# Memorandum

**DRAFT**

**August 29, 2024**

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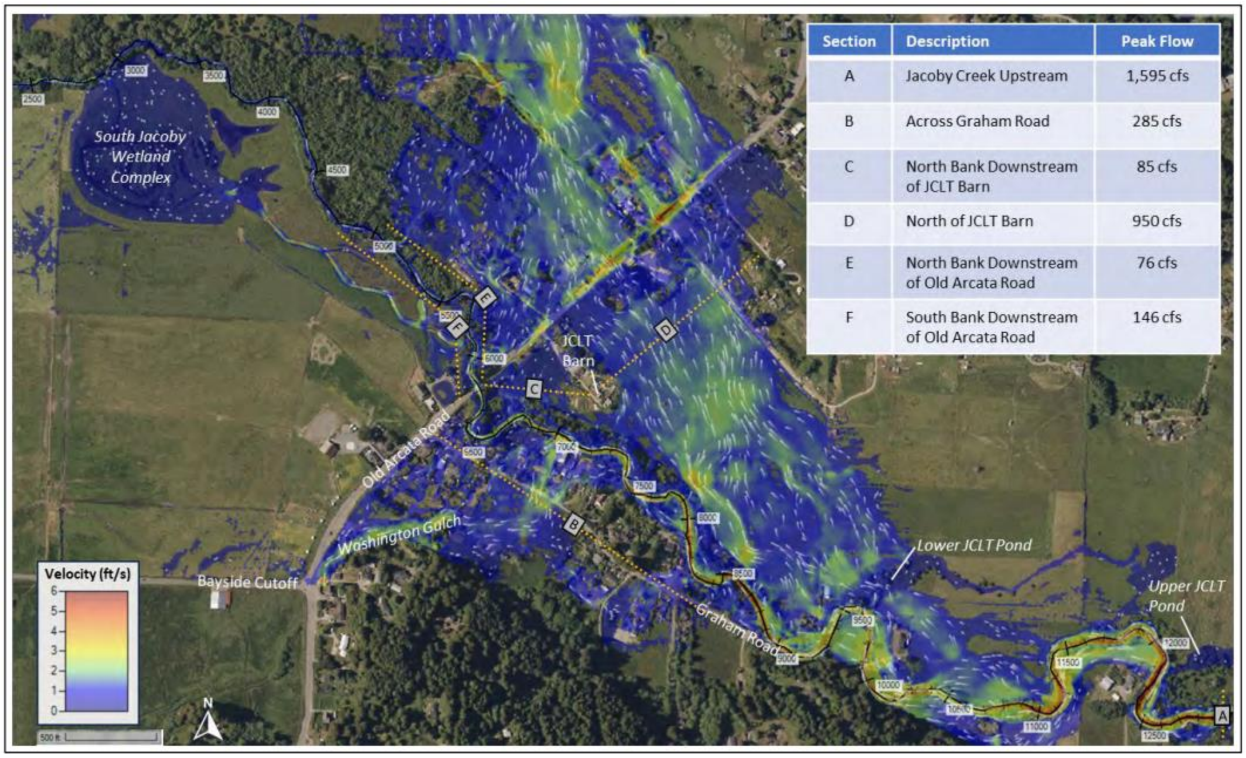
| **To** | Hank Seemann, Deputy Director (Humboldt County Public Works)<br>Stephanie Mietz, Executive Director (Jacoby Creek Land Trust) | | |
| **From** | Spencer Babcock, Jeremy Svehla PE, Brett Vivyan PE (GHD) | | |
| **Reviewed** | Michael Love & Associates (MLA) | **Tel** | +1 707 443 8326 |
| **Subject** | Jacoby Creek Enhancement Feasibility Study - Old Arcata Road Interim Drainage Improvements | **Project no.** | 11229552 |

## 1. Background

In November 2023, GHD in partnership with Michael Love & Associates, Inc. (MLA), Thomas Gast & Associates (TGAEC) and BBW & Associates (BBW) completed the draft Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study Report (Report, 2023). The Report was developed for the Jacoby Creek Land Trust (JCLT), County of Humboldt, and City of Arcata with funding from the State Coastal Conservancy (SCC). The Report was prepared as an initial phase in developing multi-benefit project concepts to enhance aquatic habitat quality and reduce flooding impacts in the lower Jacoby Creek valley adjacent to Humboldt Bay. The feasibility study included a characterization of existing conditions, identified potential solutions to meet project objectives, and proposed multiple conceptual alternatives for consideration and analysis as part of a subsequent planning phase. The conceptual alternatives identified are estimated to take at least 5 years to implement given the scope, cost and anticipated regulatory and landowner approvals. As an interim measure to reduce flood risk along Old Arcata Road (OAR), GHD assessed various improvements to the OAR drainage system which could be implemented in the short-term, providing some flood reduction and remaining compatible with the alternatives assessed in the report. This memorandum provides the basis of design for the interim OAR drainage system improvements.

## 2. Existing Conditions

OAR parallels Highway 101 connecting the City of Arcata to the City of Eureka. The segment of OAR between Bayside Cutoff and the community of Bayside is situated within the floodplain and frequently floods due to flow overtopping Jacoby Creek upstream of OAR (Figure 1). The Report describes how flood conditions have been affected by historical land use changes. The existing OAR stormwater system consists of a network of pipes, drain inlets, and an earthen channel that conveys drainage from the pastures on the east side of the road to the land on the west side. Overbank flooding from Jacoby Creek often exceeds the capacity of the stormwater system, resulting in flooding of the roadway and adjacent properties.



| Section | Description | Peak Flow |
|---|---|---|
| A | Jacoby Creek Upstream | 1,595 cfs |
| B | Across Graham Road | 285 cfs |
| C | North Bank Downstream of JCLT Barn | 85 cfs |
| D | North of JCLT Barn | 950 cfs |
| E | North Bank Downstream of Old Arcata Road | 76 cfs |
| F | South Bank Downstream of Old Arcata Road | 146 cfs |



*Figure 1 HEC-RAS simulation of February 2019 flow event with approximate 2-year return period, showing peak Inundation extents, floodplain flow patterns, and water velocities. Table lists peak flowrates across indicated section lines as presented in the Report (MLA and GHD 2023)*

## 1.1 Existing Stormwater System

The existing stormwater system conveys road drainage and Jacoby Creek floodplain flows from the east side of OAR towards the west. Figure 2 below displays the plan view of the existing stormwater system. The system consists of 10 drop inlets (DI) that are located along the eastern shoulder of OAR. Each DI is grated at the road surface and is paired to a flared inlet situated on the east face of the DI. The grated DI collects road surface runoff and the flared inlets collect drainage from the adjacent pastures. The most southern DI (#1) has two flared inlets, one connected directly to the DI, and one located 30 feet south in a ditch along the road shoulder. The 10 DIs are connected with a 24 in. diameter high density polyethylene pipe (HDPE) that runs parallel to OAR. The HDPE pipe is sloped so that the lowest elevation in the stormwater system is located at DI #5. A 4 ft wide by 3 ft tall concrete box culvert crosses under OAR and connects the HDPE pipe and DI #5 to an approximate 0.5 % slope earthen drainage channel on the west side of OAR. The drainage channel extends from the road's edge to the Arcata North Baylands, where it drains into a system of ditches and historical slough channels before exiting through tide gates to Humbold Bay. The 1989 as-built drawings of the stormwater system are located in Appendix A. See sheet A3 for the stormwater pipe profile.


*Figure 2 Plan view of existing OAR stormwater system.*

## 1.3 Existing Flooding

As described in the Report, during small and frequent storm events, flow from Jacoby Creek exits the creek's main channel on the east side of OAR on JCLT property (Kokte Ranch). A portion of the overtopping flow from Jacoby Creek is captured and conveyed through the existing stormwater system under OAR, as described above. The floodwater often overwhelms the existing stormwater system, resulting in flow sheeting over OAR before flowing towards the City of Arcata North Baylands. Figure 3 and Figure 4 below present the flooding that occurred on OAR during a storm event on March 24, 2024.

*Figure 3 Flooding on OAR (looking south)*

*Figure 4 Flooding at local resident's home on east side of OAR*

# 2. Stormwater Infrastructure Improvement Alternatives

Local residents have expressed willingness to work with the County to develop interim drainage improvements to help reduce the impact of the flooding. In response, the following design objectives were considered in developing three interim drainage improvement alternatives described below.

Design Objectives:

1. Reduce flood frequency on OAR.
2. Avoid increasing flood impacts on adjacent properties.
3. Minimize conflicts with existing above- and below-ground utilities.
4. Minimize construction impacts on private property.
5. Minimize cost.
6. Be compatible with conceptual alternatives described in the Report.

## 2.1 Alternative #1

This alternative includes the following proposed new improvements as depicted on Figure 5:

1. A flared inlet and / or headwall situated at the south side of the JCLT Kokte Ranch driveway adjacent to OAR.
2. A 240 ft long 24 in. diameter HDPE stormwater pipe that would parallel the existing stormwater line from the new inlet / headwall to the new junction box.
3. A drop inlet and junction box between DI #2 and DI #3 connecting the existing drainage system and new HDPE stormwater pipe to the new cross drain described below.
4. A 24 in. diameter HDPE cross drain will be installed under OAR, connecting the west side of the junction box to the new drainage channel. No change in the roadway elevation is anticipated to be needed to accommodate the new cross drain pipe, and potential conflicts with existing underground utilities such as water and gas would need to be verified in future design. (A larger 36 in. cross drain pipe would increase the system's conveyance, although the increased discharge may be deemed unfavorable by the owners of APN 50106118 and APN 50106112, see results section).
5. A new drainage channel extending along the shared property line of APN 50106119 and APN 50106120 and on APN 50106118, then discharging in an existing ditch along the shared property line of APN 50106118 and APN 5106112. This trapezoidal channel would be approximately 1,050 ft long with a compound slope of +/- 0.2% to +/-0.5%. The channel would have a bottom width of 4 ft, an average depth of 3 ft, and side slopes of 2H:1V. The drainage channel would terminate in an existing drainage ditch on the shared property line of APN 50106118 and 5106112 that exhibits shallow concentrated flow to Jacoby creek (Figure 6).

