The Hausten Ditch detention basin intake would cross the entire channel and would likely eliminate instream habitat within its footprint. As a result, the Expected Condition and the Worst-Case Condition were modeled with a 100% loss of habitat as a result of the intake construction. The detention basin intake would not affect passage for stream animals and flow impacts would only be at very high flood flows.

Figure 40: Looking downstream toward the Ala Wai Canal from the first pedestrian bridge over Hausten Ditch.

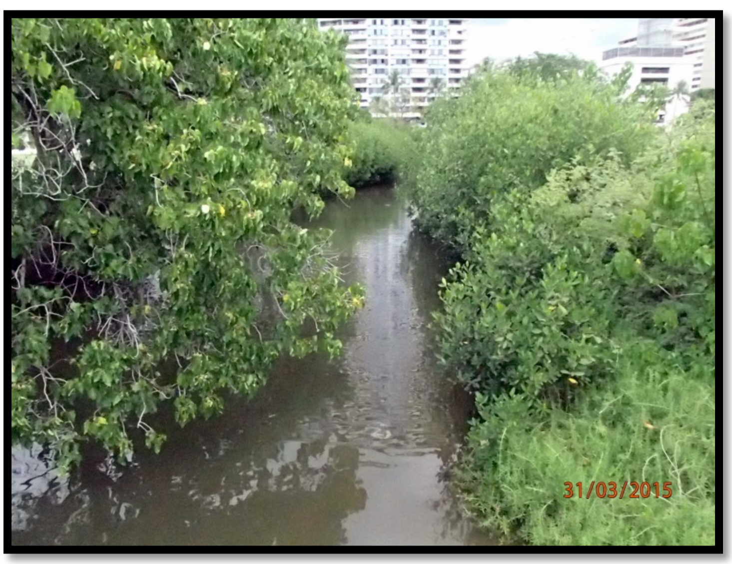


Figure 41: Looking upstream away from the Ala Wai Canal from the first pedestrian bridge over Hausten Ditch. The intake will be on the right bank in this area.

Figure 42: Downstream view from the second pedestrian bridge upstream of the intake site on Hausten Ditch.

Figure 43: The boundary fence for the Marco Polo Apartments on Hausten Ditch.

Figure 44: Looking upstream from Kapiolani Blvd. across from Marco Polo by bus stop.

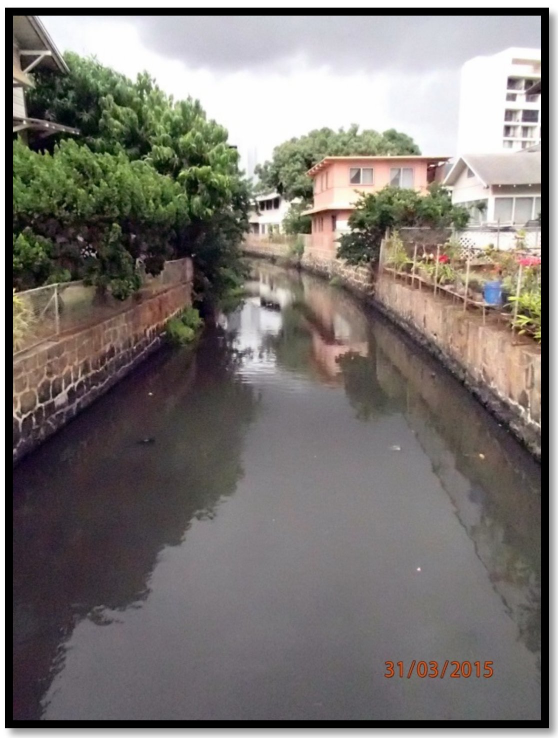


Figure 45: Upstream view from Date St. Bridge into Hausten Ditch.

<u>Mitigation Scenario 1, Manoa Stream: Mitigation of Channelized segment in Manoa Stream</u>

Segment ID: 22 and 23

Area Map:

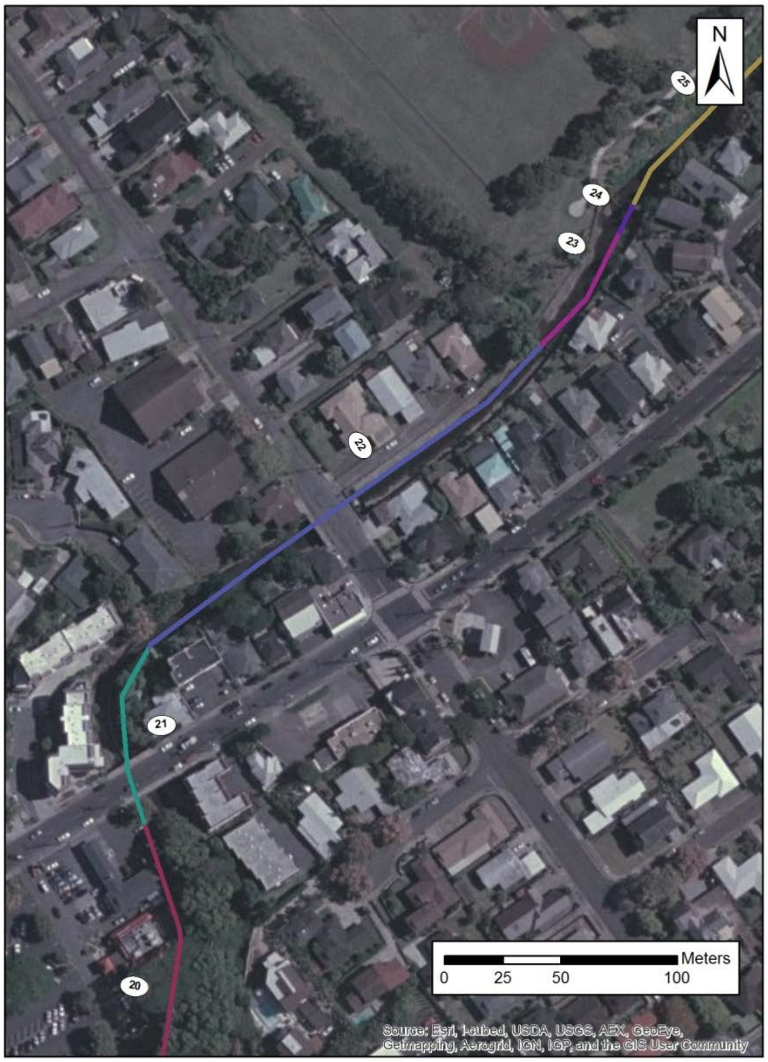


Figure 46: HSHEP segment numbers associated with Channelized section of Manoa Stream.

Mitigation Description: Improvements to the channelized section are intended to accomplish two separate goals. First, the improvements will allow easier passage across the long flat concrete bottom for migratory animals. The improvements will add some roughness and increase water depth to provide holding pools during passage. Second, the habitat pool and low flow channel designs would also provide suitable instream habitat within the channelized section. The plans would place the channel improvements starting above the curve in segment 21 and going upstream to the end of the channelized section. The drop found in the middle of this section is not currently a barrier to native stream species that could reach this location so improvements are not focused on this particular instream feature.

The three instream improvements are:

1. Resting riffles - these are small speedbump-like features that provide shallow pools on the upstream side and concentrate flow on the downstream side. This is intended to allow migratory animals places to rest as they move through the channelized segment. It is not primarily for the improvement of instream habitat with the intent of animals living within the shallow features.
2. Habitat Pools - these are small pools cut into the existing bottom of the channel. These would be deep enough to provide some instream habitat under all flow conditions. The pools would be disconnected by the otherwise flat channel bottom. They would also improve passage by providing resting pools during migratory events.
3. Low-Flow Channel - the low-flow channel would be cut into the existing bottom of the channel. The low-flow channel would constrain flow to a much narrower channel with rocks embedded in the channel to provide complex flow, a variety of depths, and more natural substrate. This feature would be continuous through the channelized segment. The low-flow channel would provide instream habitat and improve passage.

From a modeling perspective, channelized sections of the stream are a barrier to passage, affecting the availability of habitat in all upstream segments. The longer the channelized section, the more difficult it will be for fish to pass without ending up in unsuitable habitat conditions (for example overly hot water due to its shallow and fully exposed channel shape). For short distances the majority of fish would likely pass, but if distances reach more than a kilometer or two, it is likely to cause some problems for passage. Given the uncertainty in determining the proportion of time in which these features act as barriers to instream movement, two different barrier impact values were considered. The lesser impact was modeled at a barrier to passage 10% of the animals for each 100 m of channelized stream and the greater impact was modeled at a barrier to passage 15% of the animals for each 100 m of channelized stream. These provided a range of impacts to address passage uncertainty at the site.

For improvements to fish habitat, the estimates change in suitable habitat for the two instream habitat improvement is based on the designs of the structures and reflect the area of the new structure with respect to the overall channel dimension. The habitat pools were thought to add approximately 8% more suitable habitat area to the channel than without the features and the low-flow channel would add about 62% more suitable habitat area to the channel. The habitat pools are much smaller features than the continuous low flow channel. Both of these actions are improvements over the flat concrete bottom currently found in the channelized section, but neither option is a return to a natural stream bottom with complex instream habitat, therefore neither option returns 100% of potential habitat.

Figure 47: Channelized segment in Manoa Stream. Low-flow channel would begin just above wall in middle of stream.

Figure 48: Channelized segment of Manoa Stream

Figure 49: Drop in the channelized segment of Manoa Stream.

Figure 50: Above the drop in the Channelized segment of Manoa Stream.

Mitigation Scenario 2, Mitigation of overhanging barriers

Segment ID: multiple segments depending on barriers selected

Area Map:

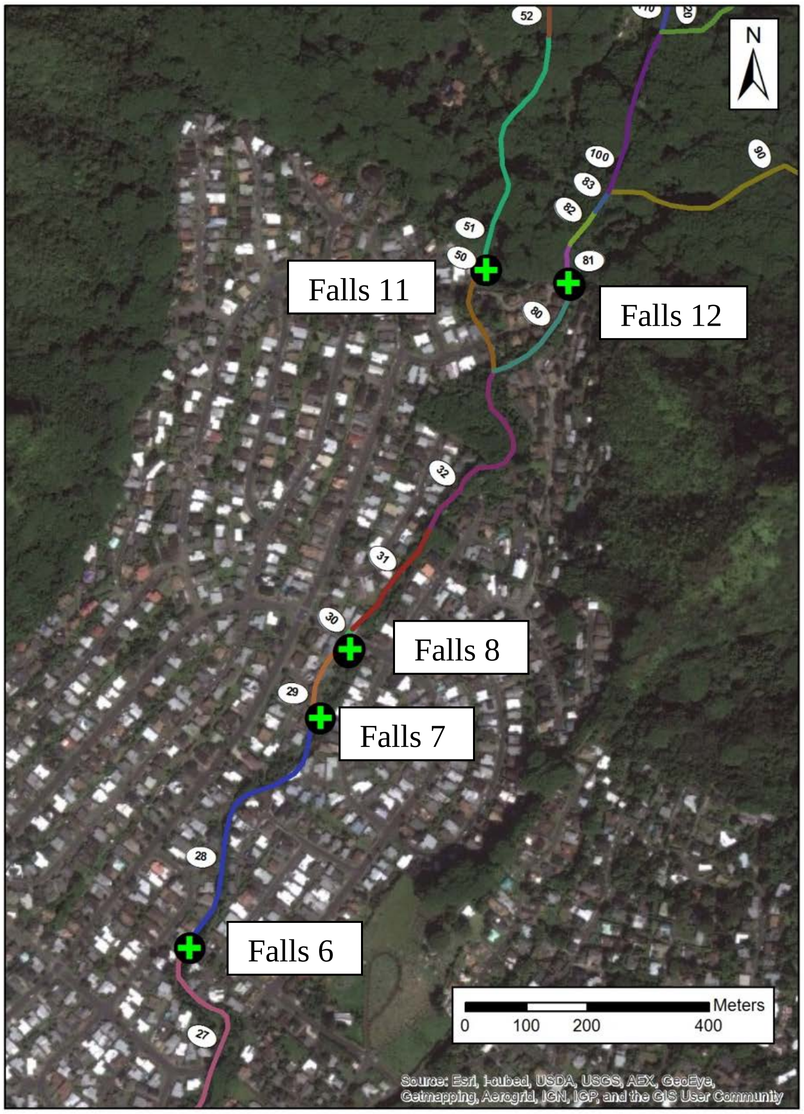


Figure 51: HSHEP segment numbers associated with overhanging falls on Manoa Stream. Falls are represented by the green cross in the black circle.

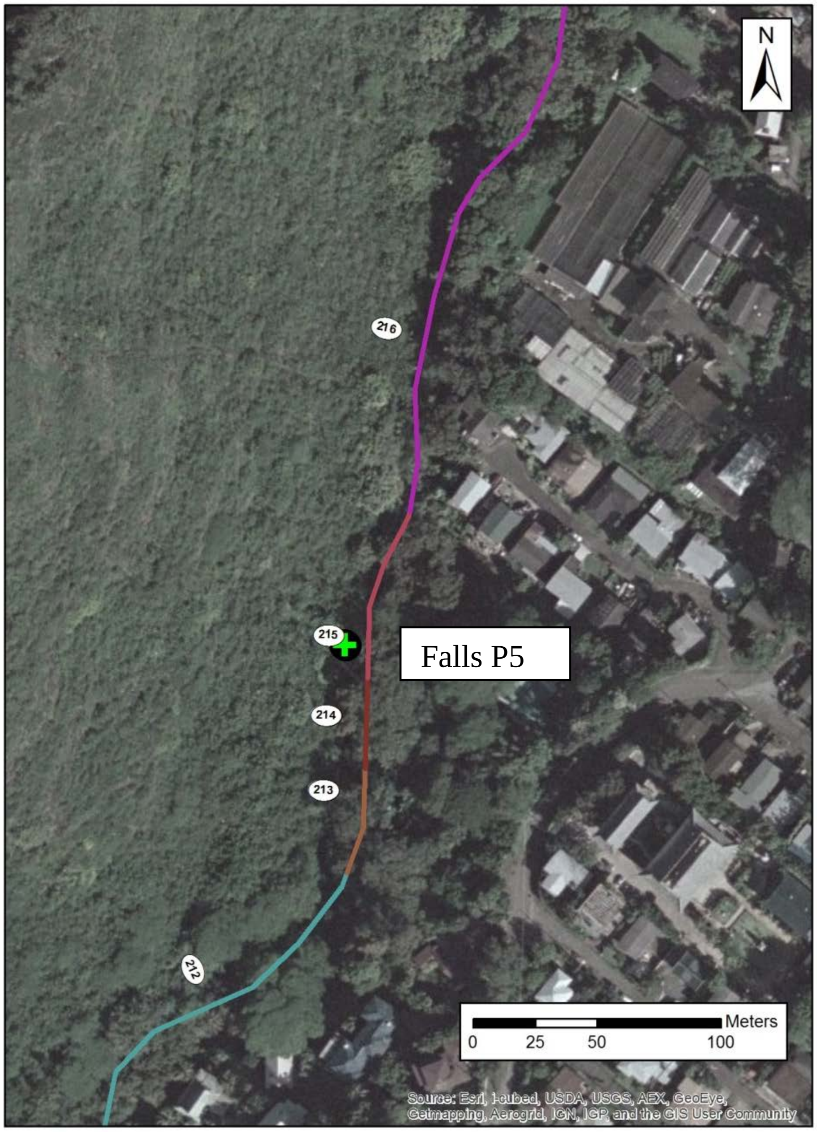


Figure 52: HSHEP segment numbers associated with overhanging falls on Palolo Stream. Falls are represented by the green cross in the black circle.

Mitigation Description: Waterfalls, either natural or man-made, which feature an overhanging lip that does not allow water to flow down the face of the waterfall with continuous contact, have been found to limit the ability of migratory animals to pass. During the surveys in the Ala Wai watershed streams, we observed a number of man-made structures that had the overhanging feature. In most cases, the overhanging feature was the result of erosion and undermining of the structure by the stream flow. These overhanging features were unlikely to be complete barriers to passage as at higher flows they may be completely underwater. At lower flows, migratory stream animals would need to wait below the feature until suitable flows aloud upstream passage. As a result each barrier would increase the time that it would take for an animal to reach suitable upstream habitats and decrease the temporal window in which passage would be available.

The mitigation action proposed to improve the structures would be to fill in the area under the structure with grouted riprap to provide a continuous wetted surface at all discharges to allow fish passage. As a secondary benefit, these improvements would also extend the life of the features and decrease the probability of their failure in the stream.

From a modeling perspective, these barriers to passage affect the suitability of habitat in all upstream segments above the barrier. Additionally, the cumulative effect of multiple barriers can greatly reduce the suitability of upstream habitats by limiting the probability that fish could reach these locations. In the Ala Wai watershed streams, this is a problem because high-quality habitat can be found in the forested upstream reaches and these barriers decrease the availability of these habitats to native stream animals. Given the uncertainty in determining the proportion of time in which these features act as barriers to instream movement, two different barrier impact values were considered. The lesser impact was modeled at a barrier to passage 50% of the time and the greater impact was modeled at a barrier to passage 65% of the time. These provided a range of impacts to address passage uncertainty at the site.

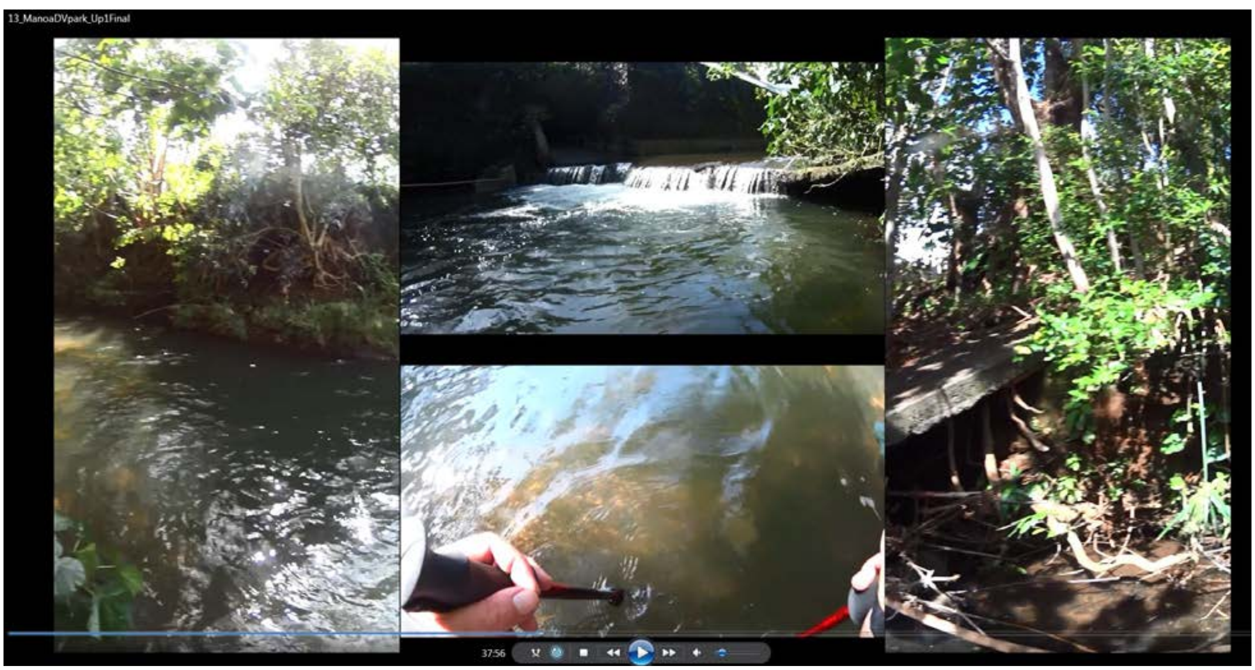


Figure 53: Overhanging barrier on the main channel of Manoa Stream (named as Falls 6).

Figure 54: Overhanging barrier on the main channel of Manoa Stream (named as Falls 7).

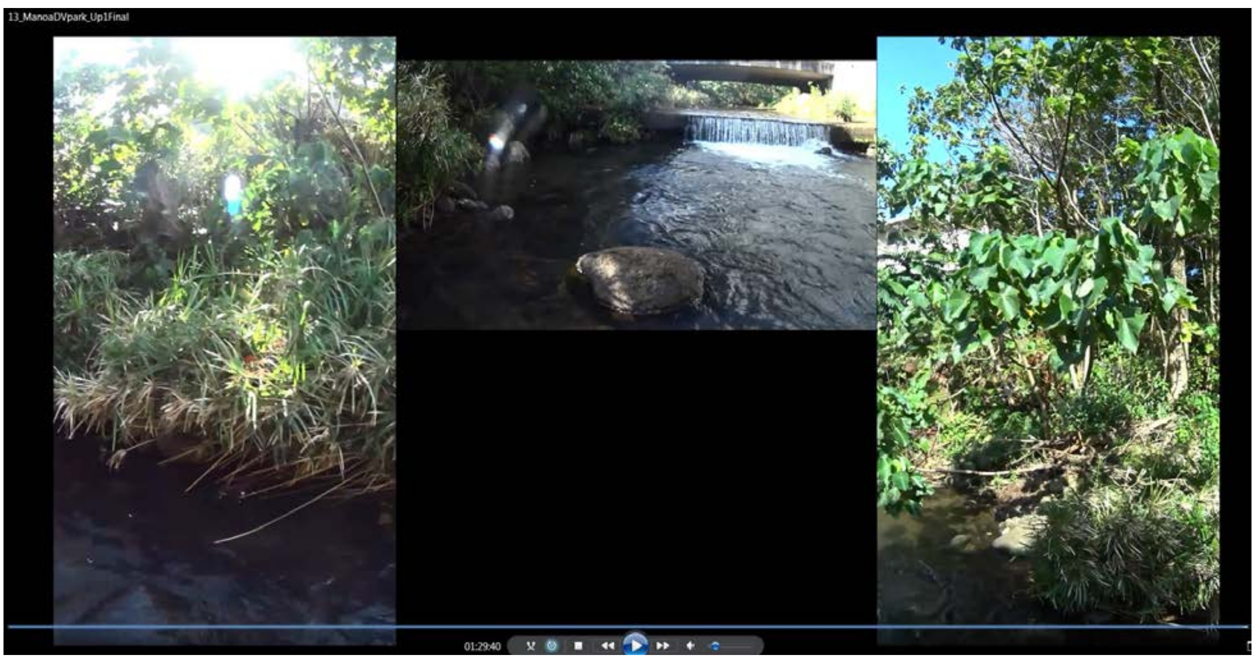


Figure 55: Overhanging barrier on the main channel of Manoa Stream (named as Falls 9).

Figure 56: Overhanging barrier on Manoa Stream tributary Waihi (named as Falls 11). This is a USGS gage that is failing.

