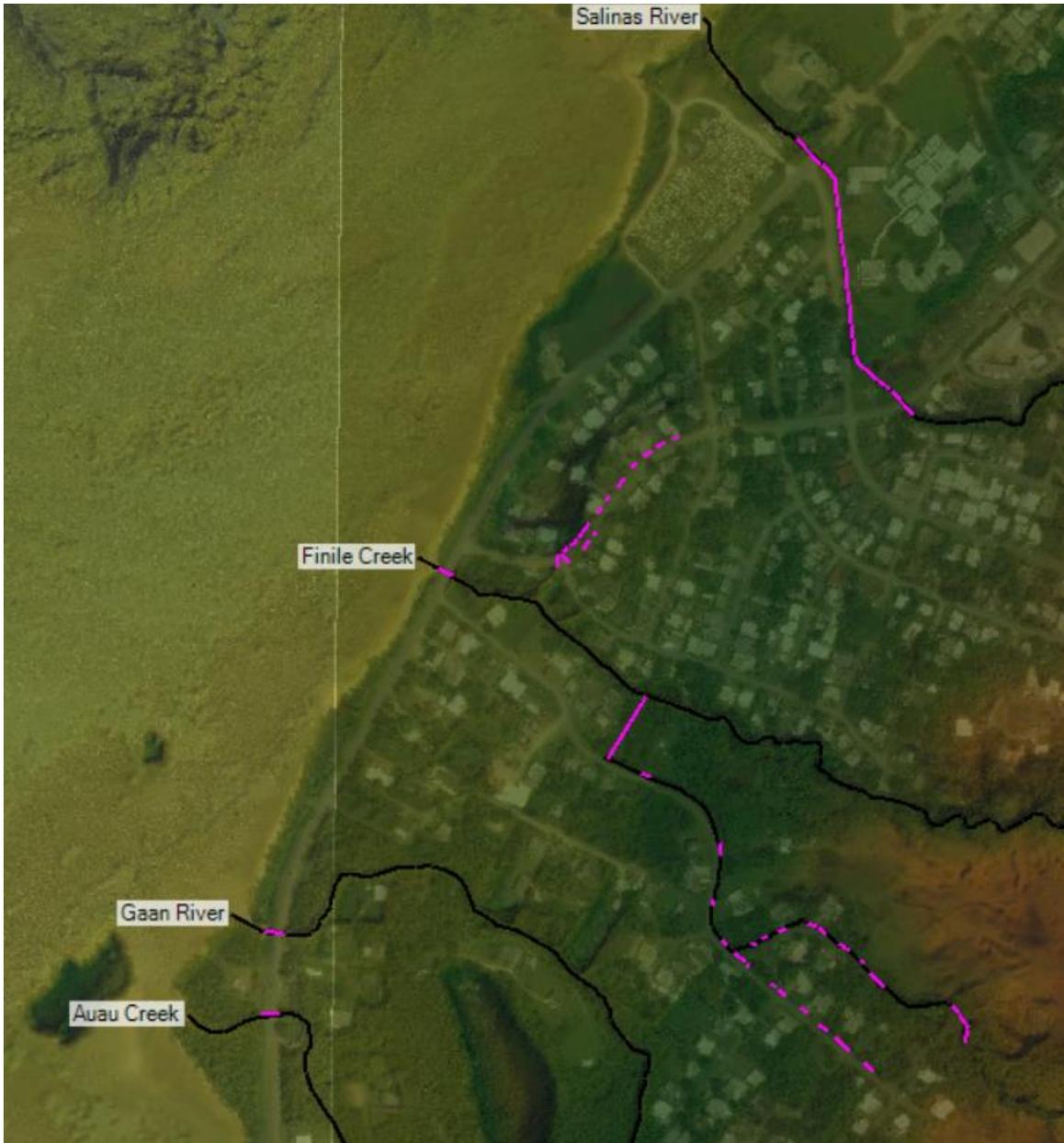


Figure 12 – Existing Conditions terrain modifications at culverts, channels, and ditches

#### 4.1.2 Geometry

##### 4.1.2.1 Imagery

The imagery used in the HEC-RAS Mapper is based on an imagery from Digital Globe, dated 18 February 2020.

#### 4.1.2.2 2D Flow Areas

The geometry consists of one overall 2D flow area for the study area, see Figure 13. The default cell size is 10 by 10. The cell size in the ocean is 20 by 20, set by a refinement region. Breaklines were added at stream centerlines, ditches, crown at along highway road, centerline of community roads, and locations where cell alignment was needed to stabilize the model.

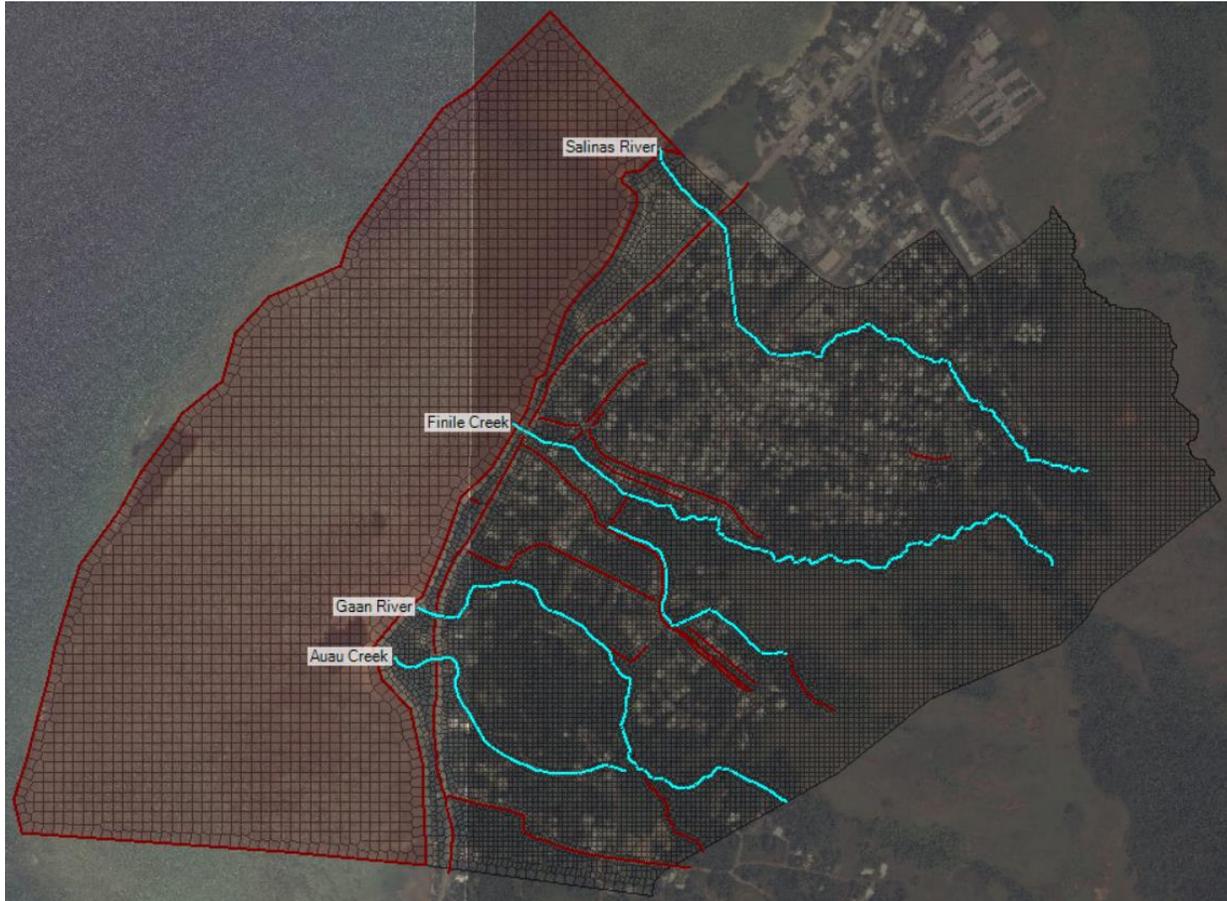


Figure 13 – 2D Flow Areas, Existing Conditions

#### 4.1.2.3 SA/2D Connections

The study includes seven culvert groups: one for each of the four streams along the highway road, one upstream in Auau Creek (Auau US1), and two upstream in Salinas River (Salinas US1 and US2). There are no available data for all the culverts. Best estimates of the invert, length, and sizes of the culverts were determined by performing site measurements and terrain/imagery investigations. No measurements were collected for Auau US1 and Salinas US2. The culverts are modeled as what was measured during the site visit, see Table 12. However, the sizes collected were not typical due to human error, skew, or standing water (Finile Creek, Gaan River, and

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Auau Creek). Therefore, in reality, the culverts may possibly have slightly higher capacity than modeled.



**Figure 14 – SA/2D Connections**

**Table 12 – Culvert Summary Table, Existing Conditions**

Culvert Name	Field measurement	Location
Auau Creek	1 – 5.83' b x 3.83' h	Auau Creek, Rt 2 highway road
Auau US1	-	Auau Creek upstream, Babauta Rd
Finile Creek	1 – 10' b x 3.583' h	Finile Creek, Rt 2 highway road
Gaan River	2 – 5' b x 3.5' h	Gaan River, Rt 2 highway road
Salinas River	1 – 5.4167' b x 4.167' h	Salinas River, Rt 2 highway road
Salinas River US1	1 – 8' b x 3' h	Salinas River upstream, De Los Marteres road
Salinas River US2	-	Salinas River upstream, San Vicente Ave
FC US R1, R2	Modeled interior drainage to allow runoff to continuously flow	
SR CH1, CH2	Modeled pedestrian access to allow runoff the continuously flow	

#### 4.1.2.4 *Boundary conditions*

Boundary conditions were added for the flow hydrographs of the drainage areas from the HEC-HMS model. This includes AC, FC1, FC2, FC3, GR1, GR2, GR3, and SR. The placement of the hydrographs were determined by considering where channel flow begins and nearest structures upstream. Boundary conditions were added at North and South ends of the highway where it tends to overtop the road.

At the downstream end of the study, a boundary condition was added for the ocean stage hydrograph.

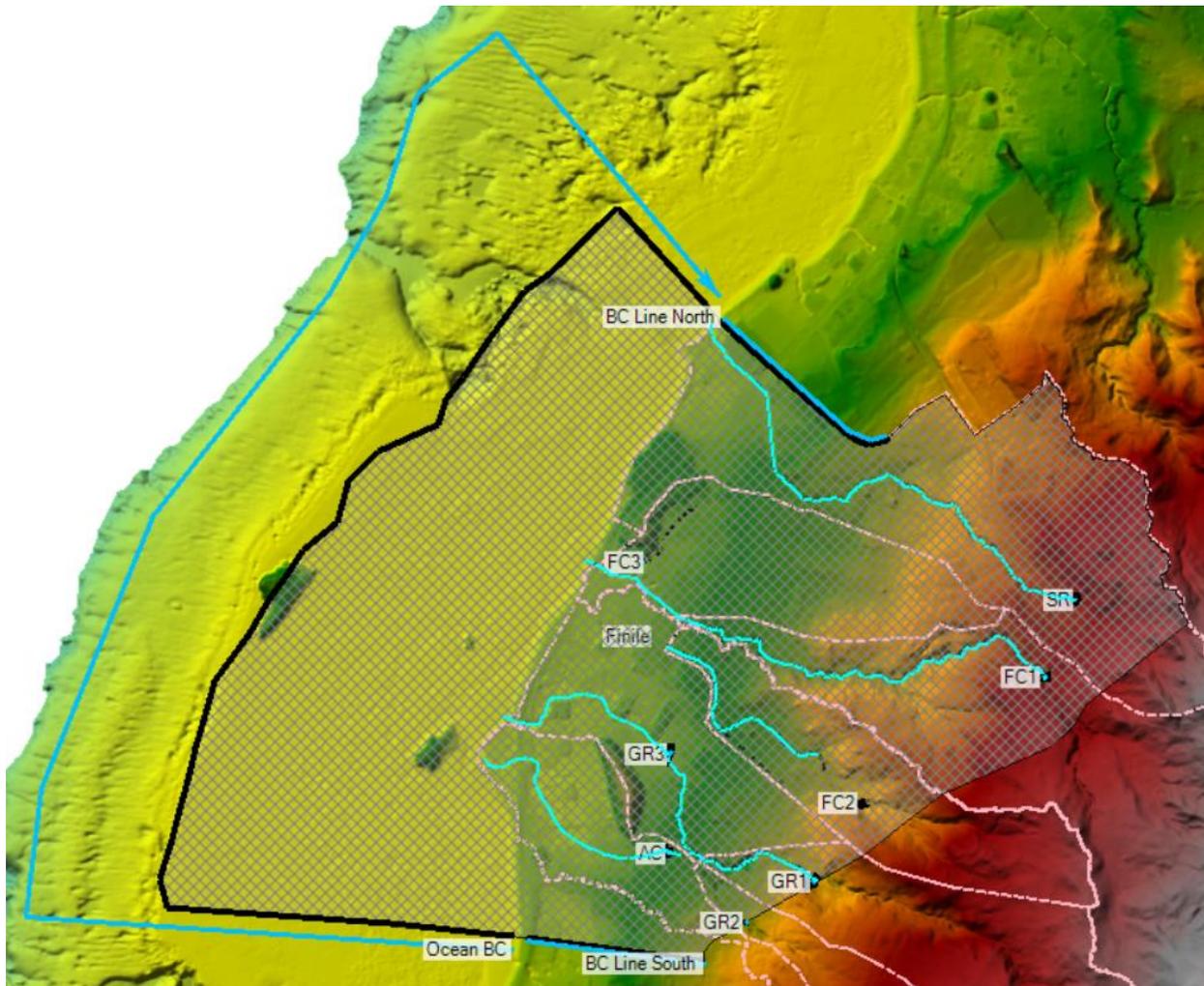


Figure 15 – Boundary Conditions, subbasins in pink dashed lines, on Existing Conditions terrain

#### 4.1.2.5 *Land Use and Land Cover*

The Manning's *n* and percent impervious was based on the 2016 NOAA High Res Land cover: Guam, downloaded from NOAA Digital Coast. The values used for both Manning's roughness coefficient *n* and percent impervious can be found on the HEC-

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RAS 2D user's Manual, see Table 13. No calibration regions were applied to the data at existing conditions.

**Table 13 – Manning's roughness coefficient n**

Land Use	n
NoData	0.035
Open Water	0.035
Unconsolidated Shore	0.04
Evergreen Forest	0.15
Developed - High Intensity	0.15
Developed - Open Space	0.035
Grassland-Herbaceous	0.04
Barren Land	0.03
Scrub-Shrub	0.05
Palustrine Forested Wetland	0.1
Palustrine Emergent Wetland	0.045
Palustrine Scrub-Shrub Wetland	0.048
Channel	0.017

#### **4.1.3 Unsteady Flow – Flow files**

Inflow hydrographs were routed from the dss output file for each boundary conditions based on the HEC-HMS results for 2, 5, 10, 25, 50, 100, 200, and 500-year flows. A flow file was created for each flood event. The hydrographs for 2, 5, and 10-year AEP were based on NOAA Atlas 14 PF Estimates, while the hydrographs for 25, 50, 100, 200, and 500-year AEP are based on the TR103 estimates, see 3.1.8.

All flow files used in existing conditions analysis have the same data for the ocean boundary condition stage hydrograph and the north and south normal depth boundary conditions lines.

The ocean stage hydrograph was determined to be at 0.296 meters above MSL for the mean higher high water (MHHW) level of NOAA Station 1630000, Apra Harbor Guam.

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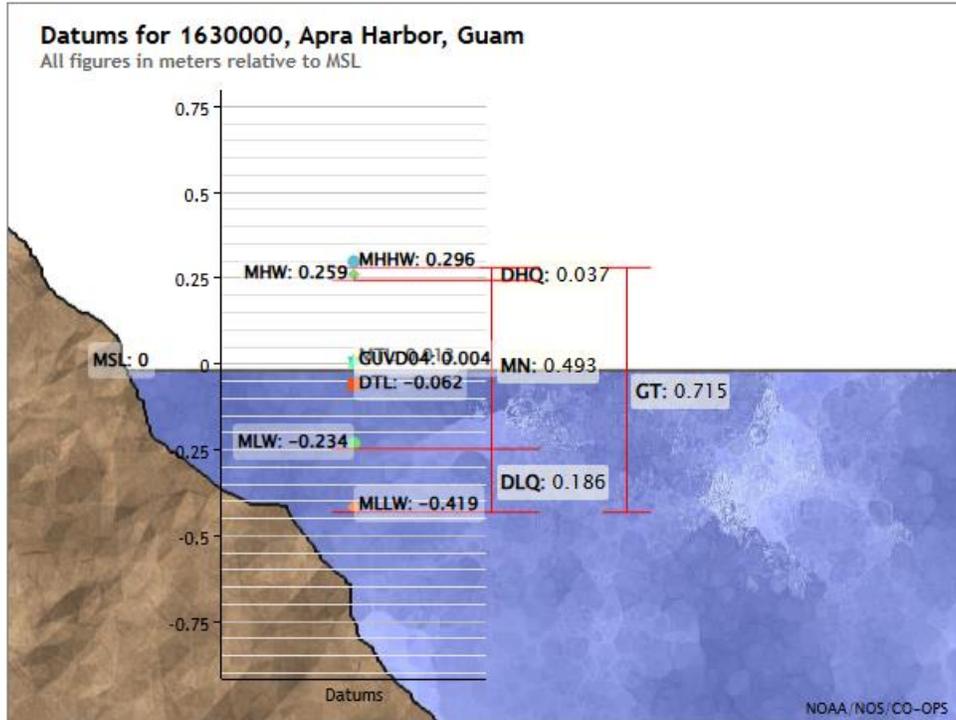


Figure 16 – Datums, NOAA Station 1630000, Apra Harbor, Guam

#### 4.1.4 Unsteady Flow Analysis – Plans files

Plan files were created for the existing conditions unsteady flow analysis. Each flood event has its own plan file as shown on Table 15.

Plan settings were changed to allow the model to run and be more stable. In addition, sensitivity tests were performed so that the results have little to negligible water surface elevation (WSEL) errors. The changes made are summarized Table 14.

**Table 14 – Flow Plan settings, Existing Conditions**

Test run	Comp Interval	Equation set	Initial Conditions time (hr)	Ramp up fraction	Advanced time step control	Run complete
Initial	Default = 1min	Default: Diffusion wave	Default	Default = 0.1	Fixed Time Step	N
Final	5 s	SWE, Shallow Wave	1	0.5	Based on courant: 1 max. courant; 0.45 min. courant; 4 steps below min.; 2 doubling base time step, max; 2 halving base time step, max.	Y

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**Table 15 – Plan file summary**

Plan file ID	Geometry file	Unsteady flow file	Description
Ex 0.2PAC (500yr)	Existing	0.2PAC(500yr)_Finile	Existing conditions geometry Ocean stage: existing conditions Inflows: 0.2% Annual Chance (PAC) or 500-year Annual Exceedance Probability (AEP)
Ex 0.5PAC (200yr)	Existing	0.5PAC(200yr)_Finile	Existing conditions geometry Ocean stage: existing conditions Inflows: 0.5PAC or 500-year AEP
Ex 1PAC (100yr)	Existing	1PAC(100yr)_Finile	Existing conditions geometry Ocean stage: existing conditions Inflows: 1PAC or 100-year AEP
Ex 2PAC (50yr)	Existing	2PAC(50yr)_Finile	Existing conditions geometry Ocean stage: existing conditions Inflows: 2PAC or 50-year AEP
Ex 4PAC (25yr)	Existing	4PAC(25yr)_Finile	Existing conditions geometry Ocean stage: existing conditions Inflows: 4PAC or 25-year AEP
Ex 10PAC (10yr)	Existing	10PAC(10yr)_Finile	Existing conditions geometry Ocean stage: existing conditions Inflows: 10PAC or 10-year AEP
Ex 20PAC (5yr)	Existing	20PAC(5yr)_Finile	Existing conditions geometry Ocean stage: existing conditions Inflows: 20PAC or 5-year AEP
Ex 50PAC (2yr)	Existing	50PAC(2yr)_Finile	Existing conditions geometry Ocean stage: existing conditions Inflows: 50PAC or 2-year AEP

#### 4.1.5 Results

The results show widespread flooding. Results for the existing conditions 1PAC (100yr AEP) Salinas River, Finile Creek, Gaan River, and Auau Creek are shown in Figure 17 to Figure 19. The map shows the inundation boundary and depths results.

The flows at Salinas River overtops and floods roads and residential properties at San Vicente Ave, San Isidro St., San Roque St., De Los Marteres St., N. Eugenio St., S. Santa Cruz St., Tomas Mesa St., Geiger St. and the Rt. 2 highway road. The Salinas River, Salinas US1, and Salinas US2 culvert crossings does not convey all flows and so weir flow overtops the road.

The flows at Finile Creek overtops and floods roads and residential properties at San Francisco Street, and Finile Drive. In addition, the Finile Creek culvert crossing does not convey all flows and so weir flow overtops Rt. 2 highway. The flows from Finile Creek’s south tributary, which is coming from subbasin FC2, overflows the ditches at Little Manila St. and overtops Finile Drive then flows to Gaan River, instead of it flowing to Finile Creek.

The flows at Gaan River and Auau Creek overtops and floods roads and residential properties adjacent to the stream, Tun Leon Road, Babauta Road, and Rt. 2 highway

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road. The Gaan River, Auau Creek, and Auau US1 culvert crossings does not convey all flows and so weir flow overtops the road.

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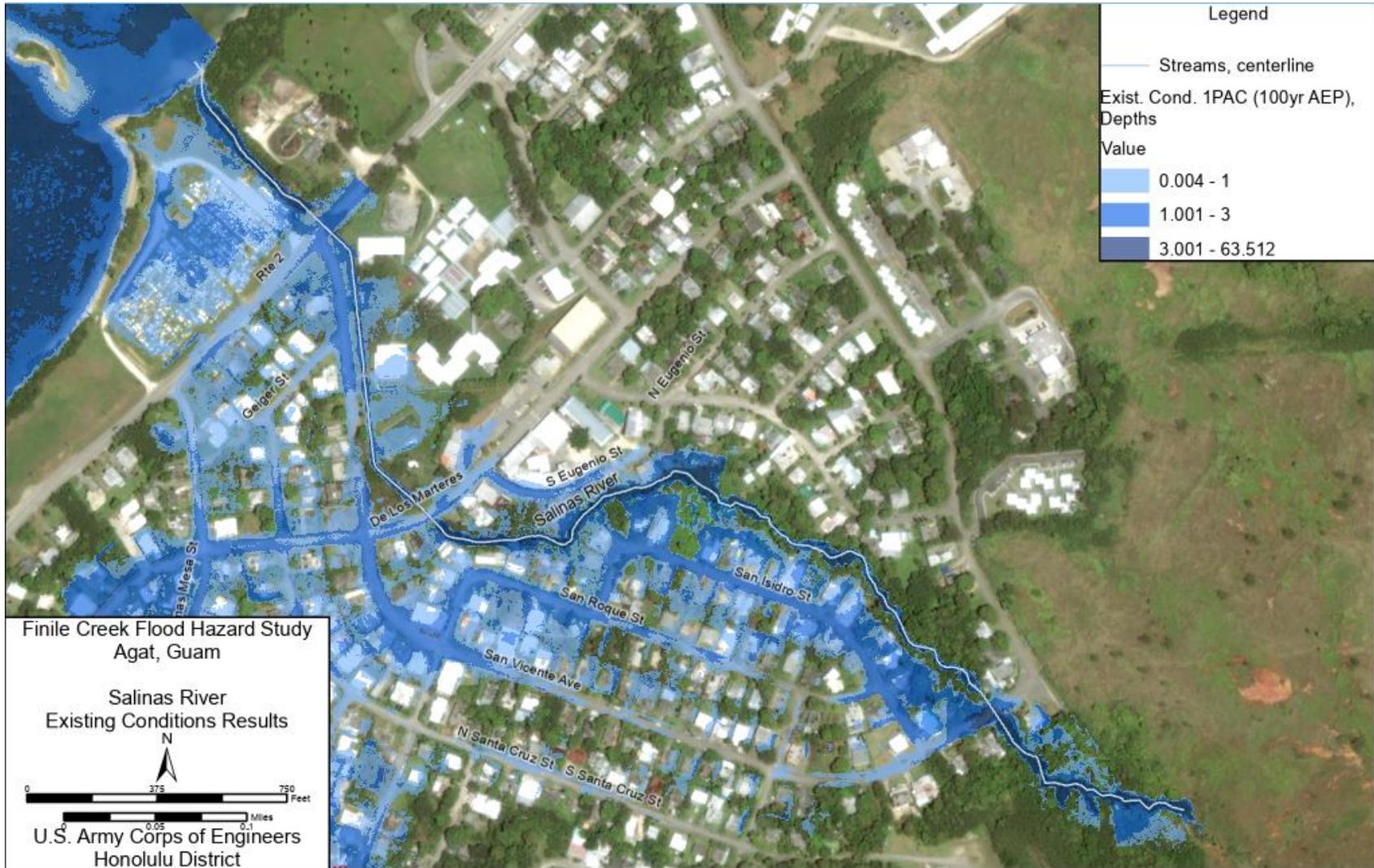


Figure 17 – Results Map, Salinas River

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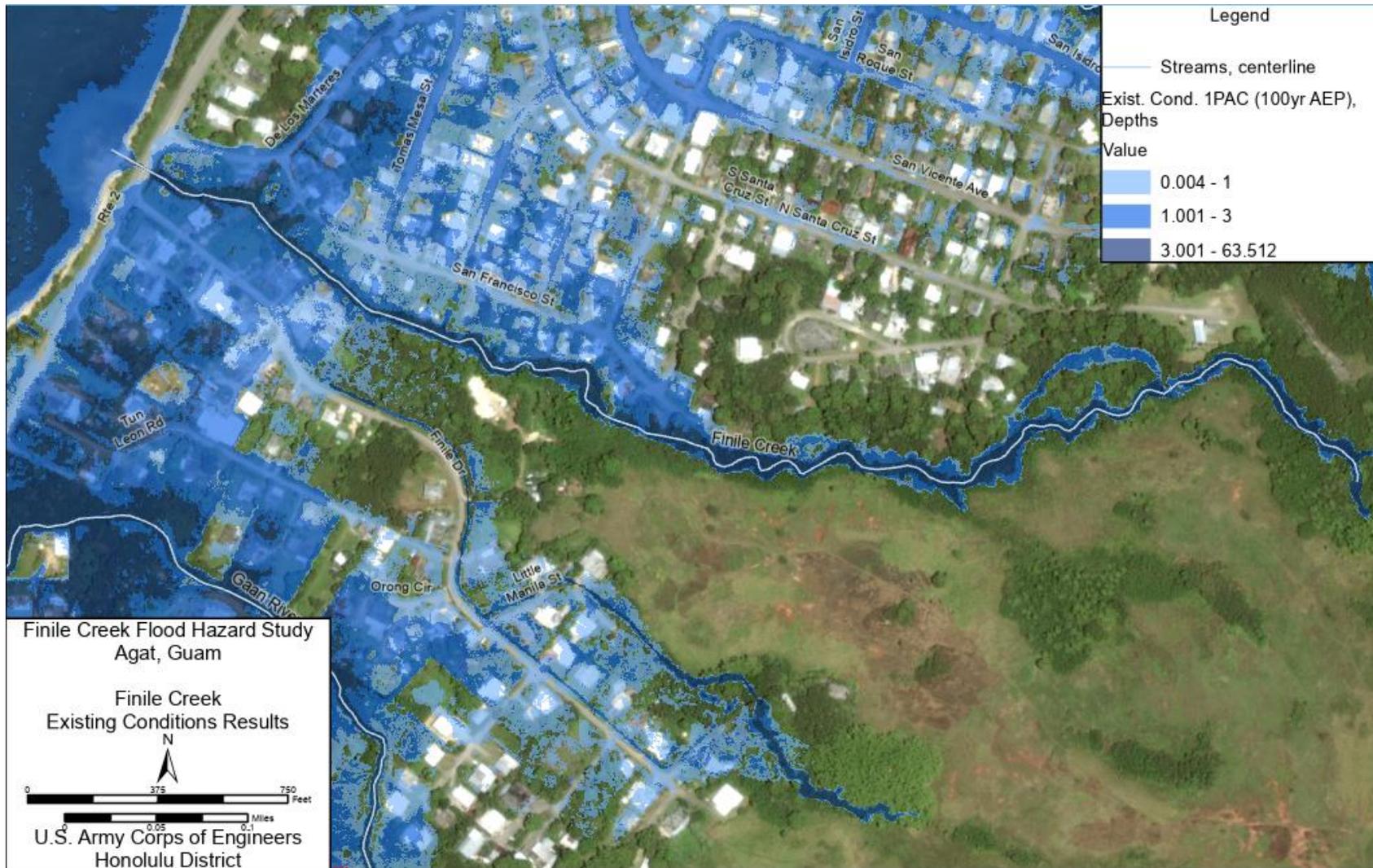


Figure 18 – Results Map, Finile Creek

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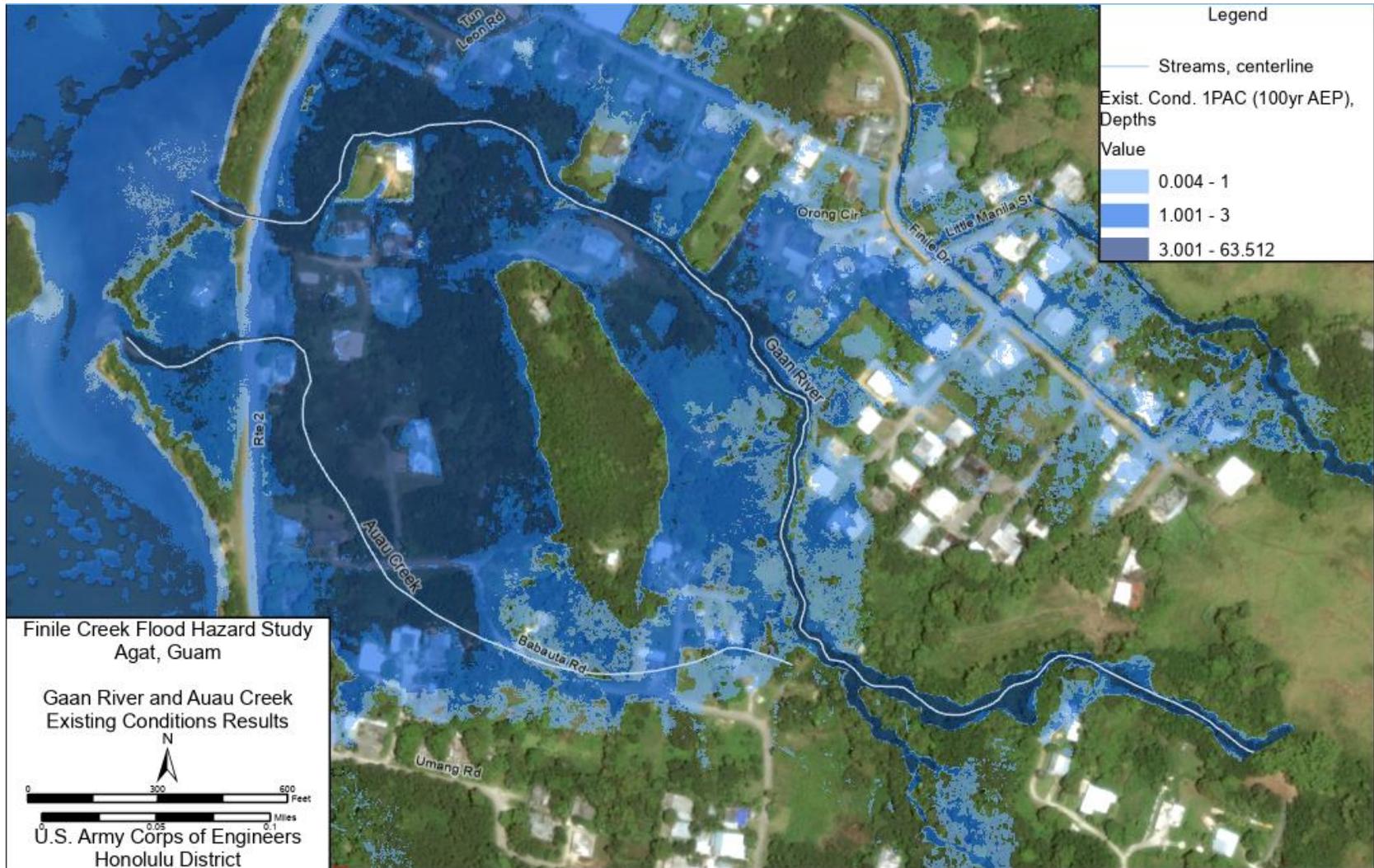


Figure 19 – Results Map, Gaan River and Auau Creek

## 4.2 FUTURE WITHOUT PROJECT CONDITIONS

### 4.2.1 Terrain

The existing conditions terrain Existing is used in the simulations for the Future Without Project (FWOP) conditions.