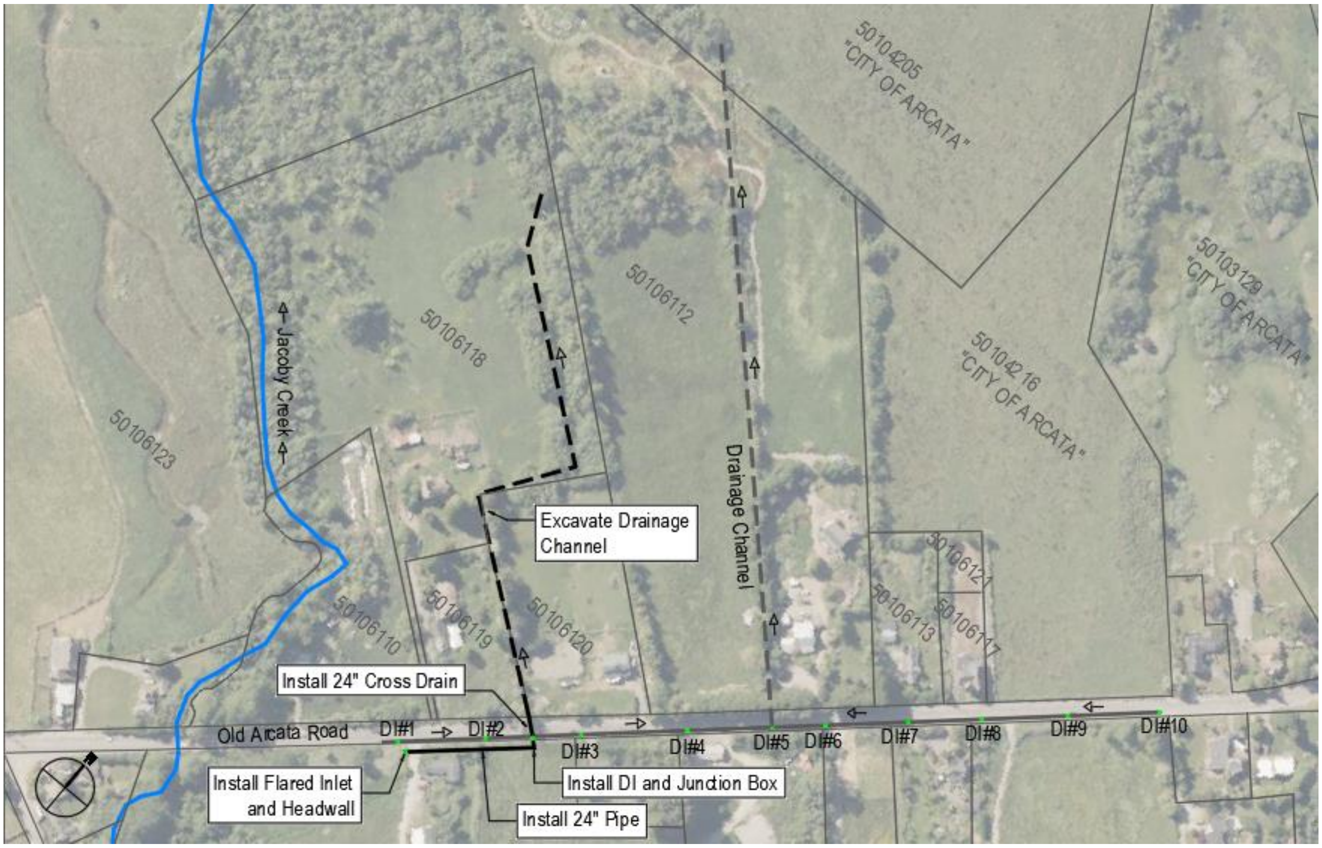



***Figure 5*** ***Plan view of Alternative 1 improvements in bold.***


***Figure 6*** ***Existing drainage dich on APN 50106112, proposed drainage ditch, and existing drainage ditch on APN 50106118 / APN 50106112. The dashed yellow line represents the proposed drainage ditch. The drainage ditch will carry shallow concentrated flow to the head of the arrow, where the drainage ditch will terminate.***

## 2.2 Alternative #2

This alternative includes the following improvements as depicted on Figure 7:

1. A drop inlet installed between DI #2 and DI #3 connecting the existing drainage system to the cross drain.
2. A 24 in. diameter HDPE cross drain installed under OAR, connecting the new DI and east side of the road to the new drainage channel.
3. Same drainage swale as described above in Alternative #1.

This design differs from Alternative #1 as it does not contain the junction box, parallel pipe, and flared inlet/headwall. Instead, it aims to increase the outflow capacity of the stormwater system and to demonstrate the difference relative to Alternative #1.

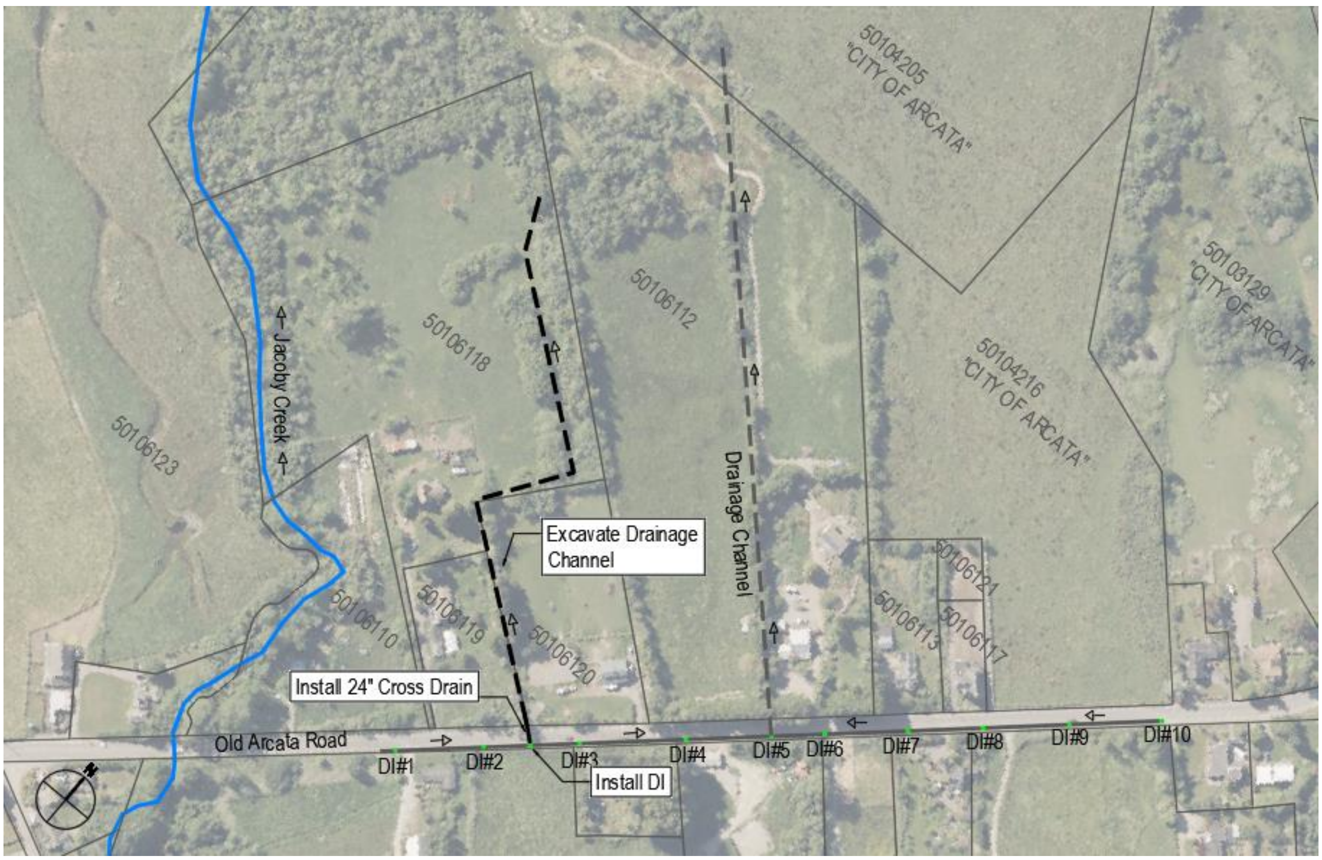



*Figure 7* *Plan view of Alternative 2 improvements in bold.*

## 2.3 Alternative #3

This alternative includes the following improvements as depicted on Figure 8:

1. A 24 in. cross drain installed diagonally across OAR connecting the first DI to the northeastern corner of APN 50106119 and to the new drainage channel. This crossing location may be advantageous relative to Alternative #1 and #2 crossing locations due to existing underground utilities which would need to be potholed and identified in future planning phases.
2. A drainage channel extending along the western OAR right-of-way and east side of APN 50106199 property line, then along APN 50106119 and APN 20106120 property line and onto APN 50106118 / APN 50106118. This trapezoidal channel would consist of two sections, one approximately 1,050 ft long with a compound slope of +/- 0.2% to +/-0.5%, and one approximately 150 ft long with a slope of 0.6%. The channel would have a bottom width of 4 ft, an average depth of 3 ft, and have side slopes of 2H:1V. The turn in the channel at the edge of APN 50106119 is not ideal and would be lined with riprap to prevent erosion. The drainage channel would terminate on parcel APN 50106118 / APN 50106112 in the same location as Alternatives 1 and 2.

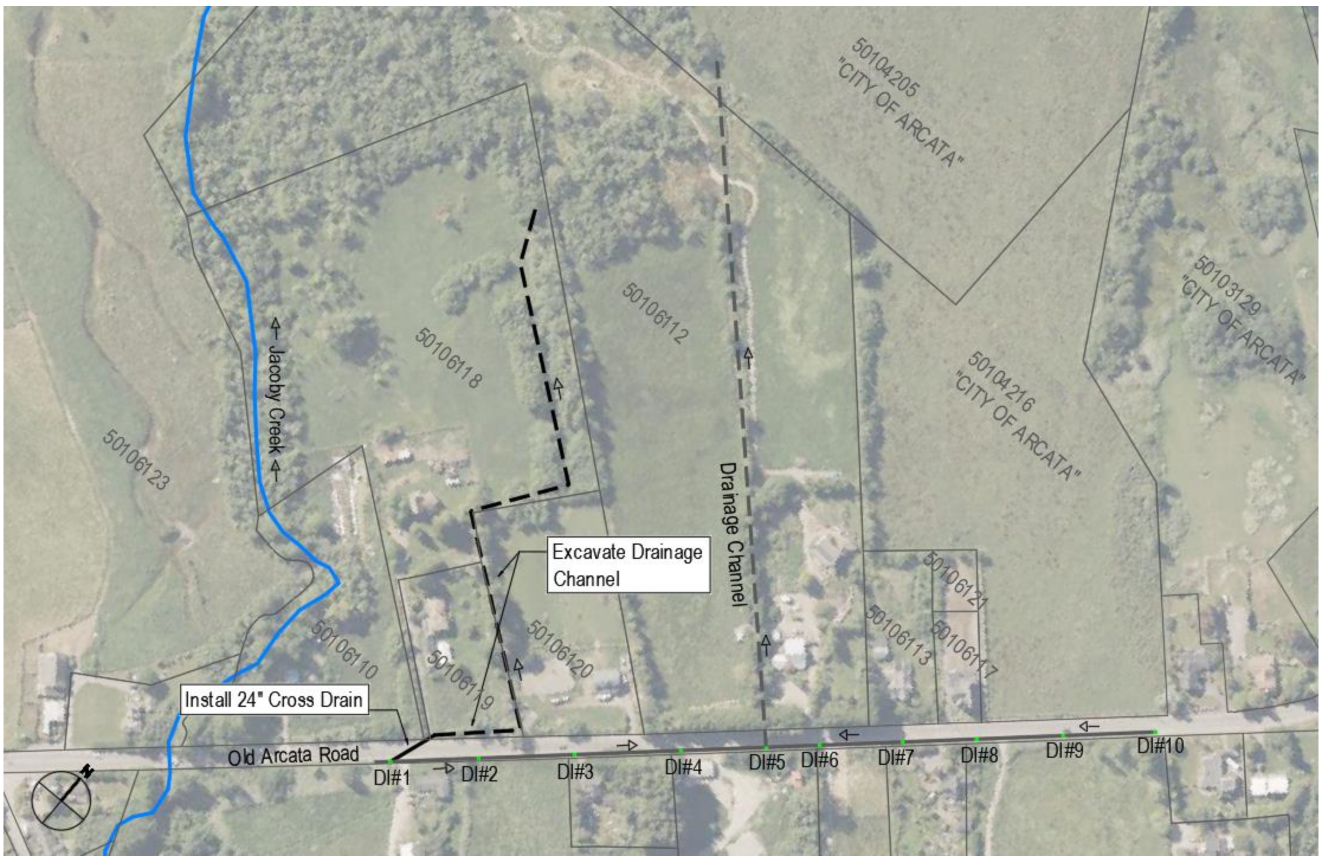



*Figure 8* ***Plan view of Alternative 3 improvements in bold.***

# 3. Hydraulic Analysis and Modeling Approach

The hydraulic modeling software PCSWMM (version 7.6.3695) was utilized to evaluate the effectiveness of each alternative. The modeling approach and results are summarized below.

## 3.1 Modeling Approach

To compare the effectiveness of each alternative, a baseline model of the existing stormwater infrastructure was developed along with a model of each alternative. The floodwater stage on the east side of OAR was fixed at each inlet and the discharge that exited the stormwater system on the west side of the road was calculated using normal depth approach. The calculated discharge that exited the system was compared between the existing conditions and alternatives. Two hydraulic scenarios were modeled, 1) initial inundation and 2) complete inundation. These scenarios were modeled to examine the effectiveness of the system during first the onset of flooding from Jacoby Creek overtopping and second when the floodplain is completely inundated.