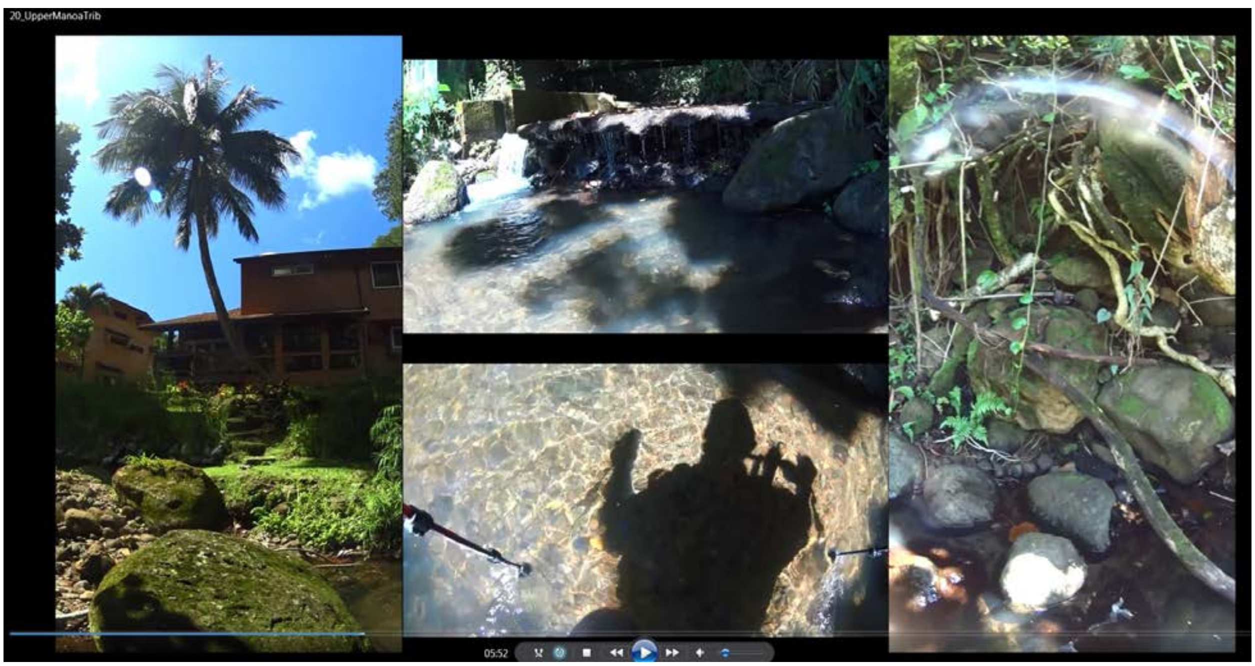


Figure 57: Overhanging barrier on Manoa Stream (named as Falls 12). This is another USGS gage that is being undermined. This is on the Waiakeakua tributary of Manoa Stream just below the Waiakeakua Debris and Detention Basin site.

Figure 58: Overhanging barrier on Palolo Stream tributary Waiomao. (named as Falls P5). This is a USGS gage that is in the footprint of the Waiomao Debris and Detention Basin.

Determination of current instream habitat availability:

Selection of Evaluation Species:

Eight species of native stream animals were selected for the purposes of quantifying habitat availability in Hawaiian streams (Table 2). The list includes five species of fish, two species of crustaceans, and one species of mollusk. This group contains the characteristic amphidromous stream animals found in Hawaiian streams and these animals make up the majority of the native species observed during the DAR point quadrat surveys and have a substantial amount of habitat information available within the DAR Aquatics Surveys Database.

Table 3: Species habitat evaluated within the Hawaiian Streams using the HSHEP model. *Identified as "Species of Greatest Conservation Need" in the Hawaii Statewide Aquatic Wildlife Conservation Strategy.

Organism Type and Family	**Scientific name**	**Hawaiian name**	**Climbing Species**
Freshwater fish (family Gobiidae)	*Awaous guamensis**	ʻOʻopu nākea	Yes
	*Lentipes concolor**	ʻOʻopu alamoʻo	Yes
	*Stenogobius hawaiiensis**	ʻOʻopu naniha	No
	*Sicyopterus stimpsoni**	ʻOʻopu nōpili	Yes
Freshwater fish (family Eleotridae)	*Eleotris sandwicensis**	ʻOʻopu akupa	No
Freshwater shrimp (Crustacean) (family Atyidae)	*Atyoida bisulcata**	ʻŌpae kalaʻ'ole	Yes
Freshwater prawn (Crustacean) (family Palaemonidae)	*Macrobrachium grandimanus**	ʻŌpae ʻoehaʻa	No
Freshwater snail (Mollusk) (family Neritidae)	*Neritina granosa**	Hīhīwai	Yes

Determination of Habitat Availability, Impact, and Mitigation:

Following the HSHEP methods approved by the USACE, the habitat suitability was determined for approximately each meter of the project area and then the average suitability within the segment was applied to each segment. A combination of habitat suitability and the length and width of the segment were used to determine the habitat units (HU) within the segment. The HU were calculated for each species and also the combination of all native species within the segment.

The current (or without project conditions) are based on the observed field conditions within the stream segments. The project impact (or with project conditions) was determined for loss of habitat and potential for restriction of passage for the native species. As discussed earlier, two impact possibilities were considered: (1) the Expect Condition based on best professional judgement (BPJ) of the impact, and (2) Worst-Case Condition with the complete elimination of habitat in the segment. The Expected Condition was based on discussions with state biologists, consulting hydrologic engineers and my professional opinion. We had a number of meetings and phone discussions to determine the extent of impacts and the potential mitigation benefits. The Worst-Case Condition provides an estimate of the upper bounds of the impact to habitat in the project area.

Table 4: Expected Condition results in Habitat Units (m^2) for all species combined associated with the current conditions and with-project conditions in the Ala Wai watershed streams.

	Existing Conditions	With-Project Conditions	With Project Negative	With Project Positive
Manoa Stream	36713	36,522	36,522	0
Palolo Stream	1377	1,484	1,366	118
Makiki Stream	7800	7,777	7,777	0
Hausten Ditch	8681	8,597	8,597	0
Total	**54572**	**54,380**	54,262	118
Overall HU Change		**-192**	-310	118
Net HU Change				

Table 5: Worst-Case Condition results for in Habitat Units (m^2) for all species combined associated with the current conditions and with-project conditions in the Ala Wai watershed streams.

	Existing Conditions	With-Project Conditions	With Project Negative	With Project Positive
Manoa Stream	35,391	34,584	34,584	0
Palolo Stream	834	863	831	32
Makiki Stream	7,495	7,484	7,484	0
Hausten Ditch	8,681	8,261	8,261	0
Total	**52,401**	**51,192**	**51,160**	**32**
Overall HU Change		**-1,210**	**-1,242**	**32**

The mitigation potential was determined for different potential mitigation efforts: (1) the improvement of passage barriers in the upstream reaches, and (2) the installation of a low-flow channel with various levels of instream habitat. Each of these mitigation efforts had different design applications and results are shown for the options below.

Table 6: Expected Condition results for in Habitat Units (m^2) for all species combined associated with the mitigation options in the Ala Wai watershed streams.

	Falls 7	Falls 7 & 8	Falls 7, 8 & 11	Falls 7, 8 & 12	Falls 7, 8, 11, & 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Manoa Stream	37,875	40,392	41,978	42,604	44,190	37,814	37,736	37,729
Palolo Stream	1,484	1,484	1,484	1,484	1,484	1,484	1,484	1,484
Makiki Stream	7,777	7,777	7,777	7,777	7,777	7,777	7,777	7,777
Hausten Ditch	8,597	8,597	8,597	8,597	8,597	8,597	8,597	8,597
Total	**55,733**	**58,250**	**59,836**	**60,462**	**62,048**	**55,672**	**55,594**	**55,587**
Overall HU Change	**1,353**	**3,870**	**5,456**	**6,082**	**7,668**	**1,292**	**1,214**	**1,207**
Net HU Change	**1,161**	**3,678**	**5,264**	**5,891**	**7,477**	**1,100**	**1,022**	**1,016**

Table 7: Worst-Case Condition results for in Habitat Units (m^2) for all species combined associated with the mitigation options for the Ala Wai watershed streams.

	Falls 7	Falls 7 & 8	Falls 7, 8 & 11	Falls 7, 8 & 12	Falls 7, 8, 11, & 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Manoa Stream	35,386	37,401	39,041	39,689	41,329	35,882	35,809	35,803
Palolo Stream	863	863	863	863	863	863	863	863
Makiki Stream	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484
Hausten Ditch	8,261	8,261	8,261	8,261	8,261	8,261	8,261	8,261
Total	**51,994**	**54,009**	**55,649**	**56,297**	**57,937**	**52,490**	**52,417**	**52,411**
Overall HU Change	**803**	**2,817**	**4,457**	**5,105**	**6,745**	**1,299**	**1,225**	**1,219**
Net HU Change	**-407**	**1,607**	**3,248**	**3,895**	**5,536**	**89**	**16**	**9**

It is important to remember that these summary tables provide the results for all of the native amphidromous species combined and are summarized at the stream level. The results of the model are far more specific than this but it is difficult to present very large spreadsheets in document form. The underlying data were collected at approximately 1 m resolution for both streambanks and the stream channel and then was summarized for the segments of concern throughout the watersheds. Next, changes for uncertainty in impact (Expected Condition and Worst-Case Condition), mitigation options, and species-specific distribution and habitat were all calculated. Changes to any one of these variables affects all the other results, and while this is an effective way to view the results in an active spreadsheet, it is difficult to reproduce in printed form.

Conclusion:

The application of the HSHEP model and High Definition Stream Surveys (HDSS) approach to habitat quantification for the assessment of current conditions with project impacts, and mitigation scenarios for the Ala Wai watershed streams in response to the USACE flood risk management project proved very successful. HDSS habitat availability data were collected broadly throughout the streams. This allowed very detailed understanding of where and what type of habitat was present in different stream segments. Prior to the HDSS fieldwork, the presence of over-hanging drops within Manoa and Palolo Streams were unknown. Covering extensive stream reaches also allowed us to see that the upper reaches of all of the streams still have suitable habitat for native amphidromous species and in many locations in the highly developed lower and middle reaches suitable habitat still exists.

The HSHEP model provides a standardized approach to assess both instream distribution and habitat suitability for the native amphidromous stream animals. It was able to address issues of fish passage as well as changes to local instream habitat. For all of the streams in the system, allowing migratory animals a pathway to reach their favorite habitats should allow for more native species to be found in the streams. Local improvement of habitat will also improve instream conditions. In many places, decent habitat existed but few native species were observed at the sites. Instead of native species, numerous introduced species were observed suggesting that habitat and water quality conditions were acceptable to stream fish.

To assess project impacts, the available habitat was multiplied by the percent of habitat likely left after the construction of the project given its design. Some loss of habitat was expected given the design criteria of the various Ala Wai Flood risk management structures. Determining exactly how habitat for native amphidromous species is changed by these construction activities is not always well understood. As a result, we combined our best professional judgment (Expected Condition) with a maximum impact (Worst-Case Condition) to provide a range of possibilities. The effect of the construction activities combined with variability instream conditions, as well as differences in species habitat use, result in a complicated matrix of outputs.

In general, Manoa Stream had the majority of the habitat units for native amphidromous species within the streams of concern. Palolo Stream had small amounts of habitat as a result of the long channelized segments of its downstream reaches. Makiki Stream had habitat for native species in both the upper and lower reaches even though it is a highly developed and impacted stream. We did observe native species in areas the model predicted they would occur although their densities were very low in comparison to introduced animals. Hausten Ditch, somewhat surprisingly, was predicted to have relatively large amounts of native stream animal habitat even though it is also highly developed. The majority of the habitat for the lower reach species was found in the lower end just upstream from the Ala Wai canal.

When viewing the with-project conditions, it is apparent that many of these flood risk management measures will not have a large impact on the overall native species habitat within the streams. The footprint of these measures is relatively small in comparison to the total length streams and the overall impacts to water quality, flow patterns, sediment movement, and fish passage are limited. There are also some positive benefits from the location of the flood risk management measures. In the Waiomao detention basin, a legacy barrier in the form of an old USGS gage will be removed during construction and will improve this passage as a result. The native fish, *Awaous stamineus*, was observed below the USGS gage and improved passage will provide more habitat for this and other native species. The use of the Expected and Worst-Case Conditions allowed a range of potential impacts to be assessed for the flood risk management measures and in both cases we expect an overall loss of habitat as a result of the construction activities.

When viewing the mitigation options, the effect of barriers to upstream movement for native species is clearly of primary concern. The majority of the gains to habitat units as result of the mitigation measures can be attributed to improving the availability of the high quality habitat in the upper ends of the streams to native species. In contrast, the impacts are high in the lower end of the streams as the streams are large and multiple native species use the available habitat. When improving fish passage, it is most beneficial to do so in a downstream-to-upstream order. The native Hawaiian stream animals are migratory and require a pathway from the ocean to instream habitats. In other words, fish and other animals need to surmount the first barrier prior to reaching any others upstream. This pattern is also true when looking at the benefits associated with habitat improvements in the channelized section of Manoa Stream. The majority of the benefits come from the improvement in fish passage and not from the construction of suitable habitat within the channelized section. This does not suggest that improving habitat is not an important goal, but it does suggest that allowing the native species to access currently suitable habitat may result in large increases in habitat units in the streams.

By design, the focus of the HSHEP model was to look at physical habitat remediation efforts (either building habitat or allowing passage primarily) as opposed to management of introduced species or water quality gains with off-channel improvements. In these urban streams, flood runoff and the potential pollutions contained in it may pose a significant threat to native stream animals. While this is surely possible, there are high densities of fish throughout the streams suggesting water quality conditions are at least marginal.

The issue of introduced species is more difficult to address. We observed large numbers of introduced species many of which may be competitive with or predatory on native amphidromous stream animals. Where native species were observed we did see many other introduced species with the exception of smallmouth bass. Throughout much of the best habitat in the middle reaches of Manoa stream smallmouth bass were common and we did not see native fishes at all in these areas. Further surveys by DAR may clarify this relationship but for now it appears that smallmouth bass limit the presence of native stream animals. Limiting the spread of introduced species should be a priority when improving fish passage for native species. The native amphidromous species observed at these upper barriers can all climb near vertical surfaces and thus fixing of these barriers can still include quite steep faces to help prevent the upstream movement of introduced species. With that said we observed introduce species throughout the streams all the way to the upper waterfalls.

When attempting to understand how the potential mitigation options will improve instream conditions over time, both adding habitat and improving fish passage will likely see benefits for years to come. From an accounting perspective the habitat opened by improving fish passage should be available at all times into the future. The actual presence of native species in these habitats may take some time to be realized as new recruits need to make it to the stream and moved to these newly opened habitats. A similar accounting could be done for the improvements to instream habitat within the channelized section. These habitats will be available as soon as they are completed and should be suitable long into the future.

Overall the combination of the HSHEP model and HDSS data collection proved very useful in determining instream habitat and passage barriers in the Ala Wai watershed streams. Improvements to this passage may be very beneficial to increasing populations of native amphidromous stream fish while continued protection of water quality and management of introduced species may also be necessary.

Attachment 4. Results of Mitigation Measure Screening

Ala Wai Canal Project, Screening of Mitigation Measures

Mitigation Measures			Location	Technical feasibility	Successful Application in Hawaii?	Compatibility - Dependency	Flood Damage Reduction	Implementation Cost	Cost-effectiveness	Availability of Land			O&M Requirements (new)	Conflict with Existing O&M Approach	Acceptability – Public Sentiment	Biological Resources		Archaeological/ Historic Structures	Potential for Contaminated Sediment?	Screening Results
				Can the mitigation measure be accomplished or not? Is it constructible?		Is the measure dependent upon another action to be functional? Does it conflict with any other action?	Does measure substantially increase flood risk within watershed?	Rough Order Magnitude (ROM) of construction cost (excluding land cost)	Is the habitat gain worth the cost?	Is there enough space for implementation of the measure? Is there access and room for staging?	Is the land owned by State/C&C (or a few private landowners)?	Can real estate rights be reasonably obtained?	Estimate level of effort for O&M (consider need for changes in practice/ equipment/etc.)	Would the measure conflict or otherwise preclude existing O&M practices?	Will the measure displace people or activities? Will the measure raise significant concerns?	Would the measure adversely affect any known sensitive biological resource?	Would the measure increase the potential for passage of non-native (invasive) species?	Would the measure adversely affect any known archaeological/ historic structures?	Would the measure be located in an area with known (or high potential for) contaminated sediments?	
Remove Existing Passage Barriers	**Manoa**	**Falls 6**	Approximately 0.3 miles above Manoa District Park	Yes; except that passage barrier is expected to be addressed by City & County	Yes, Waihee Stream	**Box culvert to be stabilized by the City & County; assumes fish passage will be addressed as part of this effort**	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	**Eliminate measure, as structure improvements are planned by City & County**
		Falls 7	Approximately 0.6 miles above Manoa District Park	Yes	Yes, Waihee Stream	No, assumes downstream barriers (Falls 6) to be addressed by City & County	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easements	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	Retain measure for further consideration
		Falls 8	Approximately 0.7 miles above Manoa District Park (just below Pawaina St. Bridge)	Yes	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easements	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	Retain measure for further consideration
		Falls 11	USGS gaging station on Waihi Stream	Yes; can either riprap undercutting portion of structure, or remove/replace entire structure	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7 and 8)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, staging and access available via existing BWS road	Privately owned	Yes; assumes real estate rights can be reasonably obtained with easement	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measure supported by USGS	Native damselfly population located upstream; measure not expected to affect this species.	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	Yes, gaging station and dam both eligible as historic property; assume these can be addressed through USACE Sec. 106 process	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would be located above urban area where inputs occur	Retain measure for further consideration
		Falls 12	USGS gaging station on Waiakeakua Stream	Yes; existing structure needs to stay in place (to support bridge), but grouted riprap can be added to eliminate undercutting	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7 and 8)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, staging and access available via existing BWS road	Primarily BWS, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measure supported by USGS	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	Yes, gaging station and dam both eligible as historic property; assume these can be addressed through USACE Sec. 106 process	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would be located above urban area where inputs occur	Retain measure for further consideration
	Palolo	**Falls P5**	USGS gaging station on Waiomao Stream	Yes; except structure to be removed for construction of Waiomao Detention Basin	Yes, Waihee Stream	**Structure is expected to be removed as part of construction for Waiomao Detention Basin**	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, assumes use of staging and access for Waiomao Detention Basin	Single private landowner	Yes; assumes real estate rights will be obtained for detention basin	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measures supported by USGS	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur)	No archaeological/historic structures identified to date	Measure would be located in upper watershed; no known input of contaminants	**Eliminate measure, as structure will be removed as part of construction of the detention basin**
Improve Passage Corridor and/or Habitat in Channelized Reach	**Manoa**	**Install low-flow channel (with embedded habitat pools)**	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; excavate low-flow channel and reinforce channel to maintain structural integrity; add natural substrate	Low-flow channel on Kahaluu Stream; issue with water temperature, capture of fine sediment; low-flow channel needs more depth and complexity	No	Channel modifications could increase roughness, trap debris and/or change sediment transport; but channel would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be relatively high cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
		Excavate habitat pools	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; excavate pool (>18" water depth) and reinforce channel to maintain integrity; add natural substrate	None known	Could be stand-alone measure or combined with resting curbs	Channel modifications could increase roughness, trap debris and/or change sediment transport; but pool would be excavated down so not expected to decrease flood capacity	Med-High	Possibly, may be relatively high cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
		Install resting pockets	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; install low-profile, raised curbs to create small pools (<6" water depth) for resting on existing concrete surface	None known	Could be stand-alone measure or combined with habitat pools	Channel modifications could increase roughness, trap debris and/or change sediment transport; curbs would be low-profile, but could still reduce flood conveyance. To be confirmed based on HEC-RAS model.	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
	Palolo	**Install low-flow channel (with embedded habitat pools)**	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; excavate low-flow channel and reinforce channel to maintain structural integrity; add natural substrate	Low-flow channel on Kahaluu Stream; issue with water temperature, capture of fine sediment; low-flow channel needs more depth and complexity	No	Channel modifications could increase roughness, trap debris and/or change sediment transport; but channel would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**

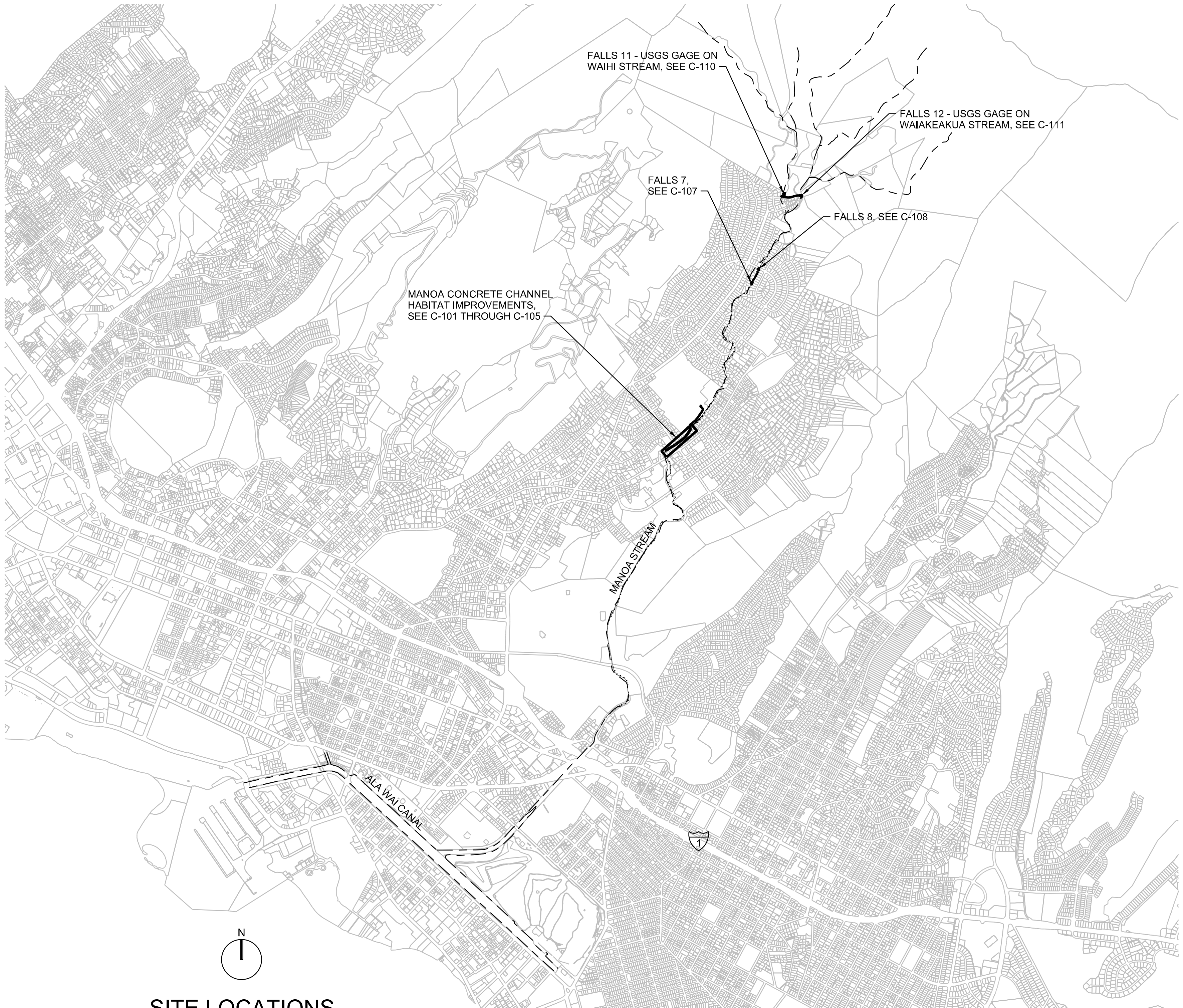
Mitigation Measures			Location	Technical feasibility	Successful Application in Hawaii?	Compatibility - Dependency	Flood Damage Reduction	Implementation Cost	Cost-effectiveness	Availability of Land			O&M Requirements (new)	Conflict with Existing O&M Approach	Acceptability – Public Sentiment	Biological Resources		Archaeological/ Historic Structures	Potential for Contaminated Sediment?	Screening Results
				Can the mitigation measure be accomplished or not? Is it constructible?		Is the measure dependent upon another action to be functional? Does it conflict with any other action?	Does measure substantially increase flood risk within watershed?	Rough Order Magnitude (ROM) of construction cost (excluding land cost)	Is the habitat gain worth the cost?	Is there enough space for implementation of the measure? Is there access and room for staging?	Is the land owned by State/C&C (or a few private landowners)?	Can real estate rights be reasonably obtained?	Estimate level of effort for O&M (consider need for changes in practice/ equipment/etc.)	Would the measure conflict or otherwise preclude existing O&M practices?	Will the measure displace people or activities? Will the measure raise significant concerns?	Would the measure adversely affect any known sensitive biological resource?	Would the measure increase the potential for passage of non-native (invasive) species?	Would the measure adversely affect any known archaeological/ historic structures?	Would the measure be located in an area with known (or high potential for) contaminated sediments?	
		Excavate habitat pools	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; excavate pool (>18" water depth) and reinforce channel to maintain integrity; add natural substrate	None known	Could be stand-alone measure or combined with resting curbs	Channel modifications could increase roughness, trap debris and/or change sediment transport; but pool would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**
		Install resting pockets	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; install low-profile, raised curbs to create small pools (<6" water depth) for resting on existing concrete surface	None known	Could be stand-alone measure or combined with habitat pools	Channel modifications could increase roughness, trap debris and/or change sediment transport; curbs would be low-profile, but could still reduce flood conveyance. To be confirmed based on HEC-RAS model.	Med	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**
	Makiki	**Add passage/ habitat improvements**	Extending through most of urbanized Makiki (including 0.75-mile of underground channel)	**Channel modifications to improve passage/habitat are not feasible in underground section of stream**	None known	No	Channel modifications could increase roughness, trap debris and/or change sediment transport	**Extremely high**	**No; channel improvements in above-ground section would not provide much benefit without improvements to underground section; improvements to underground section would be extremely expensive relative to habitat gain**	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Patchwork of public and private land	Unknown; specific requirements not investigated as measure was eliminated	Low; possibly some sediment/debris removal	Unknown; not investigated as measure was eliminated	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Makiki Stream	Makiki Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Makiki Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure as improvements would be needed to underground section, which would be extremely expensive relative to habitat gain**
Bank Stabilization	**Manoa**	**Stabilize Eroding Banks**	Above Kahaloa Bridge (Manoa Gardens Retirement Community)	Yes	Yes, successful bank replanting downstream of Kahaloa Bridge (but previous bank condition unknown)	No	No; assume little to no effect on channel capacity	**High**	**No; channel bank improvements would be extremely expensive, with only very minimal improvements to aquatic species habitat**	Yes, staging and access available via Manoa District Park	City & County land (but they are considering selling property)	Yes; assumes real estate rights can be reasonably obtained with ROE (or quit-claim deed to State if C&C sells property)	Low; temporary vegetation maintenance during plant establishment	Not expected	Could affect use of property (views; pedestrian walkway)	No sensitive biological resources identified to date	No; assumes measure would not substantially affect species passage	None identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would primarily involve the stream bank, with minimal movement of streambed sediments	**Eliminate measure as improvements would be extremely expensive relative to very minimal habitat gain**
Other	**Palolo**	**Waiomao Excavation Area**	Adjacent to residences on Waiomao Road	Yes; assumes channel form and substrate would be replaced within area excavated for detention basin	None known	**Dependent on Waiomao Detention Basin; construction of detention basin will include replacement of channel form and substrate**	Assumes these factors were considered in modeling for detention basin; not further addressed for mitigation as measure was eliminated	Med	Possibly	Yes, assumes use of staging and access for Waiomao Detention Basin	Single private landowner	Yes; assumes real estate rights will be addressed as part of detention basin	Low; assumes debris removal and already being conducted for detention basin	No	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	No; assumes measure would not substantially affect species passage	USGS gaging station may be within excavation area, but assumes it will be removed as part of project construction	Measure would be located in upper watershed; no known input of contaminants	**Eliminate measure, as channel form and substrate will be replaced as part of detention basin measure (therefore, minimal habitat improvements available for mitigation)**