### 4.2.2 Geometry

The existing conditions geometry file is used in the simulations for the FWOP conditions.

### 4.2.3 Unsteady Flow – Flow files

The unsteady flow files for existing conditions were duplicated and renamed for the FWOP conditions simulations. Each flood event at 2, 5, 10, 25, 50, 100, 200, and 500-year has its own flow file.

Ocean boundary conditions has been changed for all flow files. No changes were made to the inflow hydrographs and normal depth boundary conditions.

The ocean stage hydrograph was determined to be uniform at 0.88 meters above MSL for the 2075 MHHW, intermediate scenario, by the USACE Sea Level Analysis Tool for NOAA Station 1630000, Apra Harbor Guam. Year 2075 is selected to represent the typical life span of an infrastructure (50 years from now – 2025).

### 4.2.4 Unsteady Flow Analysis – Plans files

The existing conditions plan files were duplicated and renamed for the FWOP simulations, copying over the plan file settings. Each flood event has its own plan file following the naming convention shown on Table 16.

**Table 16 – Plan file summary, FWOP conditions**

Plan file ID	Geometry file	Unsteady flow file	Description
FWOP 0.2PAC (500yr)	Existing	0.2PAC(500yr)_Finile_FutureCond	Existing conditions geometry Ocean stage: future conditions Inflows: 0.2PAC or 500-year AEP
FWOP 0.5PAC (200yr)	Existing	0.5PAC(200yr)_Finile_FutureCond	Existing conditions geometry Ocean stage: future conditions Inflows: 0.5PAC or 500-year AEP
FWOP 1PAC (100yr)	Existing	1PAC(100yr)_Finile_FutureCond	Existing conditions geometry Ocean stage: future conditions Inflows: 1PAC or 100-year AEP
FWOP 2PAC (50yr)	Existing	2PAC(50yr)_Finile_FutureCond	Existing conditions geometry Ocean stage: future conditions Inflows: 2PAC or 50-year AEP
FWOP 4PAC (25yr)	Existing	4PAC(25yr)_Finile_FutureCond	Existing conditions geometry Ocean stage: future conditions

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			Inflows: 4PAC or 25-year AEP
FWOP 10PAC (10yr)	Existing	10PAC(10yr)_Finile_FutureCond	Existing conditions geometry Ocean stage: future conditions Inflows: 10PAC or 10-year AEP
FWOP 20PAC (5yr)	Existing	20PAC(5yr)_Finile_FutureCond	Existing conditions geometry Ocean stage: future conditions Inflows: 20PAC or 5-year AEP
FWOP 50PAC (2yr)	Existing	50PAC(2yr)_Finile_FutureCond	Existing conditions geometry Ocean stage: future conditions Inflows: 50PAC or 2-year AEP

#### 4.2.5 Results

Results for FWOP 1PAC (100yr AEP) Salinas River, Finile Creek, Gaan River, and Auau Creek are shown in Figure 20 to Figure 23. The figure shows the stream profile for the existing conditions 1PAC (100yr AEP) to compare FWOP with. The results show that only areas near the ocean have changes in the results from the existing conditions. The WSEs immediately converge to the existing conditions profile line as you move upstream. River stationing shown in HEC-RAS is in metric units. Due to the minimal changes

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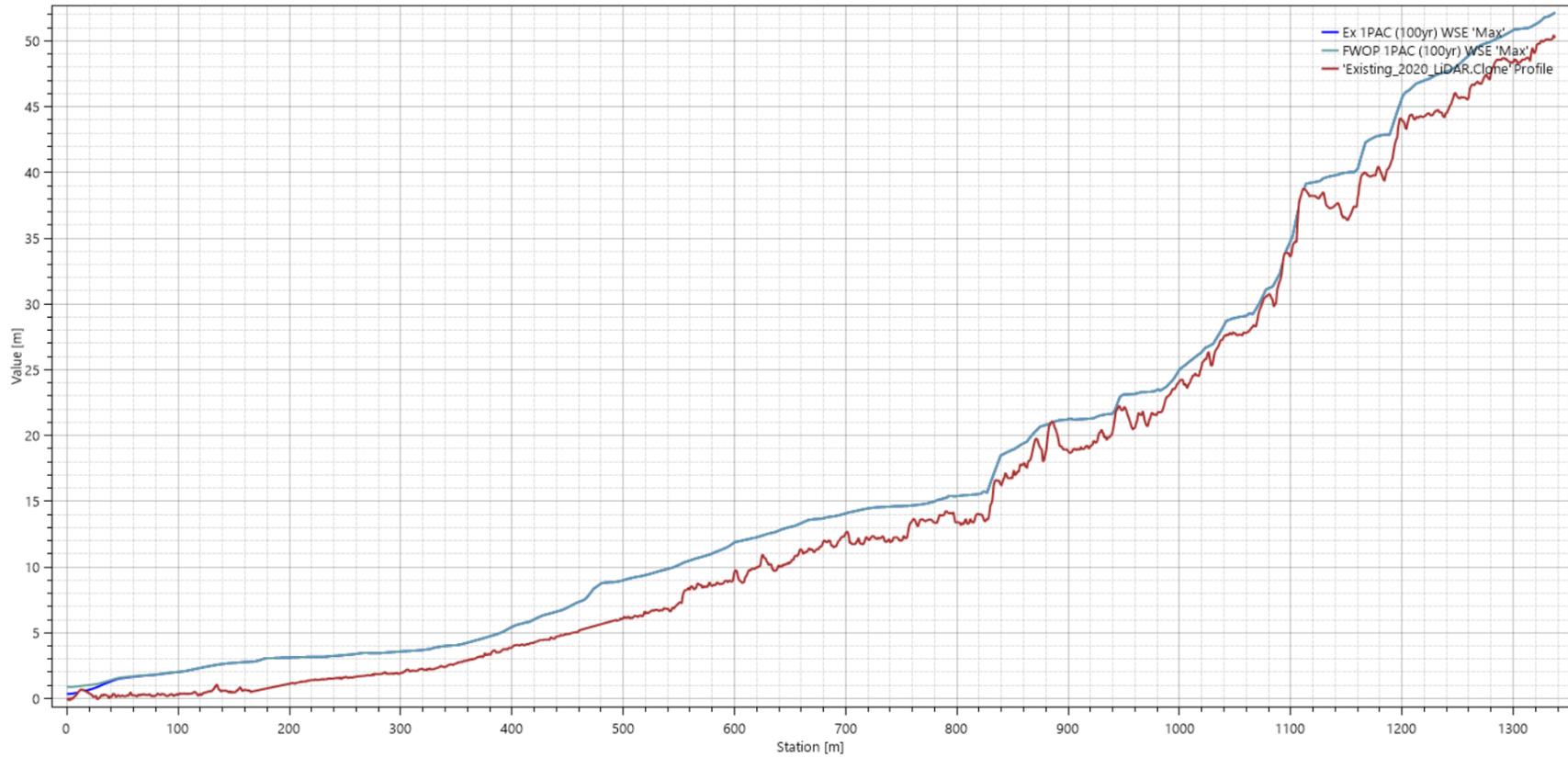


Figure 20 – WSE Profile, Salinas River

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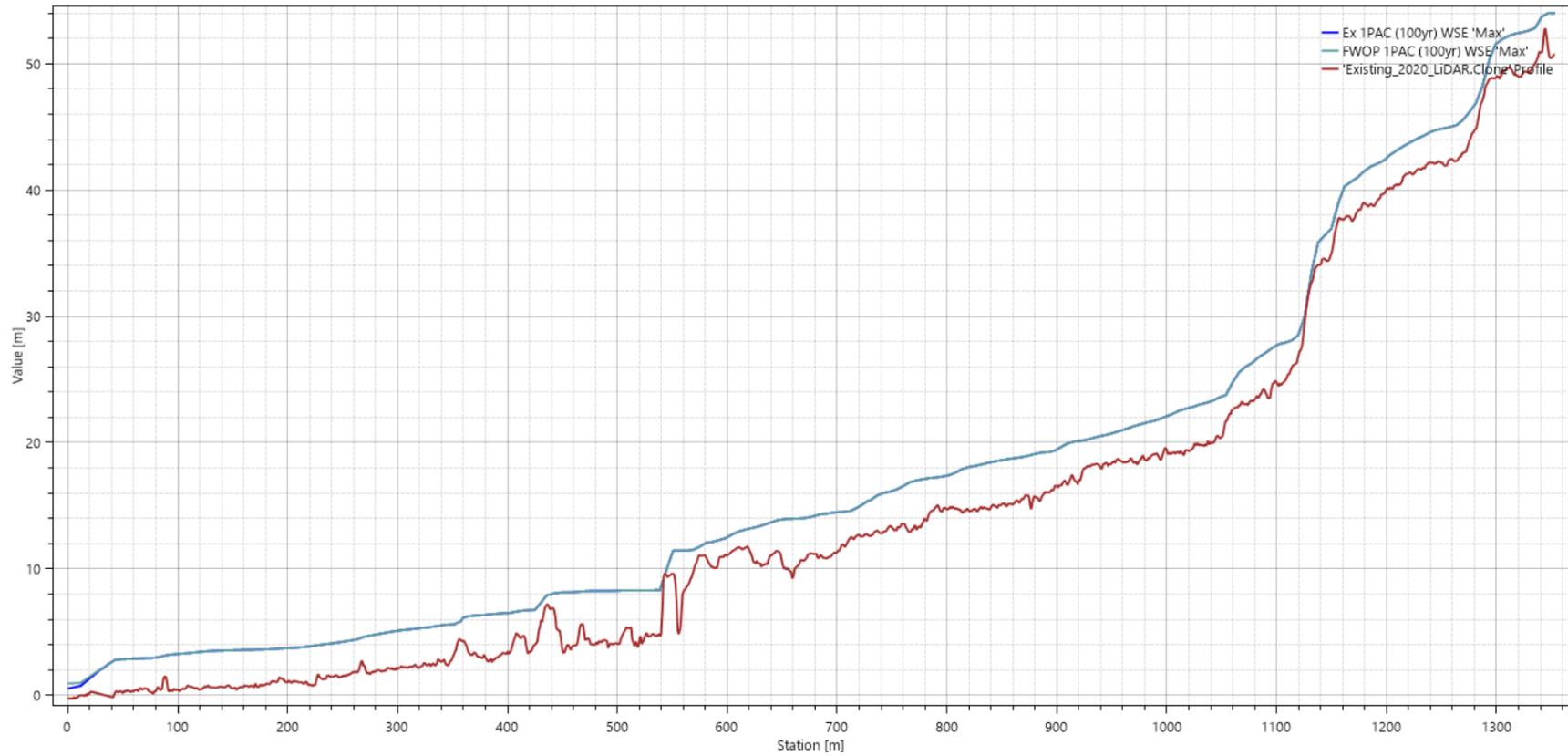


Figure 21 – WSE Profile, Finile Creek

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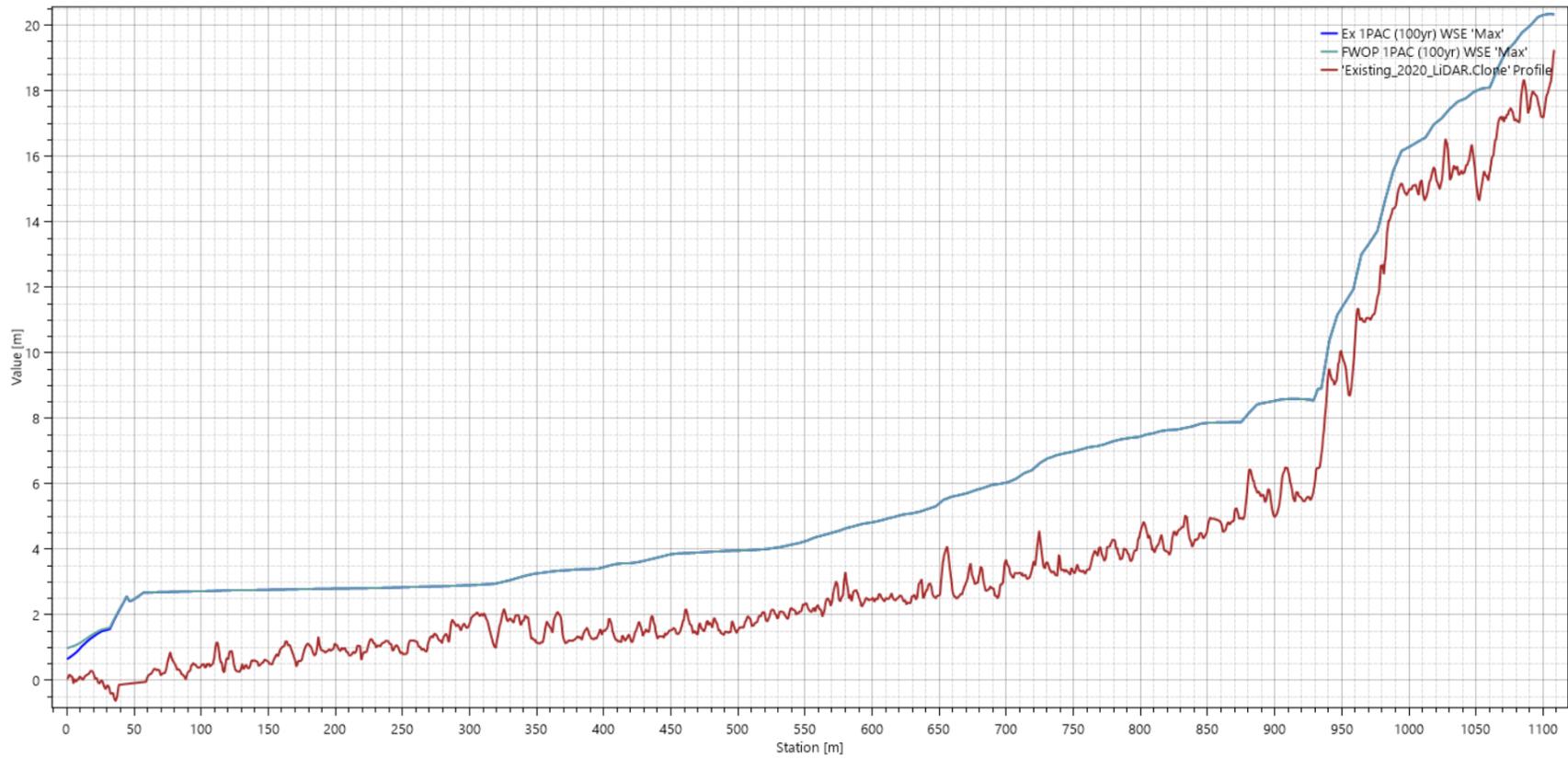


Figure 22 – WSE Profile, Gaan River

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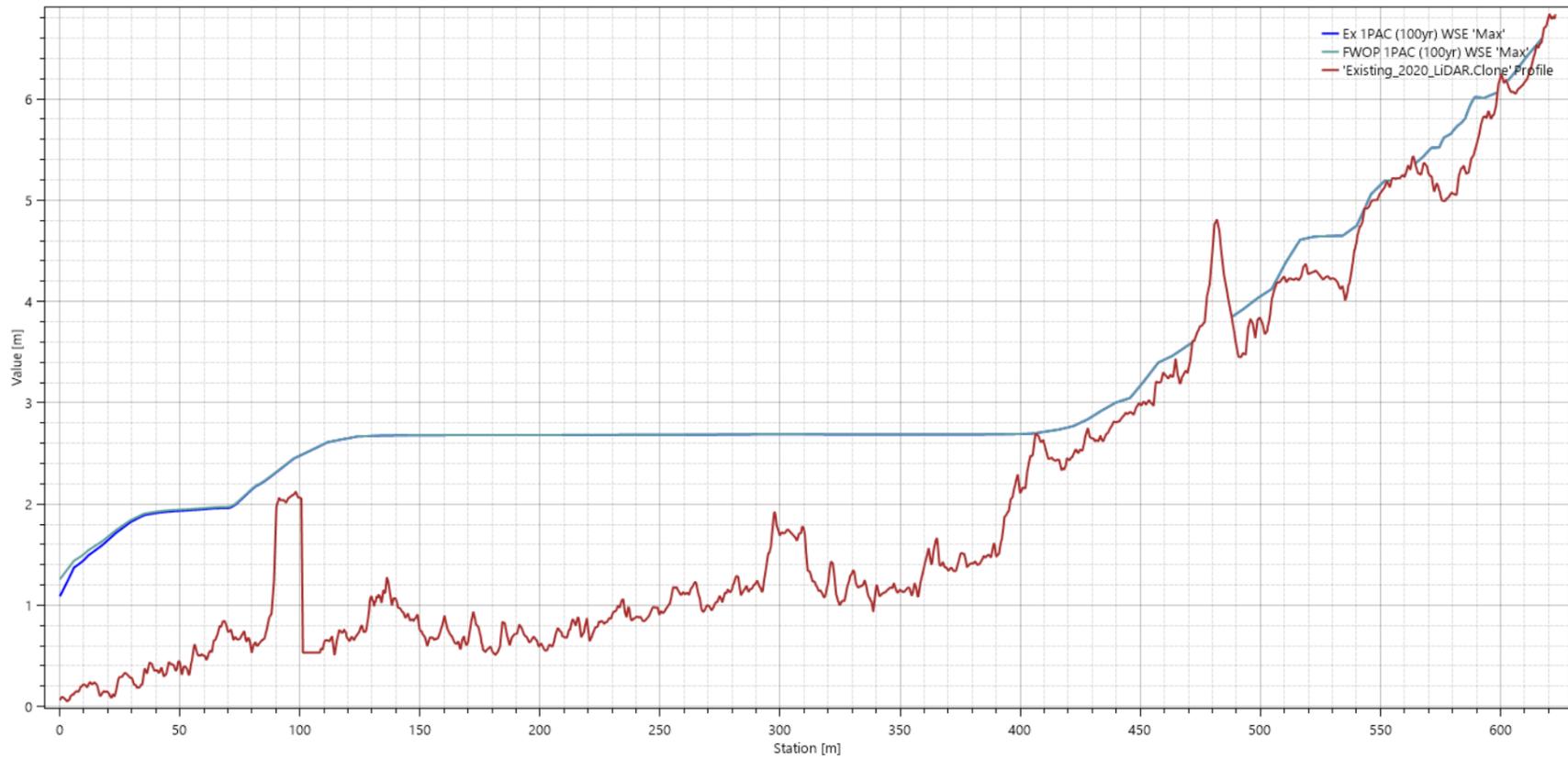


Figure 23 – WSE Profile, Auau Creek

### 4.3 ALTERNATIVE 1 FUTURE WITH PROJECT CONDITIONS

Alternative 1 (Alt1) Future With Project (FWP) conditions is located along Finile Creek.



Figure 24 – Alt1, Site map

#### 4.3.1 Terrain

The LiDAR terrain was cloned and renamed to Alt1 (terrain modification layer: Alt1.working), see Figure 25. Terrain modification from existing conditions were copied. The terrain modifications for Alt1 include:

- Channelization for the following:
  - Stream mouth widening at Finile Creek– 52.50' (wide) x 74' (length), depth varies 3H:1V side slope
  - Channelization at Finile Creek lined with concrete side wall (2H:1V side slopes), RS 0+40 to 3+32 – 20' (wide) x 12' (depth varies) x 1,090' (length)

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- Channelization at Finile Creek lined with concrete side wall (2H:1V side slopes), RS 3+32 to 6+59 – 6' (wide) x 15' (depth varies) 1,070' (length)
- South Finile bypass channel – 17' (wide) x 1,483' (length), depth varies 3H:1V side slope
- Finile Drive Channelization lined with concrete side wall (vertical) at South Finile Upstream Tributary at RS 0+00 to 5+14 – 4' (wide) x 8' (depth varies) 1,684' (length)
- Little Manila Channelization lined with concrete side wall (vertical) at South Finile Upstream Tributary at RS 5+14 to 7+49 – 30' (wide) x 22' (depth varies) x 768' (length)
- South Finile Channelization lined with concrete side wall (2H:1V side slopes) at South Finile Downstream Tributary at RS 0+00 to 0+77 – 17' (wide) x 8' (depth varies) x 253' (length)
- Road raise for new deeper culverts at Rt. 2 highway road
- Inline weir at South Finile Upstream Tributary RS 5+14 – 2' width x 22' height x 30' length reinforced concrete

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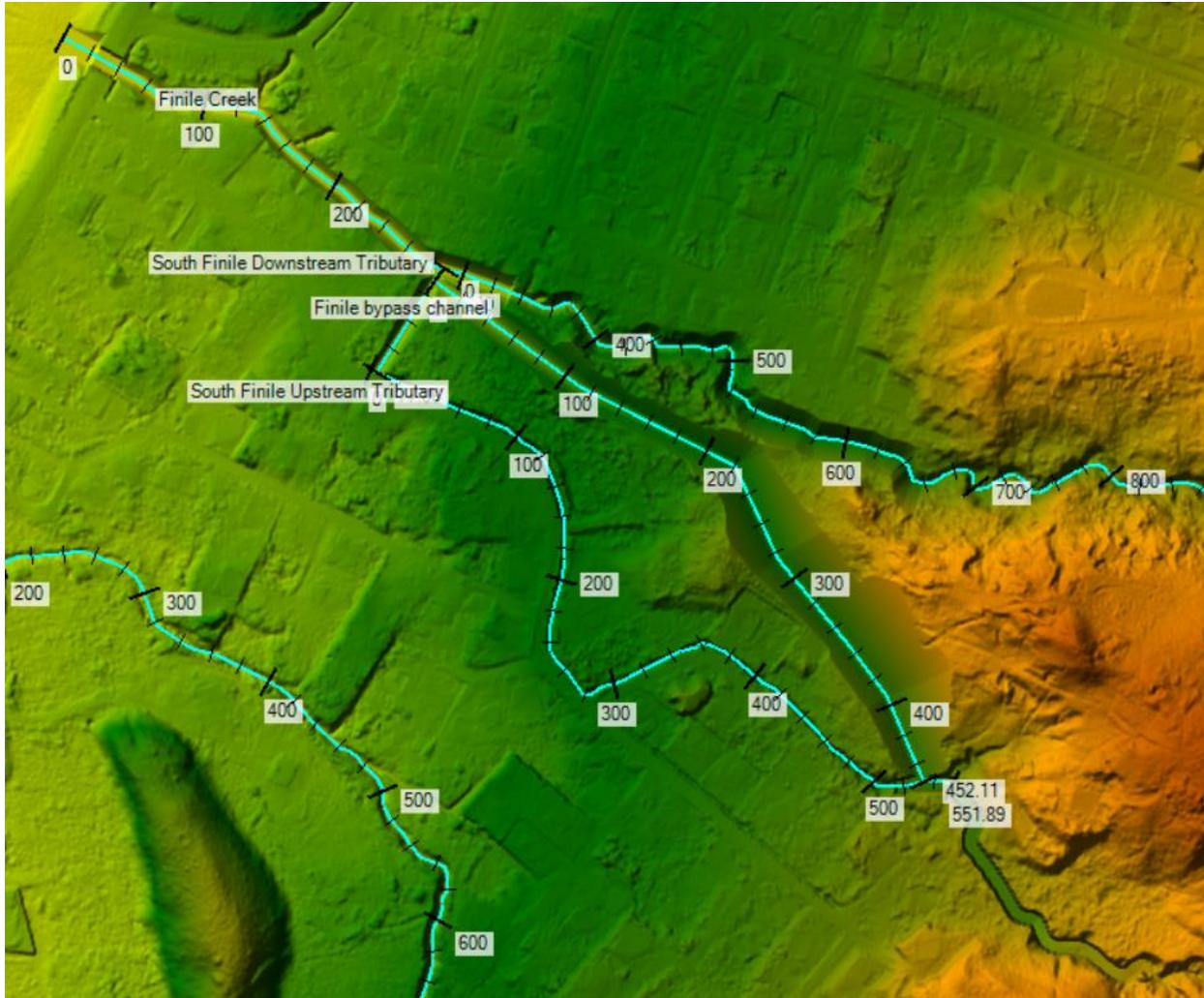


Figure 25 – Alt1 terrain modification, site map

### 4.3.2 Geometry

The existing conditions geometry file was duplicated and renamed for the Alt1 FWP conditions. No changes were made to the boundary conditions.

#### 4.3.2.1 2D Flow areas

Breaklines were added to the following new features: Finile Creek stream mouth widening and South Finile bypass channel. Minor adjustments were made to computation points to decrease WSEL error. No other changes were made.

#### 4.3.2.2 SA/2D Connections

The following culvert improvements at Finile Creek, Rt 2 highway road, were modeled for Alt1:

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Culvert improvements at Rt 2 highway road: 6 – 7' x 7' x 57.74', with road raise, see Figure 26.