The initial inundation scenario represented the onset of flooding where overtopping flow from Jacoby Creek begins to enter the stormwater system at the JCLT Kokte Ranch driveway. Jacoby Creek is located closest to DI #1. During OAR flood events, residents observed flooding first occurring on the south side of the system near DI #1. For this reason, an initial inundation scenario where flooding only occurs at the flared inlets connected to DI #1 was selected to be modeled. To represent this hydraulic scenario, flow was only allowed to enter flared inlets south of the JCLT Kokte Ranch (DI # 1). The stage of the floodwater was set to be the same as the complete floodwater inundation scenario. This scenario would allow for a comparison of existing conditions to the installation of new inlets and pipes near the Kokte Ranch during the onset of creek flooding.

The complete inundation scenario was modeled by assigning headwater elevations on the east side of OAR and allowing discharge to enter all flared inlets. Each flared inlet was assigned a headwater elevation equal to the top of the connected DI grate. The discharge that exited the system on the west side of OAR was recorded and compared to baseline conditions.

## 3.2 PCSWMM Model Development and Assumptions

The PCSWMM model was developed using existing 1989 stormwater system as-built drawings, 2019 Humboldt Bay LiDAR data, and available survey data as described in the Report. The dimensions, material type, locations, and invert elevations used in the model were based on the as-built drawings. The road elevations and ground elevations were based on the LiDAR data. The instream dimensions and elevations of the existing drainage channel were based on a combination of LiDAR data and available survey data.

Mannings roughness values for each material type was selected using multiple Manning's roughness coefficient tables (ASCE 1982) (Chow 1959). Table 1 below describes the Manning Coefficients used in the model. Entrance loss coefficients were assigned to each flared inlet and were sourced from FishXing 2006 (Table 2).

***Table 1 Manning's roughness coefficient used in model.***

| | Material Type | Manning's n |
|---|---|---|
| Stormwater Lines | HDPE pipe (smooth plastic) | 0.014 |
| Existing Drainage Main Channel | Natural channel (fairly regular section) | 0.05 |
| Existing Drainage Channel Banks | Medium to dense brush | 0.15 |
| Proposed Channel | Natural channel (clean straight) | 0.03 |

*Table 2 Inlet loss coefficients*

| | Inlet Type | Loss Coefficient |
|---|---|---|
| Flared Inlet | Corrugated metal pipe beveled to conform to hill slope | 0.7 |

## 3.3 Model Boundary Conditions

During the complete inundation scenario, the water surface elevation of all flared inlets were set to the corresponding DI grate elevation. During the initial inundation scenario, only flared inlets south of the JCLT property were set to the corresponding DI grate elevation. Table 3 below displays the headwater set at each flared inlet.

*Table 3 Headwater elevation at each flared inlet (complete inundation scenario)*

| Flared Inlet | Attached DI | Headwater Elevation (NAVD 88-ft) |
|---|---|---|
| Inlet #1 | DI #1 | 22.05 |
| Inlet #2 | DI #1 | 22.05 |
| Inlet #2.5 (proposed) | DI #3.5 (proposed) | 22.05 |
| Inlet #3 | DI #2 | 21.70 |
| Inlet #3.5 (Proposed) | DI #3.5 (proposed) | 21.70 |
| Inlet #4 | DI #3 | 21.55 |
| Inlet #5 | DI #4 | 21.29 |
| Inlet #6 | DI #5 | 21.29 |
| Inlet #7 | DI #6 | 21.29 |
| Inlet #8 | DI #7 | 21.29 |
| Inlet #9 | DI #8 | 21.29 |
| Inlet #10 | DI #9 | 21.29 |
| Inlet #11 | DI #10 | 21.75 |

The maximum inlet capacity during inlet-controlled conditions was set using the inlet function in PCSWMM. A rating curve for the flared inlets was developed with the use of a culvert capacity nomograph from the Handbook for Forest and Ranch Roads (Pacific Watershed Associates 1991) using a 24 in. pipe, mitered inlet type, and varying headwater to diameter ratio. This rating curve describes the inlet capacity during inlet-controlled conditions as a function of water depth. The model calculated the flow through each inlet, although the inlet flow was not allowed to exceed the flow set by the rating curve. If it was found that a specific inlet was inlet controlled, the rating curve was used to calculate the inlet flow.

The downstream outfalls on the west side of OAR (where discharge was evaluated) were set to normal depth in the receiving ditch in both scenarios. The plan view of the existing condition PCSWMM model, and the proposed alternatives are displayed in Appendix C.

# 4. Results

Model results are presented and described below for existing conditions and Alternatives #1, #2 and #3.

## 4.1 Existing Condition (Baseline) Results

During the complete inundation scenario, the existing stormwater system conveys approximately 78.4 cfs through the piped system and into the existing drainage channel on the west side of OAR. The capacity of the existing 24 in. stormwater pipe is the limiting factor, i.e. more flow can enter the system than can be conveyed by the 24 in. diameter pipe. Figure 9 below displays the profile view from DI #1 to #10. Figure 10 displays the profile view from the end of the existing drainage channel to DI #1.

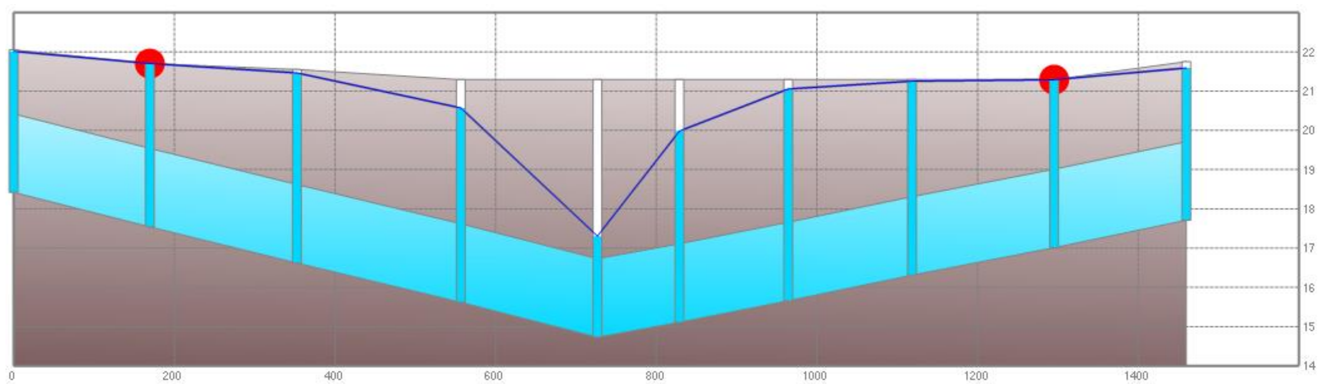



*Figure 9* ***Profile view of existing stormwater system during complete inundation scenario. The profile view runs south to north along the length of OAR. Each vertical line represents a DI. DI #1 is furthest on the left and DI#10 is furthest on the right. Red dots represent locations where flooding occurs, and water exits the DI. Discharge exiting the top of the DI is below 0.0015 CFS. The dark blue line in the figure represents the hydraulic grade line.***

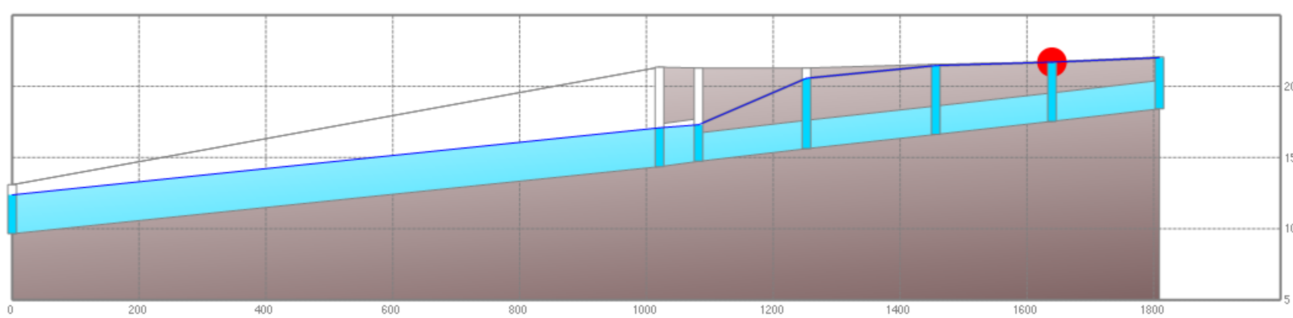



*Figure 10* ***Profile view of existing stormwater system during complete inundation scenario. Profile view from the outlet of the existing drainage ditch to DI #1. Each vertical line represents a DI or junction. DI #1 is furthest on the right. Red dots represent locations where flooding occurs, and water exits the DI. Discharge exiting the DI does not crest over the road.***

During the initial inundation scenario, discharge was only allowed to enter the system at the first two flared inlets connected to DI #1. The existing stormwater infrastructure conveyed 19.1 cfs through the system and discharged out the drainage channel (Figure 11 and 12).

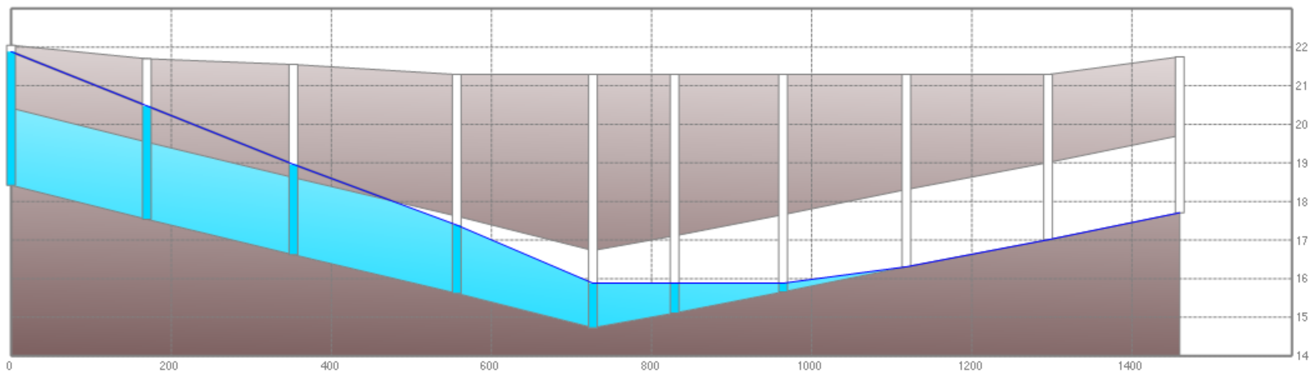



***Figure 11*** ***Profile view of existing stormwater system during Initial inundation scenario. The profile view runs south to north along the length of OAR. Each vertical line represents a DI. DI #1 is furthest on the left and DI#10 is furthest on the right.***

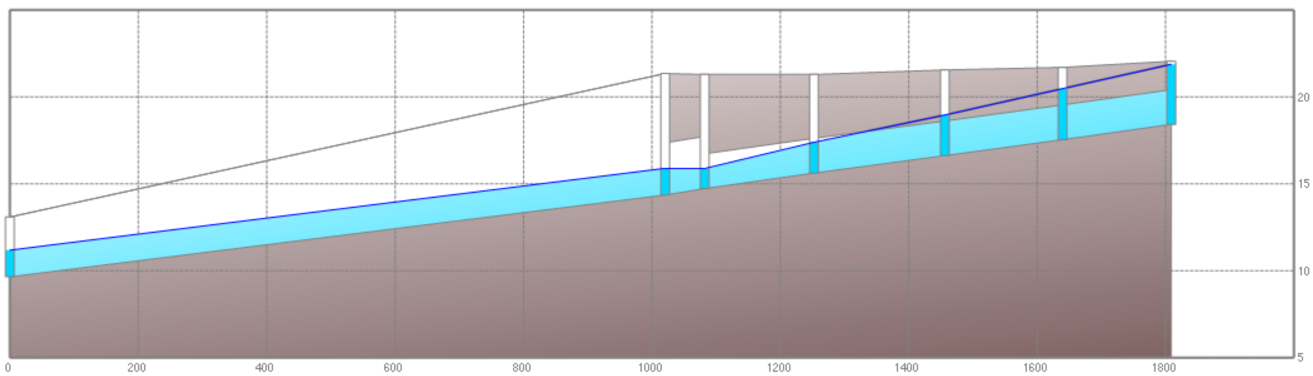



***Figure 12*** ***Profile view of existing stormwater system during Initial inundation scenario. Profile view runs from the outlet of the existing drainage channel DI # 1. Each vertical line represents a DI or junction.***

## 4.2 Alternative #1 Results

During the complete inundation scenario, the model results show approximately 76.9 cfs discharge through the existing drainage channel and 50.4 cfs of discharge through the newly excavated drainage channel, providing a total system discharge of 127.4 cfs. Figure 13 below displays the profile view from DI #1 to DI#10. Figure 14 displays the profile view from the outlet of the newly excavated drainage channel to DI # 1. Figure 15 displays the profile view from the outlet of the newly excavated drainage channel to the new inlet.