Attachment 5. Conceptual Designs for Potential Mitigation Measures

ALA WAI CANAL PROJECT

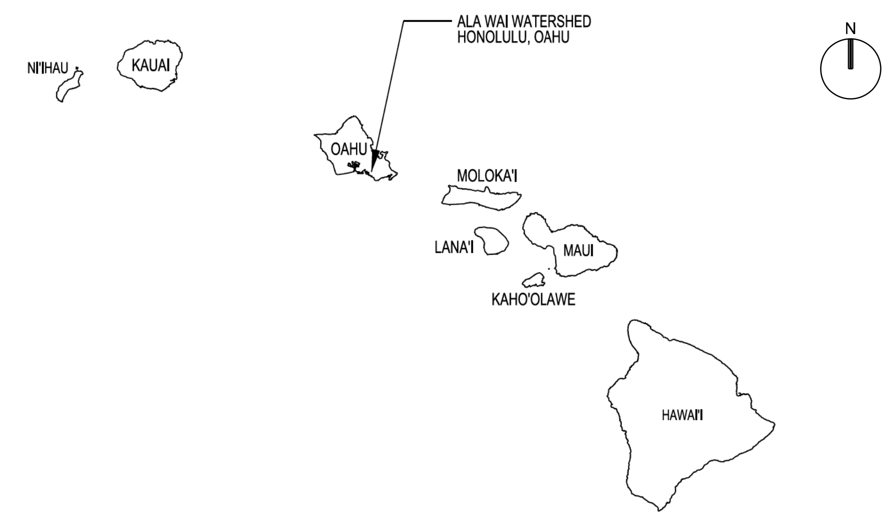
MITIGATION MEASURES
HONOLULU, OAHU, HI

PROJECT TITLE

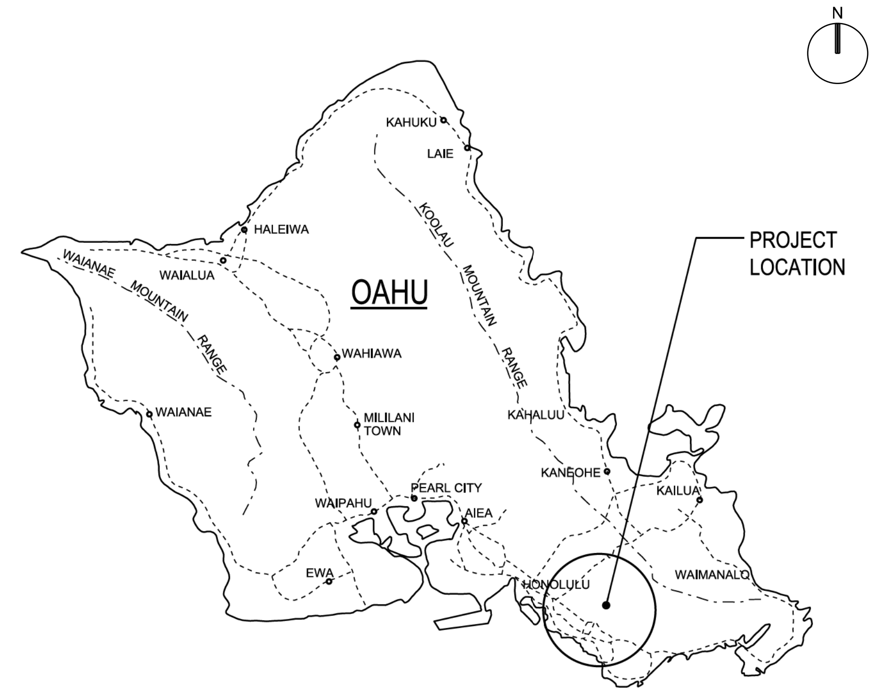


SITE LOCATIONS

NOT TO SCALE



VICINITY MAP — NOT TO SCALE



PROJECT LOCATION — NOT TO SCALE

INDEX OF DRAWINGS

DWG	TITLE
G-001	SITE LOCATIONS, PROJECT LOCATION, VICINITY MAP, AND DRAWING INDEX
G-002	CIVIL GENERAL NOTES AND LEGEND
C-001	MANOA CONCRETE CHANNEL EXISTING CONDITIONS
C-101	MANOA CONCRETE CHANNEL ACCESS AND STAGING PLAN
C-102	MANOA CONCRETE CHANNEL LOW FLOW CHANNEL CONCEPT PLAN AND PROFILE
C-103	MANOA CONCRETE CHANNEL HABITAT POOL CONCEPT PLAN AND PROFILE
C-104	MANOA CONCRETE CHANNEL RESTING RIFFLE CONCEPT PLAN AND PROFILE
C-105	MANOA CONCRETE CHANNEL TYPICAL SECTIONS
C-106	MANOA STREAM FALLS 7 AND 8 ACCESS AND STAGING PLAN
C-107	MANOA STREAM FALLS 7 REHABILITATION CONCEPT
C-108	MANOA STREAM FALLS 8 REHABILITATION CONCEPT
C-109	MANOA STREAM FALLS 11 AND 12 ACCESS AND STAGING PLAN
C-110	MANOA STREAM FALLS 11 REHABILITATION CONCEPT
C-111	MANOA STREAM FALLS 12 REHABILITATION CONCEPT

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HONOLULU, HAWAII

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HONOLULU, HI 96813

DESIGNED BY: L HAYS		DATE: 5/XX/2015	REVISION:
DRAWN BY: T STIMPSON	CHECKED BY: J YOUNG	SOLICIT./ CONTRACT NO.: 481684	
SUBMITTED BY: J YOUNG		LOCATION CODE	
PLOT SCALE: AS NOTED	PLOT DATE: 2015\05\12	DRAWING NUMBER:	
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ALA WAI CANAL PROJECT

MITIGATION MEASURES

SITE LOCATIONS, PROJECT LOCATIONS, VICINITY MAP, AND DRAWING INDEX

SHEET IDENTIFICATION

G-001

GENERAL SITE NOTES:

1. SOURCE OF TOPOGRAPHY SHOWN ON THE CIVIL PLANS ARE BASE MAPS PROVIDED BY THE US ARMY CORP OF ENGINEERS HONOLULU DISTRICT. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN ON THESE PLANS. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS AND ADJUST WORK PLAN ACCORDINGLY PRIOR TO BEGINNING CONSTRUCTION.
2. EXISTING TOPOGRAPHY, STRUCTURES, AND SITE FEATURES ARE SHOWN SCREENED AND/OR LIGHT-LINED. NEW FINISH GRADE, STRUCTURES, AND SITE FEATURES ARE SHOWN HEAVY-LINED.

   HORIZONTAL DATUM: NAD 1983, HAWAII STATE PLANE ZONE 3, US SURVEY FEET
   VERTICAL DATUM: NAVD 1988, US SURVEY FEET
3. MAINTAIN, RELOCATE, OR REPLACE EXISTING SURVEY MONUMENTS, CONTROL POINTS, AND STAKES WHICH ARE DISTURBED OR DESTROYED. PERFORM THE WORK TO PRODUCE THE SAME LEVEL OF ACCURACY AS THE ORIGINAL MONUMENT(S) IN A TIMELY MANNER, AND AT THE CONTRACTOR'S EXPENSE.
4. STAGING AREA SHALL BE FOR CONTRACTOR'S EMPLOYEE OVERFLOW PARKING AND ON-SITE STORAGE OF MATERIALS.
5. PROVIDE FENCING AS NECESSARY TO MAINTAIN SECURITY AT ALL TIMES.
6. CONTRACTOR SHALL SUBMIT A COMPLETE SOIL EROSION CONTROL PLAN FOR REGULATORY APPROVAL. CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING AND MAINTAINING EROSION CONTROL DEVICES DURING CONSTRUCTION. CONTRACTOR SHALL TAKE ALL OTHER MEASURES TO POSITIVELY PRECLUDE EROSION MATERIALS FROM LEAVING THE SITE.
7. CONTRACTOR SHALL PREPARE AND SUBMIT DEWATERING AND CREEK BYPASS PLAN FOR CONTRACTING OFFICER APPROVAL.
8. IN-WATER CONSTRUCTION WORK IS EXPECTED TO BE CONDUCTED DURING DRY SEASON FROM APPROXIMATELY MAY TO SEPTEMBER.

GENERAL YARD PIPING AND UTILITIES NOTES:

1. EXISTING UNDERGROUND UTILITIES HAVE NOT BEEN IDENTIFIED BUT IS EXPECTED TO OCCUR IN A FUTURE DESIGN PHASE. CONTRACTOR SHALL POTHOLE AND FIELD VERIFY DEPTH AND LOCATION PRIOR TO EXCAVATION. PROTECT ALL EXISTING UTILITIES TO REMAIN DURING CONSTRUCTION.
2. EXISTING PIPING AND EQUIPMENT ARE SHOWN SCREENED AND/OR LIGHT-LINED. NEW PIPING AND EQUIPMENT ARE SHOWN HEAVY-LINED.
3. UNLESS OTHERWISE SHOWN ALL PIPING SHALL HAVE A MINIMUM OF 3' COVER.
4. ALL PIPES SHALL HAVE A CONSTANT SLOPE BETWEEN INVERT ELEVATIONS UNLESS A FITTING IS SHOWN.
5. FOR SURFACE RESTORATION OF ASPHALT CONCRETE MATCH EXISTING PAVEMENT.
6. MINIMUM ALLOWABLE CLEARANCE BETWEEN PIPES AT CROSSINGS SHALL BE 3".

GENERAL NOTE:

1. THIS IS A STANDARD LEGEND SHEET. THEREFORE, NOT ALL OF THE INFORMATION SHOWN MAY BE USED ON THIS PROJECT.

CIVIL LEGEND

EXISTING	THIS CONTRACT	
157.7	158.5	SPOT ELEVATION
155	155	CONTOUR LINE
	3:1	EMBANKMENT AND SLOPE
		DRAINAGEWAY OR DITCH
		CATCH BASIN OR INLET
		TRENCH DRAIN
	OR	SIGN
		MANHOLE
		ELECTRICAL MANHOLE
		ELECTRIC HANDHOLE
		POST OR GUARD POST
		GUY ANCHOR
		FIRE HYDRANT
		UTILITY POLE
		LIGHT POLE
		BENCH MARK
		SURVEY CONTROL POINT OR POINT OF INTERSECTION
		BRUSH/TREE LINE
		TREE
		PROPERTY LINE
		CENTER LINE, BUILDING, ROAD, ETC.
		FEATURE LINES AND AVERAGE SEASONAL WATER LEVELS
	N 1000.00 E 1000.00	STRUCTURE, BUILDING OR FACILITY LOCATION POINT - COORDINATES
	B-1	BORING LOCATION AND NUMBER
	TP-2	TEST PIT LOCATION AND NUMBER
	P-3	PIEZOMETER LOCATION AND NUMBER
OR	OR	DEMOLITION
OR	OR	STRUCTURE, BUILDING OR FACILITY
		ASPHALT CONCRETE PAVEMENT
		GRAVEL SURFACING
		CONCRETE PAVEMENT
		CURB
		CURB AND GUTTER
		SINGLE SWING GATE
		DOUBLE SWING GATE
		SLIDING GATE
		GUARD RAIL
		CHAIN LINK FENCE
		ARCHITECTURAL FENCE
		WIRE FENCE
		CULVERT
		FLOW DIRECTION

YARD PIPING LEGEND

EXISTING	THIS CONTRACT	
		NOMINAL PIPE DIAMETER
		PIPE USE IDENTIFICATION
8" PE	8" PE	PIPING < 30" DIAMETER
		PIPING ≧ 30" DIAMETER
		EXISTING PIPE TO BE ABANDONED
		EXISTING PIPE TO BE REMOVED
		INDICATOR POST VALVE
		GATE VALVE AND VALVE BOX
		BUTTERFLY VALVE AND VALVE BOX
		PLUG VALVE AND VALVE BOX
		FLEXIBLE COUPLING
		90° ELBOW UP
		90° ELBOW DOWN
		BEND < 90° UP
		BEND < 90° DOWN
		CONCENTRIC REDUCER
		CAP OR PLUG
		CLEANOUT
		FIRE HYDRANT
	A	BACKFILL CLASS

ABBREVIATIONS

APPROX	APPROXIMATE
AVG	AVERAGE
B.F.	BUTTERFLY
°	DIAMETER
DIA	DIAMETER
EL	ELEVATION
ELEV	ELEVATION
EXST	EXISTING
FT	FOOT / FEET
GAL	GALLON
HDPE	HIGH DENSITY POLYETHYLENE
HP	HORSE POWER
N	NORTH
NTS	NOT TO SCALE
O.C.	ON-CENTER
PE	POLYETHYLENE
PVC	POLYVINL CHLORIDE
SQ FT	SQUARE FOOT
TYP	TYPICAL
W/	WITH

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1132 BISHOP STREET, SUITE 1100
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DESIGNED BY: L HAYS		DATE: 5/XX/2015	REVISION:
DRAWN BY: T STIMPSON	CHECKED BY: J YOUNG	SOLICIT./ CONTRACT NO.: 481684	
SUBMITTED BY: J YOUNG		LOCATION CODE	
PLOT SCALE: AS NOTED	PLOT DATE: 2015\05\12	DRAWING NUMBER:	
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ALA WAI CANAL PROJECT
MITIGATION MEASURES

CIVIL GENERAL NOTES AND LEGEND

SHEET IDENTIFICATION
G-002
SHEET 02 OF 14

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PLAN
1"=40'

0 40 80 120
Scale In Feet

PHOTO 1
NTS

PHOTO 2
NTS

PHOTO 3
NTS

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LOCATION CODE
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ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
EXISTING CONDITIONS

SHEET IDENTIFICATION
C-001
SHEET 03 OF 14

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ACCESS AND STAGING PLAN

1"=50'

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Scale In Feet

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ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
ACCESS AND STAGING PLAN

SHEET IDENTIFICATION
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SHEET 04 OF 14

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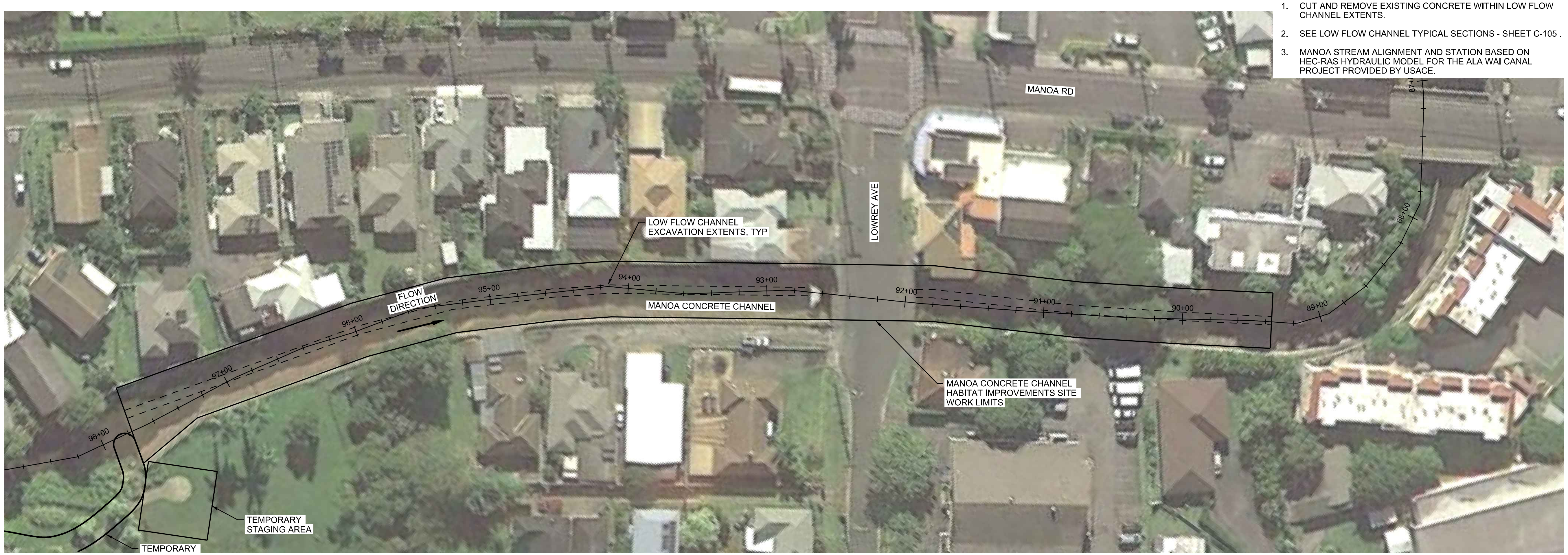
NOTES:

1. CUT AND REMOVE EXISTING CONCRETE WITHIN LOW FLOW CHANNEL EXTENTS.
2. SEE LOW FLOW CHANNEL TYPICAL SECTIONS - SHEET C-105 .
3. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.



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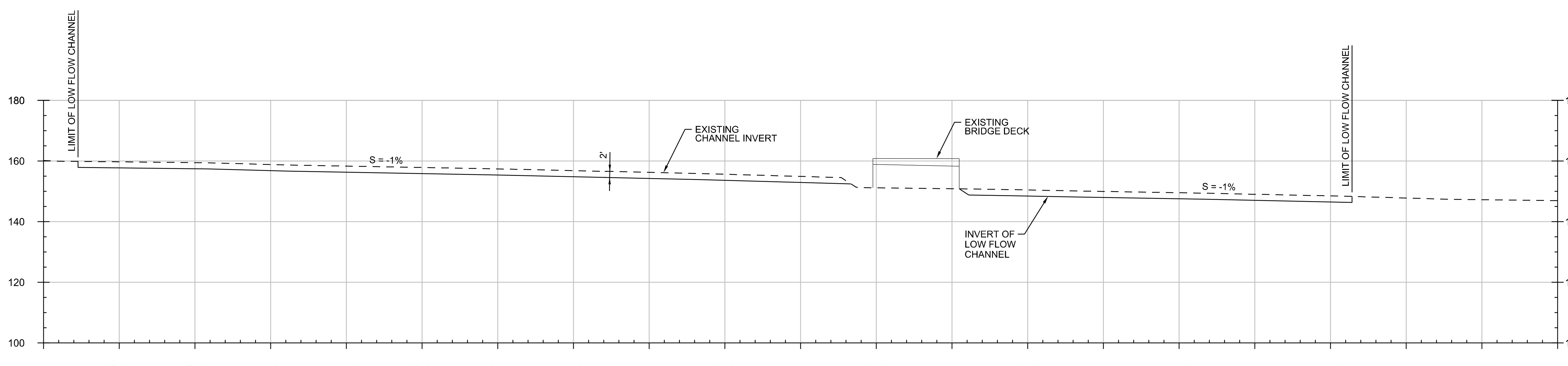

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VERT: 1"=20'

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ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL
LOW FLOW CHANNEL CONCEPT
PLAN AND PROFILE

SHEET IDENTIFICATION
C-102
SHEET 05 OF 14

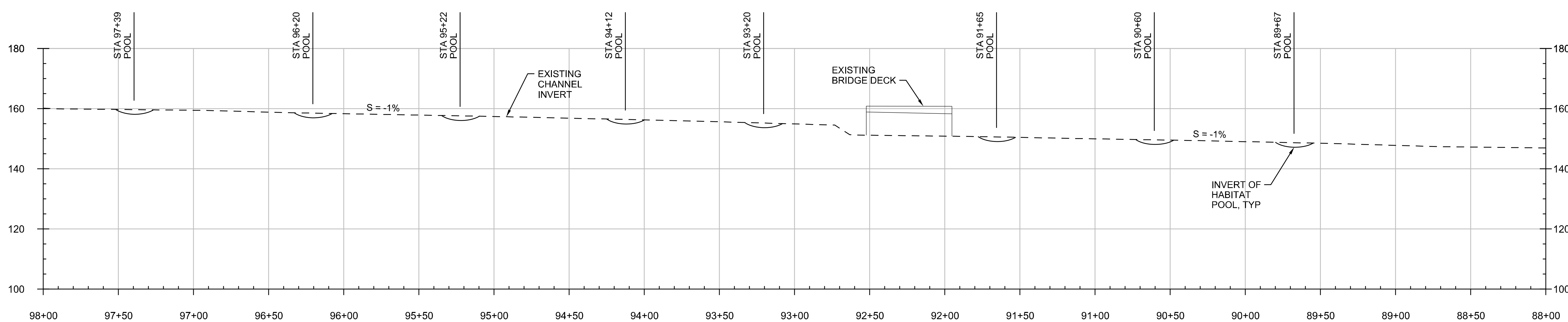
NOTES:

1. CUT AND REMOVE EXISTING CONCRETE WITHIN HABITAT POOL EXTENTS.
2. SEE HABITAT POOL TYPICAL SECTIONS - SHEET C-105.
3. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.