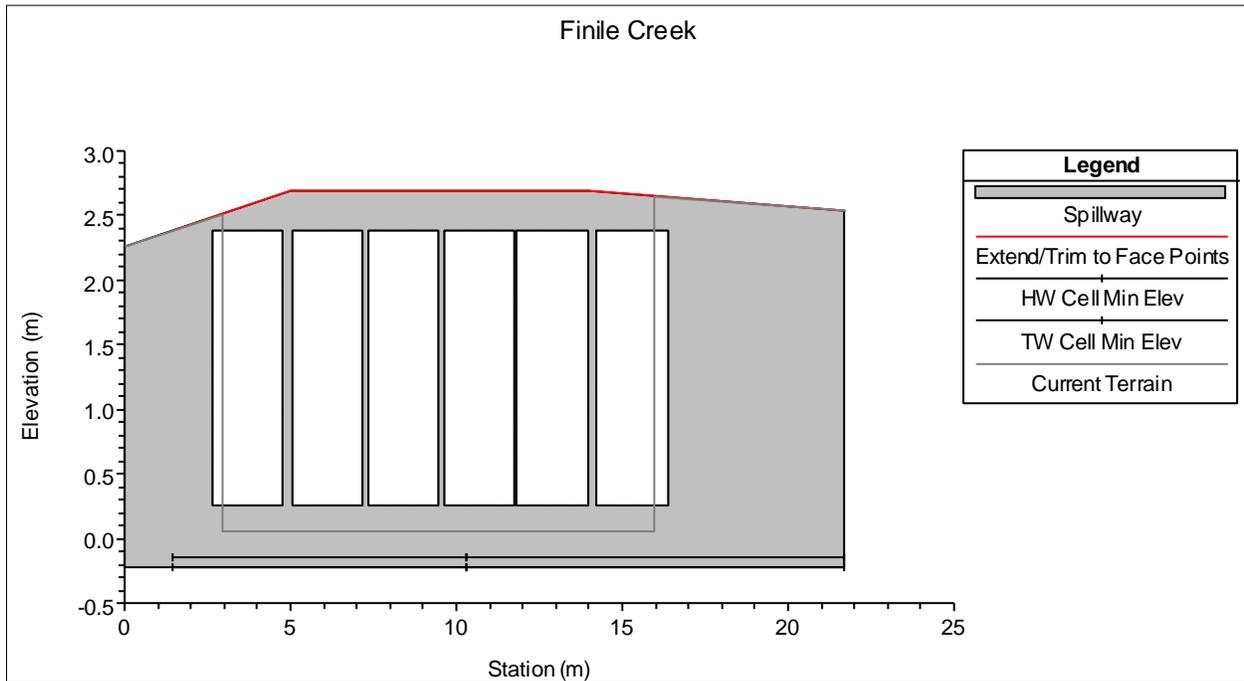


Figure 26 – Alt1, Finile Creek, Culvert improvements at Rt 2 highway road

#### 4.3.2.3 Manning's n

The Manning's roughness coefficient for the channel lining was revised to 0.012. At South Finile Upstream Tributary of Finile, from Sta. 5+16 to 5+30, baffle blocks should be installed in the stream (30' wide x 30' stream length), upstream of the weir. The baffle blocks are modeled as a Manning's roughness coefficient of 0.05.

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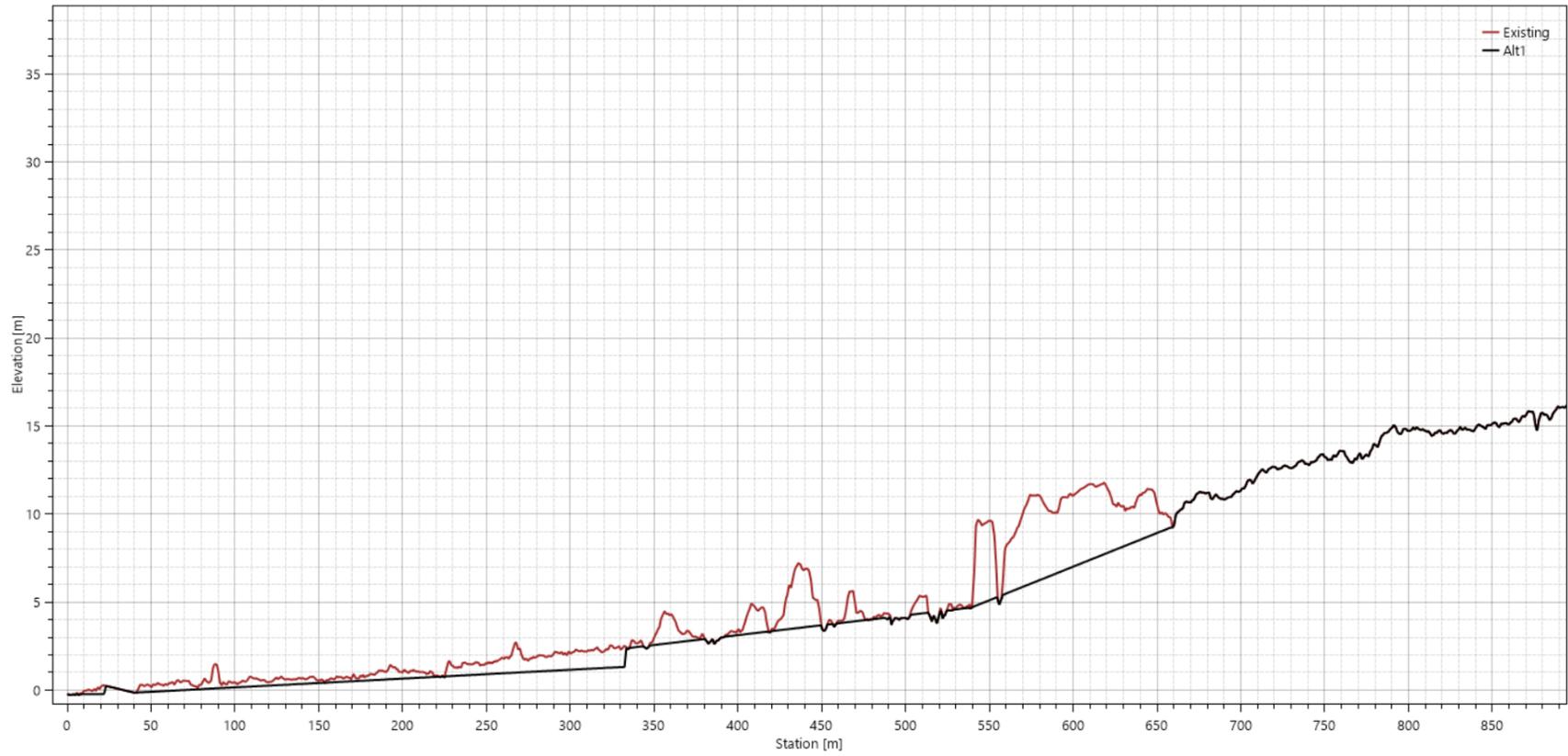


Figure 27 – Alt1, Finile Creek, Channelization

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Figure 28 – Alt1, Finile bypass channel, Channelization

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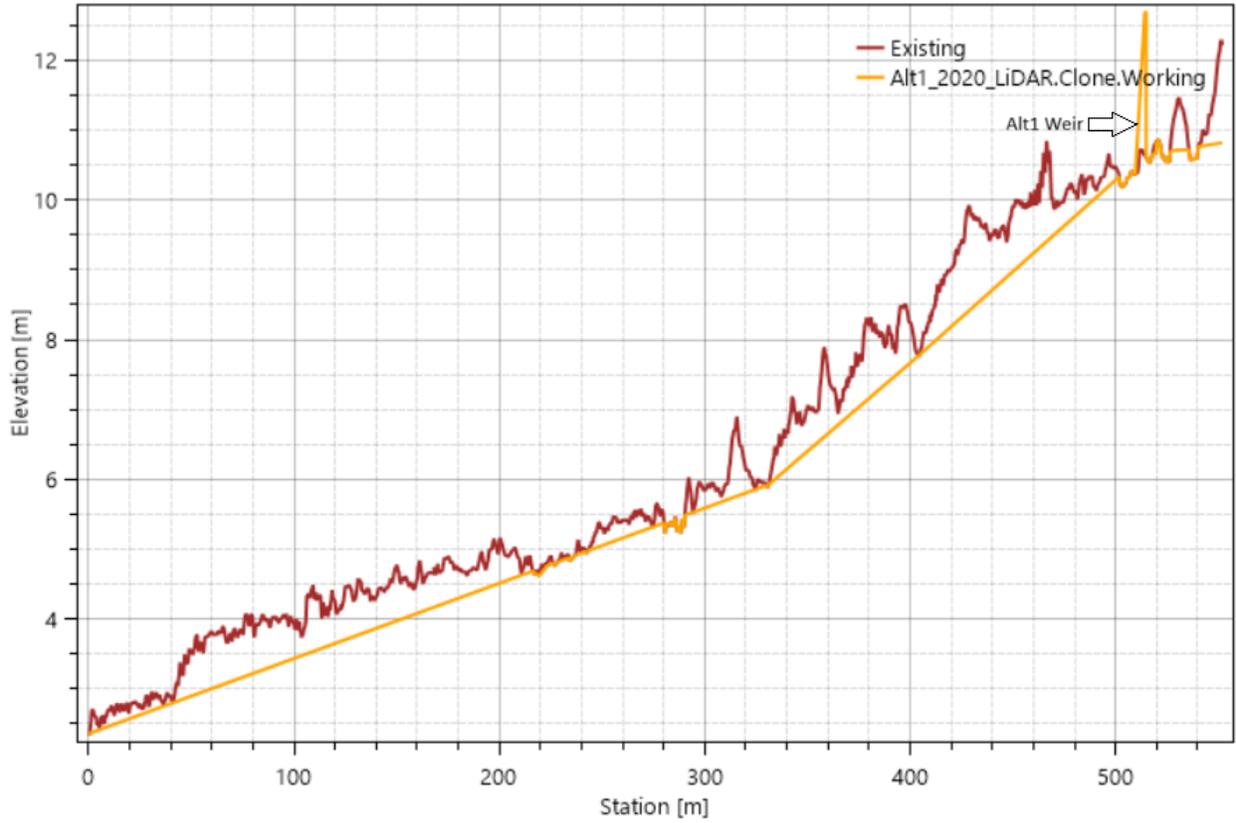
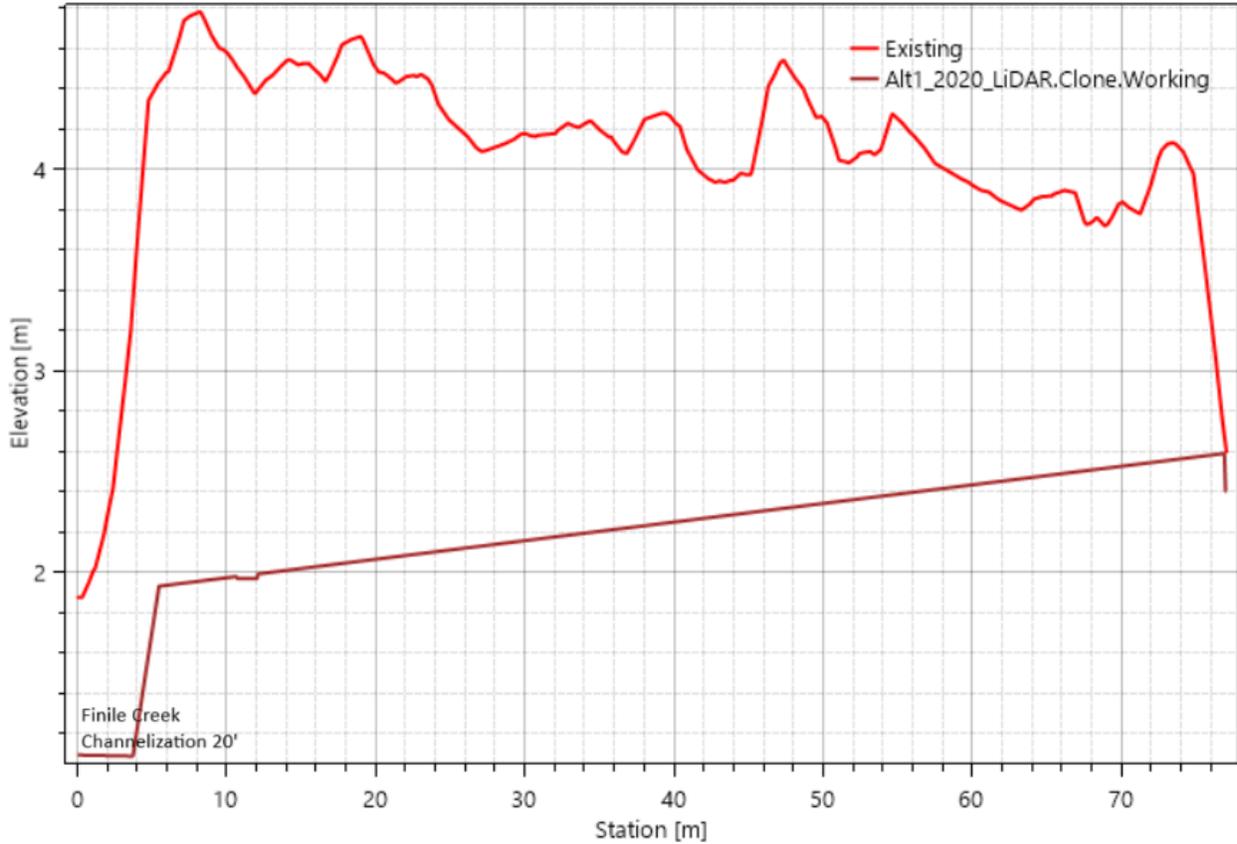


Figure 29 – Alt1, South Finile Upstream Tributary, Channelization

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**Figure 30 – Alt1, South Finile Downstream Tributary, Channelization**

**4.3.3 Unsteady Flow – Flow files**

The future conditions unsteady flow files that were used for the FWOP conditions simulations will be used for the all the FWP analysis. No changes were made to the flow files. Each flood event at 2, 5, 10, 25, 50, 100, 200, and 500-year has its own flow file.

**4.3.4 Unsteady Flow Analysis – Plans files**

The FWOP conditions plan files were duplicated and renamed for the Alt 1 FWP simulations, copying over the plan file settings. Each flood event has its own plan file following the naming convention shown on Table 17.

**Table 17 – Plan file summary, Alt1 FWP conditions**

Plan file ID	Geometry file	Unsteady flow file	Description
Alt1 FWP 0.2PAC (500yr)	Alt1	0.2PAC(500yr)_Finile_FutureCond	Alt1 geometry Ocean stage: future conditions Inflows: 0.2PAC or 500-year AEP
Alt1 FWP 0.5PAC (200yr)	Alt1	0.5PAC(200yr)_Finile_FutureCond	Alt1 geometry Ocean stage: future conditions Inflows: 0.5PAC or 500-year AEP

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Alt1 FWP 1PAC (100yr)	Alt1	1PAC(100yr)_Finile_FutureCond	Alt1 geometry Ocean stage: future conditions Inflows: 1PAC or 100-year AEP
Alt1 FWP 2PAC (50yr)	Alt1	2PAC(50yr)_Finile_FutureCond	Alt1 geometry Ocean stage: future conditions Inflows: 2PAC or 50-year AEP
Alt1 FWP 4PAC (25yr)	Alt1	4PAC(25yr)_Finile_FutureCond	Alt1 geometry Ocean stage: future conditions Inflows: 4PAC or 25-year AEP
Alt1 FWP 10PAC (10yr)	Alt1	10PAC(10yr)_Finile_FutureCond	Alt1 geometry Ocean stage: future conditions Inflows: 10PAC or 10-year AEP
Alt1 FWP 20PAC (5yr)	Alt1	20PAC(5yr)_Finile_FutureCond	Alt1 geometry Ocean stage: future conditions Inflows: 20PAC or 5-year AEP
Alt1 FWP 50PAC (2yr)	Alt1	50PAC(2yr)_Finile_FutureCond	Alt1 geometry Ocean stage: future conditions Inflows: 50PAC or 2-year AEP

#### 4.3.5 Results

There are no proposed alternatives in Salinas River, Gaan River, and Auau Creek under Alt1 therefore, the results do not change from FWOP simulations at these locations.

Figure 32 shows the inundation boundary and flood depth results at 1PAC (100yr AEP). Results show flooding has been mitigated in San Francisco Street and Finile Drive near Little Manila St.

Figure 33 shows the stream profile results for FWOP and Alt1 1PAC (100yr AEP). The results show that WSEL along the stream has decreased at Finile Creek except at RS 0+00 to 0+28, 1+97 to 2+19, and 3+85 to 4+28. Similarly, Figure 34 shows the stream profile results for the South Finile Downstream Tributary. The channelization of this segment in addition to the new bypass channel allows more flow to drain to Finile Creek. Furthermore, the bypass channel and the channelization of South Finile Upstream Tributary allows the conveyance of flows without overtopping the ditches at Little Manila St. and Finile Drive. The bypass channel fully conveys the 100-year flow. Increased WSELs are contained within the stream channel except for Finile Creek RS 1+97 to 2+19, with a maximum increase of 0.8 inches.

Figure 35 is a calculated map of the difference between the Max WSEL of Alt1 100-year and FWOP 100-year (Alt1 WSE minus FWOP WSE). The areas in red have increased WSELs, in gray has no change, and in blue have decreased WSELs. Results show areas adjacent to RS 1+97 to 2+19 have increased WSEL. This impact affects up to five structures. Therefore, to mitigate this impact, structures must be raised above the WSEL. Other measures to consider includes individual onsite drainage facilities such as catchment channels to redirect waters away from the structures and out of the lot.

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Figure 36 shows the results for the culvert crossing *Finile Creek*. The result shows that the culvert conveys the total flow therefore, total flow and total culvert flow shows the same in the figure. Consequently, there is no weir flow for Alt1 FWP. The total flow at Alt1 FWP is larger than FWOP conditions as South Finile runoff has been directed to Finile Creek as intended.

The bypass channel provides solution to the flooding in Little Manila St. but it requires excavating through high elevations, see Figure 28 and Figure 31. An alternate layout for the bypass channel can be considered to avoid excavations at high elevations. The Finile Drive Channelization on the roadside ditches shall only convey interior drainage flows from the residential areas within Subbasin FC2.

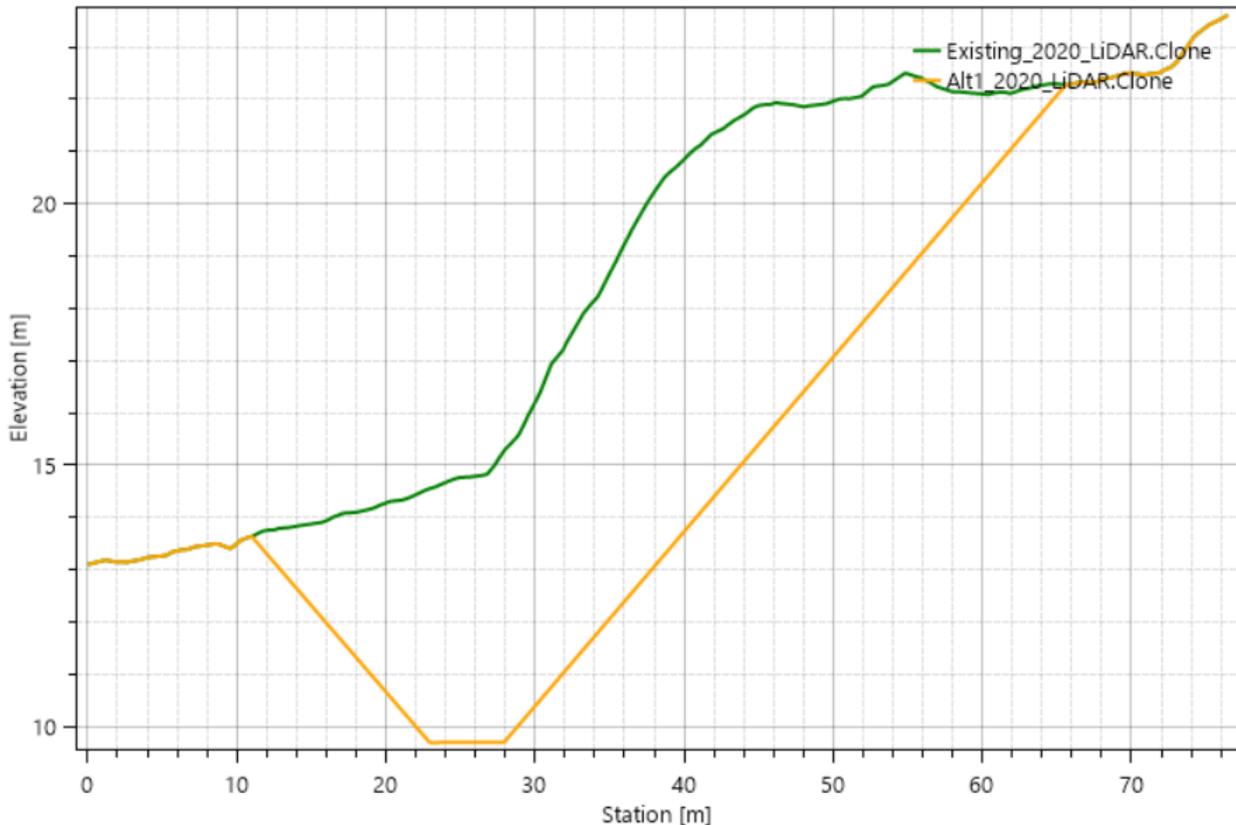


Figure 31 – XS view, bypass channel, Sta. 4+00

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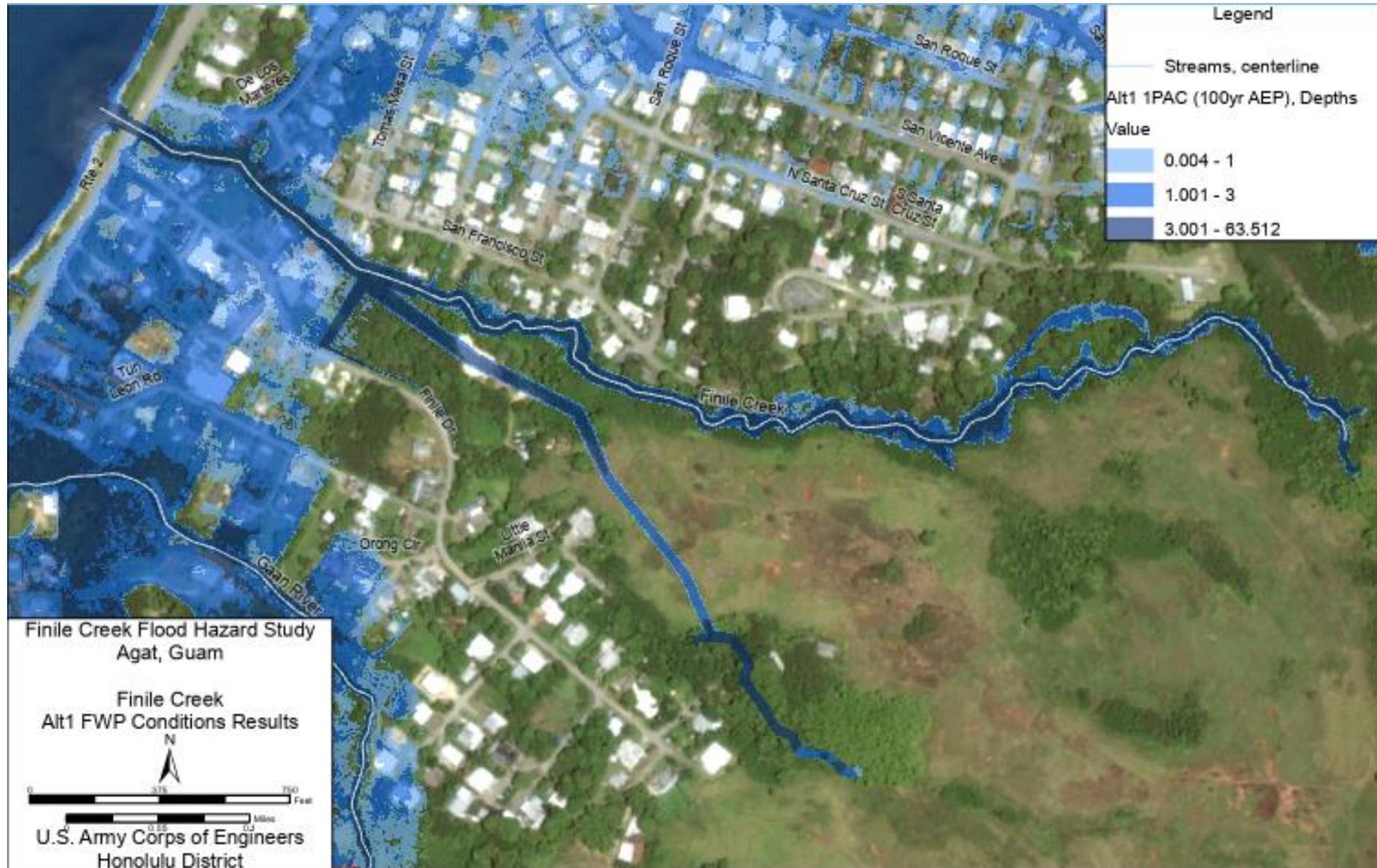


Figure 32 – Results Map, Alt1 FWP, Finile Creek

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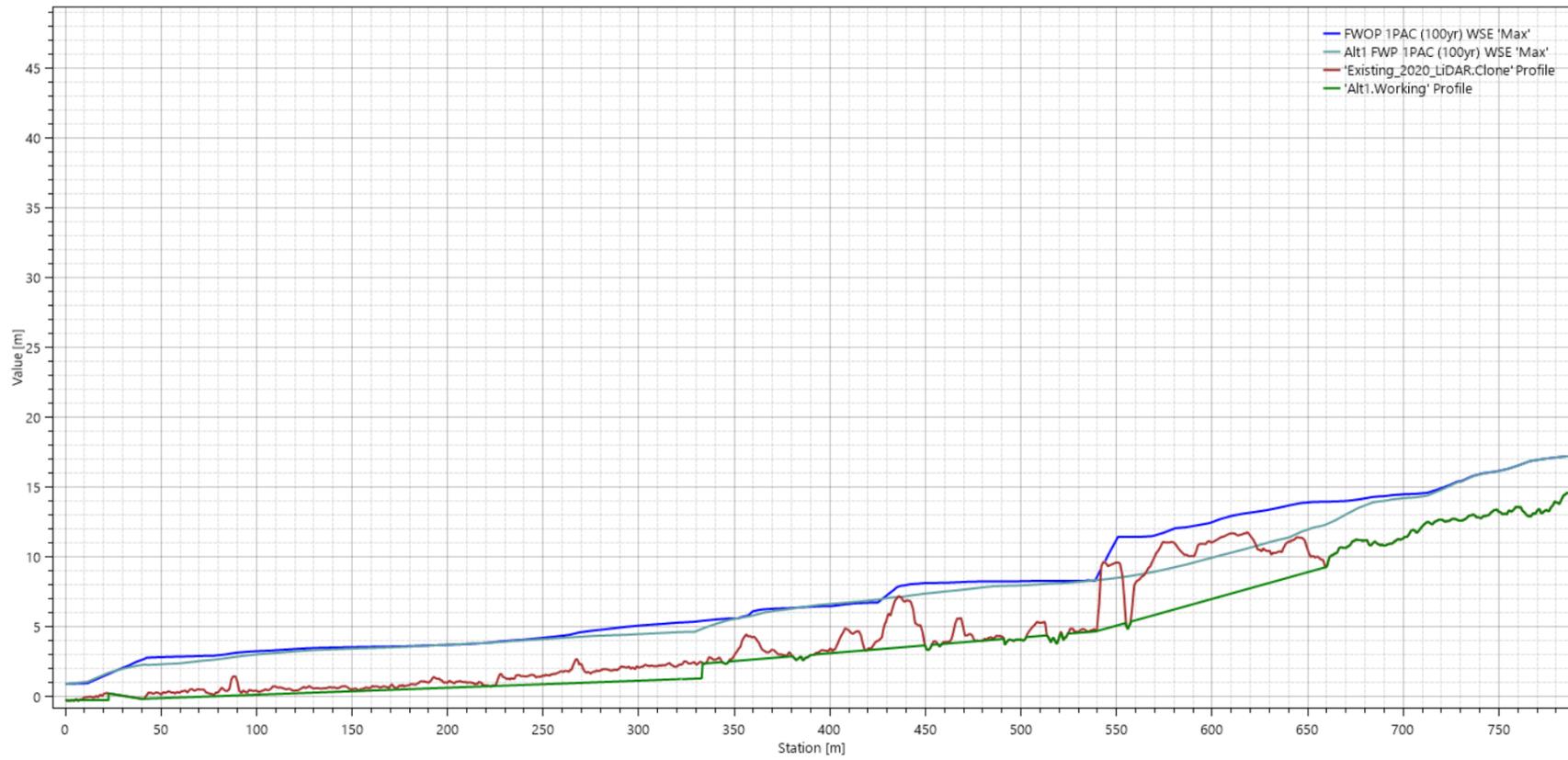