The model was used to assess the benefits from upsizing the proposed 24” cross drain that connects the east side to the west side of OAR to a 36” cross drain. The model shows that the 36” cross drain will increase the total conveyance from 127.4 cfs to 139.6 cfs. The 36” cross drain may not be feasible due to underground utilities and the increased discharge through the new drainage channel may be unfavorable on APN 50106112, 50106120, and 50106118. Potholing of existing utilities and supplemental hydraulic modeling using more detailed topographic survey should be conducted as part of final design to confirm system capacity, should this alternative be advanced.

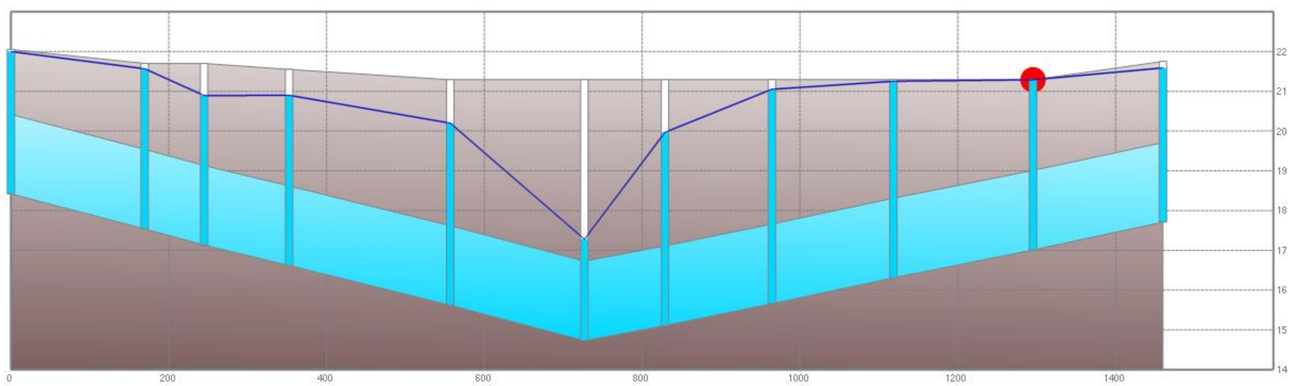


*Figure 13* ***Profile view of Alternative #1 during complete inundation scenario. The profile view runs south to north along the length of OAR. Each vertical line represents a DI. DI #1 is furthest on the left and DI#10 is furthest on the right. Red dots represent locations where flooding occurs, and water exits the DI. Discharge exiting the DI does not crest over the road.***

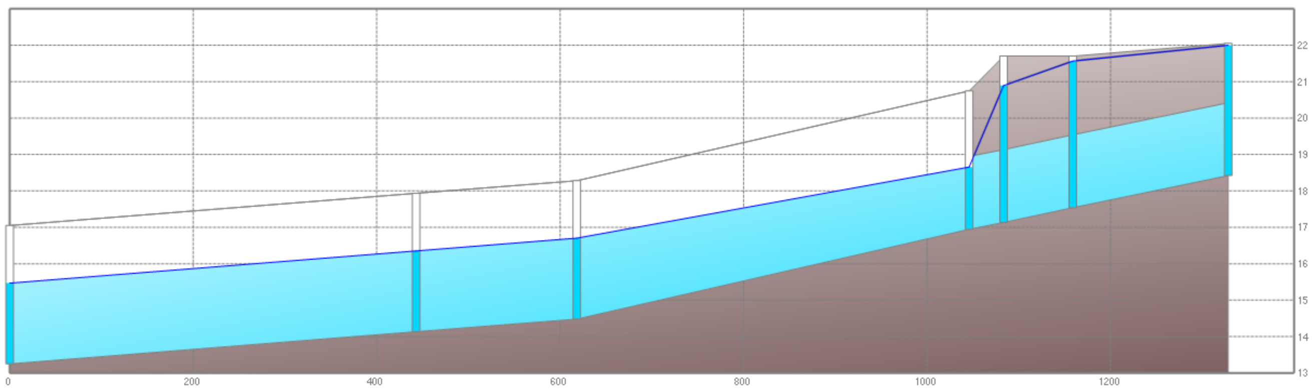


*Figure 14* ***Profile view Alternative #1 during complete inundation scenario. Profile view goes from the newly excavated channel to DI #1. Each vertical line represents a DI or junction. DI #1 is furthest on the right. The grey line over the proposed drainage ditch is not representative of the existing ground elevation.***

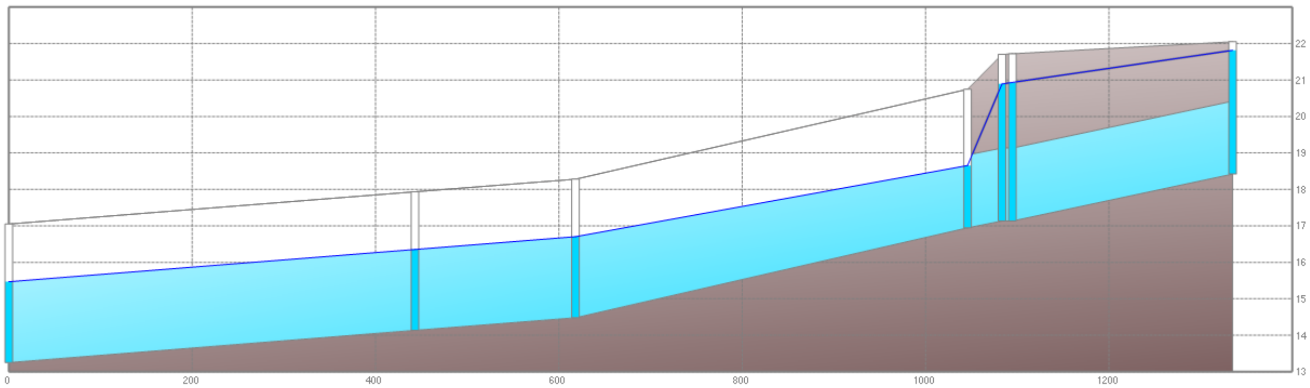



*Figure 15* ***Profile view alternative #1 during complete inundation scenario. Profile view goes from the newly excavated channel to the newly installed inlet. Each vertical line represents a DI or junction. The grey line over the proposed drainage ditch is not representative of the existing ground elevation.***

During the initial inundation scenario, Alternative #1 conveyed approximatly16.0 cfs through the existing drainage channel and 23.9 cfs through the new 24 in. culvert and newly excavated drainage channel for a total of 39.7 cfs through the drainage system. Figure 16 below displays the profile view from DI #1 to DI#10. Figure 17 displays the profile view from the outlet of the newly excavated drainage channel to DI #1. Figure 18 displays the profile view from the outlet of the newly excavated drainage channel to the new inlet.

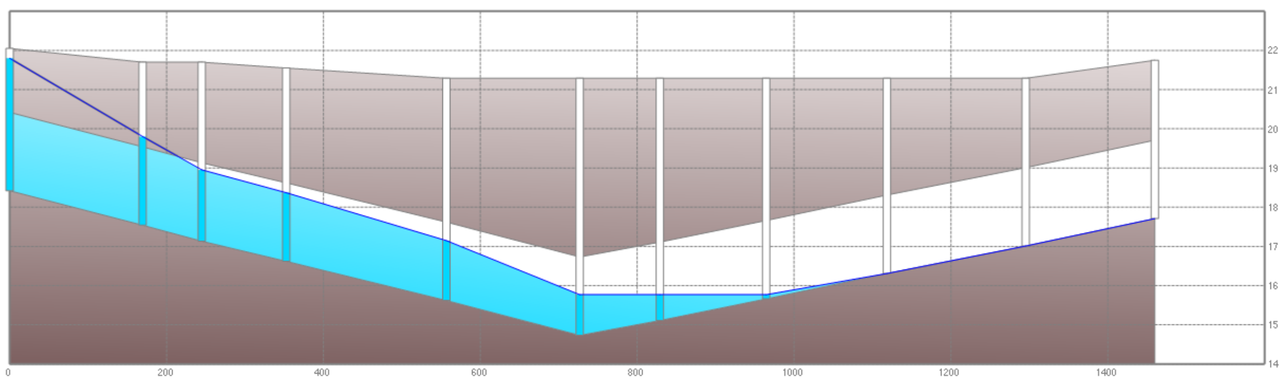



*Figure 16* ***Profile view of Alternative #1 during initial inundation scenario. The profile view runs south to north along the length of OAR. Each vertical line represents a DI. DI#1 is furthest on the left and DI#10 is furthest on the right.***

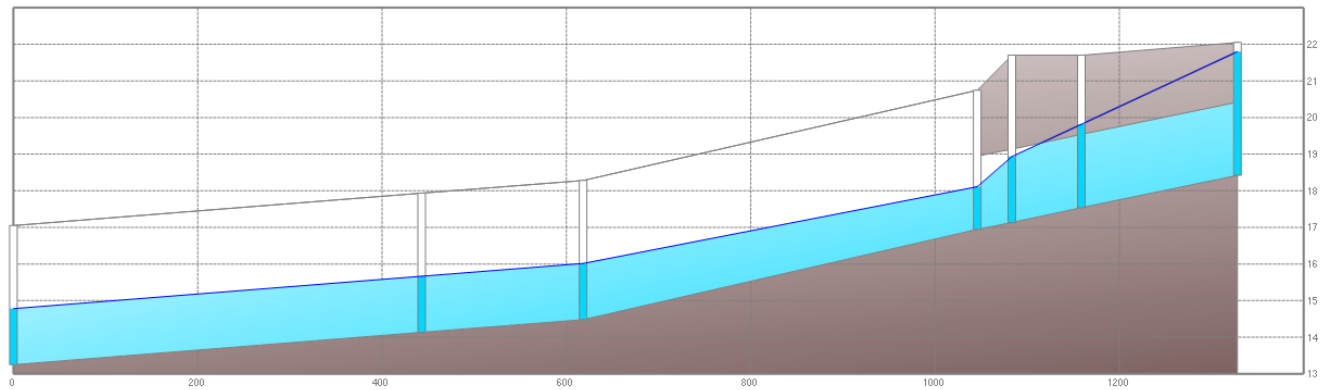



*Figure 17* ***Profile view of Alternative #1 during initial inundation scenario. Profile view goes from the newly excavated channel to DI #1. Each vertical line represents a DI or junction. The grey line over the proposed drainage ditch is not representative of the existing ground elevation.***