PLAN

1"=40'

0 40 80 120
Scale In Feet



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VERT: 1"=20'

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DATE & TIME: $DATE$ $TIME$
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MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

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DRAWN BY: T STIMPSON | CHECKED BY: J YOUNG | SOLICIT / CONTRACT NO.: 481684
SUBMITTED BY: J YOUNG | LOCATION CODE
PLOT SCALE: AS NOTED | PLOT DATE: 2015/05/13 | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: FILENAME

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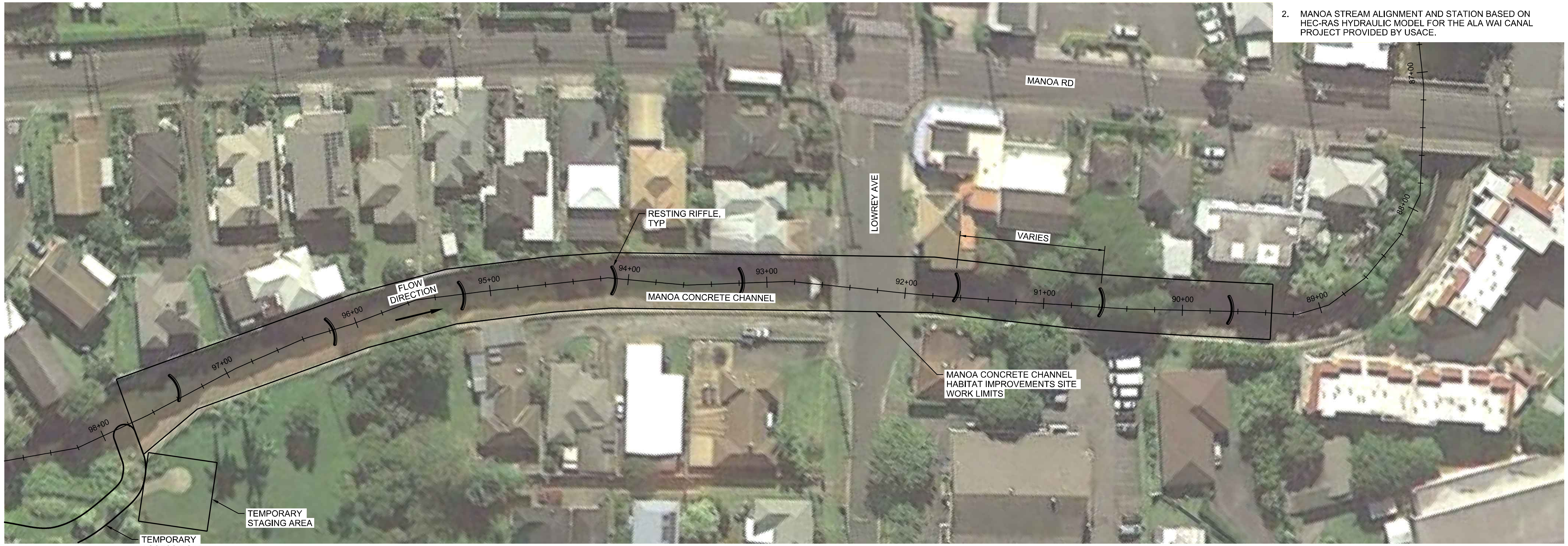
ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
HABITAT POOL CONCEPT
PLAN AND PROFILE

SHEET IDENTIFICATION
C-103
SHEET 06 OF 14

NOTES:

1. SEE RESTING RIFFLE TYPICAL SECTIONS - SHEET C-105.
2. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.



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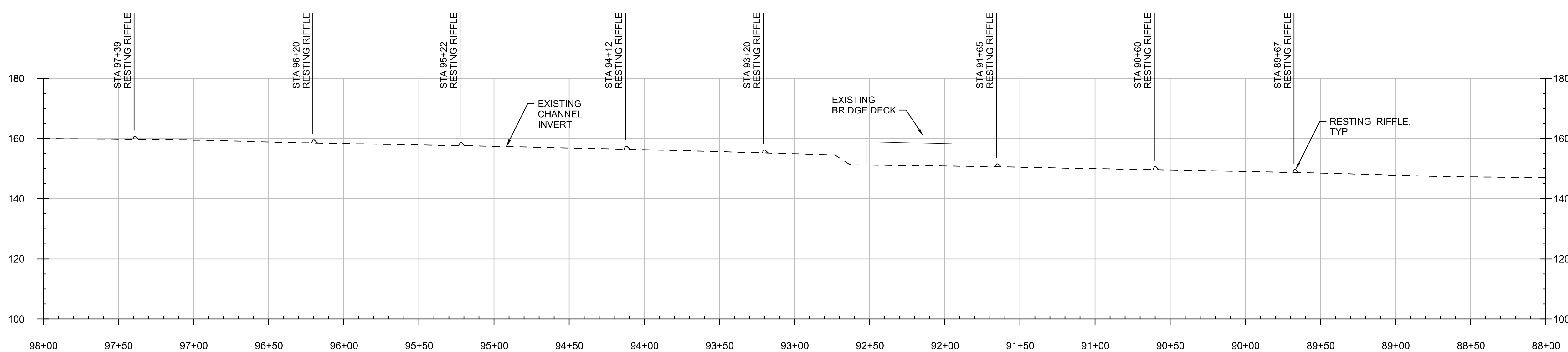
1"=40'

0 40 80 120
Scale In Feet



PROFILE
HORZ: 1"=40'
VERT: 1"=20'

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LOCATION CODE
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SIZE: ANSI D
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ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
RESTING RIFFLE CONCEPT
PLAN AND PROFILE

SHEET IDENTIFICATION
C-104
SHEET 07 OF 14

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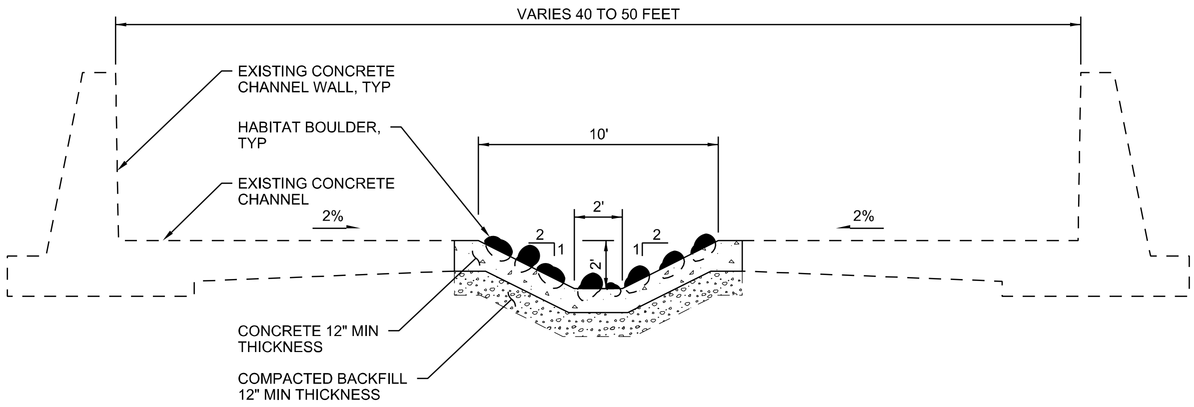

LOW FLOW CHANNEL TYPICAL SECTION

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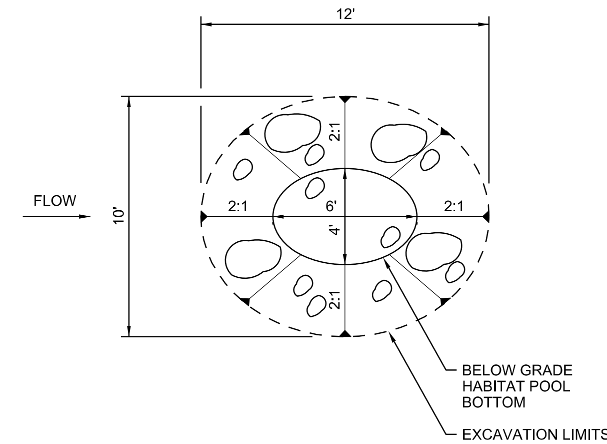
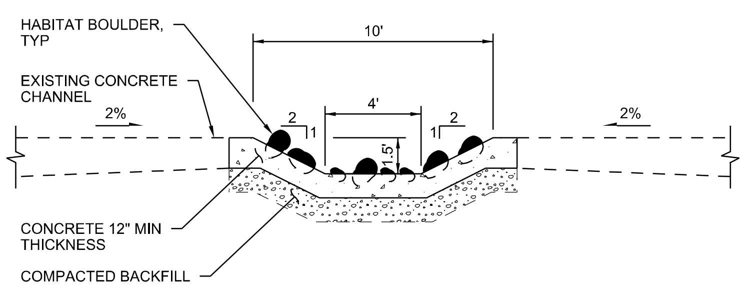


HABITAT POOL PARTIAL PLAN

1"=4'

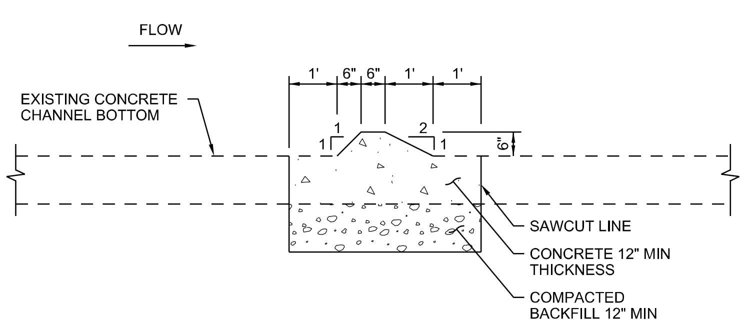
GENERAL SHEET NOTES:

1. ALL DIMENSIONS APPROXIMATE
2. REINFORCING STEEL DOWELS MAY BE INCORPORATED IN A FUTURE DESIGN PHASE.



HABITAT POOL TYPICAL SECTION

1"=4'



RESTING RIFFLE CROSS SECTION

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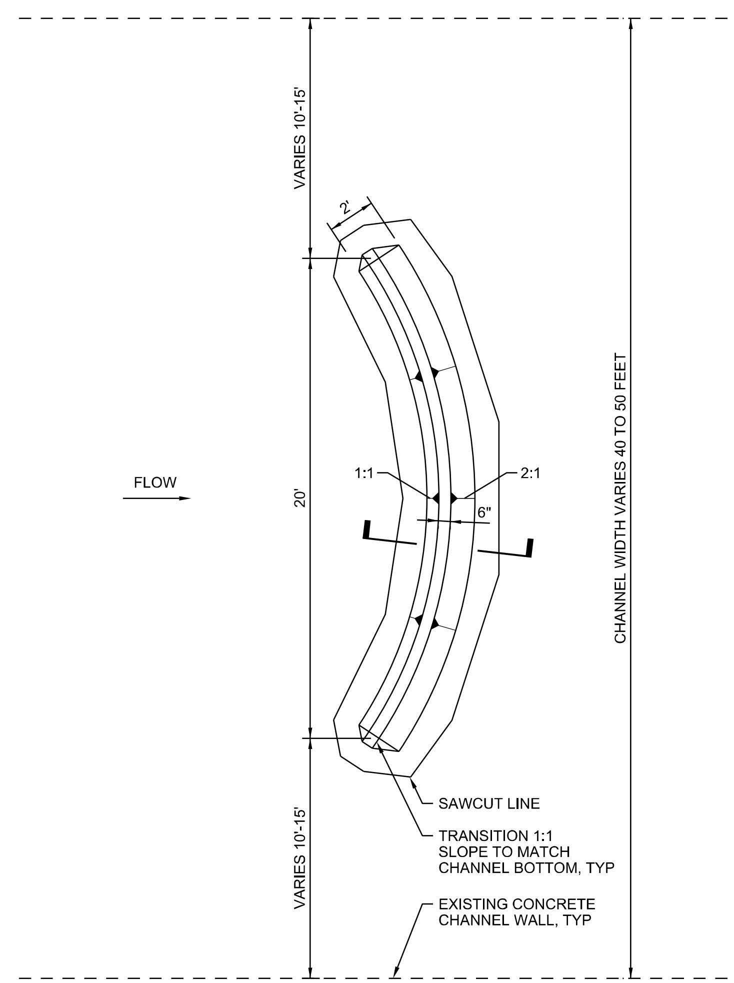

RESTING RIFFLE PARTIAL PLAN

NTS

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DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
DATE: 5/XX/2015
SOLICIT / CONTRACT NO.: 481684
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 2015/05/12
SIZE: ANSI D
FILE NAME: FILENAME
REVISION:
DRAWING NUMBER:

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL TYPICAL SECTIONS

SHEET IDENTIFICATION
C-105
SHEET 08 OF 14

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MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:
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PEN TABLE: $PENTBL$
PRINTED BY: $USER$

NOTES:

1. LOCATION OF A STAGING AREA WILL BE DETERMINED, IF NEEDED.
2. IF EQUIPMENT, MATERIALS AND/OR ACCESS IS PROVIDED VIA THE BRIDGE, THEN A PARTIAL LANE CLOSURE AND TRAFFIC CONTRL MAY BE REQUIRED.

ACCESS AND STAGING PLAN

1"=50'

0 50 100 150
Scale In Feet

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SIZE: ANSI D	FILE NAME: FILENAME		

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 7 AND 8
ACCESS AND STAGING PLAN

SHEET IDENTIFICATION
C-106
SHEET 09 OF 14

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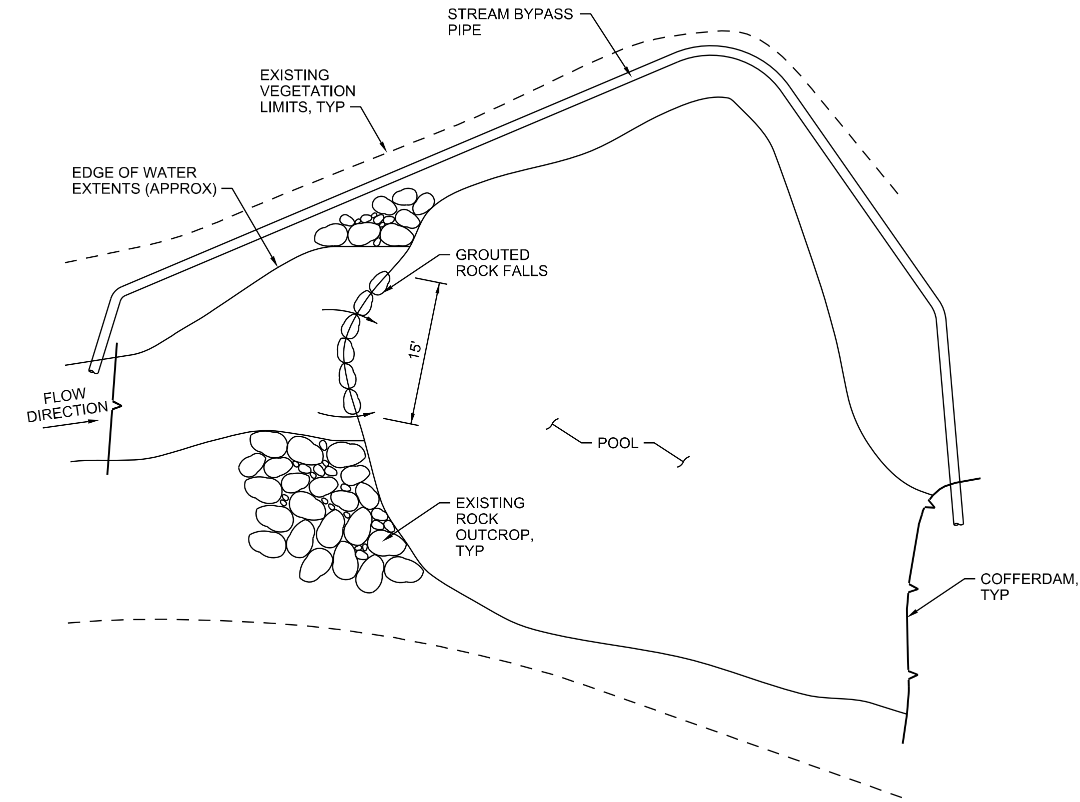
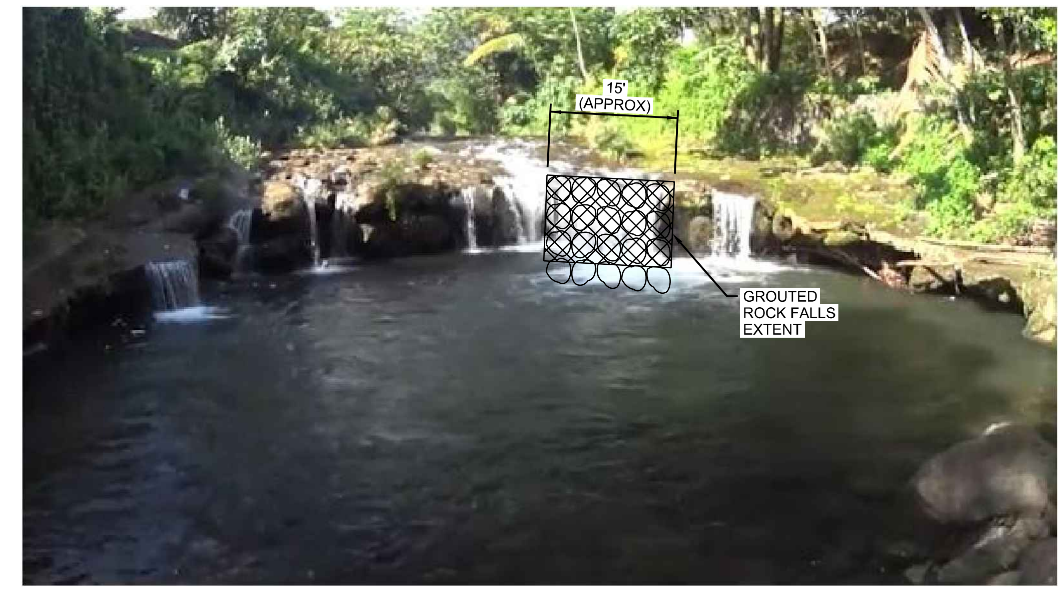


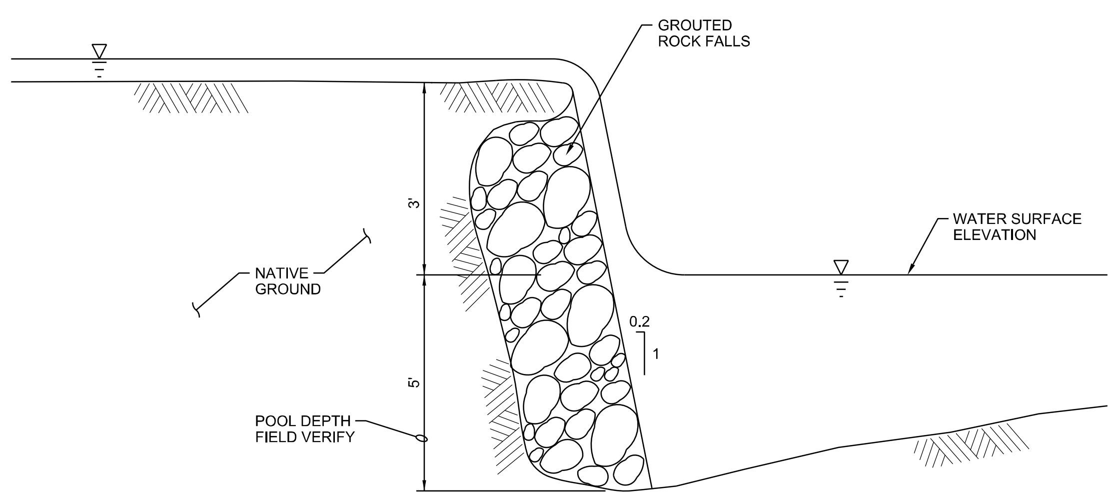
PLAN
NTS



NOTE:

DIMENSIONS ARE APPROXIMATED BASED ON FIELD PHOTO.

SITE PHOTO
NTS



NOTE:

DIMENSIONS ARE APPROXIMATED BASED ON FIELD PHOTO.

SECTION
NTS

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REVISION:
SOLICIT./CONTRACT NO.: 481684
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 2015/05/12
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

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ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 7
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-107
SHEET 10 OF 14

FILE: $FILEL$
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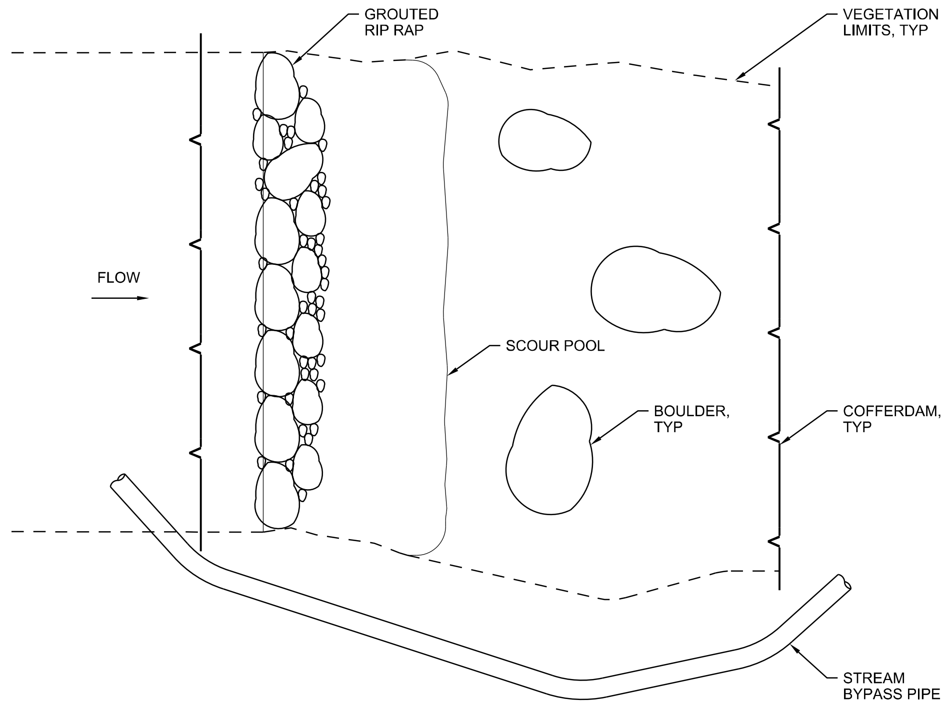
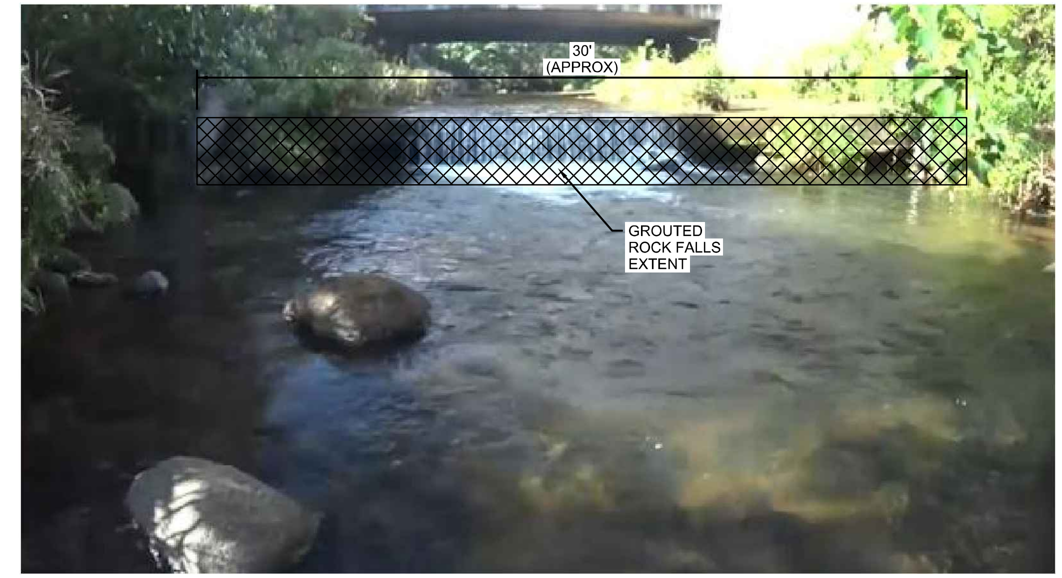


PLAN

1"=5'

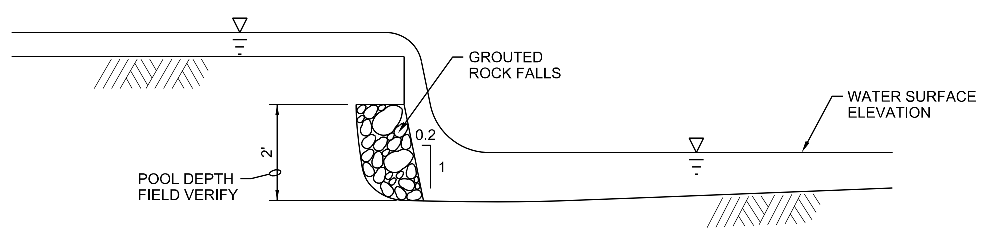


NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON FIELD PHOTO.