Figure 33 – WSEL profile results, Alt1 FWP, Finile Creek

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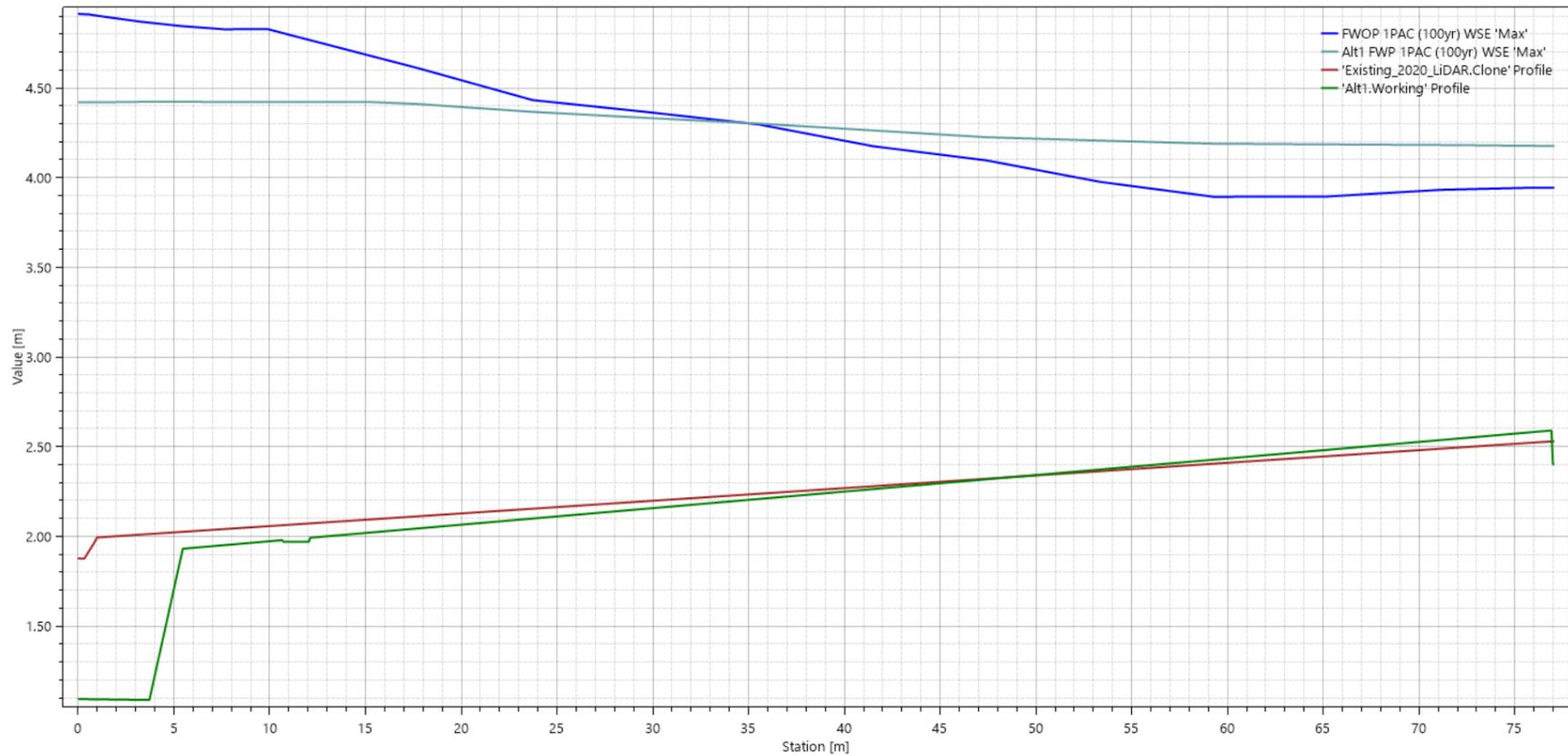


Figure 34 - WSEL profile results, Alt1 FWP, South Finile Downstream Tributary

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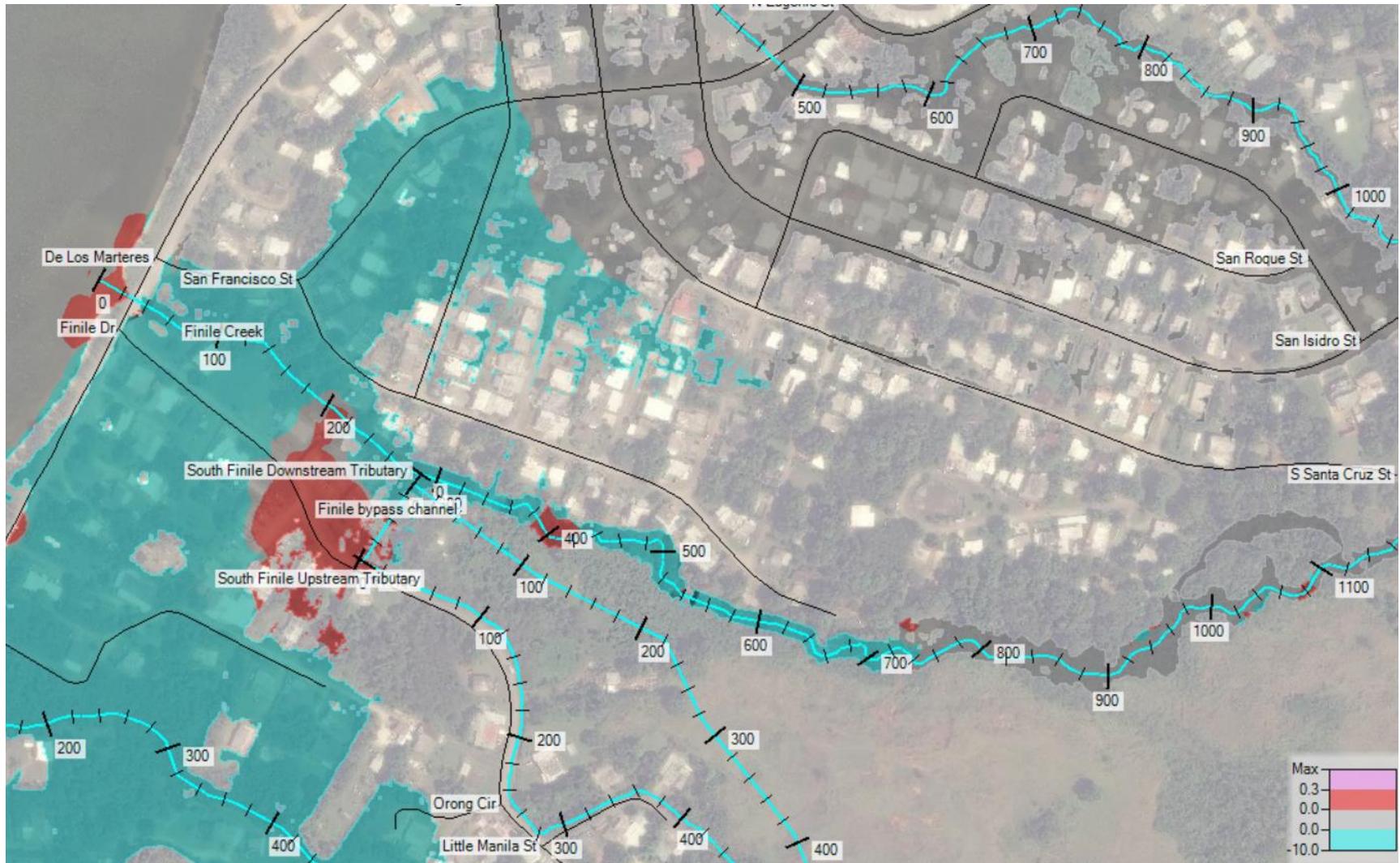
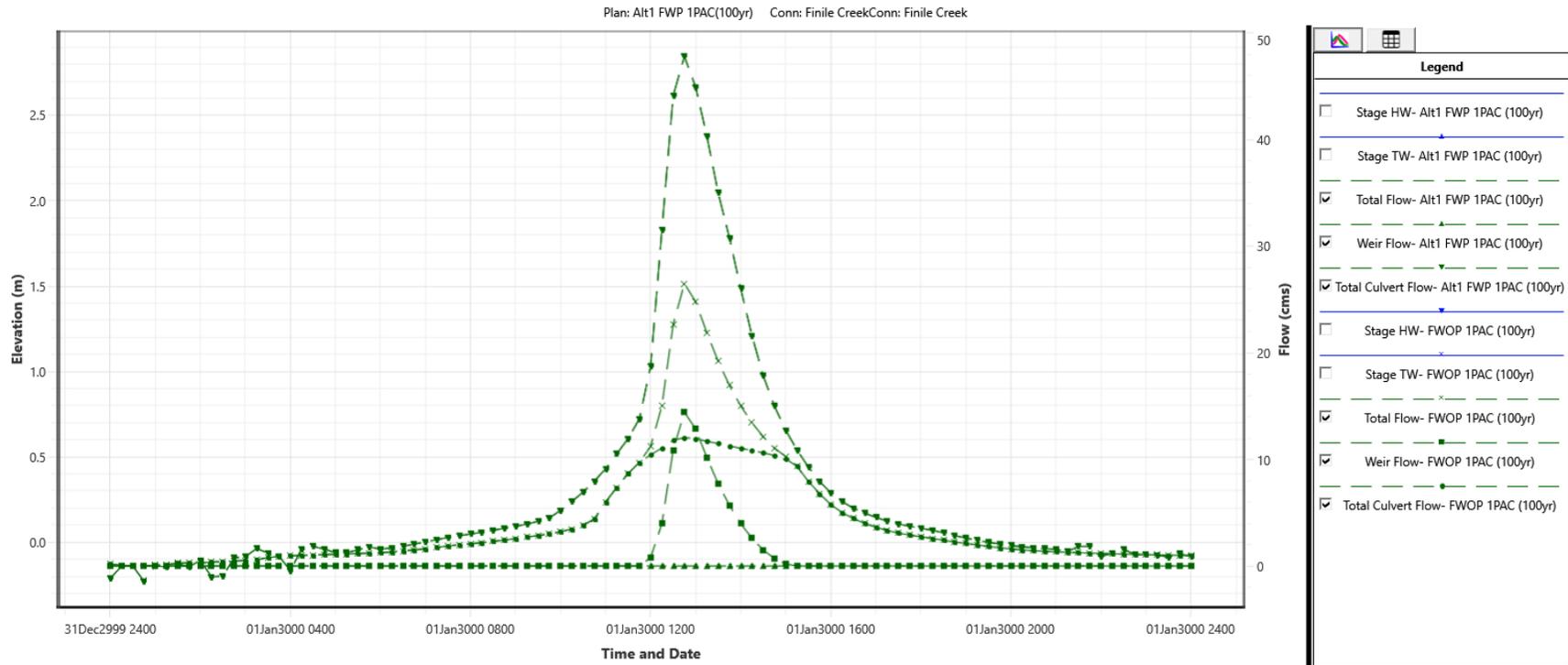


Figure 35 – Alt1, Calculated layer Max WSE Alt2 100-year minus Max WSE FWOP 100-year

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#### 4.4 ALTERNATIVE 2 FWP CONDITIONS

Alternative 2 (Alt2) FWP conditions is located along Salinas River.



Figure 37 – Alt2, Site map

##### 4.4.1 Terrain

The LiDAR terrain was cloned and renamed to Alt2 (terrain modification layer: Alt2\_2020\_LiDAR.Clone), see Figure 38. Terrain modification from existing conditions were copied. The terrain modifications for Alt2 include:

- Channelization for the following:
  - Salinas River stream mouth widening RS 0+00 to 1+60 – 30' (wide) x 161' (length), depth varies 3H:1V side slope
  - Channelization at Salinas River lined with concrete side wall (2H:1V side slopes) RS 2+02 to 2+20, upstream transition section for the culvert crossing at Rt 2 hwy rd. – 30' (wide) x 57.97' (length), depth varies

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- Channelization at Salinas River lined with concrete side wall (vertical sidewall) RS 2+20 to 4+30 – 8' (wide) x 4.25' (depth varies) x 753.1' (length)
- Channelization at Salinas River lined with concrete side wall (2H:1V side slopes) RS 4+30 to 4+63, downstream transition section for the culvert crossing at Delos Marteres St. – 50' (wide) x 10.2' (depth varies) x 103.1' (length)
- Channelization at Salinas River lined with concrete side wall (2H:1V side slopes) RS 4+91 to 5+00, upstream transition section for the culvert crossing at De Los Marteres St. – 50' (wide) x 8.86' (depth varies) x 29' (length)
- Channelization at Salinas River lined with concrete side wall (1H:1V side slopes) RS 5+00 to 6+64 – 6' (wide) x 10' (depth varies) x 537' (length)
- Channelization at Salinas River lined with concrete side wall (1H:1V side slopes) RS 6+64 to 7+55 – 10' (wide) x 3' (depth varies) x 299' (length)
- Channelization at Salinas River lined with concrete side wall (1H:1V side slopes) RS 7+55 to 9+01 – 6' (wide) x 5' (depth varies) x 480' (length)
- Channelization at Salinas River lined with concrete side wall (2H:1V side slopes) RS 10+68 to 11+05, downstream transition section for the culvert crossing at San Vicente Ave – 5' (wide) x 17' (depth varies) x 122' (length)
- Channelization at Salinas River lined with concrete side wall (1H:1V side slopes) RS 11+33 to 11+51, upstream transition section for the culvert crossing at San Vicente Ave – 50' (wide) x 9' (depth varies) x 61' (length)
- Berm on Salinas River right bank near RS 3+30 - 1' (wide) x 3.35' (depth varies) x 212' (length)
- Road raise for new deeper culverts at Rt. 2 highway road
- Road raise for new deeper culverts at De Los Marteres St.

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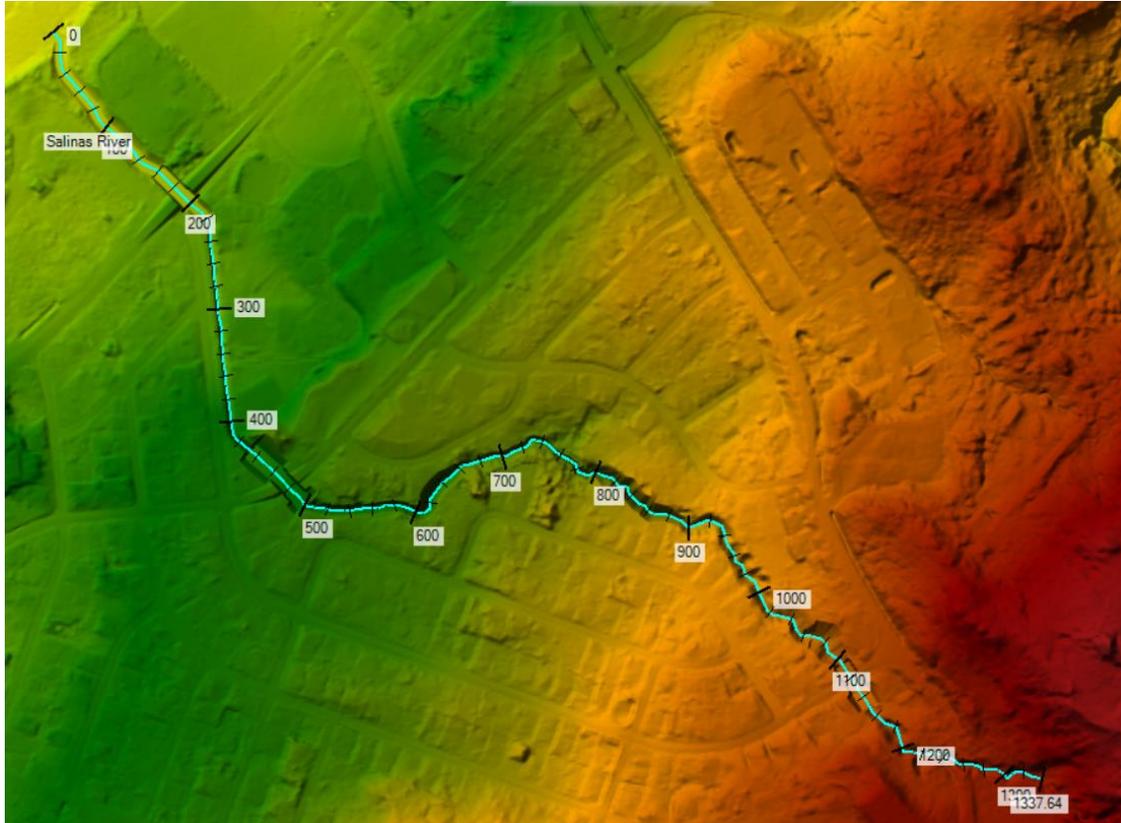


Figure 38 – Alt2 terrain modification, site map

#### 4.4.2 Geometry

The existing conditions geometry file was duplicated and renamed for the Alt2 FWP conditions. No changes were made to the boundary conditions.

##### 4.4.2.1 2D Flow Areas

Breaklines were added to the new berm near Salinas River right bank RS 3+30. Minor adjustments were made to computation points to decrease WSEL error. No other changes were made.

##### 4.4.2.2 SA/2D Connections

The following culvert improvements at Salinas River, San Vicente Ave, were modeled for Alt3:

- Culvert improvements at Rt 2 highway road: 4 – 12' x 8' x 138', includes road raise, see Figure 39.
- Culvert improvements at De Los Marteres Road: 4 – 12' x 8' x 100', includes road raise, see Figure 40.

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- Culvert improvements at San Vicente Ave: 4 – 12' x 8' x 92', see Figure 41.

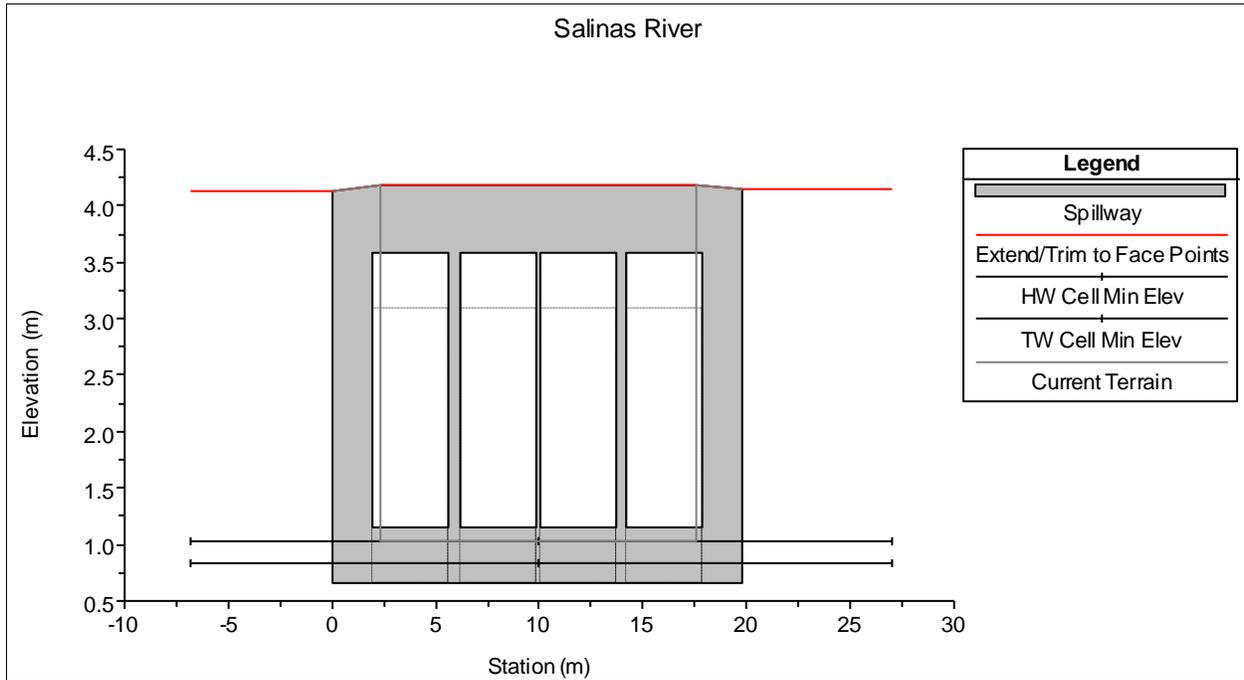


Figure 39 – Alt2, Salinas River, Culvert improvements at Rt 2 Hwy Rd

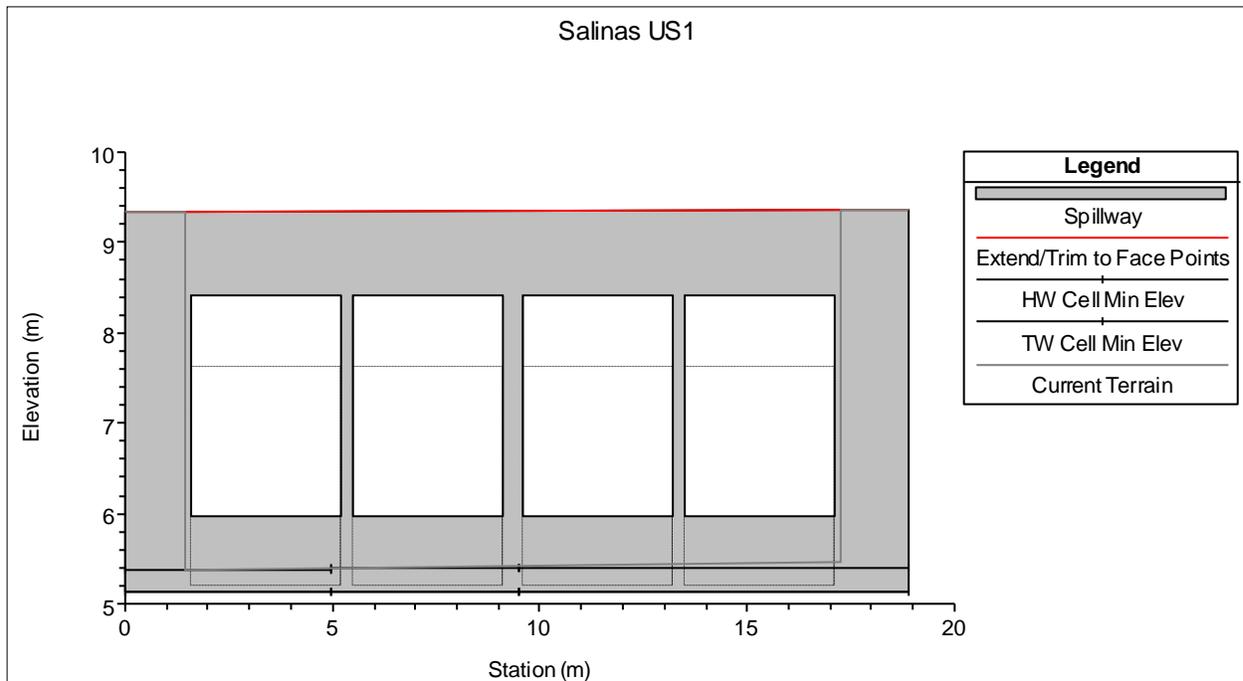
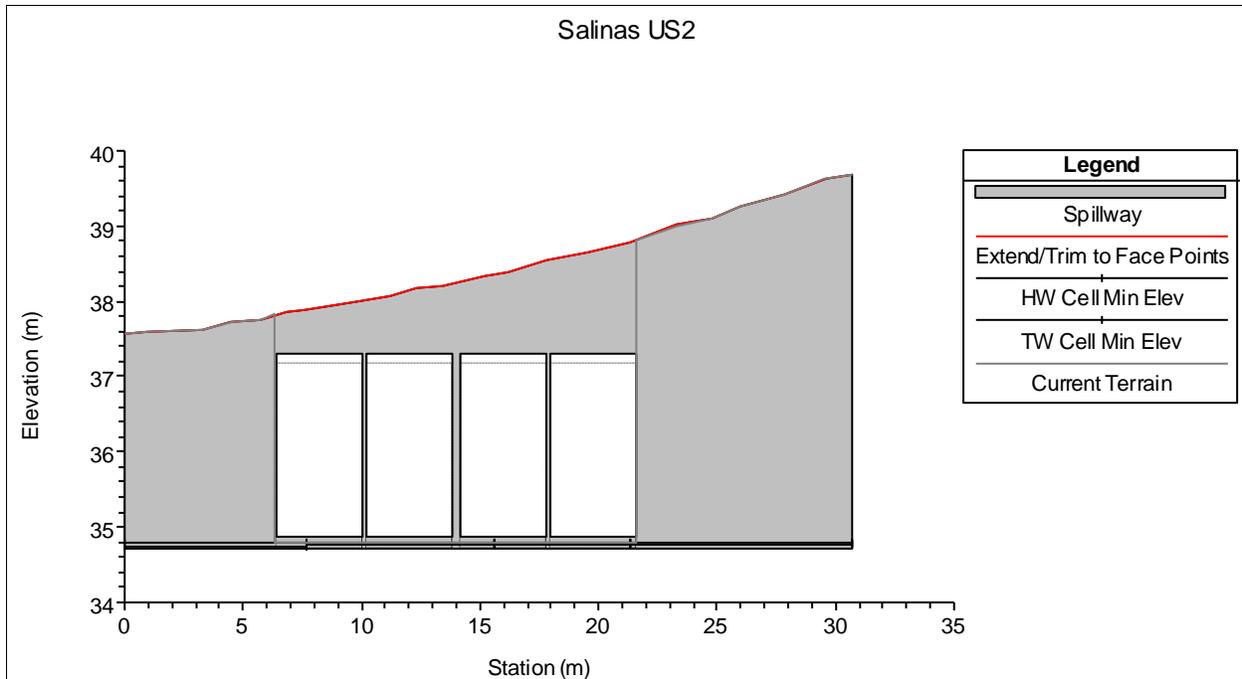


Figure 40 - Alt2, Salinas US1, Culvert improvements at De Los Marteres

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**Figure 41 - Alt2, Salinas US2, Culvert improvements at San Vicente Ave**

**4.4.2.3 Manning's n**

The calibration regions for the Manning's roughness coefficient on Alt2 was added to alleviate the WSEL errors. The Manning's roughness coefficient for the Alt2 channel lining was revised to 0.012.

**4.4.3 Unsteady Flow Analysis – Plans files**

The FWOP conditions plan files were duplicated and renamed for the Alt2 FWP simulations, copying over the plan file settings. Each flood event has its own plan file following the naming convention shown on Table 18.

**Table 18 – Plan file summary, Alt3 FWP conditions**

Plan file ID	Geometry file	Unsteady flow file	Description
Alt2 FWP 0.2PAC (500yr)	Alt2	0.2PAC(500yr)_Finile_FutureCond	Alt2 geometry Ocean stage: future conditions Inflows: 0.2PAC or 500-year AEP
Alt2 FWP 0.5PAC (200yr)	Alt2	0.5PAC(200yr)_Finile_FutureCond	Alt2 geometry Ocean stage: future conditions Inflows: 0.5PAC or 500-year AEP
Alt2 FWP 1PAC (100yr)	Alt2	1PAC(100yr)_Finile_FutureCond	Alt2 geometry Ocean stage: future conditions Inflows: 1PAC or 100-year AEP
Alt2 FWP 2PAC (50yr)	Alt2	2PAC(50yr)_Finile_FutureCond	Alt2 geometry Ocean stage: future conditions Inflows: 2PAC or 50-year AEP

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Alt2 FWP 4PAC (25yr)	Alt2	4PAC(25yr)_Finile_FutureCond	Alt2 geometry Ocean stage: future conditions Inflows: 4PAC or 25-year AEP
Alt2 FWP 10PAC (10yr)	Alt2	10PAC(10yr)_Finile_FutureCond	Alt2 geometry Ocean stage: future conditions Inflows: 10PAC or 10-year AEP
Alt2 FWP 20PAC (5yr)	Alt2	20PAC(5yr)_Finile_FutureCond	Alt2 geometry Ocean stage: future conditions Inflows: 20PAC or 5-year AEP
Alt2 FWP 50PAC (2yr)	Alt2	50PAC(2yr)_Finile_FutureCond	Alt2 geometry Ocean stage: future conditions Inflows: 50PAC or 2-year AEP

#### 4.4.4 Results

There are no proposed alternatives in Finile Creek, Gaan River, and Auau Creek under Alt2 therefore, the results do not change from FWOP simulations at these locations.

Figure 42 shows the inundation boundary and flood depth results at 1PAC (100yr AEP). Results show flooding has been mitigated in San Vicente Ave and adjacent areas. Salinas River overtops near RS 8+00 towards N Eugenio, San Isidro, and San Roque St. Salinas River also overtops at RS 0+00 to 1+80 and 2+00 to 4+00. Inundated areas for FWOP 100-year are shown inundated with Alt2 in these areas, however flood depths have been reduced to less than 1 foot (0.305 m) for the inundated residential structures.

Figure 43 shows the stream profile results for FWOP and Alt2 1PAC (100yr AEP). The results show that WSEL along the stream has decreased at Salinas River except at RS 0+00 to 1+27, 2+37 to 4+56, 5+20 to 5+72, 6+83 to 8+29, 9+04 to 11+92, 11+00 to 11+02. The flows crossing San Vicente Ave does not overtop the culvert crossing therefore, flooding at adjacent streets, San Roque and San Isidro St., has been alleviated.