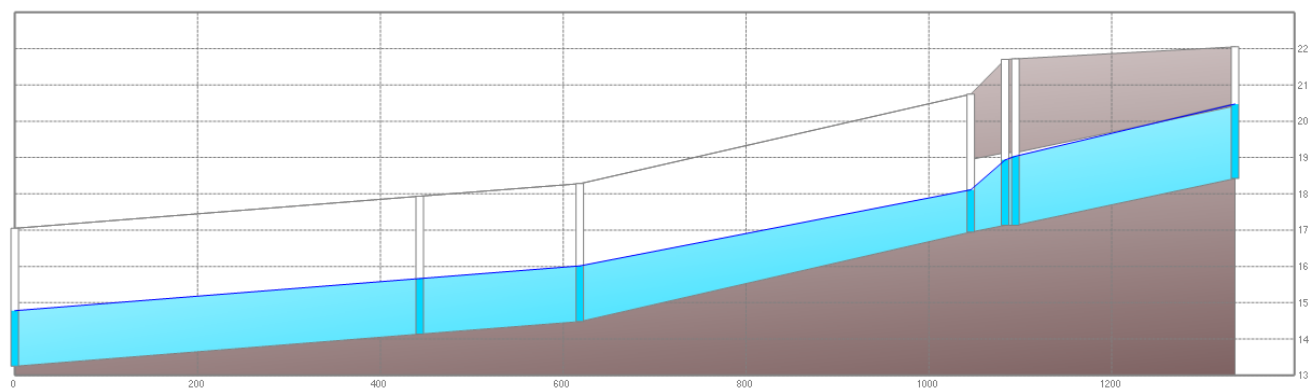



*Figure 18* ***Profile view of Alternative #1 during initial inundation scenario. Profile view goes from the newly excavated channel to new inlet. Each vertical line represents a DI or junction. The grey line over the proposed drainage ditch is not representative of the existing ground elevation.***

## 4.3 Alternative #2 Results

During the complete inundation scenario, Alternative #2 conveys approximately 75.4 cfs of discharge through the existing drainage channel and 44.5 cfs of discharge through the newly excavated drainage channel, leading to a total system discharge of 119.9 cfs. It was found in this simulation that the capacity of the cross drain under the road and the existing 24 in stormwater line connecting DI #1 to the new DI were the main limiting factors, i.e. more flow can enter the system than can be conveyed by the 24 in. diameter pipes Figure 19 below displays the profile view from DI #1 to DI#10. Figure 20 displays the profile view from the outlet of the newly excavated drainage channel to DI # 1.

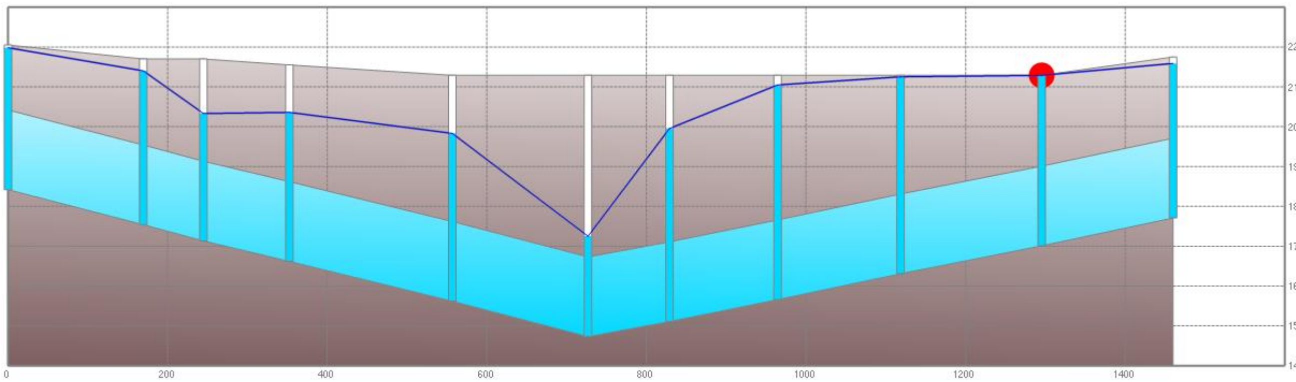


***Figure 19*** ***Profile view of Alternative #2 during complete inundation scenario. The profile view runs south to north along the length of OAR. Each vertical line represents a DI. DI #1 is furthest on the left and DI#10 is furthest on the right. Red dots represent locations where flooding occurs, and water exits the DI. The exiting water does not crest over the road.***

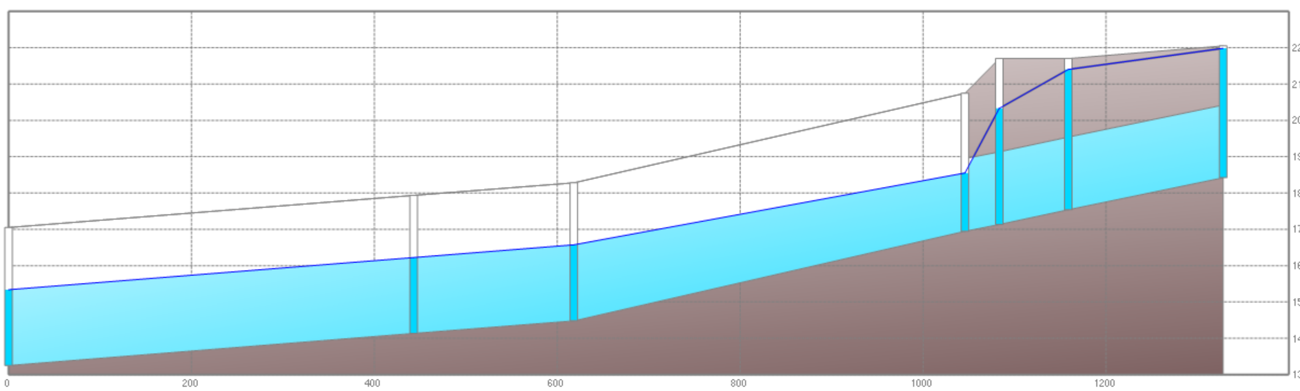


***Figure 20*** ***Profile view Alternative #2 during complete inundation scenario. Profile view goes from the newly excavated channel to DI #1. Each vertical line represents a DI or junction. DI #1 is furthest on the right. The grey line over the proposed drainage ditch is not representative of the existing ground elevation.***

During the initial inundation scenario, Alternative #2 conveyed 11.4 cfs through the existing drainage channel and 12.5 cfs through the newly excavated drainage channel for a total of 23.9 cfs through the drainage system. The stormwater line connecting DI#1 to the new DI was the main limiting factor. Figure 21 below displays the profile view from DI #1 to DI#10. Figure 22 displays the profile view from the outlet of the newly excavated drainage channel to DI # 1.

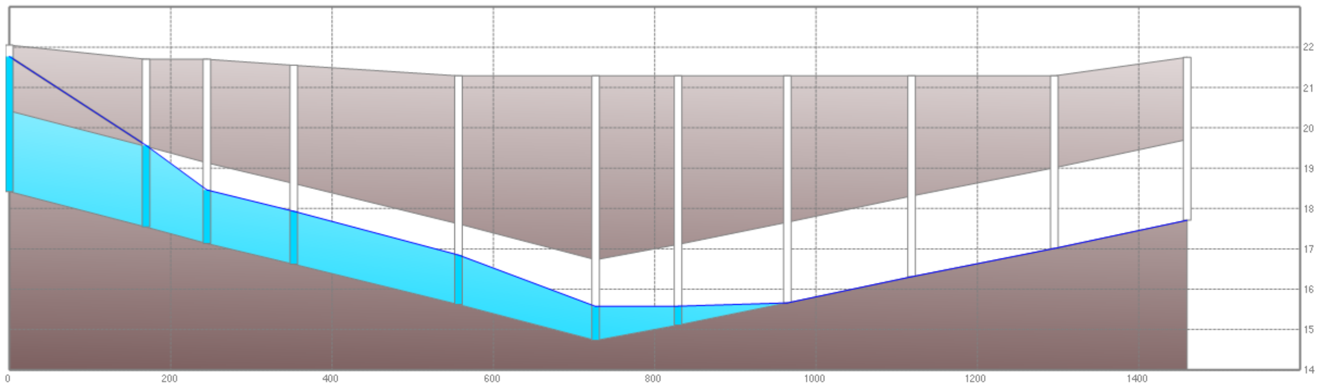



*Figure 21* ***Profile view of alternative #2 during initial inundation scenario. The profile view runs south to north along the length of OAR. Each vertical line represents a DI. DI#1 is furthest on the left and DI#10 is furthest on the right.***

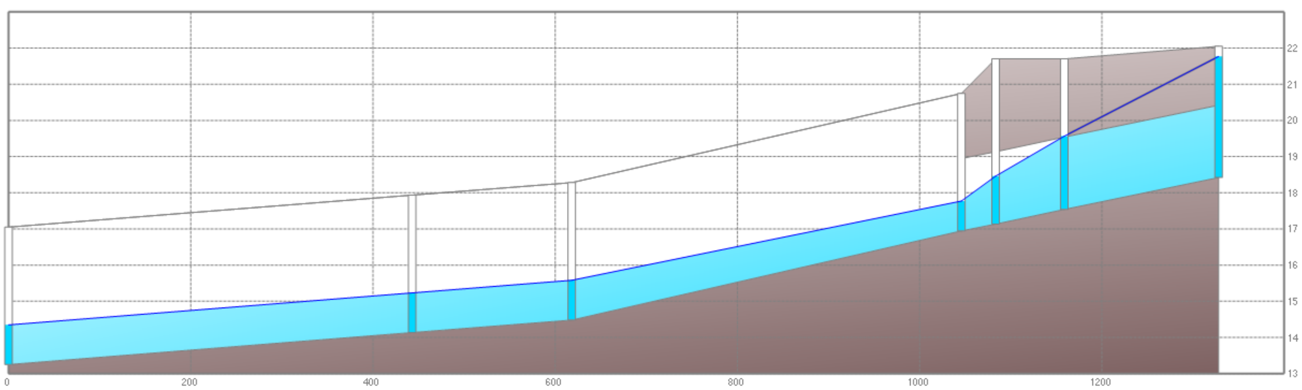



*Figure 22* ***Profile view alternative #2 during initial inundation scenario. Profile view goes from the newly excavated channel to DI #1. Each vertical line represents a DI or junction. The grey line over the proposed drainage ditch is not representative of the existing ground elevation.***

## 4.4 Alternative #3 Results

During the full flood scenario, Alternative #3 conveys 78.3 cfs of discharge through the existing drainage channel and 29.6 cfs of discharge through the newly excavated drainage channel, leading to a total system discharge of 108.0 cfs. Figure 23 below displays the profile view from DI #1 to DI #10. Figure 24 displays the profile view from the outlet of the newly excavated drainage channel to DI # 1.