SITE PHOTO

NTS



NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON FIELD PHOTO.

SECTION

1"=2'

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DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

PLOTDRIVER: $PLTDRV$
PEN TABLE: $PENTBL$
PRINTED BY: $USER$

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SUBMITTED BY: J YOUNG
DATE: 5/XX/2015
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LOCATION CODE
REVISION:
PLOT SCALE: AS NOTED
PLOT DATE: 2015/05/12
SIZE: ANSI D
FILE NAME: FILENAME
DRAWING NUMBER:

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 8
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-108
SHEET 11 OF 14

N

ACCESS AND STAGING PLAN

1"=50'

0 50 100 150
Scale In Feet

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SIZE: ANSI D	FILE NAME: FILENAME		

ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA STREAM FALLS 11 AND 12
ACCESS AND STAGING PLAN

SHEET IDENTIFICATION
C-109
SHEET 12 OF 14

FILE: $FILEL$
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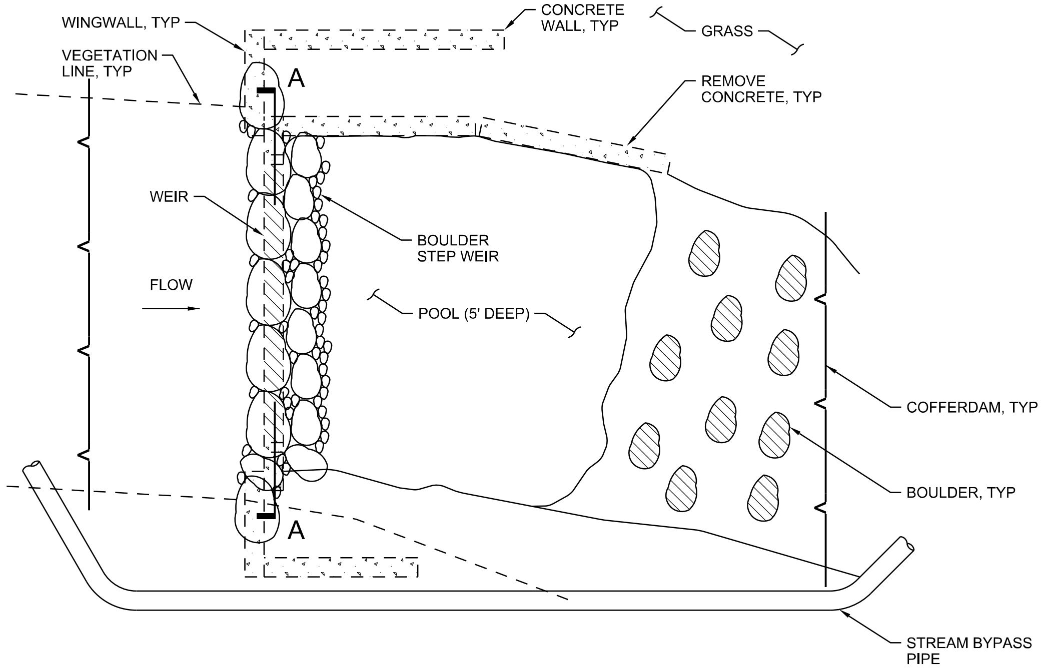
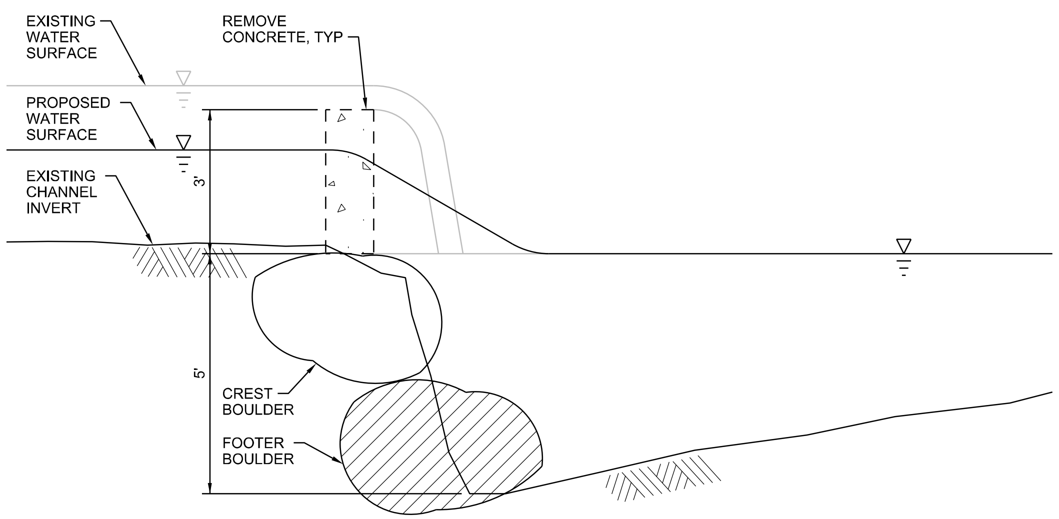


PLAN
1"=5'

NOTES:

1. REMOVE ALL EXISTING CONCRETE FROM CHANNEL.
2. DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.
3. EXISTING SITE IS AN ACTIVE US GEOLOGICAL SURVEY (USGS) STREAM GAGING STATION. ALL WORK AT THE SITE WILL BE COORDINATED WITH USGS.

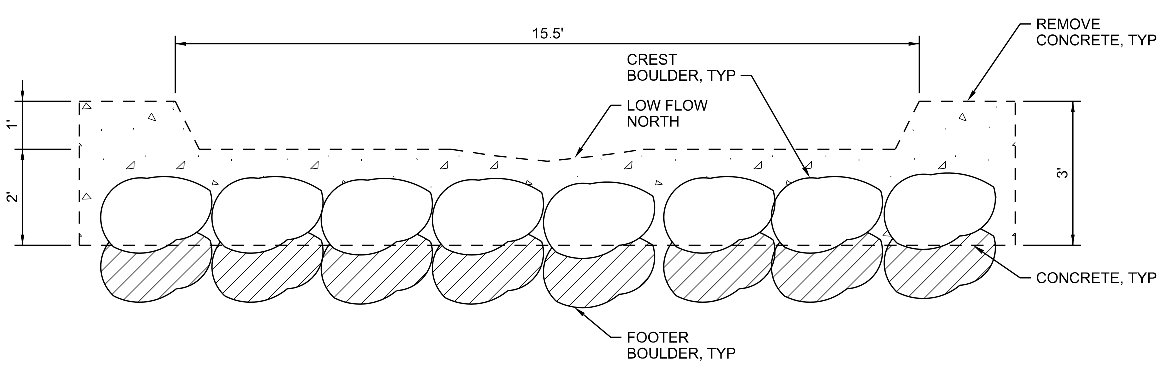
SITE PHOTO
NTS



NOTES:

DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.

PROFILE
1"=2'



NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.

SECTION A-A
1"=2'

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MARK	DESCRIPTION	DATE	APPR

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HONOLULU, HI 96813

DESIGNED BY: L HAYS		DATE: 5/XX/2015	REVISION:
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SUBMITTED BY: J YOUNG		LOCATION CODE	
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SIZE: ANSI D	FILE NAME: FILENAME		

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 11
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-110
SHEET 13 OF 14

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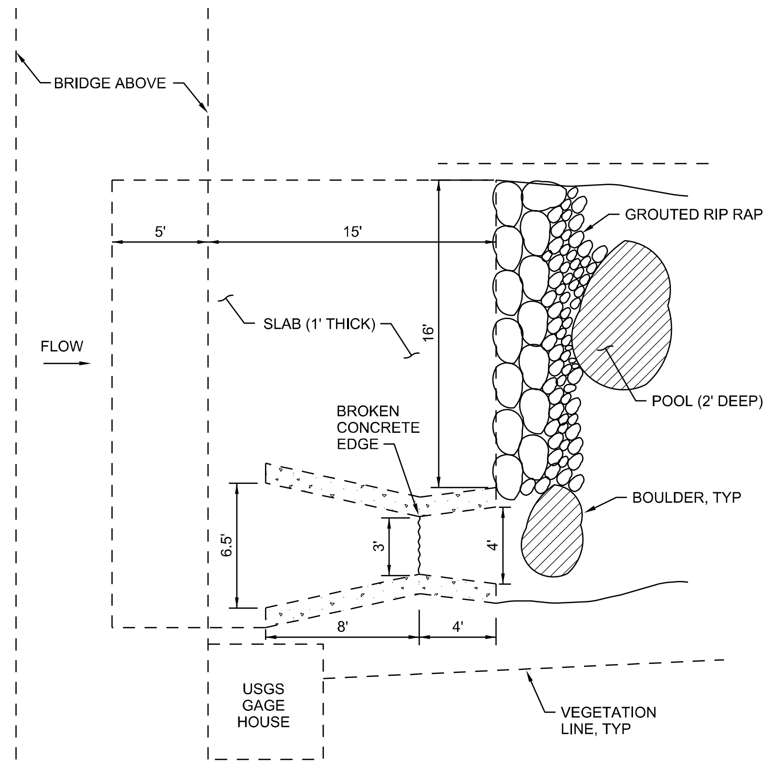


PLAN

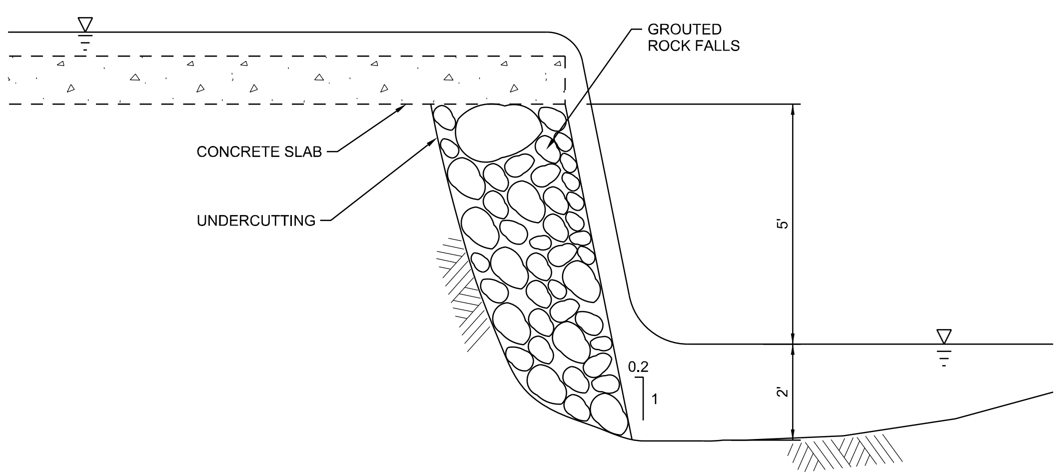
1"=5'

NOTES:

1. EXISTING SITE IS AN ACTIVE US GEOLOGICAL SURVEY (USGS) STREAM GAGING STATION. ALL WORK AT THE SITE WILL BE COORDINATED WITH USGS.

SITE PHOTO

NTS



PROFILE

1"=2'

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SUBMITTED BY: J YOUNG		LOCATION CODE	
PLOT SCALE: AS NOTED	PLOT DATE: 2015\05\12	DRAWING NUMBER:	
SIZE: ANSI D	FILE NAME: FILENAME		

ALA WAI CANAL PROJECT

MITIGATION MEASURES

MANOA STREAM FALLS 12
REHABILITATION CONCEPT

SHEET IDENTIFICATION

C-111

SHEET 10 OF 14

Attachment 6. Cost Effectiveness and Incremental Cost Analysis

Cost Effectiveness and Incremental Cost Analysis
Ala Wai Canal Project

July 2015

Contents

1.0 Introduction

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR), the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project, Oahu, Hawaii[1] (hereafter referred to as "the project"). As project implementation is expected to result in impacts to aquatic habitat, compensatory mitigation will be required to offset these impacts. The USACE planning process requires that compensatory mitigation plans be developed, evaluated and selected consistent with the requirements of their overall planning process. A detailed discussion of the mitigation development process for the project is provided in the Mitigation and Monitoring Plan; this document presents the economic analysis used to support evaluation and selection of the compensatory mitigation plan.

As outlined in Engineering Regulation (ER) 1105-2-100 "USACE Planning Guidance Notebook" (USACE, 2000), alternative plans should be evaluated based on four primary criteria: completeness, effectiveness, efficiency, and acceptability. Economic analyses are important primarily in the evaluation of efficiency. Economic analyses also play a role in the evaluation of the acceptability of an alternative, based on its estimated implementation cost, and the completeness of an alternative, based on identifying all potential costs that could result from implementation.

The USACE Institute for Water Resources (IWR) Planning Suite tool was developed in response to the intricacies of ecosystem restoration planning studies (including mitigation) and performs cost-effectiveness and incremental cost analyses (CE/ICA) on combinations of water resources alternatives. The CE analysis is employed to eliminate "production inefficient" solutions, or alternatives plans with the same level of output that can be provided at a lesser cost than another plan, and "production ineffective" solutions, or alternative plans with less output than a plan that has a lesser or equal cost. The ICA evaluates the incremental cost of cost-effective alternatives to determine which are "best buy" plans, or plans which provide the greatest increase in output for the least increase in cost.

To identify the mitigation alternative(s) that would provide the greatest benefit compared to cost for the project, CE/ICA were conducted to compare predicted future benefits (quantified by average annual habitat units) to estimated average annual costs for each of the mitigation alternatives identified for the project. This analysis is based on and follows guidance from the USACE IWR publication, *Evaluation of Environmental Investment Procedures Manual, Interim: Cost Effectiveness and Incremental Analyses*, May 1995, IWR Report #95-R-1 and *Cost Effectiveness Analysis for Environmental Planning: Nine Easy Steps*, October 1994, IWR Report 94-PS-2. The organization of this appendix follows the steps outlined in IWR Report #95-R-1k:

Plan Formulation Steps

- **Step 1:** Display Outputs and Costs of Management Measures
- **Step 2:** Identify Management Measure Relationships
- **Step 3:** Add Costs and Outputs of Combinations

Cost Effectiveness Analysis Steps

- **Step 4:** Identify "Production Inefficient" Solutions
- **Step 5:** Identify "Production Ineffective" Solutions

Incremental Cost Analysis Step

- **Step 6:** Calculate and Display Incremental Costs

Additional Analytical Steps to Assist in Scale Selection

- **Step 7:** Calculate Change in Unit Cost from No-Action Plan to All Other Plans
- **Step 8:** Recalculate Change in Unit Cost from Last Selected Plan
- **Step 9:** Tabulate and Display Incremental Costs of Selected Plans

[1] The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

2.0 Plan Formulation

Steps 1 through 3 are related to plan formulation and, in the case of this project, include an analysis of the possible management measures identified for compensatory mitigation. In the context of the USACE planning process, management measures are defined as actions that can be implemented to cause a desirable change relative to the planning objective; they are individual features or activities that serve as the building blocks of alternative plans. Formulation of mitigation measures is detailed in Section 3 of the Mitigation and Monitoring Plan and is summarized below.

2.1 Step 1: Display Outputs and Costs of Management Measures

The first step of plan formulation, as it relates to analysis of cost-effectiveness and incremental cost, is to identify the mitigation measures and their output and cost. The mitigation measures that were considered as part of the evaluation, based on the results of the mitigation development process (as described in the Mitigation and Monitoring Plan) are summarized in Table 1. Given that the mitigation effort is focused on restoring passage or habitat to stream channels based on the conditions known to favor native species, it was determined that different scales or increments of each measure would not meet the objectives of the mitigation effort, and therefore were not considered. Additional detail on the mitigation identification and screening process is provided in the Mitigation and Monitoring Plan.

TABLE 1
Conceptual Mitigation Measures

Mitigation Measure/Alternative	Description
Falls 7	Remove overhanging lip associated with undercutting at in–stream structures located approximately 0.6 mile above Manoa District Park
Falls 8	Remove overhanging lip associated with undercutting at in–stream structures located approximately 0.7 mile above Manoa District Park
Falls 11	Remove overhanging lip associated with undercutting at in–stream structures associated with USGS gaging stations on Waihi Stream
Falls 12	Remove overhanging lip associated with undercutting at in–stream structures associated with USGS gaging stations on Waiakeakua Stream
Manoa Low-Flow Channel	Notch low-flow channel into concrete and add natural substrate along approximately 1,100 feet of concrete channel below Manoa District Park
Manoa Habitat Pools	Notch habitat pools (<18" of water depth) into concrete and add natural substrate along approximately 1,100 feet of concrete channel below Manoa District Park
Manoa Resting Riffles	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat (>6" of water depth) along approximately 1,100 feet of concrete channel below Manoa District Park

2.2 Step 2: Identify Management Measure Relationships

Step 2 of plan formulation and evaluation is to identify potential groupings of management measures, based on their dependency to each other. In the case of this project, each of the mitigation measures considered as part of the CE/ICA are mutually exclusive (meaning, they could be implemented as stand-alone actions). However, recognizing that there are many possible measure combinations, it was determined that a focused set of alternatives should be defined based on estimated habitat benefits and functionality, according to the rationale summarized below.[2]

Given the limited passage allowed by existing in-stream barriers, removal of a barrier is expected to provide little to no benefit to native aquatic species if downstream barriers are still in place. Therefore, the alternatives were formulated to only include combinations of barrier removal starting at the furthest downstream barrier (i.e. Falls 7) and moving upstream. Possible alternatives involving removal of upstream barriers with downstream barriers still in place were not considered (e.g., Falls 8, 11 and/or 12). As Falls 11 and 12 are located on separate tributaries to Manoa Stream, they were combined with Falls 7 and 8, both in parallel and together. The barrier removal measures were not considered in combination with the concrete channel improvements, because individually, they are expected to provide adequate benefits to offset the habitat impacts associated with the flood risk management project.

2.3 Step 3: Derive Combinations and Calculate Costs and Outputs

Based on the concepts described above, a total of eight mitigation alternatives were identified, as follows:

- Remove passage barrier at Falls 7
- Remove passage barriers at Falls 7 and 8
- Remove passage barriers at Falls 7, 8 and 11
- Remove passage barriers at Falls 7, 8, and 12
- Remove passage barriers at Falls 7, 8, 11 and 12
- Install low-flow channel in concrete portion of Manoa Stream
- Install habitat pools in concrete portion of Manoa Stream
- Install resting riffles in concrete portion of Manoa Stream

The costs and outputs were then developed, as detailed below.

2.3.1 Estimate Alternative Costs

Planning level cost estimates are used in CE/ICA, and are comprised of two main cost elements: (1) implementation costs (explicit costs) and (2) opportunity costs of foregone National Economic Development (NED) benefits (implicit costs). For the purposes of this project, it is assumed that there are no implicit costs (as no NED benefits would be foregone), such that the total project cost is equal to the implementation cost. An estimate of the implementation costs was developed by the USACE as a bottom rolled-up type estimate at the conceptual (10 percent) design level, using FY2014 unit prices. The cost estimate for each mitigation alternative is summarized in Table 2.

As part of CE/ICA, environmental outputs and cost estimates should be annualized across the period of analysis. To annualize the project costs, an implementation timeline must be developed to identify initial costs, investment costs, and future costs. So that project costs can be evaluated in present value, the implementation timeline is used to categorize cost components as investment costs or future costs. For each alternative, the total project cost is equal to the investment cost plus future costs, in present value terms.

In the case of this project, all costs with the exception of those for monitoring and operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) are assumed to be incurred in Year 0. The IWR Planning Suite Annualizer was used to calculate the average annual cost of each alternative. The average annual cost assumes a 50-year period of analysis and a federal discount rate of 3.5%, which is the federal discount rate established for the evaluation of water resources development projects in fiscal year (FY) 2014. Table 2 shows the total

[2] Although the CE/ICA software allows for all possible measure combinations to be automatically generated based on the cost and benefit of each measure, the benefits for the passage barrier removal measures are not additive, thus requiring the HSHEP model to be run for each individual measure combination.

estimated cost and the average annual cost of the mitigation alternatives. A detailed breakdown of the present value cost for each of the 50 years of analysis is provided as an attachment to this document.

TABLE 2
Summary of Estimated Costs (FY2014 Price Level)

Implementation Cost Component	**Falls 7**	**Falls 7 and 8**	**Falls 7, 8, 11**	**Falls 7, 8, 12**	**Falls 7, 8, 11, 12**	**Manoa Low-Flow Channel**	**Manoa Habitat Pools**	**Manoa Resting Riffles**
Construction	$67,869	$132,848	$169,801	$170,544	$207,498	$798,018	$172,393	$178,294
LERRDs[1]	$15,900	$27,100	$32,700	$29,300	$34,900	$4,500	$4,500	$4,500
Pre-construction Monitoring	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250
Post-construction Monitoring[2]	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250
OMRR&R[3]	$29,467	$45,712	$67,450	$67,636	$76,874	$92,301	$55,599	$57,074
Interest During Construction[4]	$1,491	$2,918	$3,729	$3,746	$4,557	$17,526	$3,786	$3,916
Contingency[5]	$40,300	$60,118	$73,889	$74,116	$85,387	$239,055	$72,180	$73,980
Estimated Cost for CE/ICA	$240,526	$354,197	$433,070	$430,841	$494,715	$1,236,900	$393,958	$403,264
Average Annual Cost[6]	$9,014	$13,362	$16,101	$16,000	$18,440	$49,564	$14,753	$15,105

[1] Lands, Easements, Rights-of-way, Relocations, and Dredge Disposal areas
[2] Includes 5 monitoring events during Years 1, 2, 3, 4, and 5
[3] Includes 50 years of OMRR&R
[4] Assumes a 3.5% discount rate; to be updated prior to Final Feasibility Report/EIS
[5] Assumes contingency equal to 25.5% of the construction cost plus 20% of the pre-construction monitoring, post-construction monitoring, and OMRR&R costs
[6] Calculated using IWR Planning Suite annualizer: discount rate = 3.5% and period of analysis = 50 years

2.3.2 Estimate Alternative Outputs

The benefits of ecosystem mitigation are non-monetary, and therefore outputs must be quantified based on a unit of habitat improvement (that is, habitat units). In the case of this project, the Hawaii Stream Habitat Evaluation Procedure (HSHEP) was used to quantify the habitat benefits associated with each of the mitigation alternatives. A detailed discussion of the HSHEP model and its application to the project is provided in the Mitigation and Monitoring Plan (specifically including Attachments 1 and 2).