Figure 45 shows the results for the culvert crossing *Salinas River*. The results show that the culvert conveys the total flow therefore, total flow and total culvert flow shows the same in the figure. Consequently, there is no weir flow at Rt. 2 hwy road. The results show that Alt1 total flow for Salinas River culverts is larger than FWOP conditions. This is due to the channelization of the stream that provided larger flow capacity which allowed more flow within the channel.

Figure 46 and Figure 47 for the culvert crossings at Salinas US1 at De Los Marteres Rd. and Salinas US2 at San Vicente Ave shows similar results: total flow and total culvert flow is the same, and weir flow is zero.

Figure 44 is a calculated map of the difference between the Max WSEL of Alt2 100-year and FWOP 100-year (Alt2 WSE minus FWOP WSE). The areas in red have increased WSELs, in gray has no change, and in blue have decreased WSELs. Areas in red at RS 8+00 to 11+10 have increased WSELs but the runoff is contained within the stream channels. Other areas in red are affects approximately 6 structures and N Eugenio St. Therefore, to mitigate this impact, structures must be raised above the WSEL. Other

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measures to consider includes individual onsite drainage facilities such as catchment channels to redirect waters away from the structures and out of the lot.

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Figure 42 – Results Map, Alt2 FWP, Salinas River

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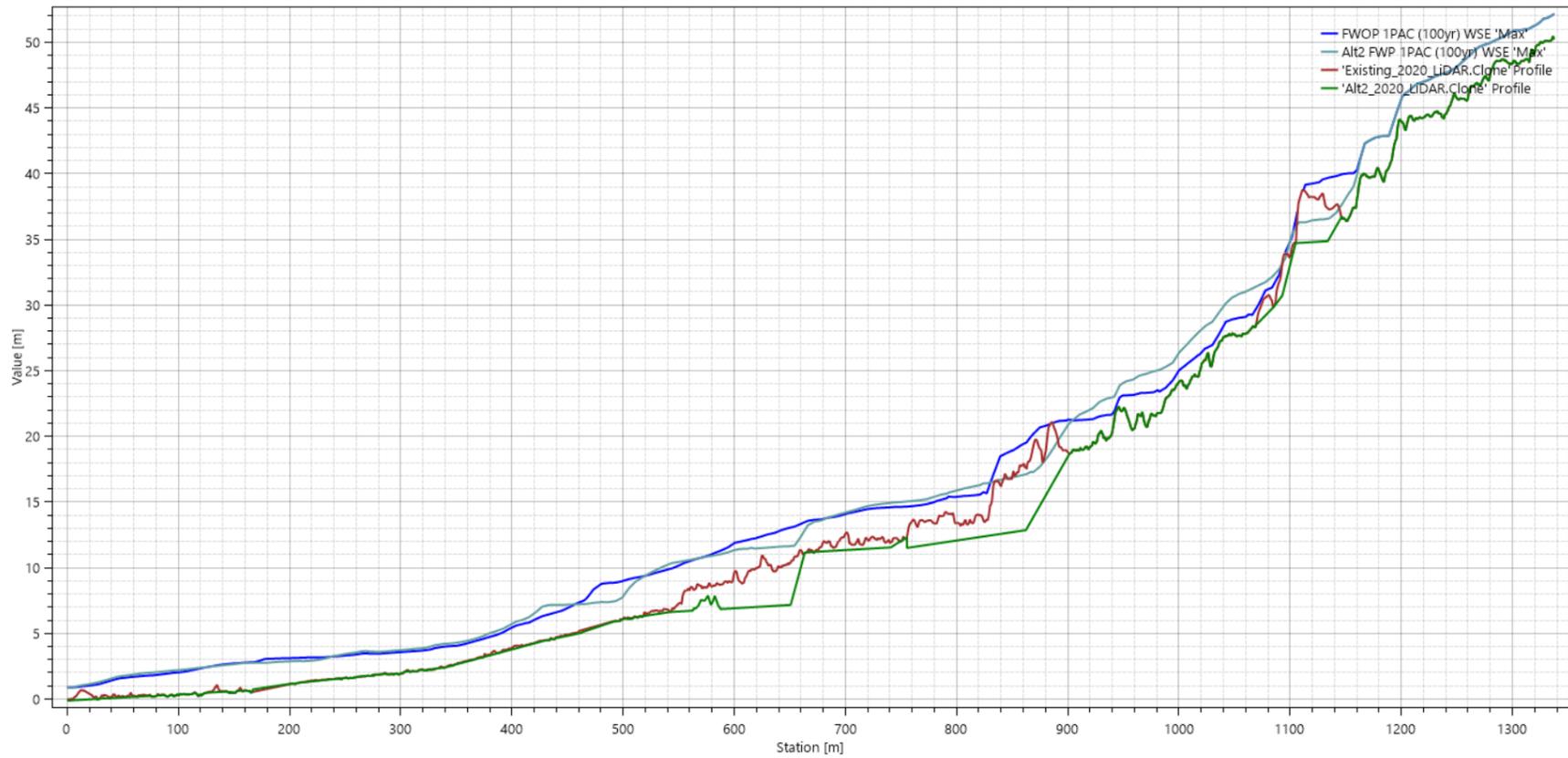


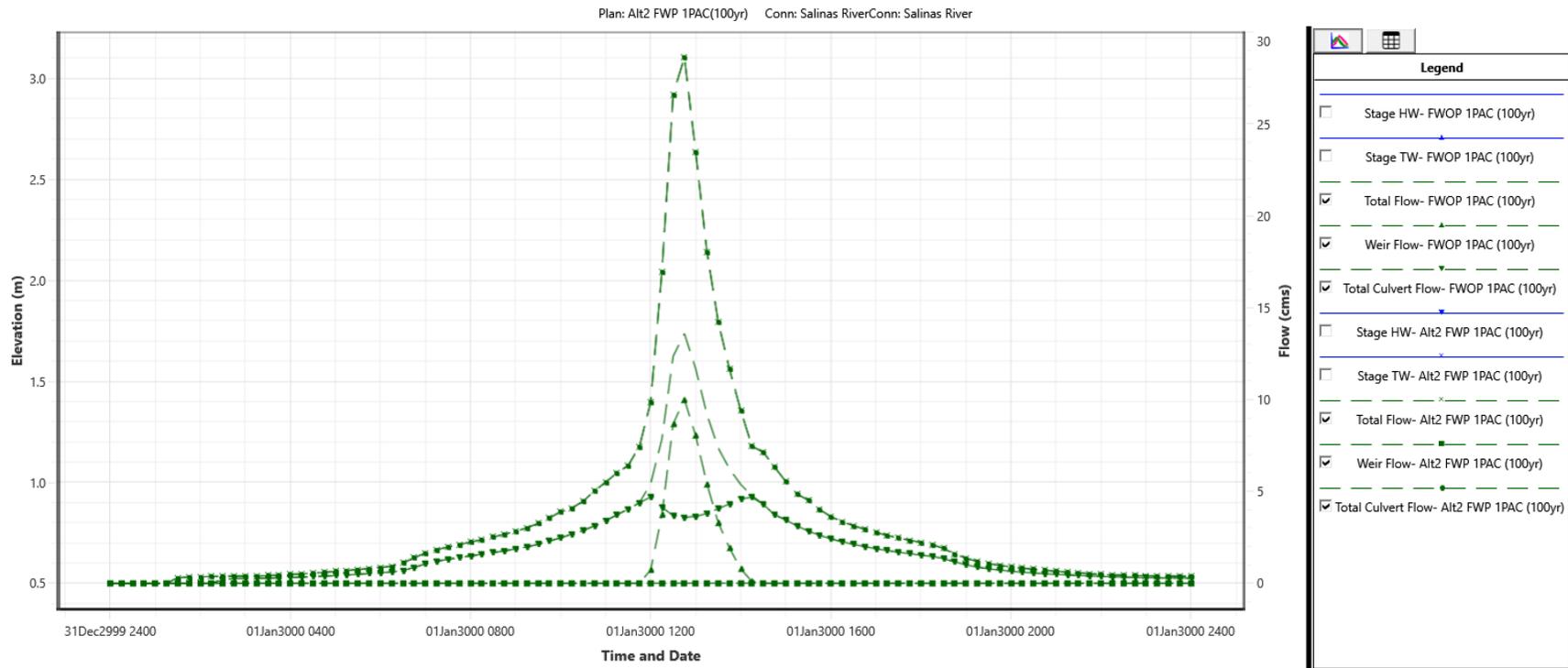
Figure 43 – WSEL profile results, Alt2 FWP, Salinas River

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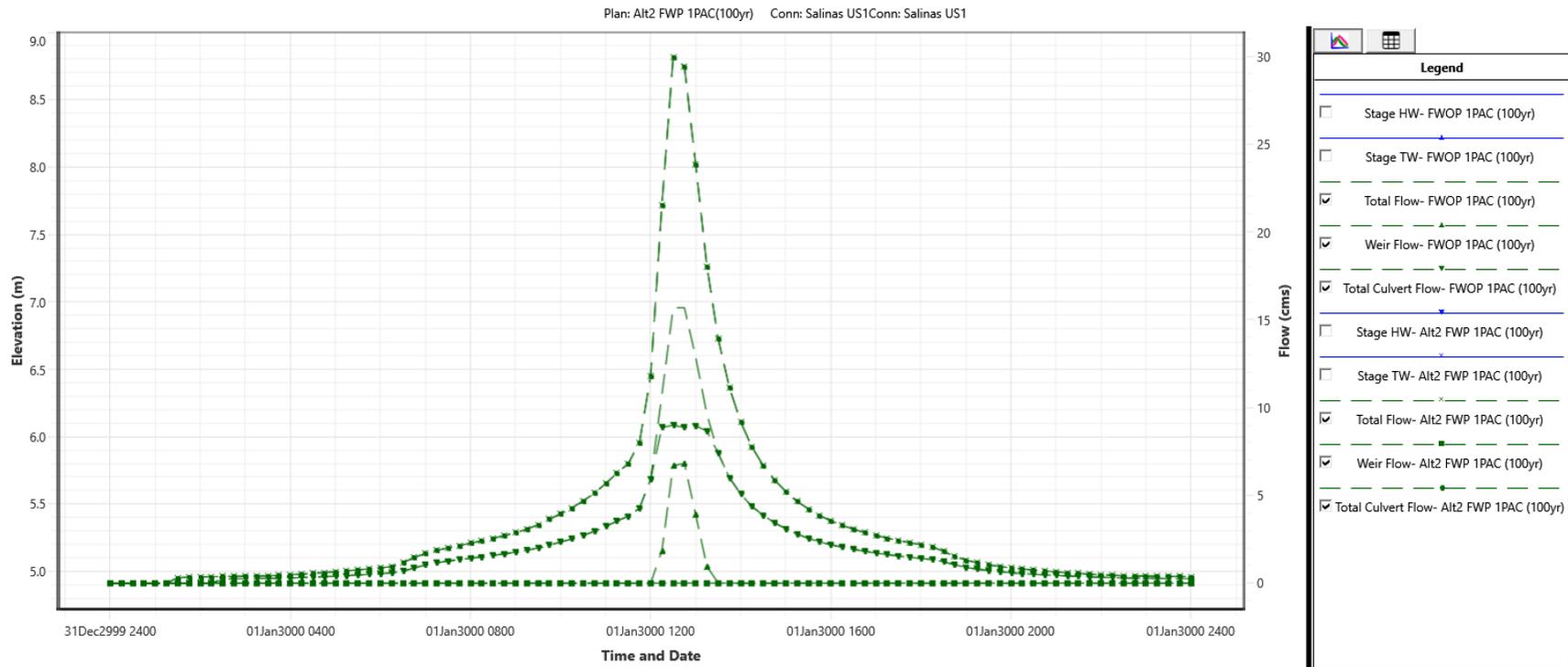
Figure 44 - Alt2, Calculated layer Max WSE Alt2 100-year minus Max WSE FWOP 100-year

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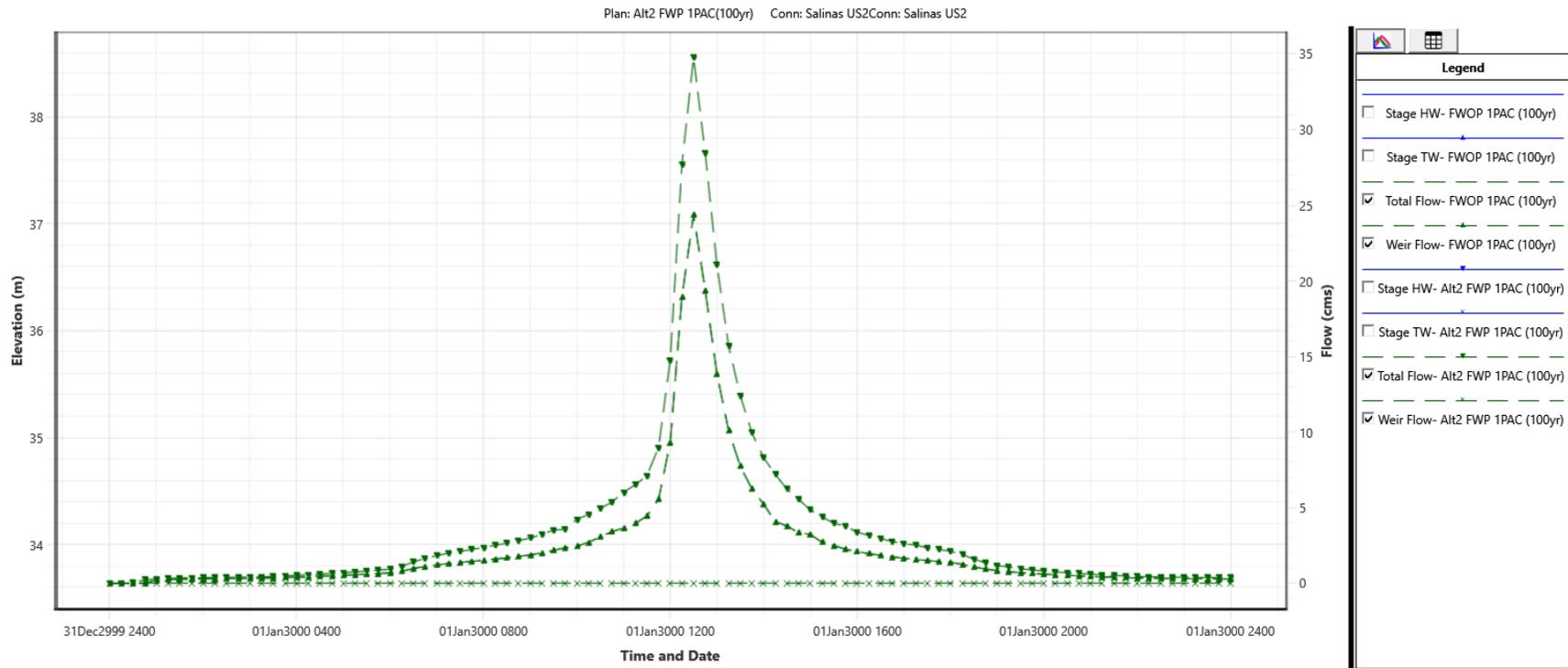
**Figure 45 – Alt2, Results for the Culvert Crossing improvements at Salinas River and Rt 2 Hwy Rd.**

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**Figure 46 - Alt2, Results for the Culvert Crossing improvements at Salinas River and De Los Marteres Rd.**

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**Figure 47 – Alt2, Results for the Culvert Crossing improvements at Salinas River and San Vicente Ave**

#### 4.5 ALTERNATIVE 3 FWP CONDITIONS

Alternative 3 (Alt3) FWP conditions is located along Gaan River and Auau Creek.



Figure 48 – Alt3 Site Map

##### 4.5.1 Terrain

The LiDAR terrain was cloned and renamed to Alt3\_2020\_LiDAR.Clone. Terrain modification from existing conditions were copied. The terrain modifications for Alt3 include:

- Channelization for the following:
  - Gaan River stream mouth widening, downstream of Rt 2 highway road at River Sta. 0+00 to 00+35.4 – 20' (wide) x 128' (length), depth varies 3H:1V side slope

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- Gaan River channelization with concrete lined side slopes, upstream of Rt 2 highway road at River Sta. 0+59 to 7+77.50 – 20' (wide) x 2,356' (length), depth varies 2H:1V side slope
- Auau Creek channelization, downstream of Rt 2 highway road at River Sta. 0+00 to 00+89 – 14' (wide) x 298' (length), depth varies 3H:1V side slope
- Auau Creek channelization with concrete lined side slopes, upstream of Rt 2 highway road at River Sta. 1+10 to 2+92.50 – 30' (wide) x 601' (length), depth varies 2H:1V side slope



Figure 49 – Alt3 terrain modification, site map

#### 4.5.2 Geometry

The existing conditions geometry file was duplicated and renamed for the Alt3 FWP conditions. No changes were made to the boundary conditions.

##### 4.5.2.1 2D Flow Areas

Minor adjustments were made to computation points to decrease WSEL error. No other changes were made.

#### 4.5.2.2 SA/2D Connections

The following culvert improvements were modeled for Alt3:

- Auau Creek culvert improvements at Rt 2 highway road: 5 – 5' x 5' x 64', see Figure 50
- Gaan River culvert improvements at Rt 2 highway road: 3 – 8' x 6' x 66.3', see Figure 51

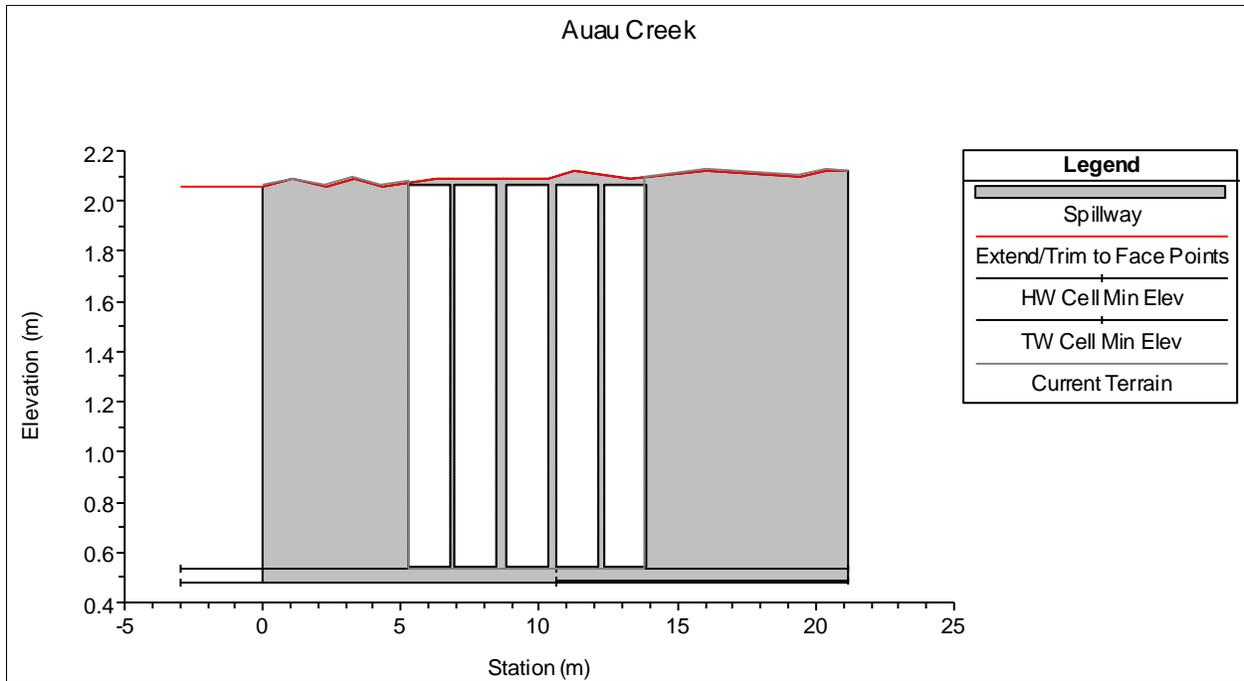
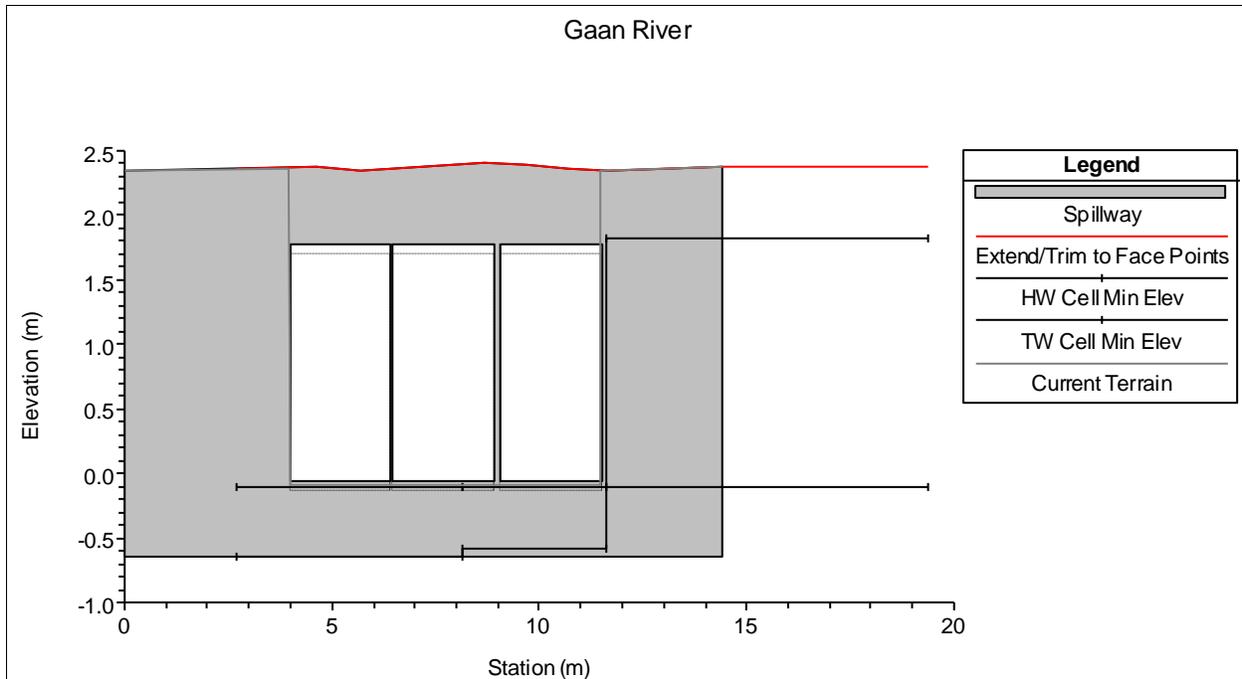


Figure 50 – Alt3, Auau Creek, Culvert improvements at Rt 2 highway road

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**Figure 51 – Alt3, Gaan River, Culvert improvements at Rt 2 highway road**

**4.5.2.3 Manning’s n**

The Manning’s roughness coefficient for the Alt3 channel lining was revised to 0.012.

**4.5.3 Unsteady Flow Analysis – Plans files**

The FWOP conditions plan files were duplicated and renamed for the Alt3 FWP simulations; copying over the plan file settings that were changed to make the model more stable. Each flood event has its own plan file following the naming convention shown on Table 19.

**Table 19 – Plan file summary, Alt5 FWP conditions**

Plan file ID	Geometry file	Unsteady flow file	Description
Alt3 FWP 0.2PAC (500yr)	Alt3	0.2PAC(500yr)_Finile_FutureCond	Alt3 geometry Ocean stage: future conditions Inflows: 0.2PAC or 500-year AEP
Alt3 FWP 0.5PAC (200yr)	Alt3	0.5PAC(200yr)_Finile_FutureCond	Alt3 geometry Ocean stage: future conditions Inflows: 0.5PAC or 500-year AEP
Alt3 FWP 1PAC (100yr)	Alt3	1PAC(100yr)_Finile_FutureCond	Alt3 geometry Ocean stage: future conditions Inflows: 1PAC or 100-year AEP
Alt3 FWP 2PAC (50yr)	Alt3	2PAC(50yr)_Finile_FutureCond	Alt3 geometry Ocean stage: future conditions Inflows: 2PAC or 50-year AEP

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Alt3 FWP 4PAC (25yr)	Alt3	4PAC(25yr)_Finile_FutureCond	Alt3 geometry Ocean stage: future conditions Inflows: 4PAC or 25-year AEP
Alt3 FWP 10PAC (10yr)	Alt3	10PAC(10yr)_Finile_FutureCond	Alt3 geometry Ocean stage: future conditions Inflows: 10PAC or 10-year AEP
Alt3 FWP 20PAC (5yr)	Alt3	20PAC(5yr)_Finile_FutureCond	Alt3 geometry Ocean stage: future conditions Inflows: 20PAC or 5-year AEP
Alt3 FWP 50PAC (2yr)	Alt3	50PAC(2yr)_Finile_FutureCond	Alt3 geometry Ocean stage: future conditions Inflows: 50PAC or 2-year AEP

#### 4.5.4 Results

There are no proposed alternatives in Finile Creek and Salinas River therefore, the results does not change from FWOP simulations at these locations.

Figure 52 shows the inundation boundary and flood depth results at 1PAC (100yr AEP). Results show flooding at the residential lots near Gaan River RS 6+00 to 7+00 has been mitigated. While majority of the areas are still inundated, areas with deeper flood depths have been reduced.

Figure 53 shows the stream profile results for Gaan River FWOP and Alt1 1PAC (100yr AEP). The results show that WSEL along the stream has decreased at Gaan River except at RS 0+00 to 0+36 and 4+84 to 5+83.

Figure 54 shows the stream profile results for Auau Creek FWOP and Alt1 1PAC (100yr AEP). The results show that WSEL along the stream has decreased.

Figure 55 is a calculated map of the difference between the Max WSEL of Alt3 100-year and FWOP 100-year (Alt3 WSE minus FWOP WSE). The areas in red have increased WSELs, in gray has no change, and in blue have decreased WSELs. Areas shown in red does not have any residential structures therefore, the improvements for Alt3 alleviate flooding and does not cause adverse impact to existing adjacent structures. However, flooding is still widespread.

Figure 56 shows the results for the culvert crossing *Auau Creek*. The results shows that the culvert does not convey the total flow. Consequently, the flow overtops and therefore, weir flow is shown.

Figure 57 shows the results for the culvert crossing *Gaan River*. The results shows that the culvert is able to convey the total flow therefore, total flow and total culvert flow shows the same in the figure. Consequently, there is no weir flow at *Gaan River* culvert.

The total flows at Alt3 FWP is larger than FWOP conditions for the culverts at Auau Creek and Gaan River as channelization of the stream provided larger flow capacity which allowed more flow within the channel.