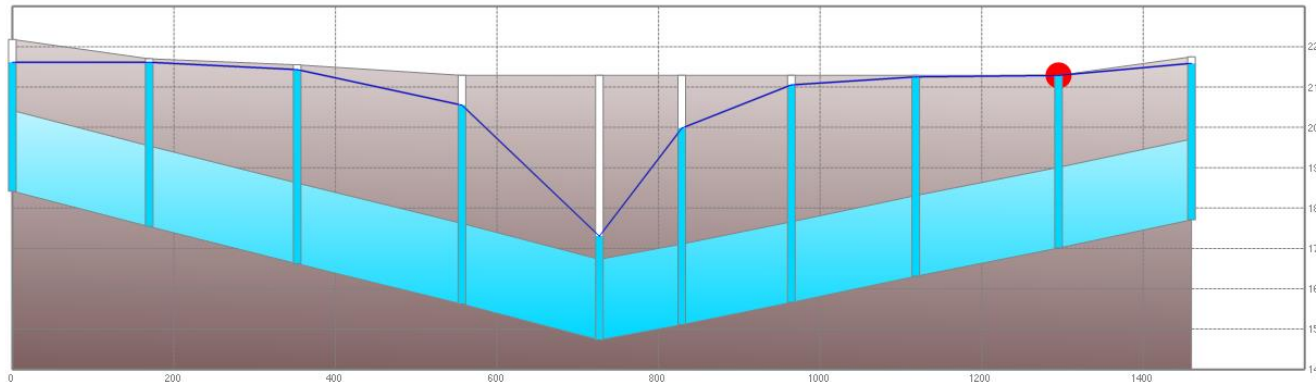



***Figure 23*** ***Profile view of Alternative #3 during complete inundation scenario. The profile view runs south to north along the length of OAR. Each vertical line represents a DI. DI #1 is furthest on the left and DI#10 is furthest on the right. Red dots represent locations where flooding occurs, and water exits the DI. The existing water does not crest over the road.***

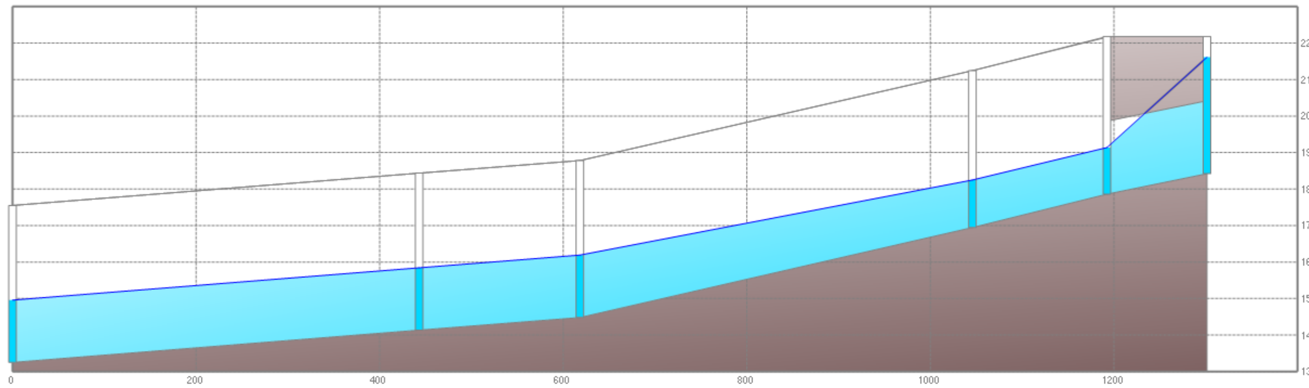



***Figure 24*** ***Profile view Alternative #3 during complete inundation scenario. Profile view goes from the newly excavated channel to DI #1. Each vertical line represents a DI or junction. DI #1 is furthest on the right. The first section on the right is the cross drain that runs under the road. The second section is the new open channel that runs parallel to OAR. Third, fourth and fifth sections are the new drainage channel. The grey line over the proposed drainage ditch is not representative of the existing ground elevation.***

During the initial inundation scenario, Alternative #3 conveyed approximately 17.0 cfs through the existing drainage channel and 24.1 cfs through the newly excavated drainage channel for a total of 41.1 cfs through the drainage system. Figure 25 below displays the profile view from DI #1 to DI #10. Figure 26 displays the profile view from the outlet of the newly excavated drainage channel to DI #1.

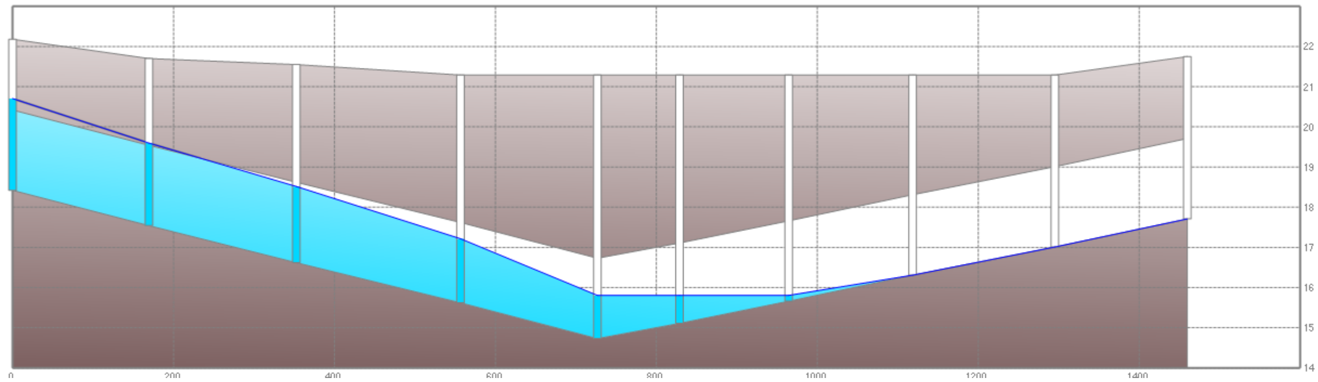


*Figure 25* ***Profile view of Alternative #3 during initial inundation scenario. The profile view runs south to north along the length of OAR. Each vertical line represents a DI. DI#1 is furthest on the left and DI#10 is furthest on the right.***

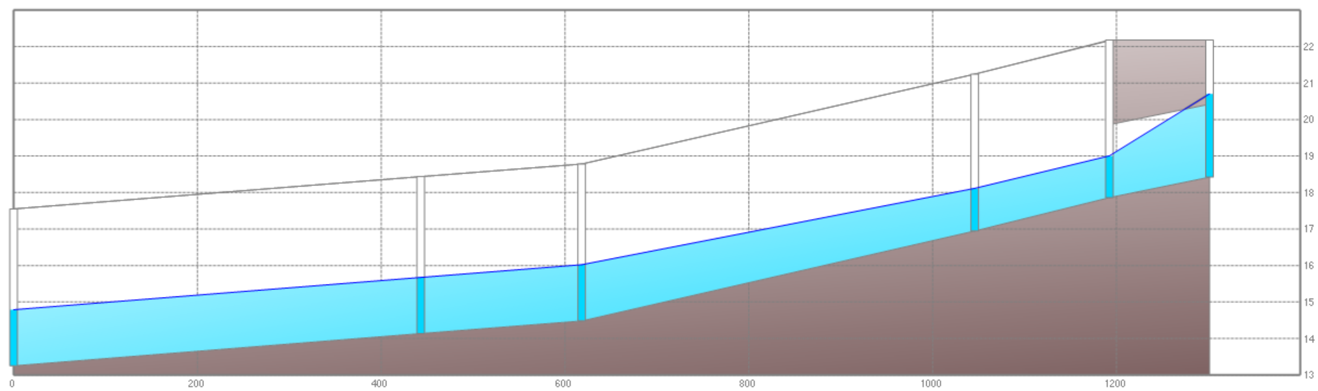


*Figure 26* ***Profile view alternative view #3 during initial inundation scenario. Profile view goes from the newly excavated channel to DI #1. Each vertical line represents a DI or junction. Grey line over the proposed drainage ditch is not representative of the existing ground elevation.***

## 4.5 Results Summary

Each alternative was simulated in PCSWMM and the discharge that exited the stormwater system was calculated during both the complete inundation and the initial inundation scenario. Each alternative was compared to the baseline existing condition model. Alternative 1 was determined to best achieve the design objectives. Alternative 1 will convey a total discharge of approximately 127.4 cfs through the existing and new drainage channels combined during the complete inundation scenario, a 62% increase from baseline; and a total discharge of approximately 39.9 cfs through the existing and new drainage channels combined during the initial inundation scenario, a 109% increase from baseline. Table 4 and Table 5 show the model results of existing and alternative conditions for each hydraulic scenario.

The initial inundation scenario represents overtopping flow from Jacoby Creek first reaching the stormwater system south of the JCLT Kokte Ranch. Local residents have observed flooding first originating in this area. Directing the maximum amount of discharge during this stage is crucial as it will reduce the frequency of OAR flooding. Alternative #1 showed the greatest overall ability of capturing and directing floodwater south of the JCLT Kokte Ranch under the road to the west of OAR. The addition of flared inlet and stormwater pipe allowed floodwater from this location to be captured and directed into the system. Alternative # 2 lacked the additional stormwater pipe and flared inlet relative to Alternative #1, so the capacity of the stormwater pipe upstream of the new DI quickly reached capacity, reducing the effectiveness of the design. Alternative #3 routed discharged from the first inlet across OAR to the new drainage channel. This alternative performed the best in the initial inundation scenario but underperformed in the complete inundation scenario relative to the others. The combination of added capacity with the proposed stormwater pipe and the added flared inlet allowed for Alternative #1 to effectively collect and convey more stormwater discharge relative to the other alternatives.

Based on the two scenarios assessed, the results indicate that the alternatives will not increase the flowrate in the existing drainage channel, however APNs 50106118 and 50106112 will likely experience a net increase in total discharge passing across the respective properties due to the discharge exiting the new drainage channel. The new drainage channel would discharge into an existing drainage ditch downstream of the homes on these properties. The new drainage channel would help convey floodwaters in a more controlled way than under existing conditions, and for portions of flood events the new drainage channel would be expected to reduce the amount of flooding near the homes and adjacent yard areas. Therefore, the changes in drainage patterns could have a net benefit to these properties. The affected landowners should be consulted regarding the acceptability of these anticipated changes in drainage, and their input will be critical in determining whether the project is feasible and community-supported.

***Table 4 PCSWMM model results (complete inundation scenario)***

| Discharge (cfs) | Existing Conditions (Baseline) | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| Existing Channel Outlet | 78.4 | 76.9 | 75.4 | 78.3 |
| New Channel Outlet | NA | 50.4 | 44.5 | 29.6 |
| Total | 78.4 | 127.4 | 119.9 | 108.0 |
| Percent Total Increase | 0% | 62% | 53% | 38% |

***Table 5 PCSWMM model results (initial inundation scenario)***

| Discharge (cfs) | Existing Conditions (Baseline) | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| Existing Channel Outlet | 19.1 | 16.0 | 11.4 | 17.0 |
| New Channel Outlet | NA | 23.9 | 12.5 | 24.1 |
| Total | 19.1 | 39.9 | 23.9 | 41.1 |
| Percent Total Increase | 0% | 109% | 25% | 115% |

As stated in Section 2, the objectives of the design alternatives are to; 1) reduce flood frequency on OAR, 2) avoid increasing flood impacts on adjacent properties, 3) minimize conflicts with existing above and below ground utilities, 4) minimize construction impacts on private property, 5) minimize cost, and 6) be compatible with conceptual alternatives described in the Report. Alternative #1 reduces flood frequency on OAR, and it does not increase the discharge through the existing channel that could otherwise increase flood impacts to adjacent properties. Alternative #2 would likely be the lowest cost relative to the other alternatives, however would provide the least flood reduction benefit during initial inundation relative to the other alternatives. Alternative #3 provides an alternative cross drain location relative to Alternative #1 should utility potholing identify potential conflicts. All three alternatives are compatible with conceptual long-term alternatives as described in the Report. Based on the results above, Alternative #1 was determined to be the apparent best alternative and therefore additional analyses of Alternative 1 were developed and presented below.

## 4.6 Alternative #1: Flood Reduction Benefits to OAR

To better quantify the reduction in flood frequency on OAR, the PCSWMM model results for Alternative #1 were used in conjunction with the 2D HEC-RAS model described in the Report. To assess the flood reduction on OAR, the 2019 flow event on Jacoby Creek, which peaked at 1,595 cfs (slightly greater than the 2-year return period flow of 1,230 cfs), was simulated in the HEC-RAS model. The HEC-RAS model was used to assess the floodplain flow patterns and flowrates over OAR. Neither the existing OAR drainage system nor the proposed drainage system described above was included in the HEC-RAS model, therefore the drainage capacity of the existing drainage system and the proposed drainage system (calculated with PCWMM) were then subtracted from the estimated HEC-RAS OAR roadway discharge. Once the OAR roadway discharge was estimated for both the existing and proposed drainage system, the amount of time OAR was inundated during the 2019 flood event was calculated and compared.

Figure 27 shows the roadway discharge with the existing and the proposed drainage system. The results indicate that during the 2019 flood event, OAR with the existing drainage system was inundated with floodwater for 68.8 hours, and OAR with the proposed Alternative #1 drainage system would be inundated with floodwater for 61.0 hours, a reduction in 7.2 hours or approximately 11% during the 2019 storm event. The shaded blue bands in Figure 27 represent the 7.2 hours flooding on OAR surface is eliminated under proposed Alternative #1 conditions relative to existing conditions. It should be noted that for lower-magnitude flood events, there would likely be a higher percent reduction in flood duration.