In order for proper comparison of costs and benefits, habitat units must be annualized over the period of analysis. Average annual habitat units were calculated using the IWR Planning Suite annualizer. It is expected that all habitat benefits would be realized in Year 1 and remain stable over the 50-year planning period, as shown in Figure 1. The total habitat units and average annual habitat units for the mitigation alternatives are listed in Table 3.

TABLE 3
Total Habitat Units and Average Annual Habitat Units for Mitigation Alternatives

Metric	**No Action**	**Falls 7**	**Falls 7 and 8**	**Falls 7, 8 and 11**	**Falls 7, 8 and 12**	**Falls 7, 8, 11 and 12**	**Manoa Low-Flow Channel**	**Manoa Habitat Pools**	**Manoa Resting Riffles**
Total Habitat Units	0	1,353	3,870	5,456	6,082	7,668	1,292	1,214	1,207
Average Annual Habitat Units[a]	0	1,340	3,831	5,401	6,021	7,591	1,279	1,202	1,195

[a] Assumes that all benefits would be realized in Year 1 and remain stable over the 50-year planning period; calculated using the IWR Planning Suite annualizer.

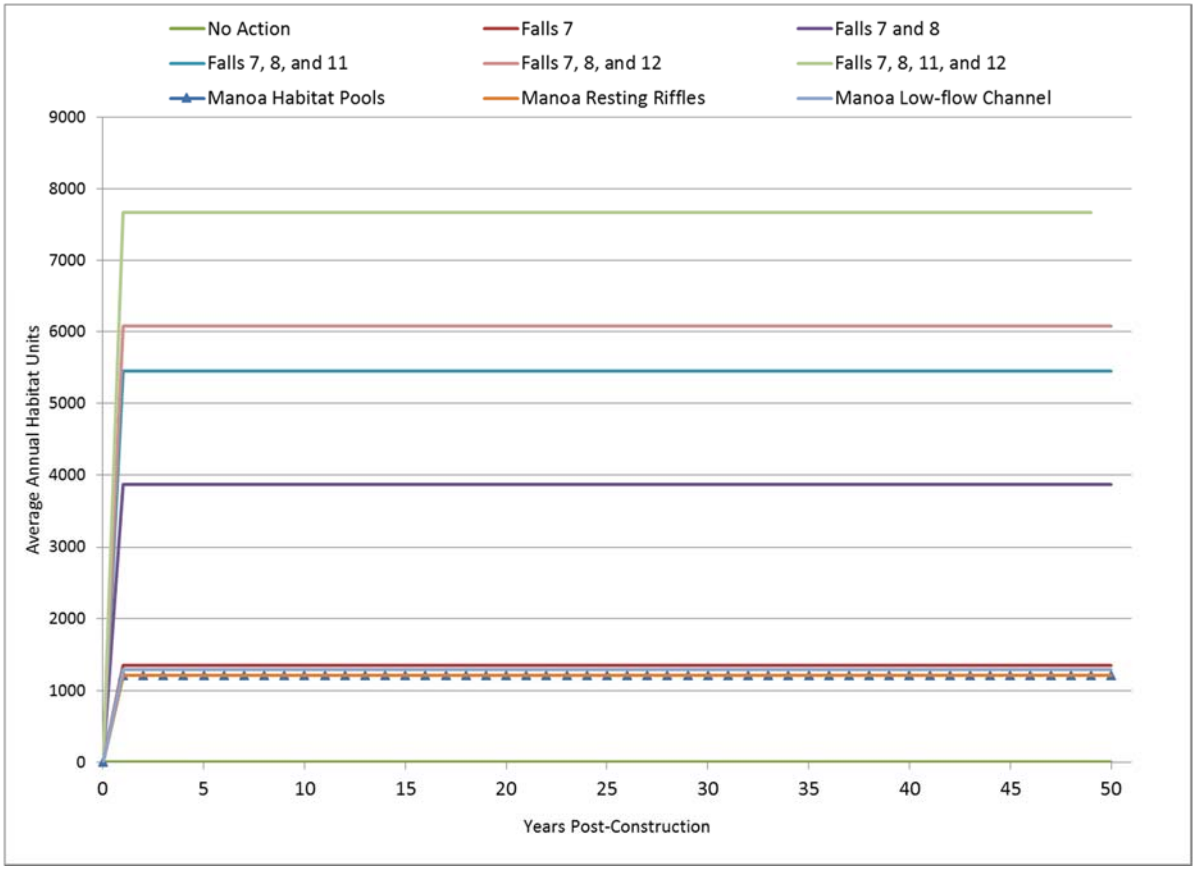

FIGURE 1
Projected Habitat Units over Period of Analysis

2.3.3 Summary of Alternative Outputs and Costs

Table 4 and Figure 2 summarize the outputs and costs of the alternatives. Costs are displayed in average annual costs, and outputs are displayed in average annual habitat units. These values are used in CE/ICA, as detailed in the remainder of this document.

TABLE 4
Summary of Alternative Outputs and Costs

Alternative	Output (Average Annual Habitat Units)	Cost (Average Annual Cost)
No Action	0	$ -
Falls 7	1,340	$ 9,014
Falls 7 and 8	3,831	$ 13,362
Falls 7, 8, 11	5,401	$ 16,101
Falls 7, 8, 12	6,021	$ 16,000
Falls 7, 8, 11, and 12	7,591	$ 18,440
Manoa Habitat Pools	1,202	$ 14,753
Manoa Resting Riffles	1,195	$ 15,105
Manoa Low-Flow Channel	1,279	$ 49,564

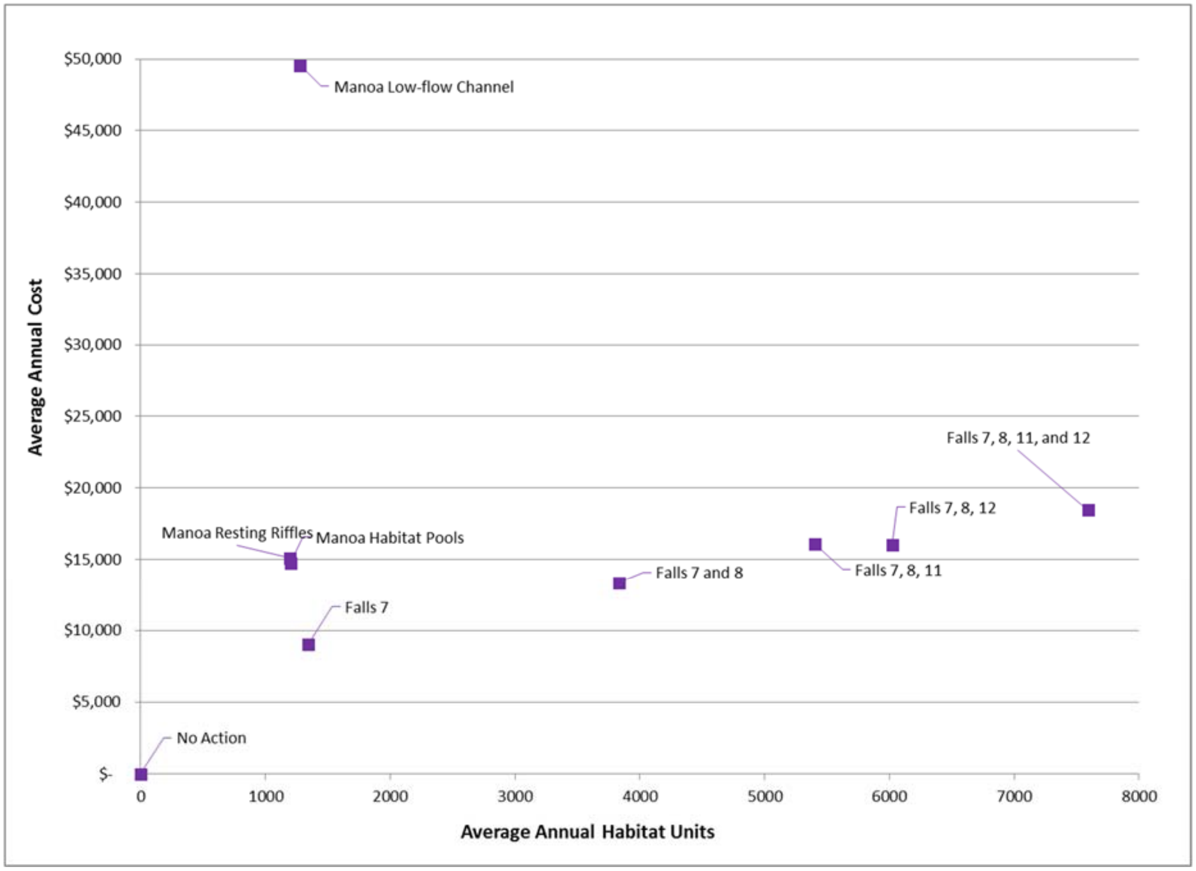

FIGURE 2
Cost and Output of Alternative Plans

3.0 Cost Effectiveness Analysis

The following section details the CE analysis, which is conducted to eliminate the least economically effective restoration alternatives. The inputs to the IWR Planning Suite include the predicted average annual habitat units (output) and the average annual cost for each alternative, each based on a 50-year period of analysis. For each level of output, only the least expensive alternative is cost-effective. As demonstrated in the following section, five of the nine alternatives were considered cost-effective and were carried forward to the ICA.

3.1 Step 4: Identify "Production Inefficient" Solutions

In Step 4, "production inefficient" solutions are identified. Production inefficient solutions are defined as alternative plans with the same level of output that can be provided at a lesser cost than another plan. Since none of the alternatives have the exact same level of output (or, average annual habitat units), there are no production inefficient solutions. These results are shown in Table 5.

TABLE 5
Identification of Production Inefficient Solutions

Alternative	Average Annual Habitat Units	Average Annual Cost	Less than Cost of Alternative with Same Output?
No Action	0	$ -	N/A
Manoa Resting Riffles	1,195	$ 15,105	N/A
Manoa Habitat Pools	1,202	$ 14,753	N/A
Manoa Low-flow Channel	1,279	$ 49,564	N/A
Falls 7	1,340	$ 9,014	N/A
Falls 7 and 8	3,831	$ 13,362	N/A
Falls 7, 8, 11	5,401	$ 16,101	N/A
Falls 7, 8, 12	6,021	$ 16,000	N/A
Falls 7, 8, 11, and 12	7,591	$ 18,440	N/A

3.2 Step 5: Identify "Production Ineffective" Solutions

In Step 5, "production ineffective" solutions are identified. Production ineffective solutions are defined as plans with less output than a plan that has a lesser or equal cost. To demonstrate analysis conducted to identify these plans, the alternatives are ordered by increasing output, and a plan is removed from further consideration if its cost is more than a plan with greater output. As shown in Table 6, there are four plans (Manoa Resting Riffles, Manoa Habitat Pools, and Manoa Low-flow Channel, and Falls 7, 8, and 11) that have a lesser output but greater cost than at least one other plan, and are therefore production ineffective solutions. Figure 3 demonstrates the results of the CE analysis (Steps 4 and 5). Five alternatives are considered cost-effective: No Action; Falls 7; Falls 7 and 8; Falls 7, 8, and 12; and Falls 7, 8, 11 and 12.

TABLE 6
Identification of Production Ineffective Solutions

Alternative	Average Annual Habitat Units	Average Annual Cost	Less than Cost of all Alternatives in Subsequent Rows?
No Action	0	$ 0	Yes
Manoa Resting Riffles	1,195	$ 15,105	No
Manoa Habitat Pools	1,202	$ 14,753	No
Manoa Low-flow Channel	1,279	$ 49,564	No
Falls 7	1,340	$ 9,014	Yes
Falls 7 and 8	3,831	$ 13,362	Yes
Falls 7, 8, 11	5,401	$ 16,101	No
Falls 7, 8, 12	6,021	$ 16,000	Yes
Falls 7, 8, 11, and 12	7,591	$ 18,440	Yes

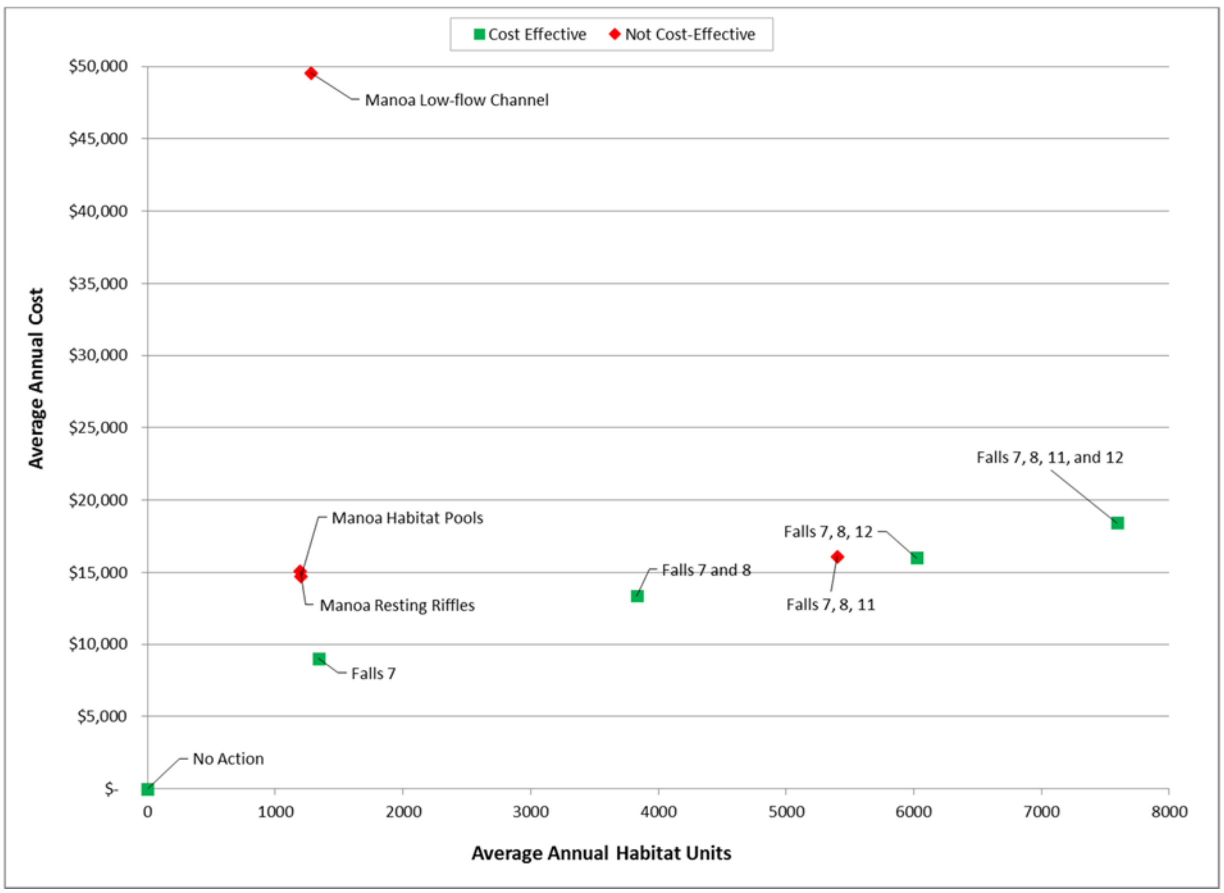

FIGURE 3
Costs and Outputs of Cost Effective Plans

4.0 Incremental Cost Analysis

The following section outlines the ICA conducted for the project. ICA is conducted on the cost-effective alternatives to determine which alternatives provide the greatest increase in output for the least increase in average annual cost. ICA serves to eliminate less economically effective solutions and determine which are best buy alternatives, or which provide the greatest increase in output for the least increase in cost. ICA is used to compare increases in average annual cost to increases in benefits, which are quantified in habitat units, among the alternatives being considered. The No Action Alternative does not have an associated cost and is therefore always considered a best buy plan. As demonstrated in the following section, of the five cost-effective alternatives, two were considered best buy plans.

4.1 Step 6: Calculate and Display Incremental Costs for Cost-Effective Plans

As previously mentioned, ICA is conducted on only the cost-effective plans identified in Steps 4 and 5. In Step 6, the incremental cost of implementing each successive cost-effective plan is calculated. While this step is not conducted to remove any alternatives, it identifies whether Steps 7 through 9 need to be completed. If the results of Step 6 show that the incremental cost per unit increases as the level of output increases, for all alternatives, the remainder of the steps do not need to be completed. However, this ideal situation is often not the case in planning studies. For the cost-effective alternatives identified in Section 3, the incremental cost per unit does not increase with increasing output (Table 7); therefore, Steps 7 through 9 must be employed.

TABLE 7
Summary of Incremental Costs per Unit (Step 6)

Alternative (Cost-Effective Solutions)	Average Annual Habitat Units	Average Annual Cost	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7	1,340	$9,014	1,340	$9,014	$6.73	No
Falls 7 and 8	3,831	$13,362	2,491	$4,348	$1.75	No
Falls 7, 8, 12	6,021	$16,000	2,190	$2,638	$1.20	Yes
Falls 7, 8, 11, and 12	7,591	$18,440	1,570	$2,440	$1.55	Yes

4.2 Step 7: Calculate and Display Incremental Costs per Unit from No Action Plan

In Step 7, alternative plans that have a higher incremental cost of implementation over the No Action Plan than an alternative with a higher output level are removed. For example, Falls 7 and 8 has a higher incremental cost per unit over the No Action Plan than does an alternative with a greater output (e.g, Falls 7, 8, and 12); therefore, Falls 7 and 8 is not considered a best buy plan (Table 8). After alternatives are removed based on this analysis, the incremental cost of remaining alternatives should increase with increasing cost (Table 8). In Step 7, three alternatives were removed: Falls 7; Falls 7 and 8; and Falls 7, 8, 11, and 12.

TABLE 8
Summary of Incremental Costs per Unit (Step 7)

Cost-Effective Alternatives	Average Annual Habitat Units	Average Annual Cost	Incremental Output from No Action	Incremental Cost from No Action	Incremental Cost Per Unit Output from No Action	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7	1,340	$9,014	1,340	$9,014	$6.73	No
Falls 7 and 8	3,831	$13,362	3,831	$13,362	$3.49	No
Falls 7, 8, 12	6,021	$16,000	6,021	$16,000	$2.66	No
Falls 7, 8, 11, and 12	7,591	$18,440	7,591	$18,440	$2.43	Yes

Note: Shaded alternatives were removed as potential best buy plan.

4.3 Step 8: Recalculate Incremental Cost from Last Selected Plan

In Step 8, the two remaining alternatives (No Action and Falls 7, 8, 11, and 12) are evaluated. The incremental cost of implementing each plan over the plan with the next lower output is calculated (Table 9). Any alternative plan that has higher incremental cost of implementation over the previous plan than an alternative with a higher output level is removed. After alternatives are removed based on this analysis, the incremental cost of remaining alternatives should increase with increasing cost (Table 9). In Step 8, no alternatives were removed. Therefore, the No Action Plan and Falls 7, 8, 11, and 12 are both considered best buy plans.

TABLE 9
Summary of Incremental Costs per Unit (Step 8)

Cost-Effective Alternatives	Average Annual Habitat Units	Average Annual Cost	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7, 8, 11, and 12	7,591	$18,440	7,591	$18,440	$2.43	Yes

4.4 Step 9: Tabulate and Graph Incremental Costs

In Step 9, the incremental costs of implementing each alternative over the No Action Plan are tabulated and graphed. The purpose of Step 9 is to clearly display the CE/ICA results to be used for alternative selection. Since no alternatives were removed in Step 8, the incremental costs do not change (Table 10). Table 10 also provides the average cost per habitat unit, which is often an additional consideration in the decision-making process.

TABLE 10
Summary of Incremental Costs per Unit (Step 9)

Alternative (Cost-Effective Solutions)	Average Annual Habitat Units	Average Annual Cost	Average Cost per Output	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan
No Action	0	$0	$ 0	0	$0	$0
Falls 7, 8, 11, and 12	7,591	$18,440	$2.43	7,591	$18,440	$2.43

Figure 4 displays the average annual cost and average annual habitat units of the alternatives. Figure 5 shows the incremental cost of implementing each successive best buy alternative (in this case only one alternative, Falls 7, 8, 11, and 12, is a successive best buy alternative), and the average annual cost of each best buy alternative. As shown, the average annual cost of Falls 7, 8, 11, and 12 is $18,440, and the incremental cost of implementing Falls 7, 8, 11, and 12 over the No Action Alternative is $2.43 per unit output. This information provides one decision factor for selection of mitigation alternative for the project.