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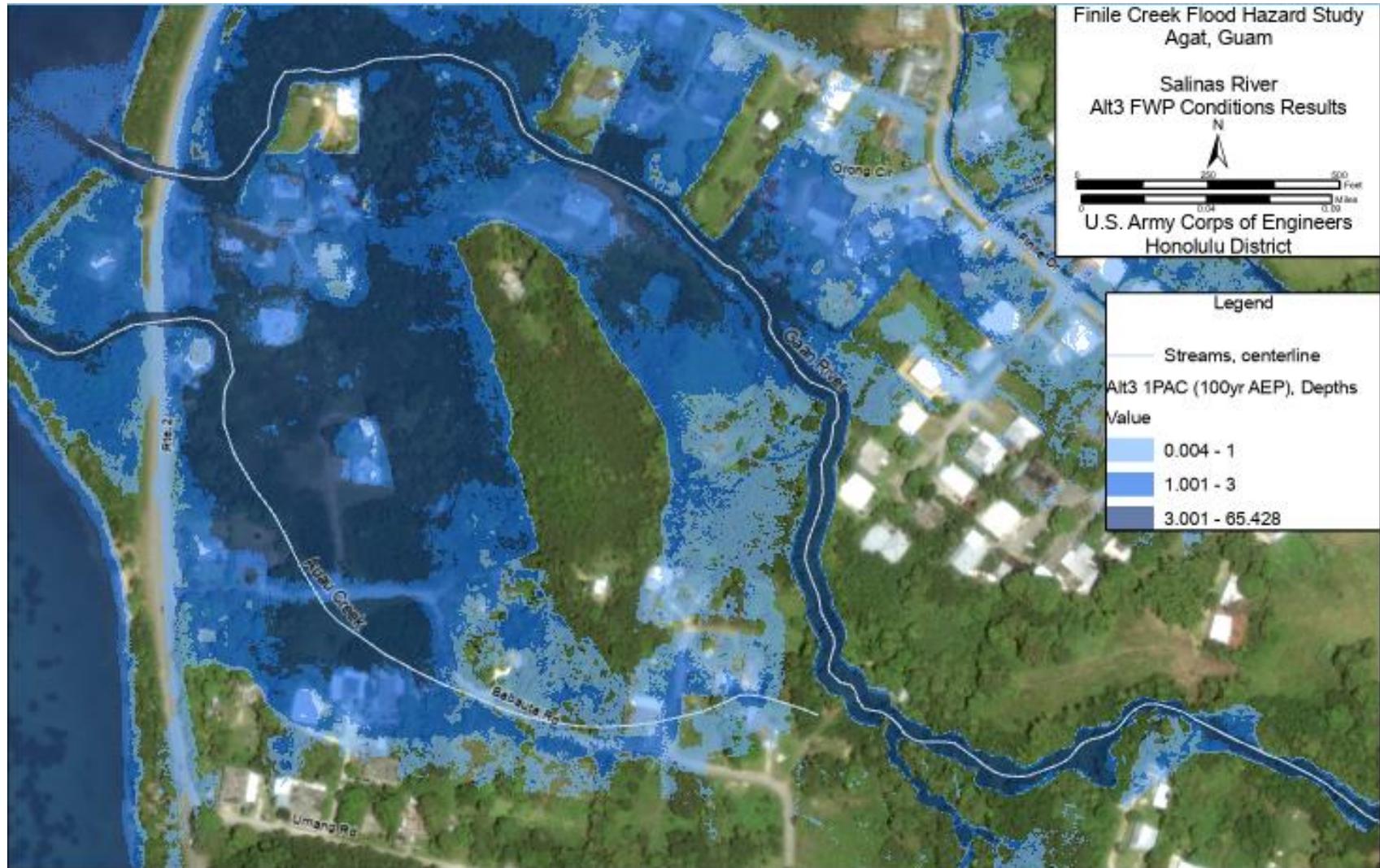


Figure 52 - Results Map, Alt3 FWP, Gaan River and Auau Creek

FINILE CREEK FLOOD HAZARD STUDY  
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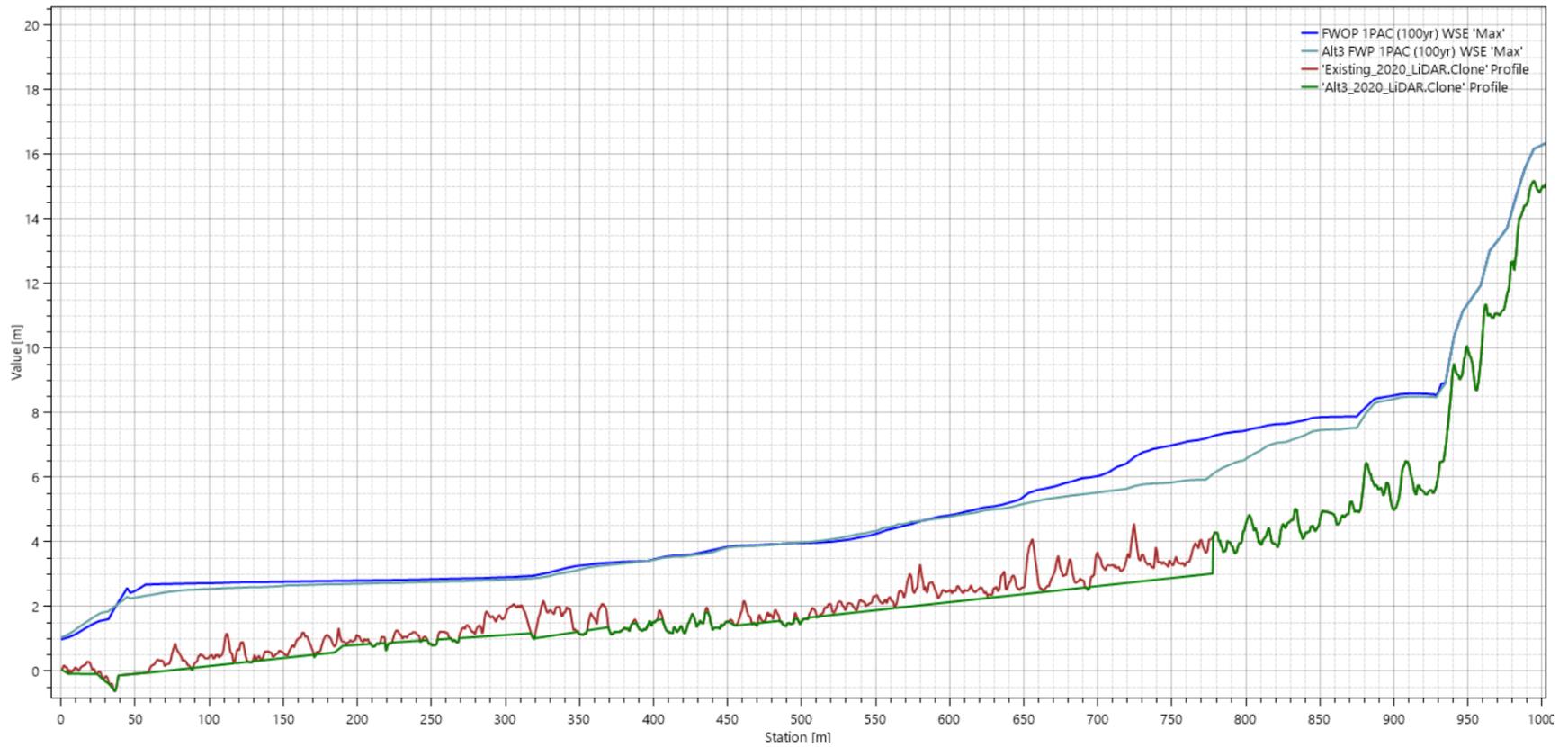


Figure 53 - WSEL profile results, Alt5 FWP, Gaan River

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Figure 54 – WSEL profile results, Alt5 FWP, Auau Creek

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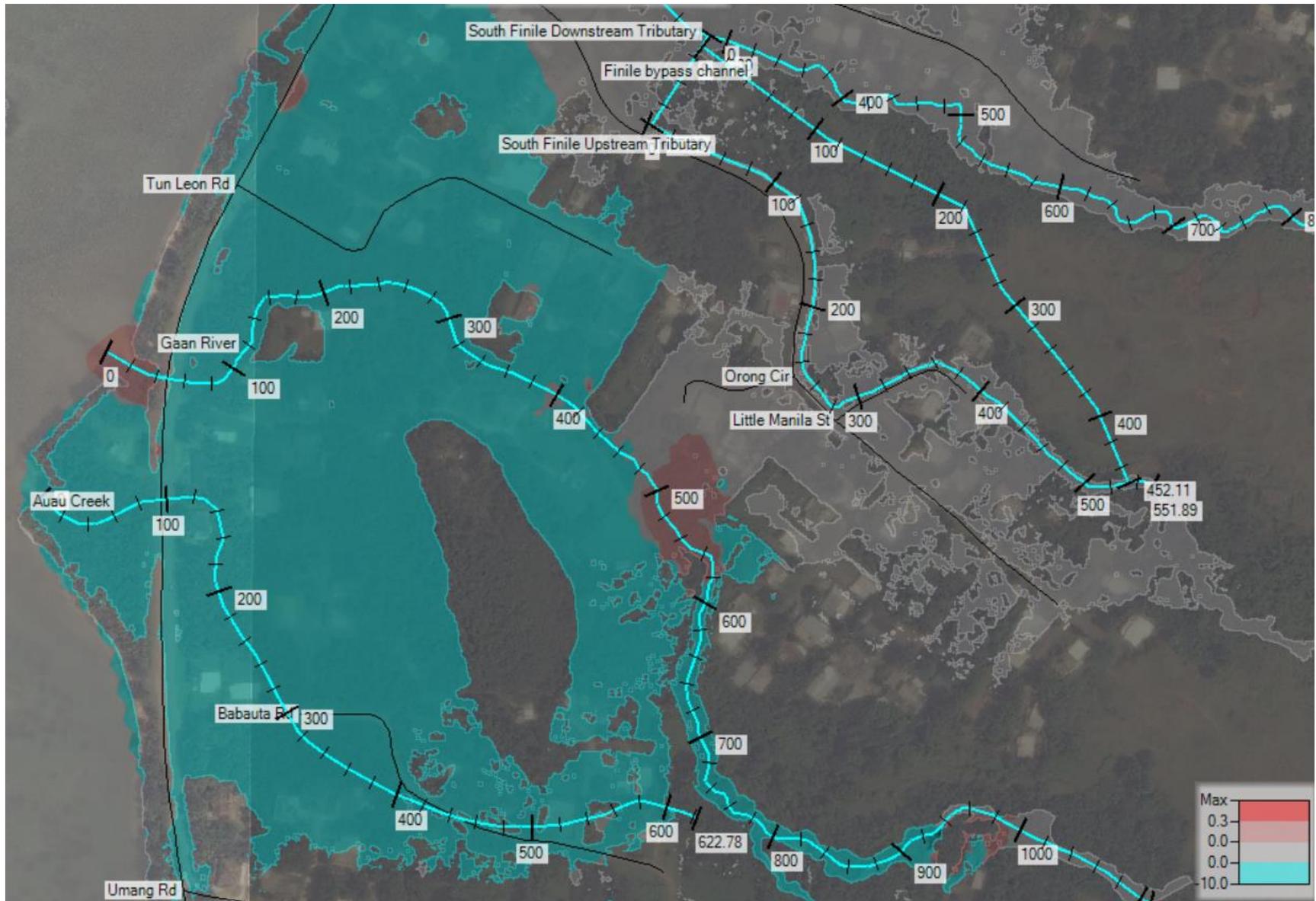
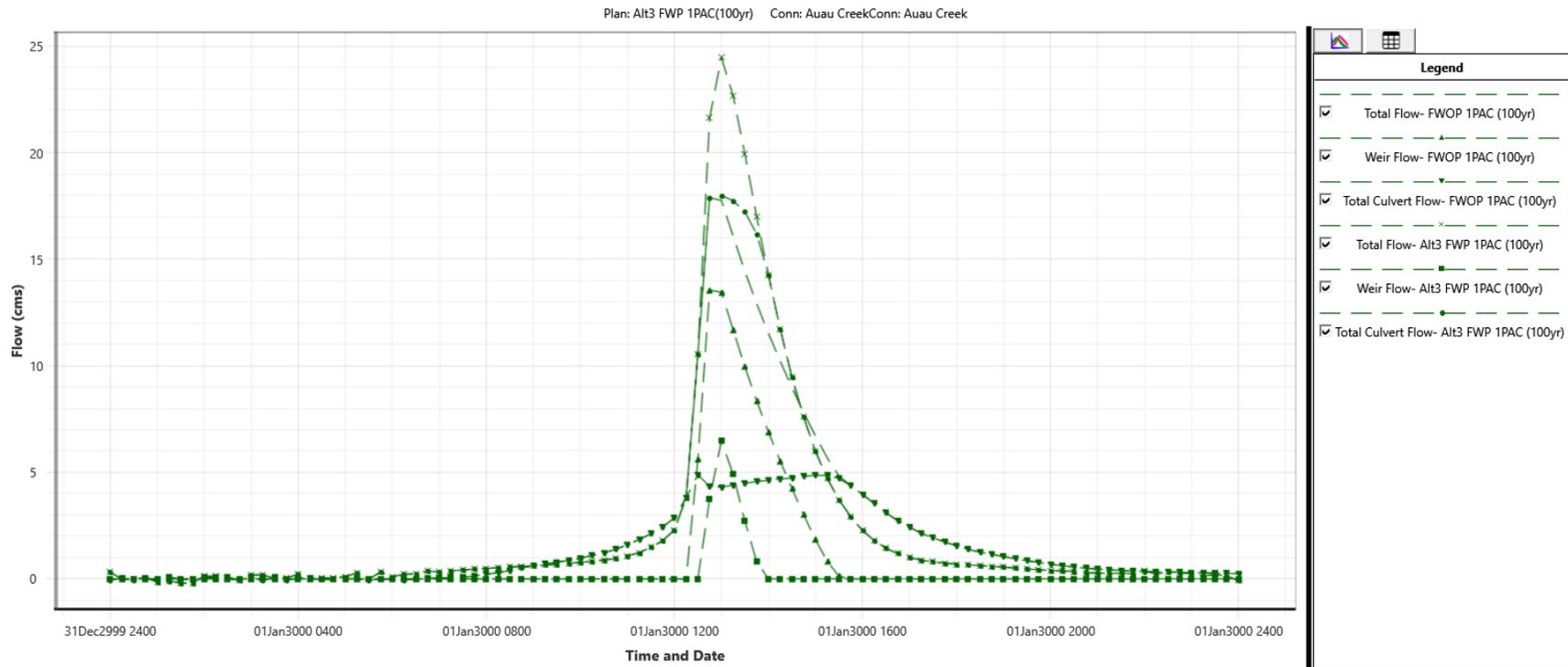


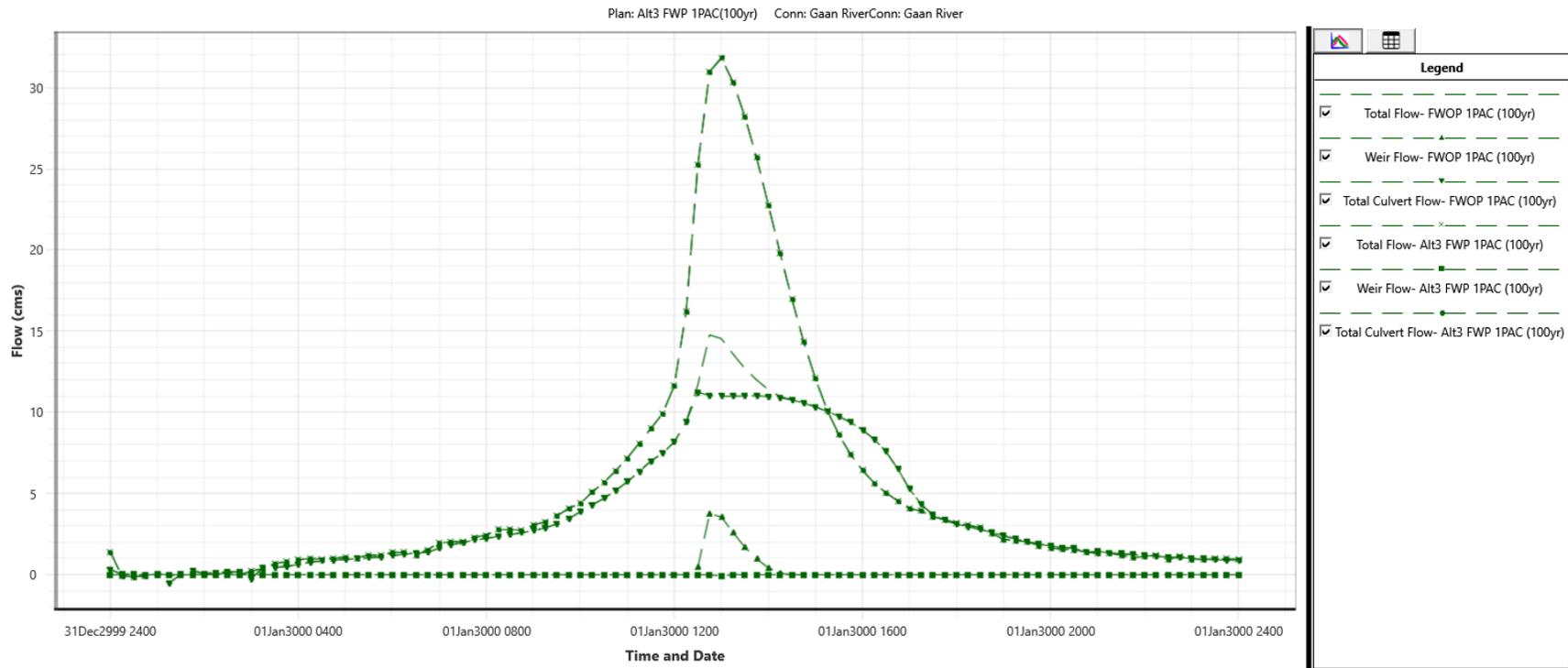
Figure 55 - Alt3, Calculated layer Max WSE Alt3 100-year minus Max WSE FWOP 100-year

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**Figure 56 – Alt3, Results for the Culvert Crossing improvements at Auau Creek and Rt 2 Hwy Rd.**

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**Figure 57 – Alt3, Results for the Culvert Crossing improvements at Gaan River and Rt 2 Hwy Rd.**

## SECTION 5 - QUANTITY TAKEOFF FOR COST ESTIMATES

### 5.1 ALT1

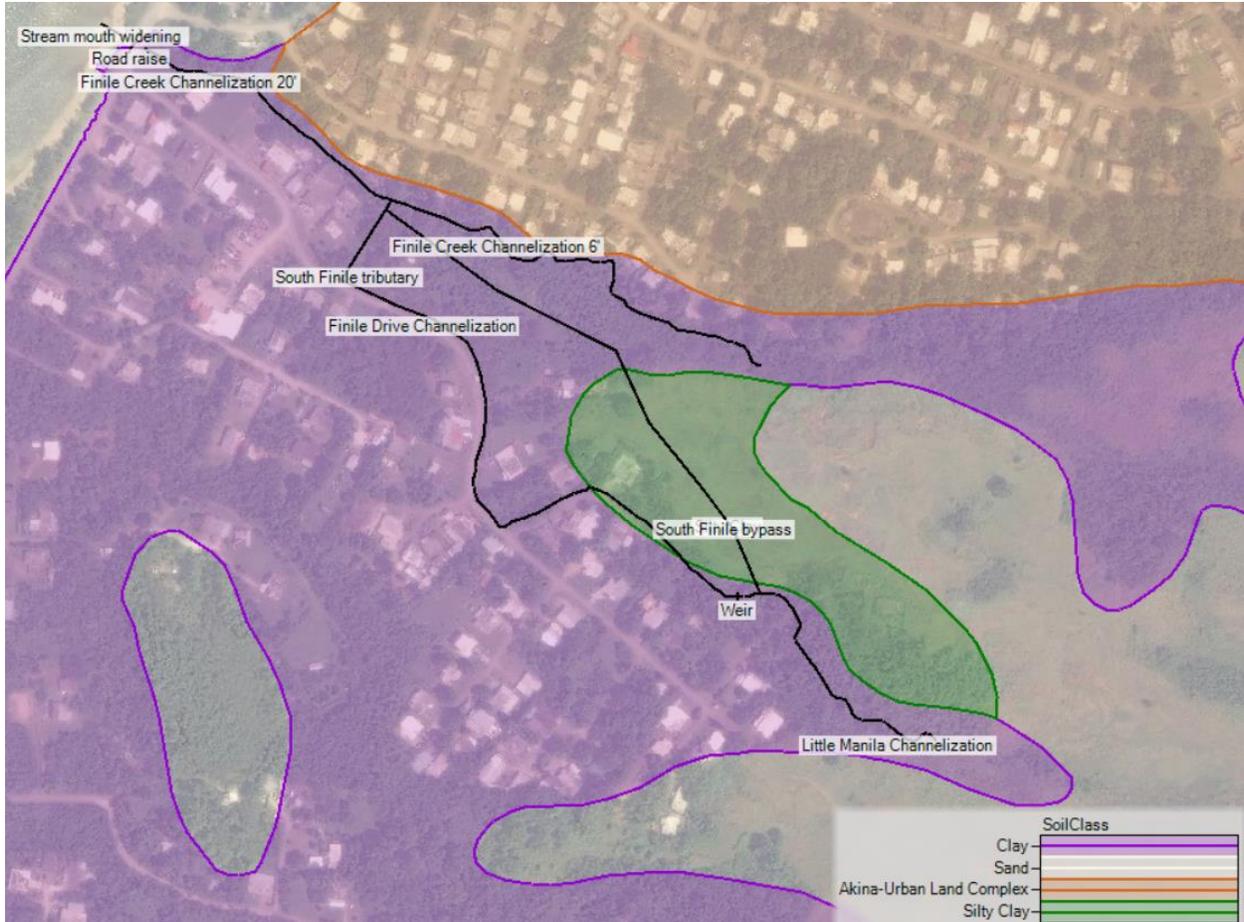


Figure 58 – Alt1 Soils at surface, locations of excavations

The cost estimates for Alt1 includes the following:

- Stream mouth widening at Finile Creek– 52.50' (wide) x 74' (length), depth varies 3H:1V side slope, 364 yd<sup>3</sup> of earthwork, see Figure 59.

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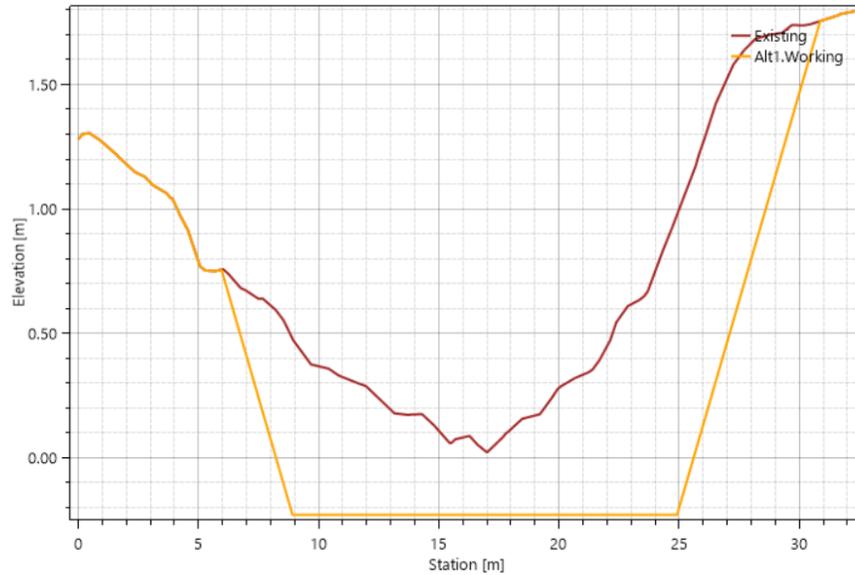


Figure 59 – Finile Creek, RS 0+16

- Channelization at Finile Creek lined with concrete side wall (2H:1V side slopes), RS 0+40 to 3+32 – 20' (wide) x 12' (depth varies) x 1,090' (length), 180 yd<sup>3</sup> of earthwork and 888 yd<sup>3</sup> (0.5' x 44' x 1090') of concrete for sidewall and channel bottom, see Figure 60.

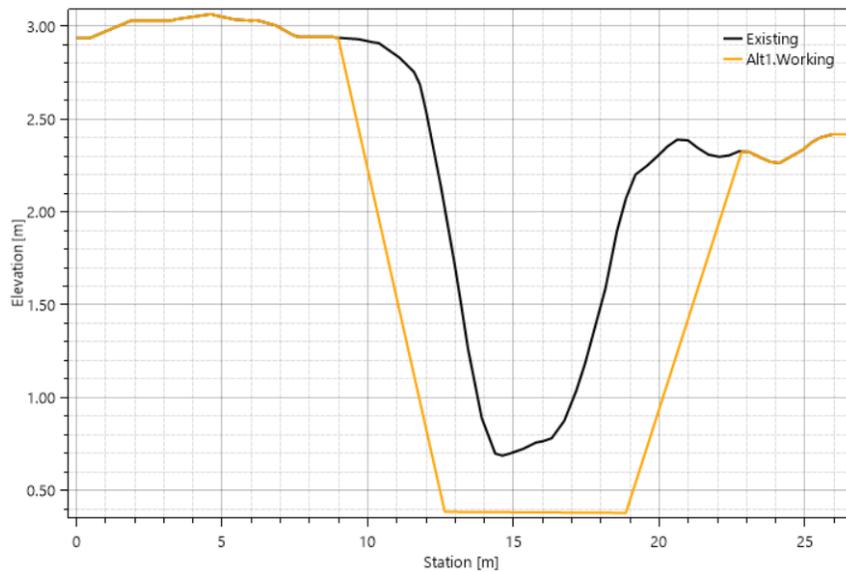


Figure 60 – Finile Creek, RS 1+45

- Channelization at Finile Creek lined with concrete side wall (2H:1V side slopes), RS 3+32 to 6+59 – 6' (wide) x 15' (depth varies) 1,070' (length), 316 yd<sup>3</sup> of earthwork and 713 yd<sup>3</sup> (0.5' x 36' x 1070') of concrete for sidewall and channel bottom, see Figure 61.

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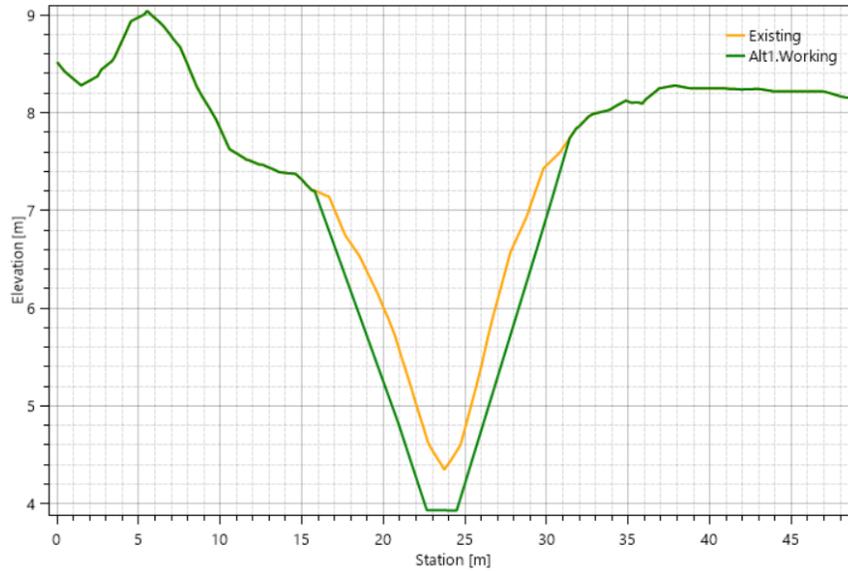


Figure 61 – Finile Creek, RS 4+74

- South Finile bypass channel – 17' (wide) x 1,483' (length), depth varies 3H:1V side slope, 65,385 yd<sup>3</sup> of earthwork, see Figure 62.

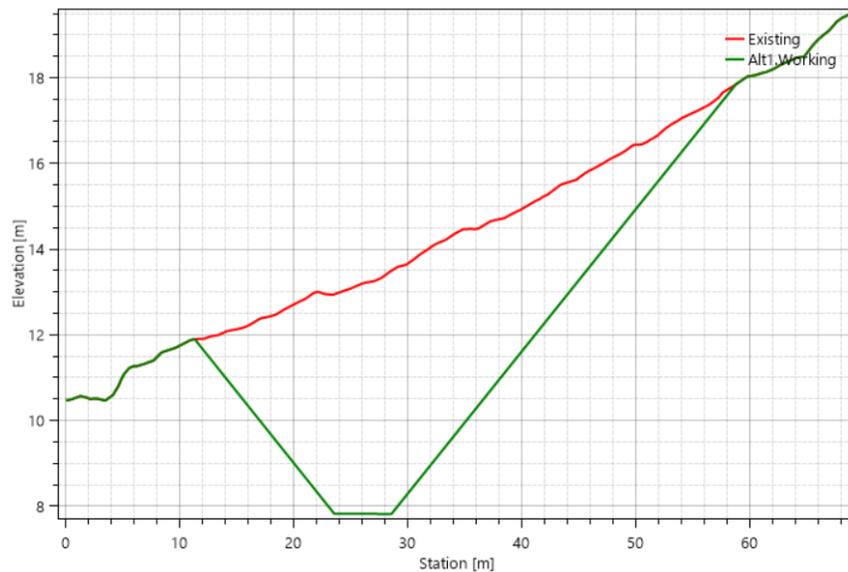


Figure 62 – South Finile Bypass Channel, RS 3+05

- Finile Drive Channelization lined with concrete side wall (vertical) at South Finile Upstream Tributary at RS 0+00 to 5+14 – 4' (wide) x 8' (depth varies) 1,684' (length), 10.5 yd<sup>3</sup> of earthwork and 623 yd<sup>3</sup> (0.5' x 20' x 1684') of concrete for sidewall and channel bottom, see Figure 63.

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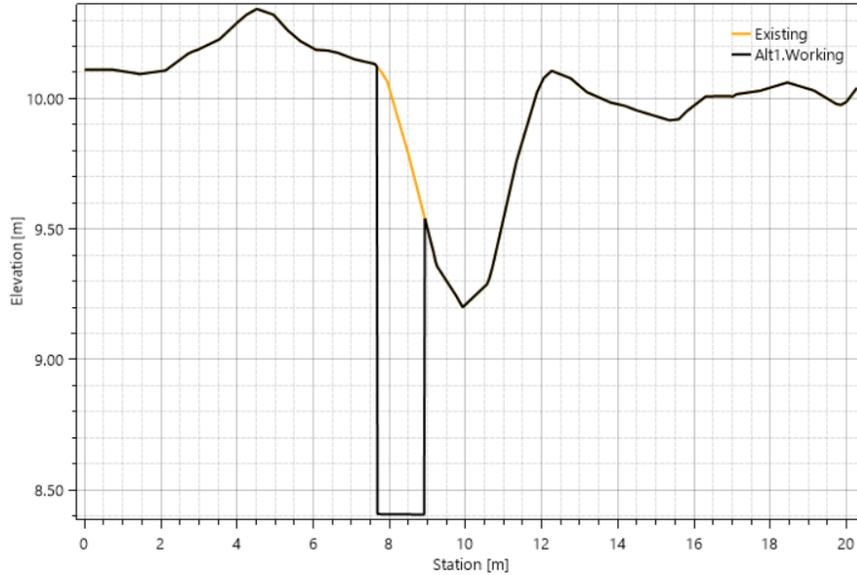


Figure 63 – South Finile Upstream Tributary, RS 4+28

- Little Manila Channelization lined with concrete side wall (vertical) at South Finile Upstream Tributary at RS 5+14 to 7+49 – 30' (wide) x 22' (depth varies) x 768' (length), 9,174 yd<sup>3</sup> of earthwork and 1,052 yd<sup>3</sup> (0.5' x 74' x 768') of concrete for sidewall and channel bottom, see Figure 64.