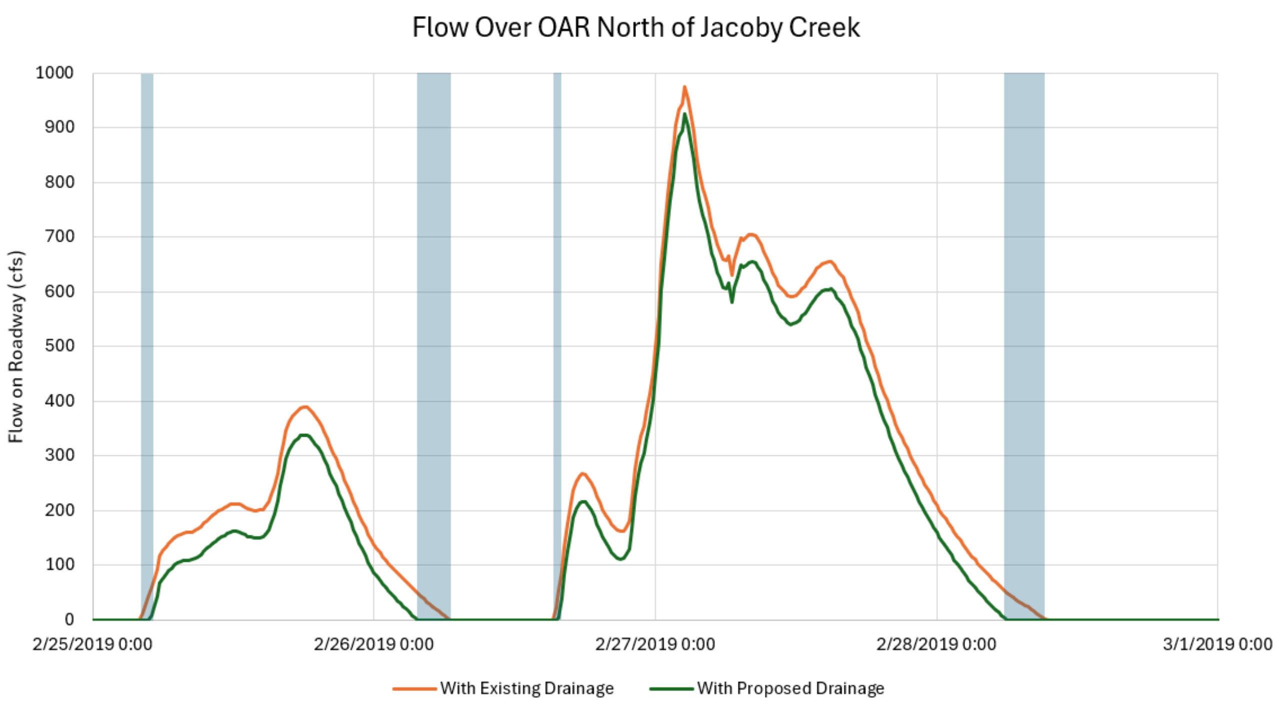



*Figure 27* ***Jacoby Creek floodplain flow at OAR with existing drainage system (orange) and proposed (green) Alternative #1 drainage system improvements during 2019 flood event. Shaded blue bands represent the portion of time flooding on OAR surface is eliminated under proposed Alternative #1 conditions relative to existing conditions.***

## 4.7 Alternative #1: Assessment of Downstream Flood Patterns

The 2D HEC-RAS model of Jacoby Creek was used to assess the potential change in floodplain flow patterns resulting from Alternative #1, and to address design objective #2 (avoid increasing flood impacts on adjacent properties). Figure 28 below displays the floodplain inundation associated with a Jacoby Creek discharge of ~145 cfs. At this discharge flow is not overtopping the banks upstream of OAR. However inundation from out of bank flooding originating from downstream of OAR is present where the proposed Alternative #1 ditch terminates (red circle). The results suggest that the floodplain downstream of OAR becomes inundated with floodwater prior to OAR drainage system collecting and conveying overbank flow.

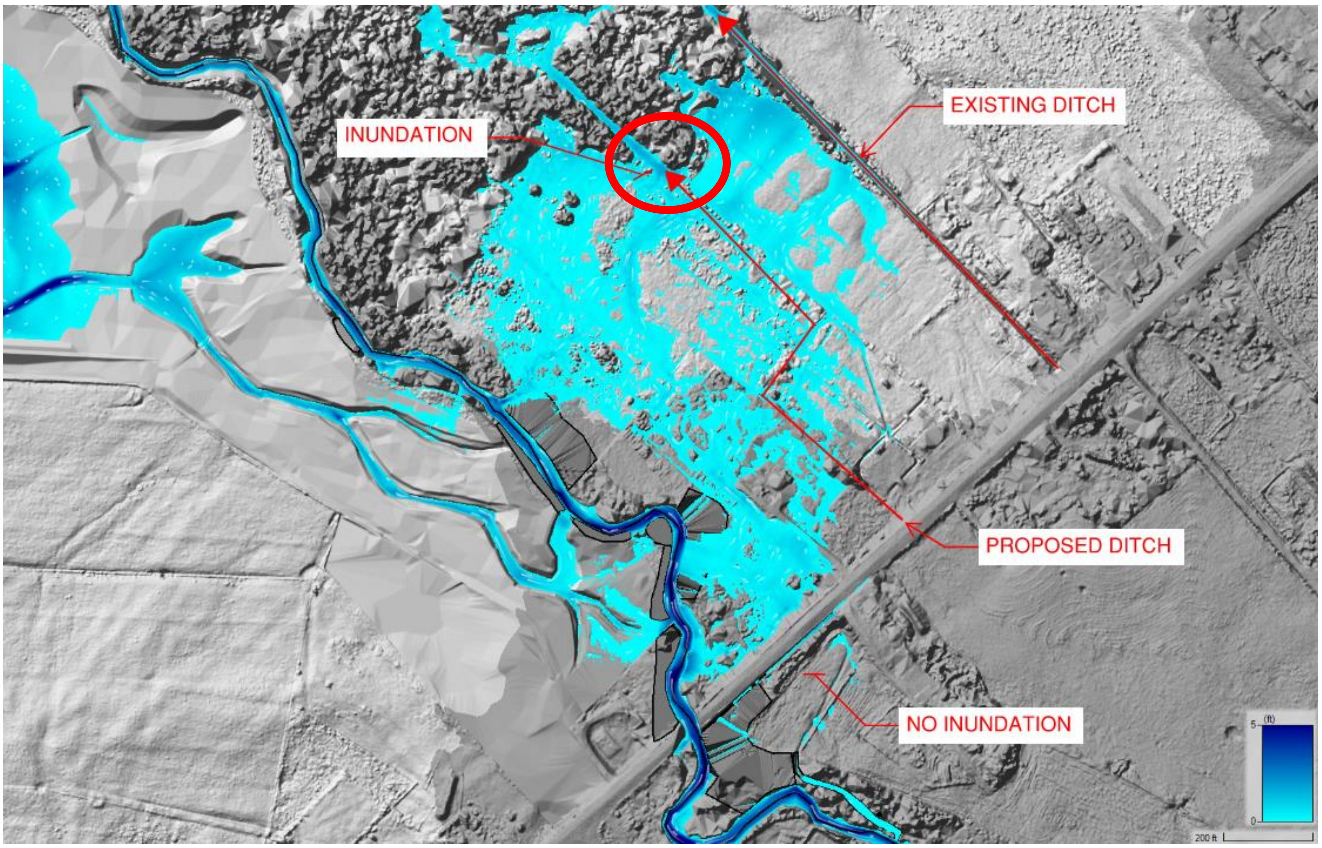



***Figure 28*** ***Inundation map of Jacoby Creek floodplain during a creek discharge of ~145 cfs. Small while lines represent floodwater velocity.***

Figure 29 below displays the floodplain inundation associated with a Jacoby Creek discharge of ~200 cfs with no OAR drainage system. This figure illustrates the floodplain inundation that occurs just prior to OAR overtopping. Similar to Figure 28 above, Figure 29 shows the floodplain in which the proposed drainage ditch will terminate is already inundated (red circle) and the additional flow conveyed in the proposed Alternative #1 OAR drainage system is not anticipated to alter the existing inundation patterns throughout the area circled in red.

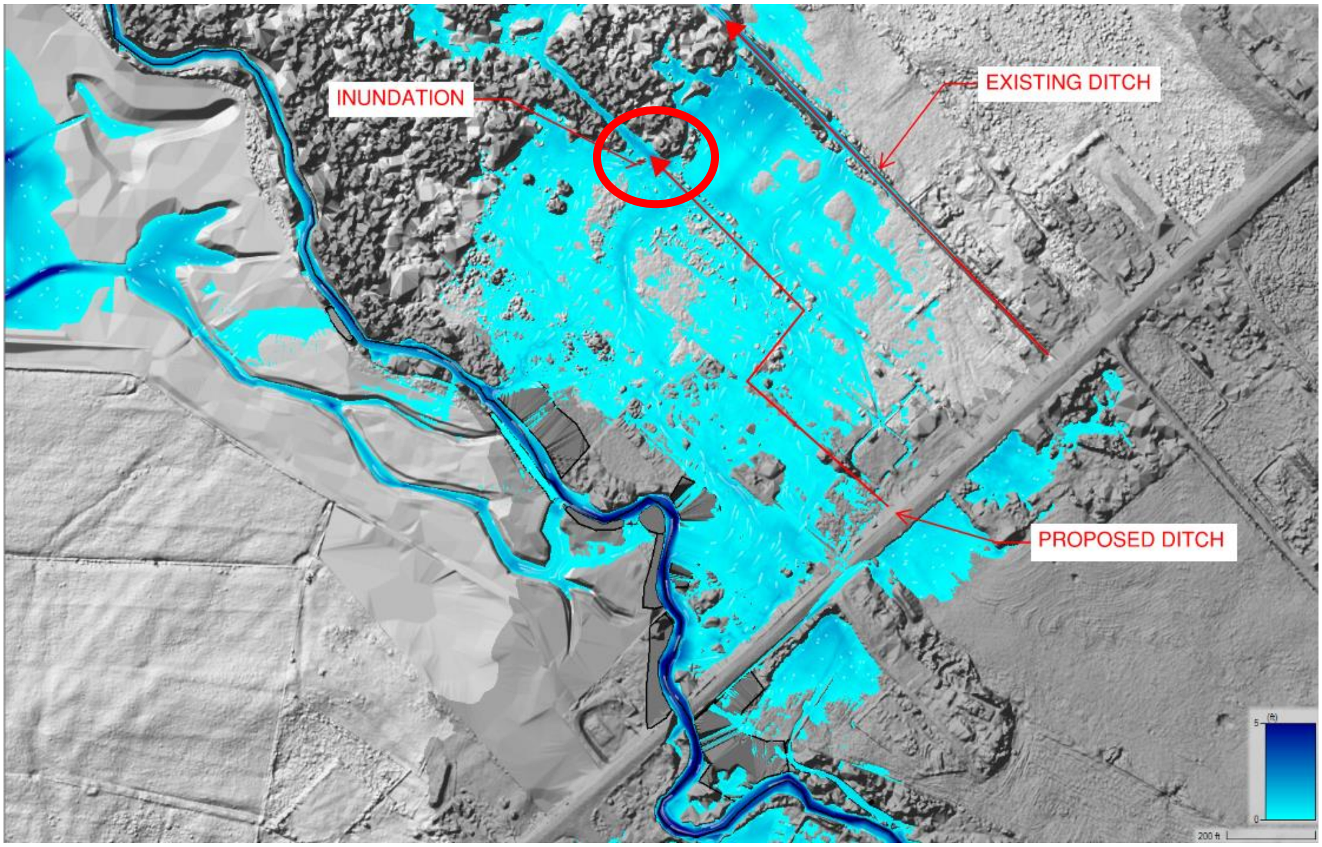



*Figure 29* ***Inundation map of Jacoby Creek floodplain during a creek discharge of ~200 cfs. Small while lines represent floodwater velocity.***

When compared to the existing drainage system, the proposed Alternative #1 drainage system is expected to convey an additional ~50 cfs under OAR before the roadway begins to overtop. HEC-RAS model simulations were performed at varying Jacoby Creek discharges until a 50 cfs roadway discharge was achieved. The floodplain inundation map that corresponds to the 50 cfs roadway discharge was compared to the same inundation map that was edited to visually show the absence of flow over the crest of OAR. Figure 30 and Figure 31 below show the floodplain inundation that corresponds to a 50 cfs roadway discharge with and without an edited roadway image. These inundation maps provide a visual representation of the effectiveness of the proposed Alternative #1 drainage system and the undetectable change in the downstream inundation. It should be noted that neither the existing nor the proposed drainage systems have been simulated in a HEC-RAS model, these figures should only be used as a visual representation and not as definitive modeling results. It should also be noted that the HEC-RAS model was developed using LiDAR data that may have inaccuracies due to vegetation, these elevation inaccuracies may have created errors in the model results and therefore additional survey data may result in different results. However, the preliminary model shows that the floodplain inundation that occurs downstream of OAR before floodplain inundation upstream of OAR.