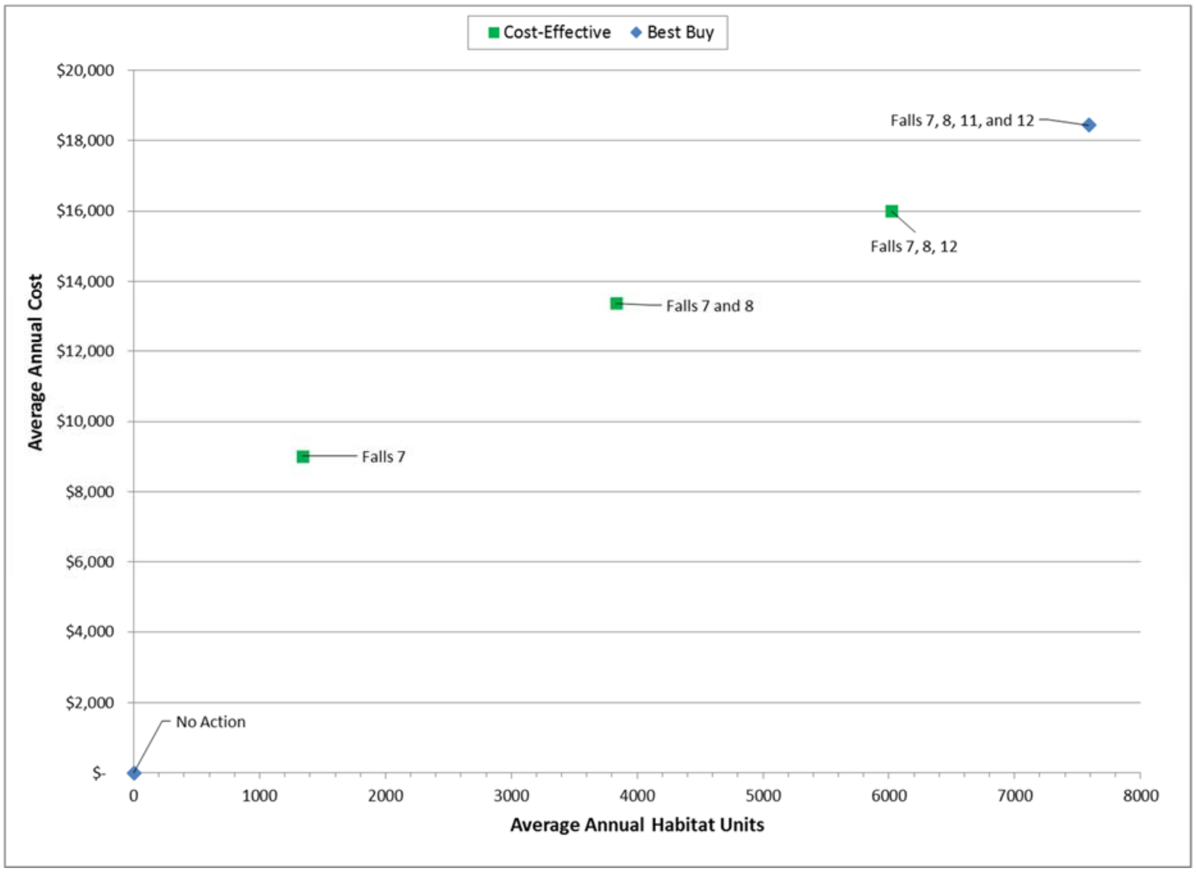

FIGURE 4
Costs and Outputs of Cost Effective and Best Buy Plans

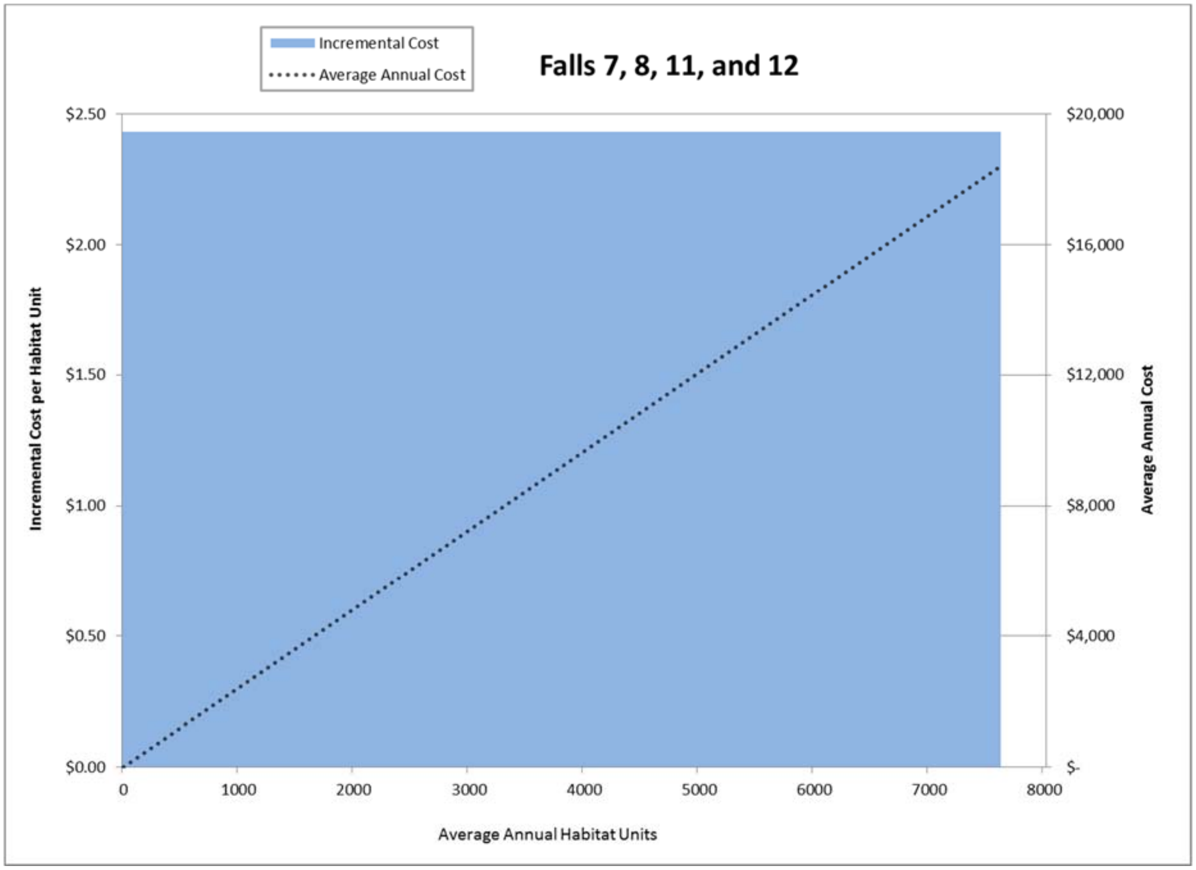

FIGURE 5
Incremental Cost of Best Buy Plans

5.0 References

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Attachment 1

IWR Planning Suite Detailed Cost Output

Annualized Cost for Falls 7, 8, 11, and 12

7/30/2015 9:05:02AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $18,439.89

Total initial cost:
Construction $260,409.00 + Real Estate $34,900.00 + Monitoring $11,100.00 + Other $0.00 = $306,409.00

Total Investment cost:
Total Initial Cost $306,409.00 + PED $0.00 + IDC $4,557.16 = $310,966.16

Initial investment:
Total Investment Cost $310,966.16 PV Factor 1.000000 Present Value = $310,966.16

Year	Cost	PV Factor	Present Value
0	$310,966.16	1.0000	$310,966.16
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$13,050.00	0.7089	$9,251.39
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$13,050.00	0.5026	$6,558.48
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$13,050.00	0.3563	$4,649.43
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$13,050.00	0.2526	$3,296.07
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$13,050.00	0.1791	$2,336.65

Net Totals: Cost: $494,716.16 Present Value: $432,518.94 Avg Annual Cost: $18,439.89

Annualized Cost for Falls 7, 8, and 11

Initial terms:
Discount rate %: 3.5 | Period of analysis: 50 | Capital recovery factor: 0.042633709 | Avg annual cost: $16,101.07

Total initial cost:
Construction $213,101.00 + Real Estate $32,700.00 + Monitoring $11,100.00 + Other $0.00 = $256,901.00

Total Investment cost:
Total Initial Cost $256,901.00 + PED $0.00 + IDC $3,729.27 = $260,630.27

Initial investment:
Total Investment Cost $260,630.27 PV Factor 1.000000 Present Value = $260,630.27

Year	Cost	PV Factor	Present Value
0	$260,630.27	1.0000	$260,630.27
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$10,788.00	0.7089	$7,647.82
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$10,788.00	0.5026	$5,421.68
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$10,788.00	0.3563	$3,843.53
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$10,788.00	0.2526	$2,724.75
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$10,788.00	0.1791	$1,931.63

Net Totals: Cost: $433,070.27 Present Value: $377,660.43 Avg Annual Cost: $16,101.07

Annualized Cost for Falls 7, 8, and 12

7/30/2015 9:00:46AM

Initial terms:

Discount rate %: 3.5 | Period of analysis: 50 | Capital recovery factor: 0.042633709 | Avg annual cost: $16,000.38

Total initial cost:

Construction $214,033.00 + Real Estate $29,300.00 + Monitoring $11,100.00 + Other $0.00 = $254,433.00

Total Investment cost:

Total Initial Cost $254,433.00 + PED $0.00 + IDC $3,745.58 = $258,178.58

Initial investment:

Total Investment Cost $258,178.58 PV Factor 1.000000 Present Value = $258,178.58

Year	Cost	PV Factor	Present Value
0	$258,178.58	1.0000	$258,178.58
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$10,833.00	0.7089	$7,679.72
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$10,833.00	0.5026	$5,444.30
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$10,833.00	0.3563	$3,859.56
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$10,833.00	0.2526	$2,736.12
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$10,833.00	0.1791	$1,939.69

Net Totals: Cost: $430,843.58 Present Value: $375,298.71 Avg Annual Cost: $16,000.38

Annualized Cost for Falls 7 and 8

7/30/2015 8:50:19AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $13,361.51

Total initial cost:
Construction $166,724.00 + Real Estate $27,100.00 + Monitoring $11,100.00 + Other $0.00 = $204,924.00

Total Investment cost:
Total Initial Cost $204,924.00 + PED $0.00 + IDC $2,917.67 = $207,841.67

Initial investment:
Total Investment Cost $207,841.67 PV Factor 1.000000 Present Value = $207,841.67

Year	Cost	PV Factor	Present Value
0	$207,841.67	1.0000	$207,841.67
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$8,271.00	0.7089	$5,863.47
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$8,271.00	0.5026	$4,156.72
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$8,271.00	0.3563	$2,946.78
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$8,271.00	0.2526	$2,089.03
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$8,271.00	0.1791	$1,480.95

Net Totals: Cost: $354,196.67 Present Value: $313,402.50 Avg Annual Cost: $13,361.51

Annualized Cost for Falls 7

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $9,014.08

Total initial cost:
Construction $85,175.00 + Real Estate $15,900.00 + Monitoring $11,100.00 + Other $0.00 = $112,175.00

Total Investment cost:
Total Initial Cost $112,175.00 + PED $ 0.00 + IDC $1,490.56 = $113,665.56

Initial investment:
Total Investment Cost $113,665.56 PV Factor 1.000000 Present Value = $113,665.56

Year	Cost	PV Factor	Present Value
0	$113,665.56	1.0000	$113,665.56
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$4,372.00	0.7089	$3,099.39
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$4,372.00	0.5026	$2,197.22
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$4,372.00	0.3563	$1,557.65
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$4,372.00	0.2526	$1,104.25
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$4,372.00	0.1791	$782.82

Net Totals: Cost: $240,525.56 Present Value: $211,430.78 Avg Annual Cost: $9,014.08

Annualized Cost for Manoa Habitat Pools

7/30/2015 9:11:30AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $14,753.16

Total initial cost:
Construction $216,353.00 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $231,953.00

Total Investment cost:
Total Initial Cost $231,953.00 + PED $0.00 + IDC $3,786.18 = $235,739.18

Initial investment:
Total Investment Cost $235,739.18 PV Factor 1.000000 Present Value = $235,739.18

Year	Cost	PV Factor	Present Value
0	$235,739.18	1.0000	$235,739.18
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$10,644.00	0.7089	$7,545.73
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$10,644.00	0.5026	$5,349.31
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$10,644.00	0.3563	$3,792.23
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$10,644.00	0.2526	$2,688.38
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$10,644.00	0.1791	$1,905.84

Net Totals: Cost: $393,959.18 Present Value: $346,044.56 Avg Annual Cost: $14,753.16

Annualized Cost for Manoa Low-Flow Channel

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $49,564.05

Total initial cost:
Construction $1,001,513.0 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $1,017,113.00

Total Investment cost:
Total Initial Cost $1,017,113.00 + PED $0.00 + IDC $17,526.48 = $1,034,639.48

Initial investment:
Total Investment Cost $1,034,639.4 PV Factor 1.000000 Present Value = $1,034,639.48

Year	Cost	PV Factor	Present Value
0	$1,034,639.48	1.0000	$1,034,639.48
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$19,452.00	0.7089	$13,789.89
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$19,452.00	0.5026	$9,775.91
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$19,452.00	0.3563	$6,930.33
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$19,452.00	0.2526	$4,913.04
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$19,452.00	0.1791	$3,482.95

Net Totals: Cost: $1,236,899.48 Present Value: $1,162,555.48 Avg Annual Cost: $49,564.05

Annualized Cost for Manoa Resting Riffles

7/30/2015 9:08:36AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $15,104.61

Total initial cost:
Construction $223,759.00 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $239,359.00

Total Investment cost:
Total Initial Cost $239,359.00 + PED $0.00 + IDC $3,915.78 = $243,274.78

Initial investment:
Total Investment Cost $243,274.78 PV Factor 1.000000 Present Value = $243,274.78

Year	Cost	PV Factor	Present Value
0	$243,274.78	1.0000	$243,274.78
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$10,998.00	0.7089	$7,796.69
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$10,998.00	0.5026	$5,527.22
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$10,998.00	0.3563	$3,918.35
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$10,998.00	0.2526	$2,777.79
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$10,998.00	0.1791	$1,969.23

Net Totals: Cost: $403,264.78 Present Value: $354,287.95 Avg Annual Cost: $15,104.61

Attachment 7

Addendum to

Mitigation, Monitoring and Adaptive Management Plan

Ala Wai Canal Project

U.S. Army Corps of Engineers, Honolulu District

14 July 2016

1. The draft Mitigation, Monitoring, and Adaptive Management Plan (MMAMP; USACE 2015) and its attachments describe the use of the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) to evaluate the impacts of the Ala Wai Canal project on aquatic habitat, and summarize the results of the HSHEP modeling effort. As with other Habitat Evaluation Procedure (HEP) models, the HSHEP uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density. The suitability relationships are converted into standardized Habitat Suitability Indices (HSI) that encompass the range of observed habitat conditions. Habitat quality is assessed based on the HSI values and habitat quantity is defined based on area, which when multiplied, provide overall habitat units (HUs) for a given area. Adverse impacts to stream habitat can then be expressed as HUs lost, while mitigation efforts that improve stream habitat can be quantified as HUs gained.

2. When the HSHEP was applied to the Ala Wai Canal project, following the methodology and assumptions detailed in the MMAMP, the resulting total HUs lost within the Ala Wai watershed due to project impacts was calculated as 192 under the “expected scenario” (described in Section 2.2 of the MMAMP) and 1,210 under the “worst-case scenario”. When these HU losses were compared against the HU gains calculated for an array of mitigation alternatives developed for the project, it was apparent that the mitigation alternative involving the removal of migration barriers at “Falls 7” and “Falls 8” would provide a sufficient gain in HUs to offset the HU losses from project impacts (Table 7 of the MMAMP).

3. In May 2016, the Corps’ internal review of the project revealed that several of the project elements would need to be redesigned to provide sufficient stormwater retention and management capacity. Some of the design changes, such as additional excavation within the detention basins and riprap scour protection downstream of the detention structures, represented additional impacts to stream habitat beyond what had been modeled by the HSHEP.

4. The Corps contracted James Parham of Parham and Associates Environmental Consulting, LLC, to update and rerun the HSHEP model to reflect the changes to project design (Parham 2016a). Dr. Parham’s update of the HSHEP spreadsheet included creating new model stream segments to reflect the updated plans, reviewing the impacts of the project changes and determining criteria for them. The most relevant design changes included in the updated model included:

- The addition or expansion of an upstream excavation area at three sites;
- The replacement of the open bottom arch culverts with box culverts at three sites; and
- The addition of downstream riprap scour protection areas at five sites.

Dr. Parham consulted with Glenn Higashi at the Hawaiian Division of Aquatic Resources in determining the impacts of the design changes. They followed a similar impact criteria methodology as had been developed for the first model, as much as possible. For the upstream excavation areas, they applied the expected and maximum impact criteria values as had been previously determined for the first model; similar criteria values were applied to the new downstream riprap scour protection areas. In both of these cases, it is likely that there will be some habitat in the stream in these areas although it is not considered a natural stream bottom. The maximum impact would remove 100% of habitat in these areas. No changes in criteria scoring were made for the actual detention dam footprint as that had already been determined for the first model. For the change from the natural bottom arch culvert to the box culvert, they applied the same values as the determined for channelized stream segments in the first model. Each box culvert was assigned the barrier impact value of 100 meters of channelized stream, although the box culverts will range in length from roughly 49 to 62 meters, providing some conservatism to the assessment of impact of the box culverts (Parham 2016b).

5. Table 1 below updates Table 7 from the MMAMP, comparing the calculated HUs lost with the redesigned project ("2016 Scope") with those calculated for the original scope, and with the net HU gained from an abbreviated set of mitigation alternatives. Despite the additional impacts to stream habitat inherent in the project design changes, <u>the benefit from the "Falls 7 and 8" mitigation alternative remains sufficient to offset the total project impacts.</u>

Table 1. Comparison of HUs Lost/Gained between Original and Expanded Project Scope

Location	*2015 Scope With-Project HUs Lost*	2016 Scope With-Project HUs Lost	Mitigation Alternatives – Net HUs Gained		
			"Falls 7"	"Falls 7, 8"	"Falls 7, 8, 11"
EXPECTED SCENARIO					
Manoa Stream	*191*	233	1,308	3,736	5,147
Palolo Stream	*-107*	-59	0	0	0
Makiki Stream	*24*	38	0	0	0
Hausten Ditch	*84*	84	0	0	0
Total	***192***	**295**	**1,308**	**3,736**	**5,147**
WORST CASE SCENARIO					
Manoa Stream	*808*	825	796	2,688	4,065
Palolo Stream	*-29*	-15	0	0	0
Makiki Stream	*11*	29	0	0	0
Hausten Ditch	*420*	420	0	0	0
Total	***1,210***	**1,259**	**796**	**2,688**	**4,065**

References:

U.S. Army Corps of Engineers, Honolulu District (USACE). 2015. Mitigation, Monitoring, and Adaptive Management Plan (draft), Ala Wai Canal Project, Oahu, Hawaii. August 2015.

Parham, James E. 2016a. Ala Wai HSHEP Impact Worksheet Final 07/07/2016 with updated plans. 7 July 2016.

Parham. 2016b. Report on updating the spreadsheet results for the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) associated with the streams in the Ala Wai Canal Flood Risk Management Study. 12 July 2016.

Report on updating the spreadsheet results for the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) associated with the streams in the Ala Wai Canal Flood Risk Management Study.

7/12/2016

Submitted to:

Michael D. Wyatt, POH

US Army Corps of Engineers

Honolulu, Hawaii

Submitted by:

James E. Parham. Ph.D.

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Introduction:

The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) was used to estimate current conditions and project impacts for proposed actions in Manoa, Makiki, and Palolo Streams associated with the Ala Wai Canal Flood Mitigation Project. The application of the model was based on extensive field surveys within the streams as well as stream surveys statewide. To estimate project impacts, the designs of the flood mitigation projects were used as defined at the time. As the project has advanced, changes to the design specification occurred in response to overall project review. This report documents changes to the original HSHEP model which reflect the new project design specifications.

In addition to this report, an updated spreadsheet of the results and GIS shapefiles of the newly defined segments has been provided to the US Army Corps of Engineers (USACE).

Methods:

Several steps needed to be completed to update the spreadsheet to allow the new changes to be reflected in the results:

1. New stream segments associated with the updated plans were created in ArcGIS 10.2.
2. The new segments had their instream habitat conditions associated with them from the prior model.
3. The new segments had the habitat suitability for the native instream biota associated with them from the prior model.
4. The impacts of the new design specification changes were reviewed and criteria were determined for them.
5. All of these changes were updated into the HSHEP spreadsheet and new impacts were determined for the current conditions and eight different mitigation scenarios.

The following further describes the steps:

<u>Development of New Stream Segments:</u>

The USACE provided PDF copies of the new flood mitigation projects sites (Appendix 1) and associated GIS shapefiles. In addition to the drawings, a spreadsheet of the changes was also provided (Appendix 2). Some additional guidance to understanding the changes was also provided by USACE in an email discussion.

Primarily, there were three changes associated with the new plans:

1. The addition or expansion of an upstream excavation area,
2. the replacement of the open bottom arch culverts with box culverts, and
3. the addition of downstream riprap scour protection areas.

These changes were not found at all sites and impacted different amounts of the stream channel. To create the new stream segments, the old stream segments were split and redefined based on the GIS shapefiles to reflect the new designs. At all five sites, all three types of plan changes were included within the model (Figure 1). When the project did not call for one of the changed types, a segment with zero length was included in the model. This was done for consistency of approach and for flexibility in modeling possible future changes to the plans. Stream segment code numbers were modified to clearly identify the site changes.

30	28	Manoa	Manoa	
31	29	Manoa	Manoa	
32	30	Manoa	Manoa	
33	31	Manoa	Manoa	
34	32	Manoa	Manoa	
35	50	Manoa	Waiahi	
36	51	Manoa	Waiahi	
37	52	Manoa	Waiahi	
38	53	Manoa	Waiahi	Waiahi Detention Basin
39	54	Manoa	Waiahi	
40	55	Manoa	Waiahi	
41	56	Manoa	Waiahi	
42	61	Manoa	Unnamed off Waiahi	
43	80	Manoa	Luaalaea	
44	81	Manoa	Luaalaea	
45	82	Manoa	Luaalaea	Waiakeakua Detention Basin
46	83	Manoa	Luaalaea	
47	90	Manoa	Waiakeakua	
48	100	Manoa	Luaalaea	
49	110	Manoa	Luaalaea	
50	120	Manoa	Naniuapo	

31	29	Manoa	Manoa		Barrier: Falls 7
32	30	Manoa	Manoa		Barrier: Falls 8
33	31	Manoa	Manoa		
34	32	Manoa	Manoa		
35	50	Manoa	Waiahi		
36	51	Manoa	Waiahi		Barrier: Falls 11
37	52	Manoa	Waiahi		
38	5301	Manoa	Waiahi	Waiahi Detention Basin Scour	yes
39	5302	Manoa	Waiahi	Waiahi Detention Basin	box
40	5303	Manoa	Waiahi	Waiahi Detention Basin Excavation	no
41	54	Manoa	Waiahi		
42	55	Manoa	Waiahi		
43	56	Manoa	Waiahi		
44	61	Manoa	Unnamed off Waiahi		
45	80	Manoa	Luaalaea		
46	81	Manoa	Luaalaea		Barrier: Falls 12
47	8201	Manoa	Luaalaea	Waiakeakua Detention Basin Scour	yes
48	8202	Manoa	Luaalaea	Waiakeakua Detention Basin	arch
49	8203	Manoa	Luaalaea	Waiakeakua Detention Basin Excavati	no
50	83	Manoa	Luaalaea		
51	90	Manoa	Waiakeakua		

Overal | Summary&Impacts | SegmentInfo | HSI | Current

Figure 1. Screen capture of Segment Info pages in old (left) and updated (right) HSHEP model result spreadsheets showing the creation of the new segment identification numbers.

<u>Associating Habitat Availability and Habitat Suitability to the New Segments from Prior Model Information</u>:

A similar process was used to associate the information from the HSHEP model with the newly defined stream segments. Given the short turnaround time allowed for this update, a complete redo of all stream segments within the model was not done. The new stream segments were reviewed against the model data for each segment and the appropriate data was included in the spreadsheet defining the results. As a result of this approach, there are small differences in some of the nearby segments that result in small changes to the overall habitat units within the model (54,572 HU in original model vs 54,458 HU in the new model). These changes are minuscule (0.209 % difference between models) and are unlikely to affect the overall conclusions for appropriate mitigation actions.

When reviewing the data for the new stream segment information, the original detention basin and upstream area were associated with the new detention basin footprint and upstream excavation area and the downstream riprap scour protection area was associated with the immediate downstream segment. In some cases, the new project site footprints included more than one downstream or upstream segment and in these cases the appropriate information was applied from all affected stream segments. The exact linear measurements for each area were determined from the associated spreadsheet information provided by USACE and included within the model spreadsheet (Figure 2). This allowed for some discrepancies between GIS data sources while capturing the specifics of the new project designs.

	A	B	C	D	E	S	T	U	V	W
43	56	Manoa	Waiahi			567	15	90%	4	2333
44	61	Manoa	Unnamed off Waiahi			531	15	90%	4	2184
45	80	Manoa	Luaalaea			191	34	90%	9	1768
46	81	Manoa	Luaalaea		Barrier: Falls 12	12	24	90%	7	80
47	8201	Manoa	Luaalaea	Waiakeakua Detention Basin Scour	yes	46	24	90%	7	306
48	8202	Manoa	Luaalaea	Waiakeakua Detention Basin	arch	61	27	90%	8	458
49	8203	Manoa	Luaalaea	Waiakeakua Detention Basin Excavati	no	0	25	90%	7	0
50	83	Manoa	Luaalaea			38	25	90%	7	261
51	90	Manoa	Waiakeakua			864	15	90%	4	3557
52	100	Manoa	Luaalaea			257	20	90%	5	1413
53	110	Manoa	Luaalaea			960	15	90%	4	3949
54	120	Manoa	Naniuapo			815	15	90%	4	3354
55	200	Palolo	Palolo			44	30	85%	8	344
56	201	Palolo	Palolo	Channelized	Chan Barrier	528	40	33%	4	2086
57	202	Palolo	Palolo			570	30	86%	8	4522
58	203	Palolo	Palolo	Channelized	Chan Barrier	2003	38	45%	5	10451
59	210	Palolo	Waiomao	Channelized	Chan Barrier	154	35	45%	5	739
60	211	Palolo	Waiomao			789	35	45%	5	3788
61	212	Palolo	Waiomao			269	22	83%	6	1489
62	213	Palolo	Waiomao			0	25	90%	7	0
63	2141	Palolo	Waiomao	Waiomao Detention Basin Scour	yes	46	25	90%	7	318
64	2142	Palolo	Waiomao	Waiomao Detention Basin	box	52	20	90%	5	285
65	2143	Palolo	Waiomao	Waiomao Detention Basin Excavation	Barrier: P_Falls 5 (yes)	122	35	89%	9	1150
66	216	Palolo	Waiomao			1768	15	90%	4	7275
67	220	Palolo	Pukele	Channelized	Chan Barrier	566	40	50%	6	3447
68	221	Palolo	Pukele			459	30	90%	8	3777
69	222	Palolo	Pukele			262	30	90%	8	2156
70	2231	Palolo	Pukele	Pukele Detention Basin Scour	yes	46	30	90%	8	379
71	2232	Palolo	Pukele	Pukele Detention Basin	box	49	30	90%	8	403

Figure 2. Screen capture of the updated HSHEP model spreadsheet showing the newly determined stream lengths (column S) for the site changes. For row 49, the Waiakeakua Upstream excavation area the stream length is 0 reflecting no upstream excavation area although the stream segment coding is in place for future site modifications. Row 65 shows the Waiomao Excavation area and its appropriate length of 122m (400 ft).