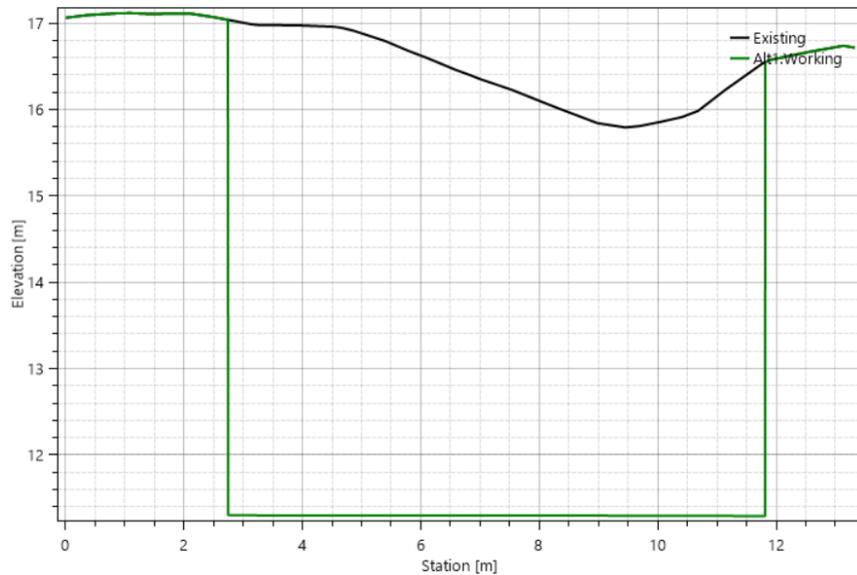


Figure 64 – South Finile Upstream Tributary, RS 6+57

- South Finile Channelization lined with concrete side wall (2H:1V side slopes) at South Finile Downstream Tributary at RS 0+00 to 0+77 – 17' (wide) x 8' (depth varies) x 253' (length), 44 yd<sup>3</sup> of earthwork and 155 yd<sup>3</sup> (0.5' x 33' x 253') of concrete for sidewall and channel bottom

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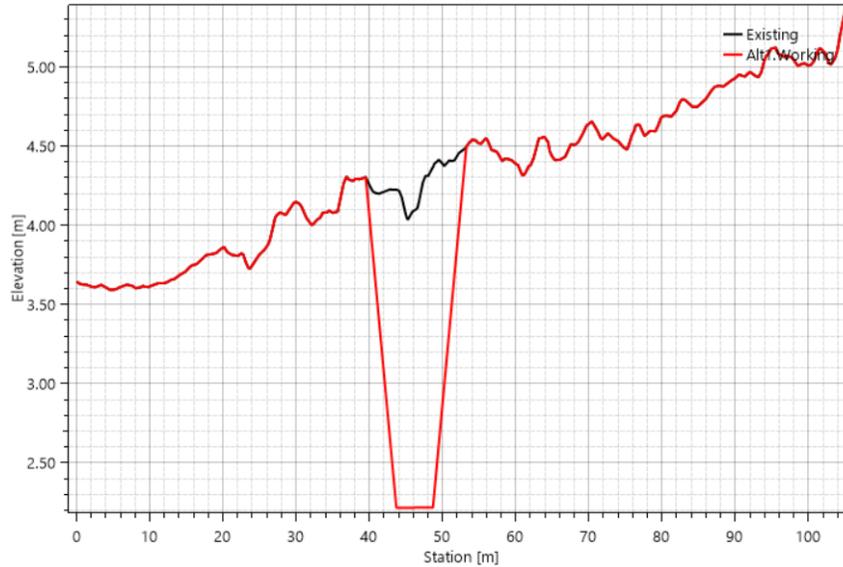


Figure 65 – South Finile Downstream Tributary, RS 0+33

- Inline weir at South Finile Upstream Tributary RS 5+14 – 2' width x 22' height x 30' length reinforced concrete
- Weir Footing – 22' width x 3' depth x 30' length reinforced concrete, 74 yd<sup>3</sup> of earthwork
- Culvert improvements at Rt 2 highway road: 6 – 7' x 7' x 57.74', with road raise, see Figure 26.
- Road raise for new deeper culverts at Rt. 2 highway road - 5 yd<sup>3</sup> of earthwork and 46' wide x 75' length of pavement, see Figure 26.
- Baffle blocks at South Finile Upstream Tributary of Finile, from Sta. 5+16 to 5+30, install throughout 30' wide x 30' stream length

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5.2 ALT2

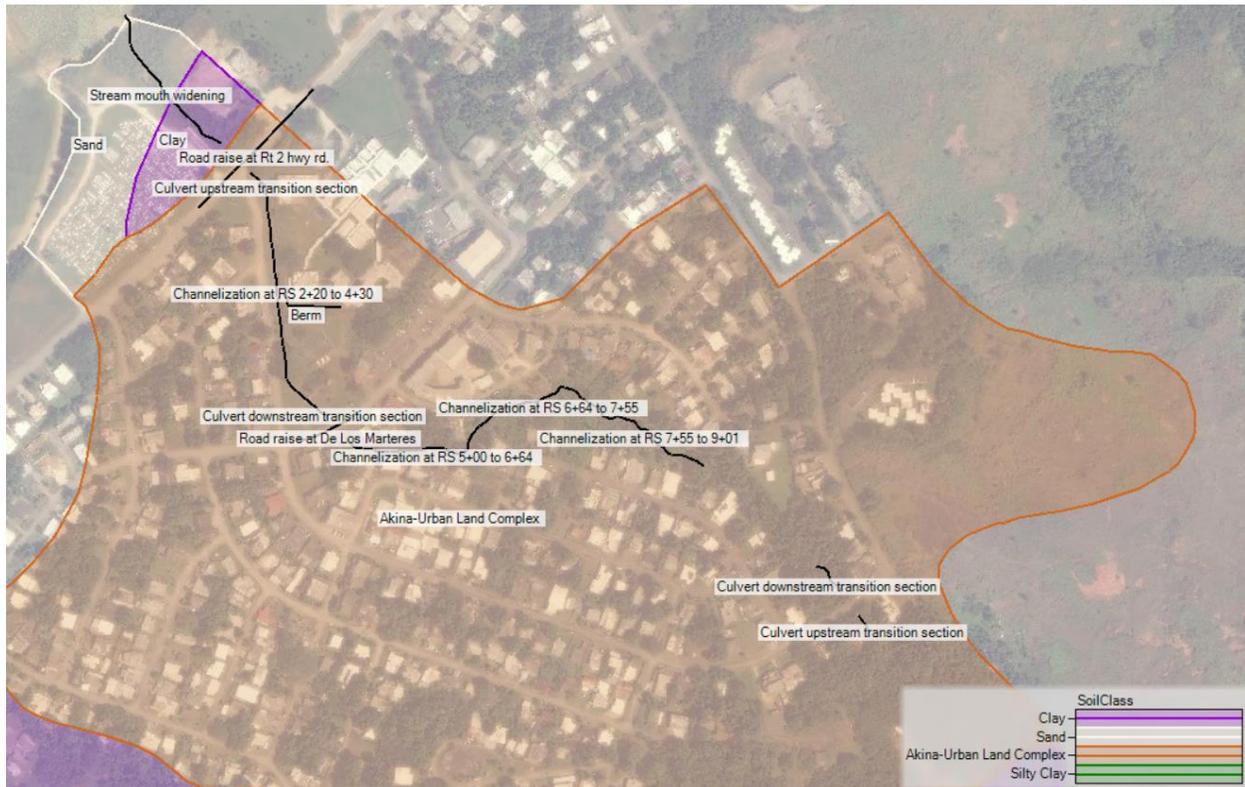


Figure 66 – Alt2 Soils at surface, locations of excavations

The cost estimates for Alt2 includes the following:

- Salinas River stream mouth widening RS 0+00 to 1+60 – 30' (wide) x 161' (length), depth varies 3H:1V side slope, 2,651.2 yd<sup>3</sup> of earthwork, see Figure 67.

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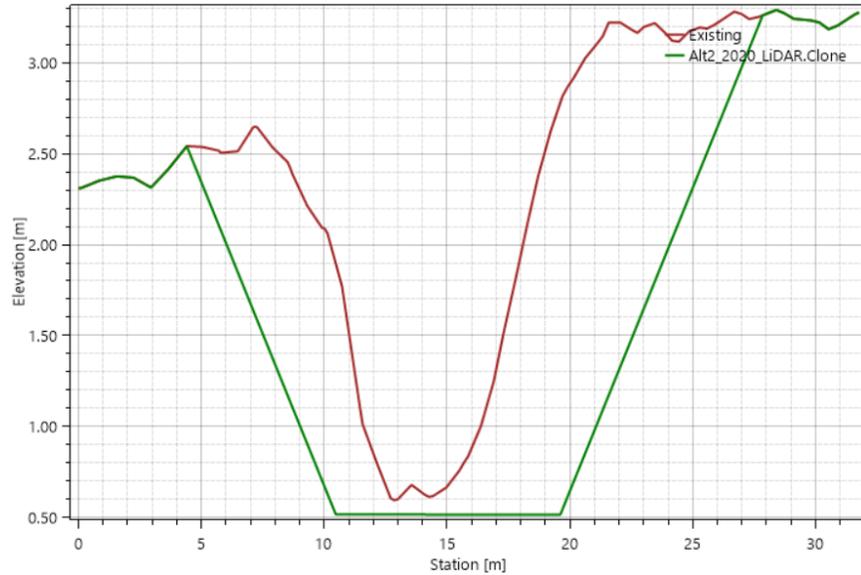


Figure 67 – Salinas River, RS 1+31

- Channelization at Salinas River lined with concrete side wall (2H:1V side slopes) RS 2+02 to 2+20, upstream transition section for the culvert crossing at Rt 2 hwy rd. – 30' (wide) x 57.97' (length), depth varies, 400.3 yd<sup>3</sup> of earthwork and 326.51 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom, see Figure 68.

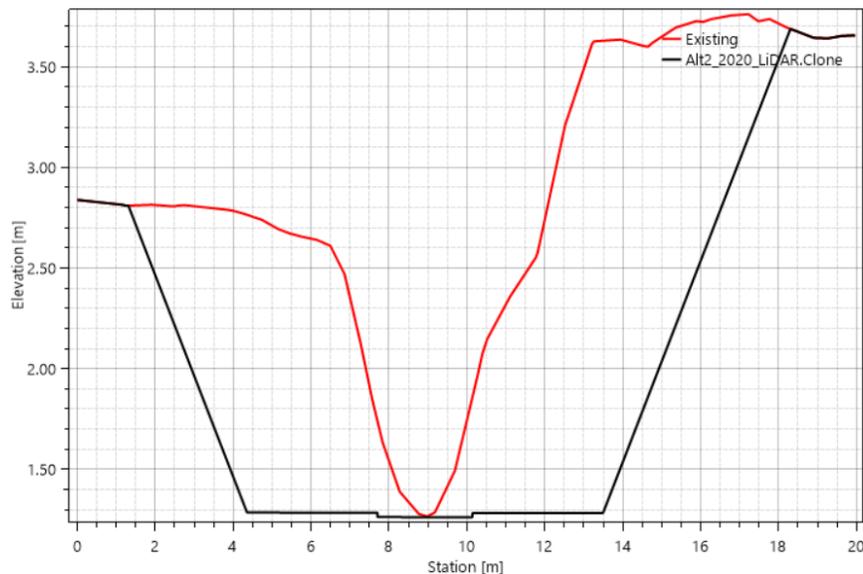


Figure 68 – Salinas River, RS2+10

- Channelization at Salinas River lined with concrete side wall (vertical sidewall) RS 2+20 to 4+30 – 8' (wide) x 4.25' (depth varies) x 753.1' (length), 91.22 yd<sup>3</sup> of earthwork and 230 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom, see Figure 69.

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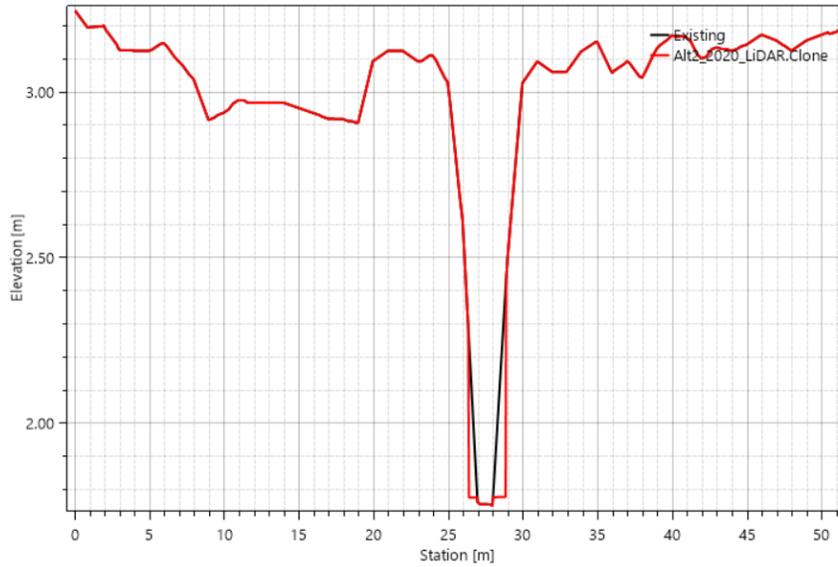


Figure 69 – Salinas River, RS 2+69

- Channelization at Salinas River lined with concrete side wall (2H:1V side slopes) RS 4+30 to 4+63, downstream transition section for the culvert crossing at Delos Marteres St. – 50' (wide) x 10.2' (depth varies) x 103.1' (length), 2305.8 yd<sup>3</sup> of earthwork and 264.6 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom, see Figure 70.

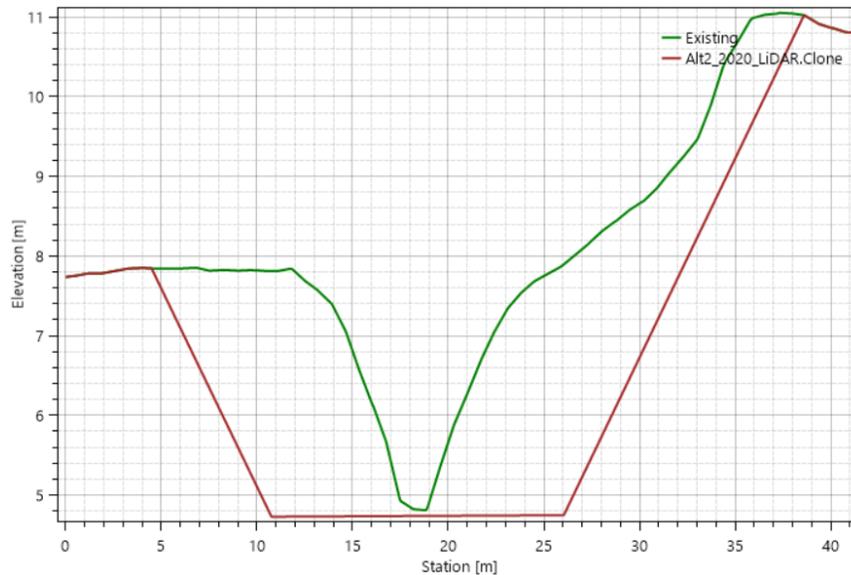


Figure 70 – Salinas River, RS 4+45

- Channelization at Salinas River lined with concrete side wall (2H:1V side slopes) RS 4+91 to 5+00, upstream transition section for the culvert crossing at De Los Marteres St. – 50' (wide) x 8.86' (depth varies) x 29' (length), 578 yd<sup>3</sup> of

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earthwork and 55 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom, see Figure 71.

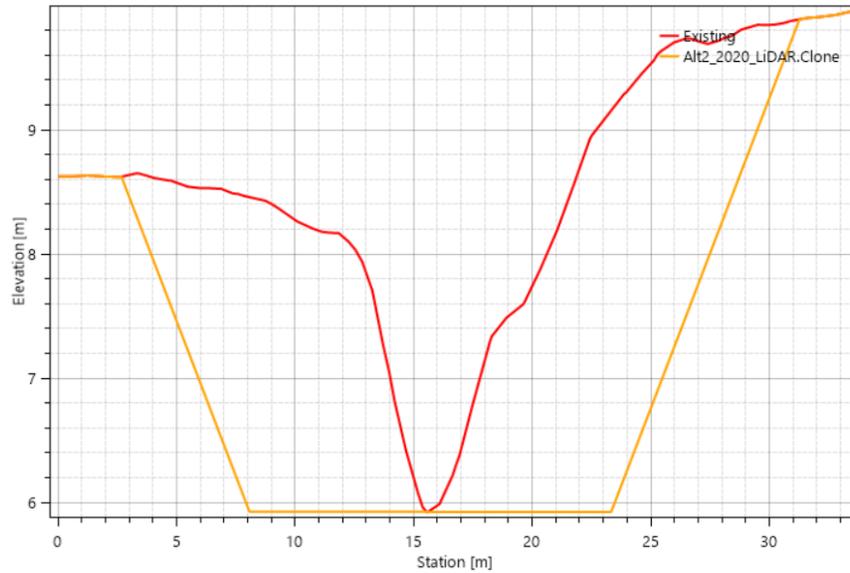


Figure 71 – Salinas River, RS 4+95

- Channelization at Salinas River lined with concrete side wall (1H:1V side slopes) RS 5+00 to 6+64 – 6' (wide) x 10' (depth varies) x 537' (length), 3,179 yd<sup>3</sup> of earthwork and 304 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom, see Figure 72.

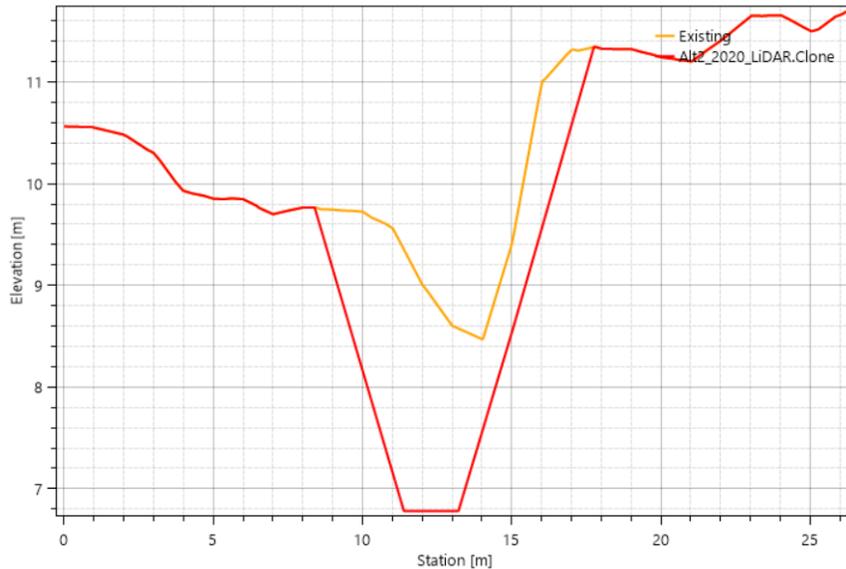


Figure 72 – Salinas River, RS 5+78

- Channelization at Salinas River lined with concrete side wall (1H:1V side slopes) RS 6+64 to 7+55 – 10' (wide) x 3' (depth varies) x 299' (length), 421 yd<sup>3</sup> of

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earthwork and 103 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom,  
see Figure 73.

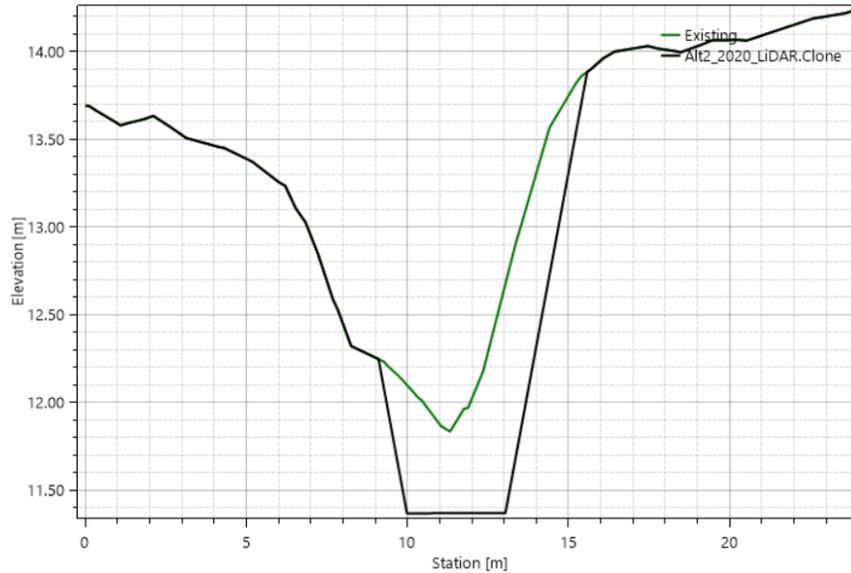


Figure 73 – Salinas River, RS 7+02

- Channelization at Salinas River lined with concrete side wall (1H:1V side slopes) RS 7+55 to 9+01 – 6' (wide) x 5' (depth varies) x 480' (length), 3902 yd<sup>3</sup> of earthwork and 282 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom, see Figure 74.

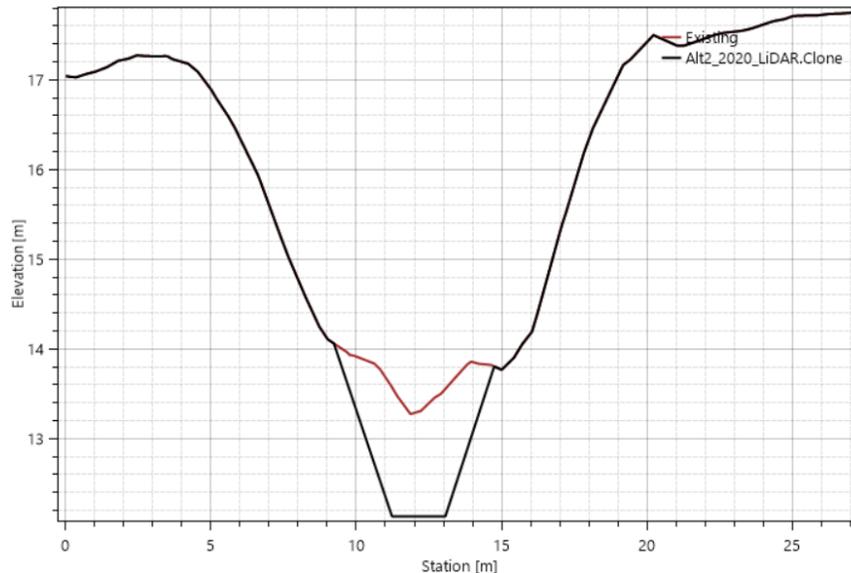


Figure 74 – Salinas River, RS 8+05

- Channelization at Salinas River lined with concrete side wall (2H:1V side slopes) RS 10+68 to 11+05, downstream transition section for the culvert crossing at San

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Vicente Ave – 5' (wide) x 17' (depth varies) x 122' (length), 1,532 yd<sup>3</sup> of earthwork and 186 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom, see Figure 75.

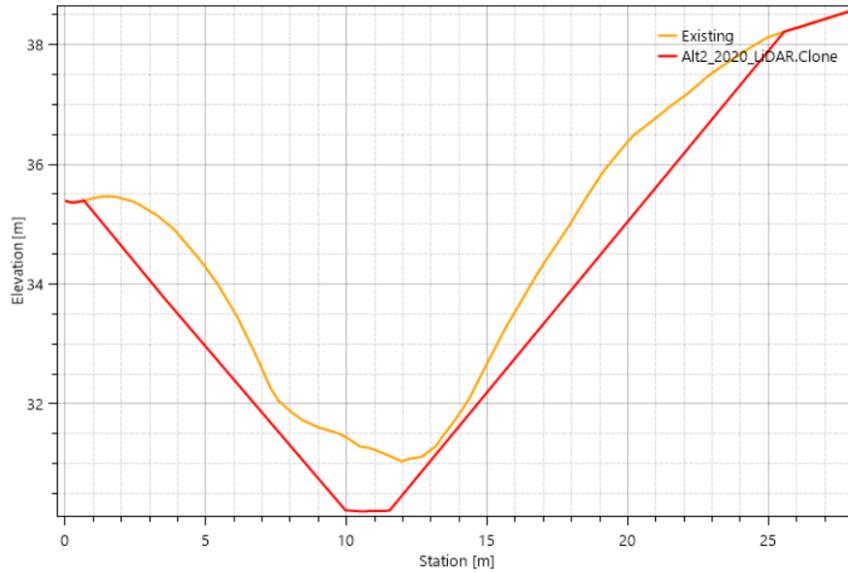


Figure 75 – Salinas River, RS10+88

- Channelization at Salinas River lined with concrete side wall (1H:1V side slopes) RS 11+33 to 11+51, upstream transition section for the culvert crossing at San Vicente Ave – 50' (wide) x 9' (depth varies) x 61' (length), 1,167 yd<sup>3</sup> of earthwork and 82 yd<sup>3</sup> (0.5' thick) of concrete for sidewall and channel bottom, see Figure 76.

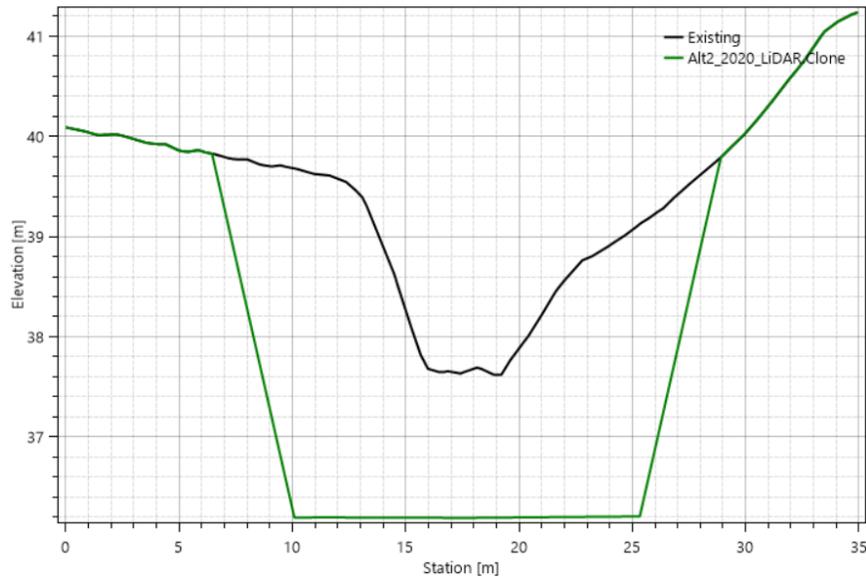


Figure 76 – Salinas River, RS 11+42

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- Berm on Salinas River right bank near RS 3+30 - 1' (wide) x 3.35' (depth varies) x 212' (length), 27 yd<sup>3</sup> of concrete berm
- Culvert improvements at Rt 2 highway road: 4 – 12' x 8' x 138', includes road raise, see Figure 39.
- Road raise for new deeper culverts at Rt. 2 highway road – 1,919 yd<sup>3</sup> of earthwork and 27' wide x 525' length of pavement, see Figure 39.
- Culvert improvements at De Los Marteres Road: 4 – 12' x 8' x 100', includes road raise, see Figure 40.
- Road raise for new deeper culverts at De Los Marteres St. – 681 yd<sup>3</sup> of earthwork and 27' wide x 220' length of pavement, see Figure 40.
- Culvert improvements at San Vicente Ave: 4 – 12' x 8' x 92', see Figure 41.

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5.3 ALT3



Figure 77 – Alt3 Soils at surface, locations of excavations

The cost estimates for Alt3 includes the following:

- Gaan River stream mouth widening, downstream of Rt 2 highway road at River Sta. 0+00 to 00+35.4 – 20' (wide) x 128' (length), depth varies 3H:1V side slope, 71 yd<sup>3</sup> of earthwork, see Figure 78.