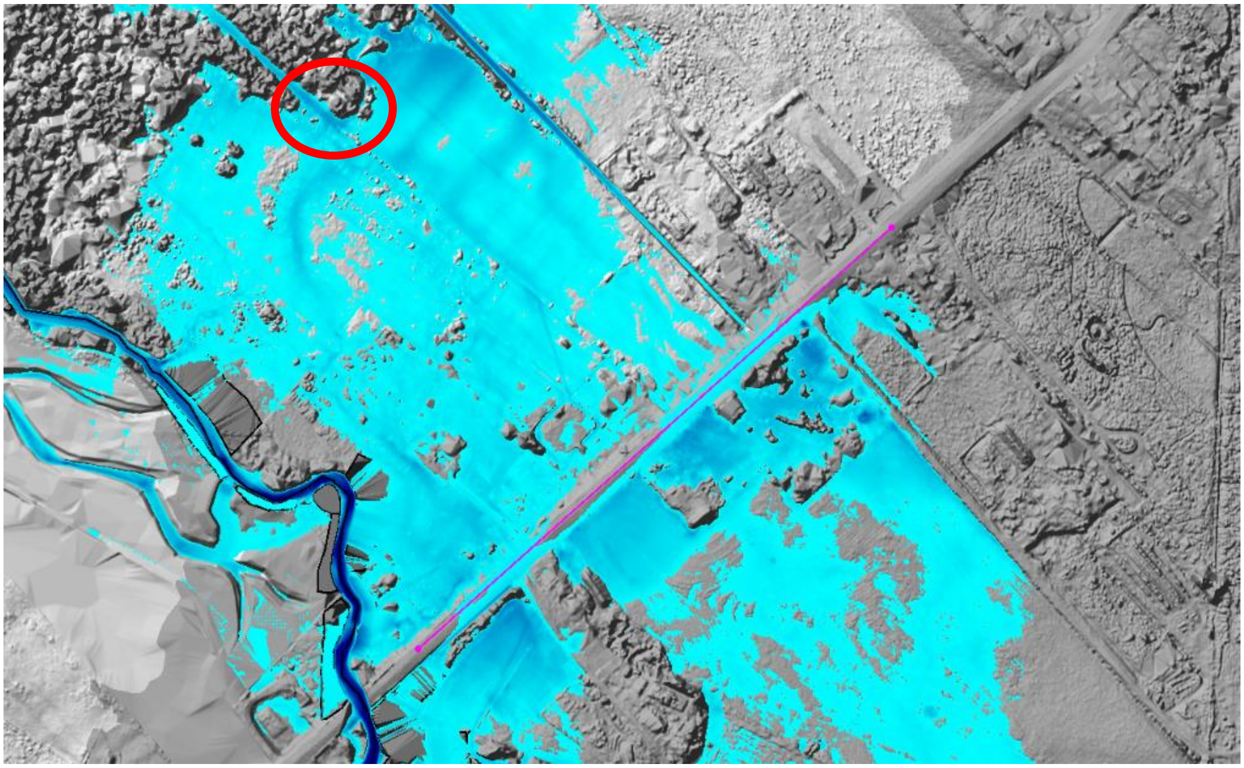


*Figure 30* ***Image of floodplain inundation that corresponds to 50 cfs OAR overtopping flow. Figure represents the inundation with the existing drainage system.***

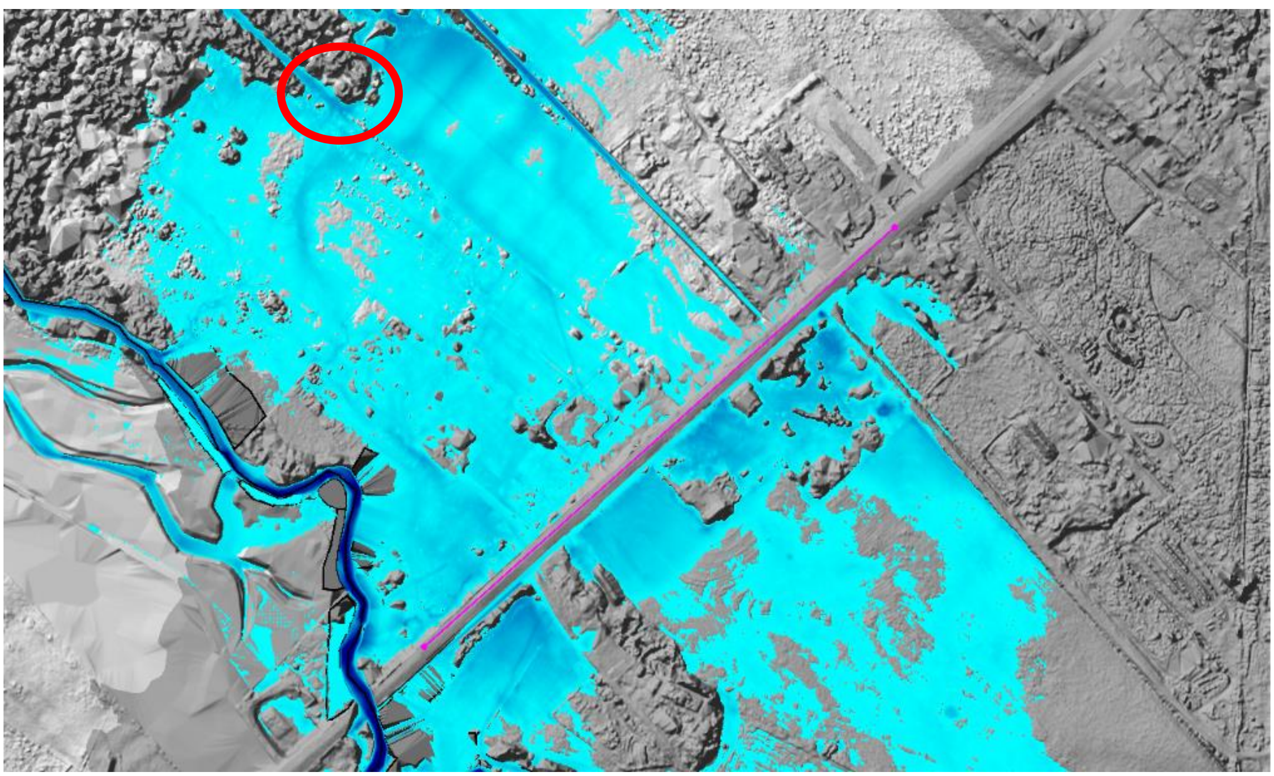


*Figure 31* ***Image of floodplain inundation that corresponds to 50 cfs OAR overtopping flow. Roadway image has been edited to account for the additional 50 cfs conveyance of the proposed drainage system. Figure represents the inundation with the proposed drainage system.***

# 5. Opinion of Probable Construction Cost

An opinion of probable construction cost was developed for Alternative #1 concept design with an estimated 30% contingency to account for unknowns associated with the early stage of this concept design (Table 6). Project construction costs are subject to variations in contractor bidding, labor rates, material costs and availability, permitting conditions, site accessibility, general economic pressures, and other unforeseen costs associated with a project in the current planning level. Given these potential variations, GHD makes no warranty, express or implied, that actual project costs will not vary from the estimated cost. Note that this cost estimate does not include additional technical studies, engineering, environmental review and permitting, or construction management.

*Table 6 Opinion of Probable Construction Cost for Alternative #1*

| Item | Item Description | Qty | Unit | Unit Cost | Total |
|---|---|---|---|---|---|
| 1 | Mobilization/Demobilization | 1 | LS | $ 15,000 | $15,000 |
| 2 | Temporary Traffic Control | 1 | LS | $ 15,000 | $15,000 |
| 3 | Potholing / Locate Utilities | 1 | LS | $ 10,000 | $10,000 |
| 4 | Sediment Control, Water Pollution Control | 1 | LS | $ 15,000 | $15,000 |
| 5 | Construction Staking/Surveying | 1 | LS | $ 15,000 | $15,000 |
| 6 | Clearing, Grubbing and Disposal | 0.40 | ACRE | $ 10,000 | $4,000 |
| 7 | Saw Cutting and Pavement Removal | 1 | LS | $ 5,000 | $5,000 |
| 8 | Drainage Swale Excavation & Disposal | 1,200 | CY | $ 50 | $60,000 |
| 9 | 24" HDPE Storm Drain Pipe | 300 | LF | $ 125 | $38,000 |
| 10 | Cast-in-Place Concrete Headwall | 3.2 | CY | $ 4,000 | $13,000 |
| 11 | 24" Flared Inlet | 1 | EA | $ 1,000 | $1,000 |
| 12 | 30" x 30" Pre-Cast Storm Drain Drop Inlet | 1 | EA | $ 5,000 | $5,000 |
| 13 | 30" x 30" Pre-Cast Junction Box | 1 | EA | $ 5,000 | $5,000 |
| 14 | AC Patch Paving | 1 | LS | $ 10,000 | $10,000 |
| | | | | **Subtotal:** | **$211,000** |
| | | | | **Estimating Contingency @ ~ 30%** | $64,000 |
| | | | | **Total Cost:** | **$275,000** |

# 6. Next Steps

Should the County desire to advance an alternative forward, the following next steps should be considered.

1. Discuss the alternatives with owners of APNs 50106119, 20106120, 50106118, and 501031112.
2. Seek concurrence from parcel owners to obtain necessary Right-of-Way (ROW) / drainage easements for improvements placed outside of County ROW.
3. Conduct topographic survey along extent of selected alternative footprint.

4. Pothole utilities along OAR to determine the location and elevation of underground PG&E gas and water lines.
5. Update hydraulic models with additional topographic survey data.
6. Update hydraulic model to include both the existing and proposed drainage system.
7. Finalize hydraulic design based on above information and develop final construction plans.
8. Obtain necessary permits and approvals.

Should the County be unable to obtain permissions to construct the new drainage channel as described in all alternatives, the County could consider the following improvements:

1. Install parallel stormwater pipe from DI #1 to DI#5
2. Install junction boxes at D1#1 and DI #5 to connect the DIs to the new stormwater pipe.
3. Upsize existing drainage channel to accommodate additional flow as needed.

# 7. References


1. ASCE. 1982. Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60
2. Chow. 1959. Manning's n for Channels
3. County of Humboldt Department of Public Works. 1989. Project Plans for Construction of Old Arcata Road – Phase 2
4. FishXing. 2006. Entrance Loss Coefficients for Pipe or Pipe Arch Culverts
5. GHD, MLA, BBW and TGAEC. 2023. Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study Draft Report (Report).
6. Pacific Watershed Associates. 1994. Handbook for Forest and Ranch Roads