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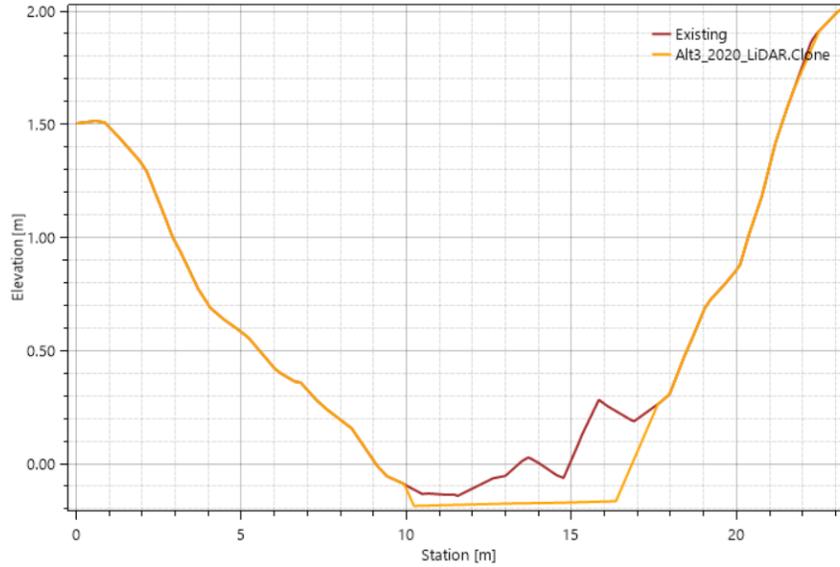


Figure 78 – Gaan River, RS 0+26

- Gaan River channelization with concrete lined side slopes, upstream of Rt 2 highway road at River Sta. 0+59 to 7+77.50 – 20' (wide) x 2,356' (length), depth varies 2H:1V side slope, 10,400 yd<sup>3</sup> of earthwork and 1,766 yd<sup>3</sup> of 0.5' thick concrete for sidewall and channel bottom, see Figure 79.

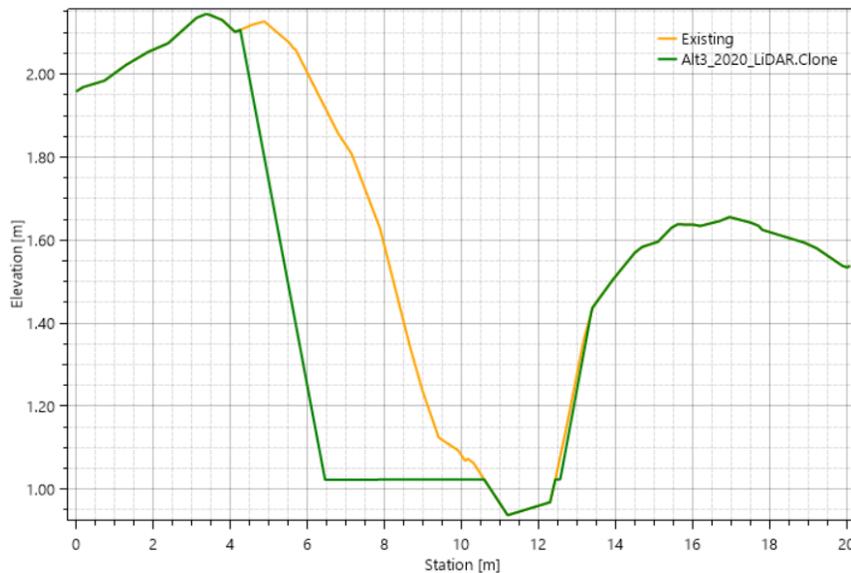


Figure 79 – Gaan River, RS 2+69

- Auau Creek channelization, downstream of Rt 2 highway road at River Sta. 0+00 to 00+89 – 14' (wide) x 298' (length), depth varies 3H:1V side slope, 159 yd<sup>3</sup> of earthwork, see Figure 80.

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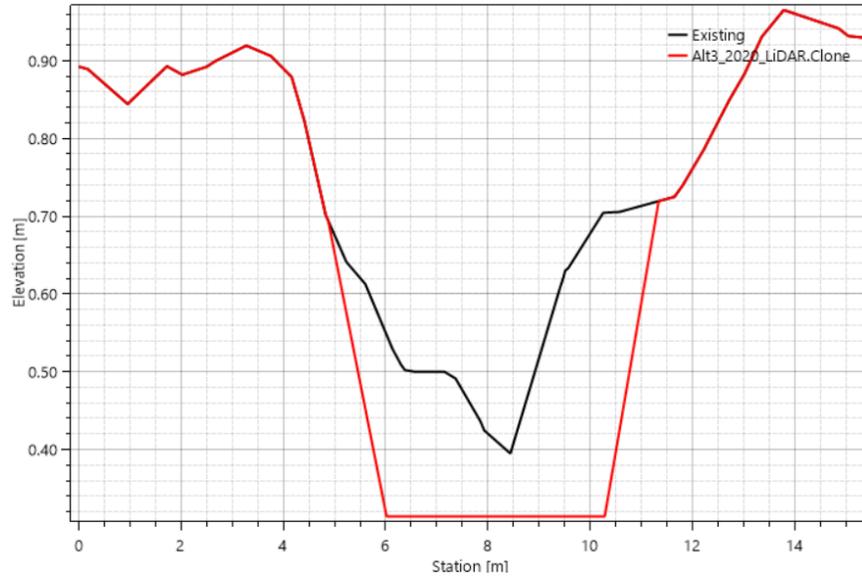


Figure 80 – Auau Creek, RS 0+50

- Auau Creek channelization with concrete lined side slopes, upstream of Rt 2 highway road at River Sta. 1+10 to 2+92.50 – 30' (wide) x 601' (length), depth varies 2H:1V side slope, 715 yd<sup>3</sup> of earthwork and 108 yd<sup>3</sup> of 0.5' thick concrete for sidewall and channel bottom, see Figure 81.

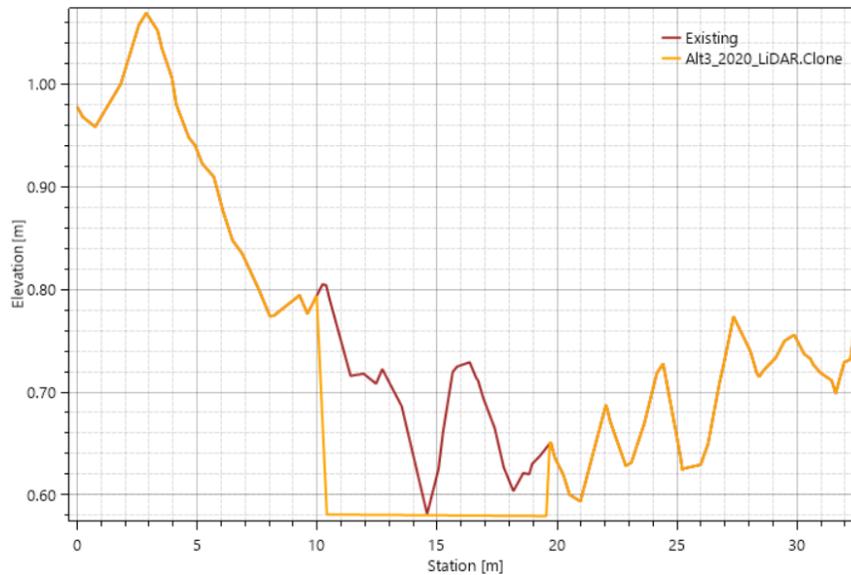


Figure 81 – Auau Creek, RS 2+00

- Auau Creek culvert improvements at Rt 2 highway road: 5 – 5' x 5' x 64', see Figure 50
- Gaan River culvert improvements at Rt 2 highway road: 3 – 8' x 6' x 66.3', see Figure 51

## SECTION 6 - REFERENCES

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FINILE CREEK FLOOD HAZARD STUDY  
ENGINEERING APPENDIX

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**APPENDIX A – COST BASIS AND REPORT**

## Project Scope and Alternatives

The IIS project involves three distinct alternatives for flood hazard mitigation in Agat, Guam, just south of Apra Harbor. These alternatives, designed by ECT and referencing the H&H Finile Creek Flood Hazard Study report (dated June 30, 2025), focus on channel improvements. Each alternative shares common construction elements, including clearing and grubbing, topsoil removal, temporary diversion of perennial streams, dewatering of groundwater springs (assumed based on internet research using Gemini and NIPRGPT), earthwork channelization, concrete channel lining (primarily trapezoidal), and adjustments to roadway crossings, typically involving raising grades and installing reinforced concrete rectangular box culverts (RCBs). The current estimate is a Class 4, as defined by ASCE 56R-08, based on the IIS Finile flood hazard concept study (2%-15% design maturity). Cost estimates are derived from parametric models from similar projects, with an expected cost range of -20% to +30% at an 80% confidence interval.

### Alternative 1: Finile Creek

This alternative focuses on Finile Creek itself and its tributaries. The work includes concrete-lined channelization of the existing Finile Creek (2160 linear feet), the existing South Finile Tributary (260 linear feet downstream and 2455 linear feet upstream, including a concrete weir), and a proposed unlined South Finile Bypass channel (1480 linear feet). The South Finile Tributary design incorporates a concrete weir with energy-dissipating concrete baffle blocks. The project requires raising and paving seven roadway crossings, primarily private roads, but also including the major highway Route 2 and Dew Salas Street, along with redesigned culverts.

### Alternative 2: Salinas River

This alternative centers on the Salinas River, requiring concrete-lined channelization of the existing river (3775 linear feet) and the construction of a 212-foot long concrete berm. Three roadway crossings – Route 2, Calle de Los Marteres Street, and San Vicente Ave – will be raised and paved, with redesigned culverts.

### Alternative 3: Gaan River and Auau Creek

This alternative addresses the Gaan River (778 linear feet at the mouth) and Auau Creek (293 linear feet), using concrete-lined channelization. Crossings are primarily located at Route 2. The H&H modeler has included redesigned or additional culverts for these locations.

## Means and Methods: Construction Approach Assumptions

Construction will begin with the COSA area, followed by the implementation of relevant Best Management Practices (BMPs) as the project progresses. Access routes, assumed to be 12 feet wide with a 12-inch gravel fill, will be constructed on both sides of each inland waterway.

Construction along each waterway will be phased in sections, up to each upstream road crossing or tributary, or in shorter lengths (100-200 feet or 30-60 meters), to minimize erosion of clay soils. Work will start with widening the beach sand at the mouth and proceed upstream (though this portion could be completed at the end of each waterway sequence to capture more upstream sediments). Based on Google Earth imagery, an outer reef exists beyond the tidally influenced mouth of each waterway, suggesting no breaking waves will impact construction.

#### Alternative 1 Specifics: Finile Creek

The main highway, Route 2, will require a road bypass with temporary culverts (potentially encountering unknown underground utilities). Excavated material from the proposed South Finile Tributary bypass will be used as fill for the Route 2 temporary roadway bypass. The upstream phased construction will involve clearing and grubbing, topsoil removal, and temporary diversion of the waterway near and below the existing water surface elevation. Based on NIPRGPT research, an estimated baseflow of up to 1 cubic foot per second (cfs) is expected during the dry season (due to minimal watershed drainage areas less than 50 square miles and unlikely groundwater contribution from impermeable clay soils), increasing to up to 25 cfs during the wet season. Excavation will be performed by excavators, with two 12-20 cubic yard dump trucks per excavator hauling soil disposal to the Eddie Cruz hardfill in Yigo, Guam. The excavated material is classified as Inarajan clay per NRCS. Temporary access to each 200-foot phased half-cross-section will be provided by a built-up ramp of excess excavated soil from the waterway upstream end bottom to the overbank top. The temporary diversion will use a 24-inch diameter HDPE pipe with a capacity of up to 20 cfs at a 0.5% slope. Rip rap (or a newly proposed concrete channel) will be placed at the pipe outlet to mitigate erosion. Existing upstream vegetation will serve as sedimentation controls at the pipe inlet. Construction will proceed one half of the waterway cross-section at a time. This includes some pump dewatering, and a 6-inch bedding layer with channel invert PVC seepage pipes under a 6-inch reinforced concrete bottom and side slope lining, assuming rebar of 120 lb/cy. All seven roadway (including Route 2) culvert bypasses will assume a proposed representative length/section precast RCB culvert crossings for the purposes of this study as provided by ECT and will require bypass roadway construction, which will not account for potential unknown underground utilities. A proposed 30-foot concrete weir with baffle blocks is another feature of this alternative.

#### Alternative 2 Specifics: Salinas River

Construction will start or end with mouth widening via excavator and dump trucks haul to Eddie Cruz Hardfill. Next, upstream of Route 2 to 200ft upstream to construct temporary bypass road for Route 2 following similar methods as discussed in Alt1. Then work will be on Route 2 roadway raising and culverts. Then the bypass road for Route 2 will be demolished and work (upstream diversion, clearing and grubbing, topsoil removal, excavation and concrete channelization of inland waterway) will continue further upstream phased every 200ft half cross sections. Excavated material is also considered clay soils per ECT, however there is the potential for some harder soils materials per NRCS citing bedrock beyond a depth of 24-in that is not captured in the estimate due to unknowns. Three roadway culvert bypasses will assume a proposed representative length/section precast RCB culvert crossings for the purposes of this study as provided by ECT and will require bypass roadway construction, which will not account for potential unknown

underground utilities. A proposed 212LF long concrete berm is another feature of this alternative per H&H modeler.

#### Alternative 3 Specifics: Gaan River and Auau Creek

Same process for each of the two inland waterways. Construction will start or end with mouth widening via excavator and dump trucks haul to Eddie Cruz Hardfill. Next, upstream of Route 2 to 200ft upstream to construct temporary bypass road for Route 2 following similar methods as discussed in Alt1. Then work will be on Route 2 roadway raising and culverts. Then the bypass road for Route two will be demolished and work (upstream diversion, clearing and grubbing, topsoil removal, excavation and concrete channelization of inland waterway) will continue further upstream phased every 200ft half cross sections. Excavated material is considered Inarajan clay per NRCS. Route 2 roadway culvert bypass will assume a proposed representative length/section precast RCB culvert crossings for the purposes of this study as provided by ECT, one for Gaan and another for Auau, and will require bypass roadway construction, which will not account for potential unknown underground utilities.

#### Other Assumptions

The project assumes a civil site prime contractor with subcontractors for asphalt paving. The inland waterway clay soils are assumed to be non-hazardous, and no designated wetland areas are expected.

#### Quantities

Quantities were sourced from ECT documents (“Finile\_Alt1-3\_Qty.xlsx”), assuming bcy (bank cubic yards). These quantities have been adjusted by ECS in MII to account for waste, additional quantities needed to construct features not captured by ECT, and soil shrink/swell factors (which are not explicitly shown in the Excel documents but are considered by ECS).

#### Schedule

- Alternative 1 (Finile Creek): Estimated construction duration is 5 years, including the performance period. The H&H design is expected to require at least one additional year to mature, followed by another year for construction design plans, specifications, and the Design Approval (DA). The earliest possible start is 7 years from now, but potential delays related to environmental factors, funding, political issues, and design (both H&H and plans/specs) could push this schedule further to the right. A more realistic estimate is 10 years from now, with the construction midpoint at 7.5 years from today.
- Alternative 2 (Salinas River): Estimated construction duration is slightly under 2.5 years, including the performance period. Adding one year for H&H design maturation and another year for construction design plans, specifications, and the DA, the earliest possible start is

4.5 years from now. Factoring in potential delays, a more realistic estimate is 7 years from now, with the construction midpoint at 3.5 years from today.

- Alternative 3 (Gaan River and Auau Creek): Estimated construction duration is slightly over 2 years, including the performance period. With one year for H&H design maturation and another year for construction design plans, specifications, and the DA, the earliest possible start is 4 years from now. Considering potential delays, a more realistic estimate is 6 years from now, with the construction midpoint at 3 years from today.

#### Sensitivity Analysis of Large Dollar Cost Definable Features of Work:

All costs discussed are based on Rough Order of Magnitude (ROM) Engineer Cost Calculations (ECC).

- Alternative 1 (\$61.3M ROM ECC): The most significant cost drivers are earthwork hauling and disposal of excess clay soil from Guam's mountainous south to the flatter plateau limestone terrain in the north (over \$18M), tree removal (heavy density assumed at 1000 trees/acre) and disposal (over \$7M each), reinforcing steel for channel lining (over \$9M), concrete formwork for channel lining side slopes (under \$4M), structural concrete for channel lining (\$2.5M), finishing of this concrete (under \$2M), structural concrete in place for weir and baffle blocks (under \$2M), basecourse for the access roads (under \$2M), and clearing vegetation (over \$1M).
- Alternative 2 (\$19.9M ROM ECC): The largest cost components are earthwork hauling and disposal (over \$5M), precast concrete box culverts (\$4.5M), reinforcing steel for channel lining (\$4M), structural concrete for channel lining (over \$1M), and tree removal and disposal (over \$1M each).
- Alternative 3 (\$14.6M ROM ECC): The major costs are earthwork hauling and disposal (\$2.6M), reinforcing steel for channel lining (\$4M), tree removal and disposal (over \$1M each), precast concrete box culverts (over \$1M), and structural concrete for channel lining (over \$1M).

#### Risk and Uncertainty

The design is at an early stage, lacking detailed topography, geotechnical reports, and engineering design plans. Design details and H&H modeling are subject to change. While NRCS soils data indicates primarily clay excavation, there is a potential for encountering boulders not accounted for in the ROM. Alternative 3 specifically has the potential for weathered volcanic bedrock excavation after 24", which is not directly captured in this cost estimate and could significantly increase costs beyond the 80% confidence level of a Class 4 estimate. The availability of disposal locations for excavated soils is uncertain, and if alternative disposal options are required, costs could increase. Conversely, community utilization of excavated soils and green waste could potentially reduce or eliminate disposal costs. The amount of tidally influenced seawater, potential groundwater intrusion, and typhoon-related flows may exceed current assumptions. Flash floods have not been

considered in the schedule. If the project is limited to one construction crew instead of the assumed two, the schedule could double, increasing FOOH and escalation costs. The roadway crossing designs for larger RCBs are not finalized and may require larger grade transitions not fully accounted for. Unknown existing utilities at roadway culvert crossings pose a risk. Quantity estimates are not precise at this stage. ROM costs only include ECC, excluding administrative costs, construction contingency, and owner oversight costs. Procurement assumptions involve a prime contractor with limited subcontractors, but a worst-case scenario of small business 8a sole sourcing could arise. Real estate issues with private landowners and potential land ownership complexities for the South Finile tributary bypass channel could arise. Detours along the main highway and private roadways may be more extensive than currently accounted for. Environmental permit requirements for in-stream and tidally influenced areas are not fully understood or captured in the ROM.

### MII Libraries

- Labor: Based on Sam.gov Davis-Bacon (DB) wage rates for Guam (General Decision Number GU20250010 dated 01/03/2025). The minimum DB wage rate is \$17.75/hr per EO 14026. A construction labor rate of \$20/hr is assumed for this study. Guam construction laborer rates are approximately 60% of the U.S. average wage rate (based on BLS data from May 2024).
- Equipment: EP 1110-1-8 Region X (Hawaii) is used, with adjustments for Guam-specific fuel and shipping prices. Per NIPRGPT (July 2025), Guam gas is \$5.50/gal; no change to electricity; diesel (off-road) is \$5.5/gal and (on-road) is \$6.5/gal. Shipping costs vary based on weight. Sales tax is 4%, and a Labor Adjustment Factor of 0.75 is used (compared to Hawaii's 1.23).
- Materials: The 2024 cost book is used, supplemented with recent material quotes. Material prices from Oahu are assumed for items where quotes were unavailable (RCBs, ready-mix concrete, asphalt, and basecourse). Freight is estimated at \$9,000 per TEU (based on West Coast shipping rates from 2021-2024) or an additional 15% on top of cost book material prices.

### MII Direct Cost Markups

- Productivity: Assumed at 85% due to hot, humid conditions and tree clearing laborers dealing directly with brown tree snakes.
- Design Contingency: Assumed at 30% (but potentially much higher based on the Risk and Uncertainty section).
- Escalation: Based on NAVFAC BCI 2025 Q1, approximately 5% per year to the Mid-Point of Construction (MOC).
- Owner Contingency and S&A: Not applied for the IIS study.

### MII Contractor Markups

- JOOH (Job Office Overhead): 15% for site civil projects.
- HOOH (Home Office Overhead): 5% for prime contractors and 10% for subcontractors.
- Profit: 10% for the IIS study.
- Bond and Insurance: 3% due to risks associated with perennial streams and potential groundwater presence.
- Guam's Business Privilege Tax (BPT): 4%.

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SOW:

The IIS project consists of three alternatives (all different geographic locations within Agat, Guam just south of Apra Harbor) designed by ECT referencing H&H for Finile Creek Flood Hazard Study report dated 30 June 2025. All alternatives require clearing and grubbing, topsoil removal, perennial stream temporary diversion, dewatering of existing perennial streams from groundwater springs assumed based on internet research using Gemini and NIPRGPT of the study area, earthwork channelization, concrete channel lining (mostly trapezoidal), and crossing roadway adjustments (usually raising grades) with culverts consisting of reinforced concrete rectangular concrete boxes, RCB. Estimate is a Class 4 per ASCE 56R-08 based on the IIS Finile flood hazard concept study (2%-15% design maturity) which will contain some cost parametric models from other similar projects with costs range from -20% to +30% at the 80% confidence interval.

The first alternative is Finile Creek consisting of concrete lined channelization work on existing Finile Creek (2160 LF and at the mouth), existing South Finile Tributary (260LF downstream tributary and 2455LF upstream tributary with a concrete weir), and a proposed South Finile Bypass unlined channel (1480 LF). The existing South Finile Tributary includes a proposed concrete weir with energy dissipating concrete baffle blocks. Seven roadway crossings, mostly private roadways with one major highway Route 2 and Dew Salas Street, will be raised and paved with redesigned culverts.

The second alternative is Salinas River consisting of concrete lined channelization work on existing Salinas River (3775LF and at the mouth). There is also a construction of a 212ft long concrete berm. Three roadway crossings, highway Route 2, Calle de Los Marteres Street and San Vicente Ave, will be raised and paved with redesigned culverts.

The third alternative is Gaan River (778LF and at mouth) and Auau Creek (293LF and at mouth) consisting of concrete lined channelization work. The crossings appear to only be at Route 2. Redesigned or additional culverts have been included per H&H modeler.

Means and Methods Construction Approach Assumptions (to include site access and usage of heavy equipment):

COSA area constructed first and then relevant BMPs will be setup as the project progresses. Access routes (say 12' wide with 12" gravel fill) are assumed to be constructed on both sides of the inland waterway. Construction for each inland waterway will be phased by sections to each upstream inland waterway road crossing or tributary or a smaller length (100-200ft or 30-60m) to minimize erosion of clay soils. Construction will begin at the beach sand widening of the mouth and proceed upstream (note this portion could potentially be constructed at the completion of each waterway sequence as it will capture more upstream sediments). Based on Google Earth, there appears to be an outer reef well beyond the tidally influenced mouth of all the study inland waterways, indicating no breaking waves.

Alt1, Finile Creek. The main highway Route 2 will require a road bypass with temporary culverts constructed (note potential of unknown underground utilities unaccounted for). To construct the inland waterway diversion, portions of the proposed south Finile tributary bypass will be excavated as fill soil for the highway Route 2 temporary roadway bypass. The upstream phased portion will require clearing and grubbing and topsoil removal before or in conjunction with temporary diversion of the inland waterway near and below the existing water surface elevation (per NIPRGPT assumes up to 1cfs baseflow during dry season due to minimal watershed drainage areas less than 50 mi2 with unlikely groundwater contribution due to impermeable clay soils and up to 25cfs during wet season) on one side of the cross section via excavation by excavator and the use of two 12-20cy dump trucks per excavator to haul soil disposal to Eddie Cruz hardfill in Yigo, Guam. Excavated material is considered Inarajan clay per NRCS. Access to each 200ft phased half cross section will consist of a temporary built-up excess excavated soil ramp from the inland waterway upstream end bottom to the overbank top. The upstream temporary diversion will consist of a 24-in diameter HDPE pipe to allow up to 20cfs at 0.5% slope with the pipe outlet having rip rap (or newly proposed concrete channel) to mitigate outlet erosion; the inlet of the temporary diversion pipe will assume existing upstream vegetation as sedimentation controls. One half of the inland waterway cross section will be constructed at a time. This includes some pump dewatering, assumed 6-in bedding layer with channel invert PVC seepage pipes under 6-inch reinforced concrete bottom and side slope lining assuming rebar of 120lb/cy. All seven roadway (including Route 2) culvert bypass will assume a proposed representative length/section precast RCB culvert crossings for the purposes of this study as provided by ECT and will require bypass roadway construction, which will not account for potential unknown underground utilities. A proposed 30LF concrete weir with baffle blocks is another feature of this alternative.

Estimated by ECS  
Designed by ECT  
Prepared by Eric Li

Preparation Date 7/7/2025  
Effective Date of Pricing 7/7/2025  
Estimated Construction Time Days

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Description	ContractCost	ProjectCost
<b>Project Cost Summary Report</b>	<b>95,738,318</b>	<b>95,738,318</b>
	<i>95,738,317.99</i>	<i>95,738,317.99</i>
<b>15 Floodway Control-Diversion Struc</b>	<b>95,738,318</b>	<b>95,738,318</b>
	<i>9,640.42</i>	<i>9,640.42</i>
<b>1500 Alt1 Finile Creek(~1225 working days ~56 calendar months say contract period of 5years)</b>	<b>61,255,218</b>	<b>61,255,218</b>
	<i>258,134.90</i>	<i>258,134.90</i>
<b>150001 Mob, Demob &amp; Preparatory Work (assume 10 workingdays)</b>	<b>258,135</b>	<b>258,135</b>
	<i>1,012,620.11</i>	<i>1,012,620.11</i>
<b>Clearing and Grubbing (230 working days with 3 crews)</b>	<b>16,333,562</b>	<b>16,333,562</b>
	<i>254.69</i>	<i>254.69</i>
<b>\$_Access Roads - 12"thk basecourse (8 working days)</b>	<b>1,690,411</b>	<b>1,690,411</b>
	<i>19,707,449.36</i>	<i>19,707,449.36</i>
<b>Earthwork Excavation (say 2crews - 80days separate from diversion though)</b>	<b>19,707,449</b>	<b>19,707,449</b>
	<i>21,672,585.50</i>	<i>21,672,585.50</i>
<b>Concrete Channel Lining</b>	<b>21,672,585</b>	<b>21,672,585</b>
	<i>1,593,075.22</i>	<i>1,593,075.22</i>
<b>Roadway Construction</b>	<b>1,593,075</b>	<b>1,593,075</b>
	<i>6,523.17</i>	<i>6,523.17</i>
<b>1500 Alt2 Salinas River (~537 working days ~25 calendar months say contract period of 29months)</b>	<b>19,863,047</b>	<b>19,863,047</b>
	<i>140,951.60</i>	<i>140,951.60</i>
<b>150001 Mob, Demob &amp; Preparatory Work (assume 7 workingdays)</b>	<b>140,952</b>	<b>140,952</b>
	<i>827,438.04</i>	<i>827,438.04</i>
<b>Clearing and Grubbing (80 working days with 3 crews)</b>	<b>2,457,491</b>	<b>2,457,491</b>
	<i>208.97</i>	<i>208.97</i>
<b>Access Roads - 12"thk basecourse (3 working days)</b>	<b>531,003</b>	<b>531,003</b>
	<i>3,705,371.53</i>	<i>3,705,371.53</i>
<b>Earthwork Excavation (say 2crews - 28days separate from diversion though)</b>	<b>3,705,372</b>	<b>3,705,372</b>
	<i>6,871,082.17</i>	<i>6,871,082.17</i>
<b>Concrete Channel Lining</b>	<b>6,871,082</b>	<b>6,871,082</b>
	<i>6,157,147.91</i>	<i>6,157,147.91</i>
<b>Roadway Construction</b>	<b>6,157,148</b>	<b>6,157,148</b>
	<i>4,165.26</i>	<i>4,165.26</i>
<b>1500 Alt3 Gaan River and Auau Creek (~467 working days ~21.5 calendar months say contract period of 25.5months)</b>	<b>14,620,052</b>	<b>14,620,052</b>

<b>Description</b>	<b>ContractCost</b>	<b>ProjectCost</b>
<b>150001 Mob, Demob &amp; Preparatory Work (assume 8 workingdays)</b>	<i>147,744.11</i> <b>147,744</b>	<i>147,744.11</i> <b>147,744</b>
<b>Clearing and Grubbing (100 working days with 3 crews)</b>	<i>807,701.90</i> <b>2,956,189</b>	<i>807,701.90</i> <b>2,956,189</b>
<b>Access Roads - 12"thk basecourse (2 working days)</b>	<i>203.92</i> <b>642,967</b>	<i>203.92</i> <b>642,967</b>
<b>Earthwork Excavation (say 2crews - 8days separate from diversion though)</b>	<i>3,014,833.72</i> <b>3,014,834</b>	<i>3,014,833.72</i> <b>3,014,834</b>
<b>Concrete Channel Lining</b>	<i>6,594,688.72</i> <b>6,594,689</b>	<i>6,594,688.72</i> <b>6,594,689</b>
<b>Roadway Construction (10 working days)</b>	<i>1,263,629.79</i> <b>1,263,630</b>	<i>1,263,629.79</i> <b>1,263,630</b>