Determining Impacts of New Design Changes:

Determining the impacts of the new design changes was done in consultation with Glenn Higashi at the Hawaii Division of Aquatic Resources. We attempted to follow similar impact criteria as had been developed for the first model. For the upstream excavation areas, we applied the expected and maximum impact criteria values as had been previously determined for the first model. For the downstream riprap scour protection areas, we applied similar criteria values (Figure 3). In both of these cases, it is likely that there will be some habitat in the stream in these areas although it is not considered a natural stream bottom. The maximum impact would remove 100% of habitat in these areas. No changes in criteria scoring were made for the actual detention dam footprint as that had already been determined for the first model. For the change from the natural bottom arch culvert to the box culvert, we applied the same values as the channelized barriers determined for the first model. In this case, we had assumed some decrease in passage for each 100 m of channelized stream (Figure 4). Although the box culverts were not 100 m in length, we considered them to have passage barrier values as if they were 100 m in length. This estimate avoided underestimating the impact of the fish passing under these dams through the box culverts.

	A	B	C	D
1	Habitat Impact Variables			
2		Habitat Remaining		
3	Type	Current Impact (live Values)	Expected Impact	Max Impact
4	Off-channel Detention Intakes	0.8	0.8	0
5	In-channel Sites	0	0	0
6	Upstream Detention Excavation	0.5	0.5	0
7	Channel Maintenance	0.5	0.5	0.5
8	Downstream Scour Area	0.5	0.5	0

Figure 3. Screen capture of the habitat impact weighting criteria used for the updated HSHEP model.

G	H	I	J	K
Barrier Impact Variables				
	Habitat Remaining			
Type	Current Impact (live Values)	Expected	Max Barrier	
Channelized Barriers (per 100m)	0.9	0.9	0.85	
Undercut Barriers	0.5	0.5	0.35	
Box Culverts	0.9	0.9	0.85	

Figure 4. Screen capture of the barrier impact weighting criteria used for the updated HSHEP model.

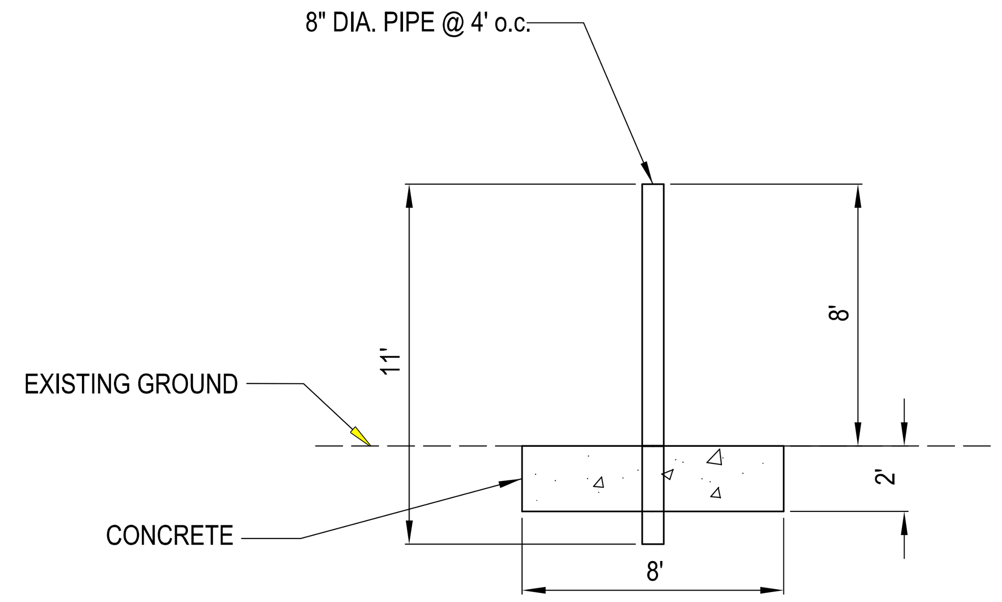
Updating the HSHEP Model Result Spreadsheet:

Results from the new model were added to the HSHEP model result spreadsheet. All formulas and dependencies were updated and double checked. The mitigation values for each of the eight different scenarios were recalculated and added to the overall results page.

Results and Conclusion:

An updated spreadsheet and associated GIS file were provided to the USACE with this report. The intent of this report is not to discuss the findings but to document the process in which the spreadsheet was updated with the new site information.

In a general sense, the conclusions of this updated model are unchanged from the first model run. The biggest difference is the loss of habitat associated with the increased footprint of the projects and a decrease in upstream passage where box culverts are used. The removal of the falls 7 and 8 as a mitigation scenario remains the most promising scenario in terms of habitat units gained for effort expended.



WAIHI DEBRIS AND DETENTION BASIN SECTION C-C

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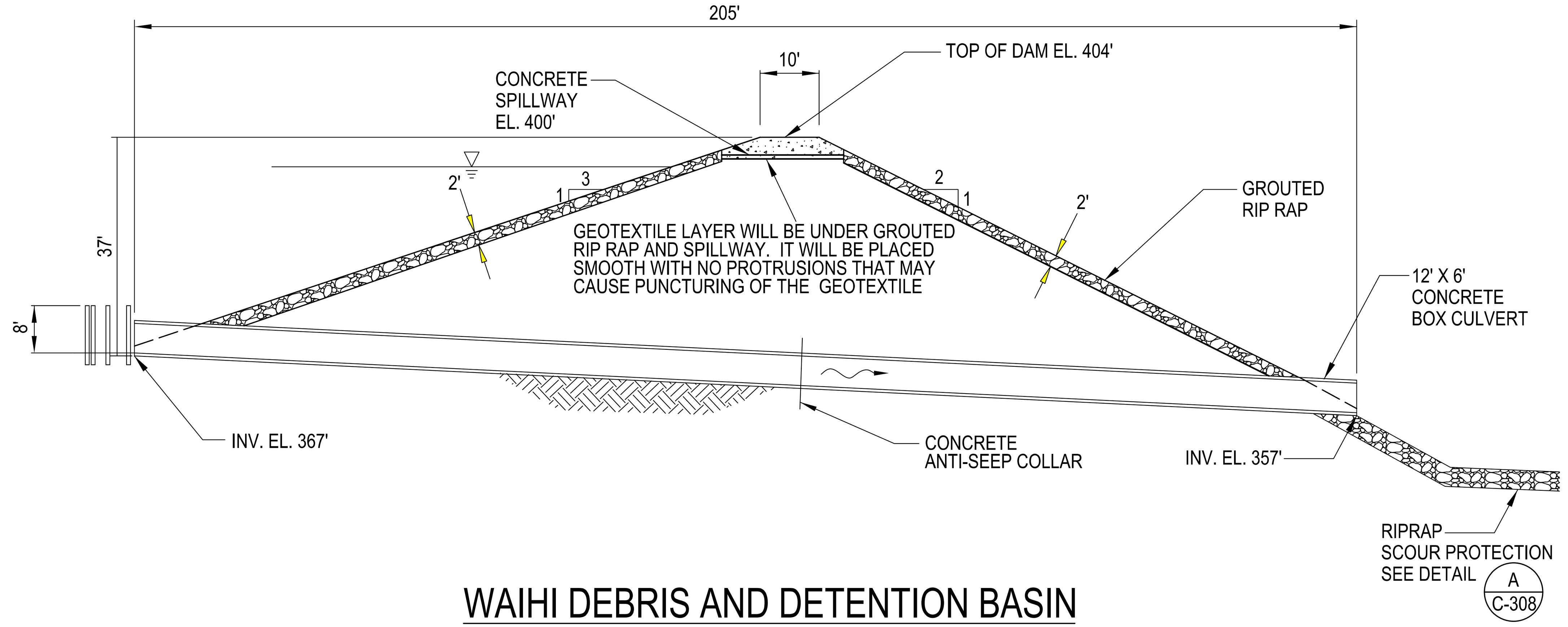

WAIHI DEBRIS AND DETENTION BASIN SECTION A-A

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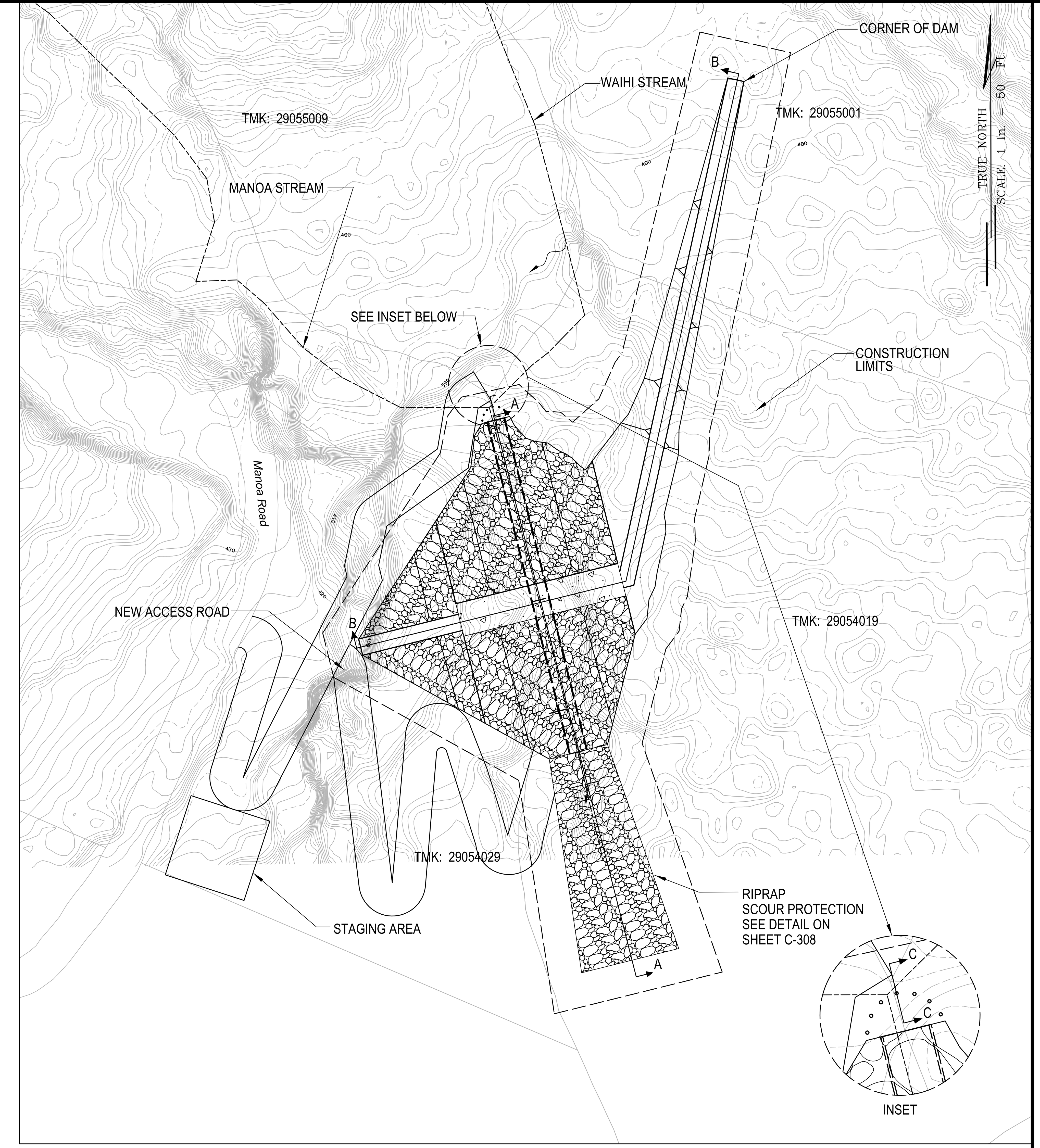

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PLAN

SCALE: 1"=50'

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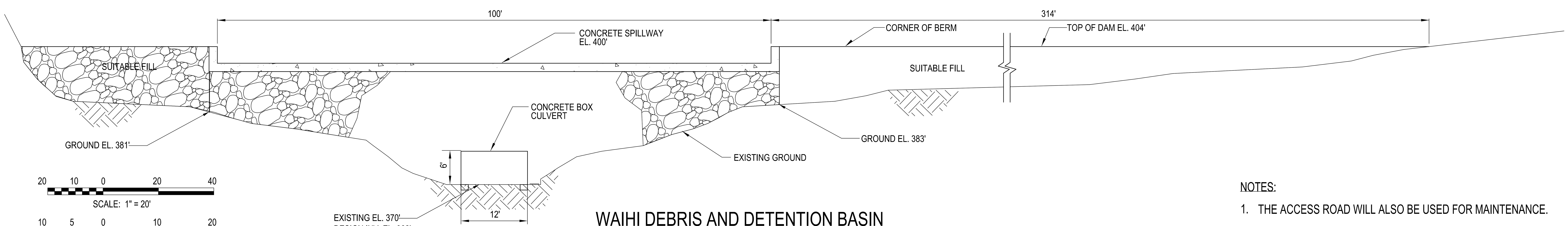
DOTTED LINE = 1' CONTOURS



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SCALE: 1" = 10'

Note: All elevations are feet MSL

WAIHI DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=10'

NOTES:

1. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

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ALA WAI CANAL PROJECT

WAIHI DEBRIS AND DETENTION BASIN PLAN AND SECTIONS

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C-301
SHEET 0 OF 31

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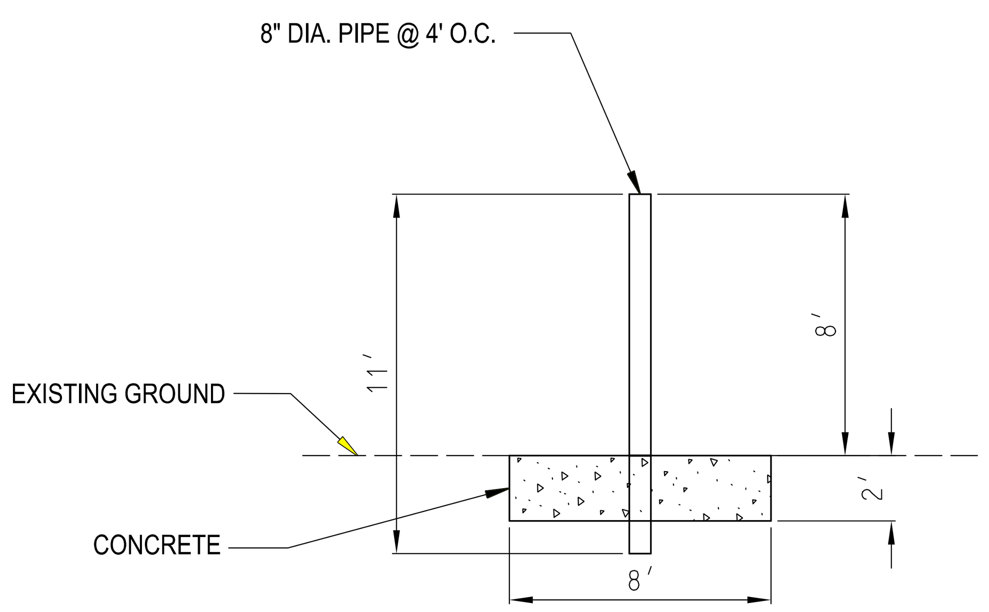

WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION C-C
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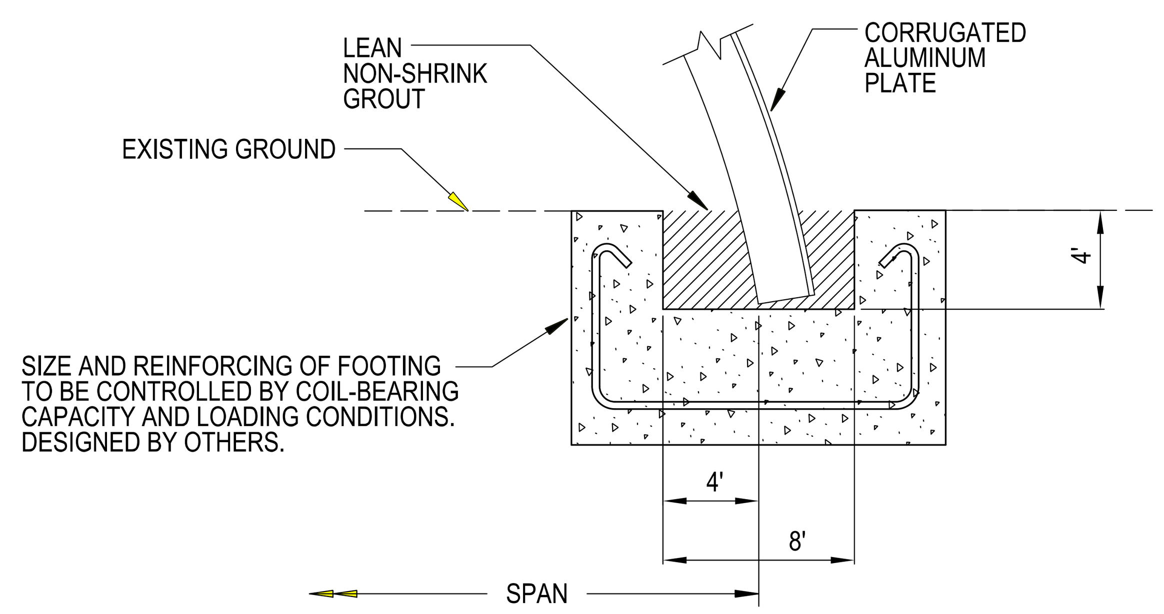

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WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION D-D
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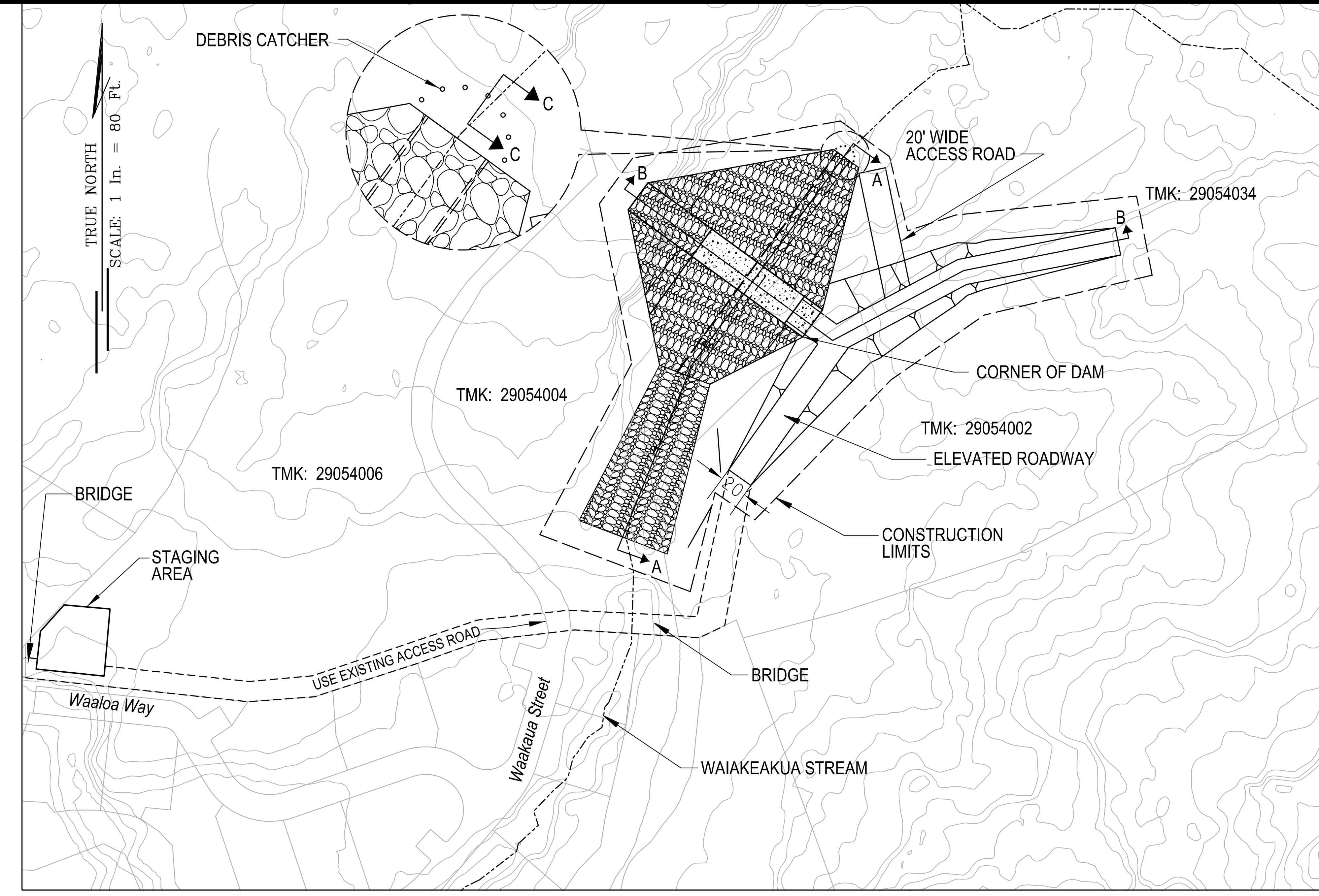

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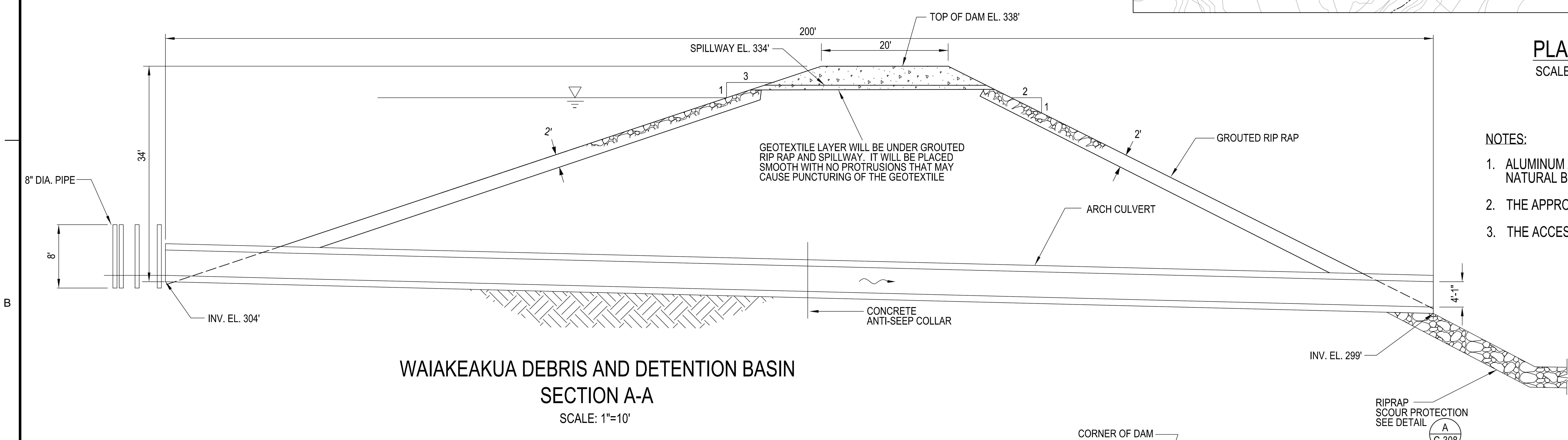
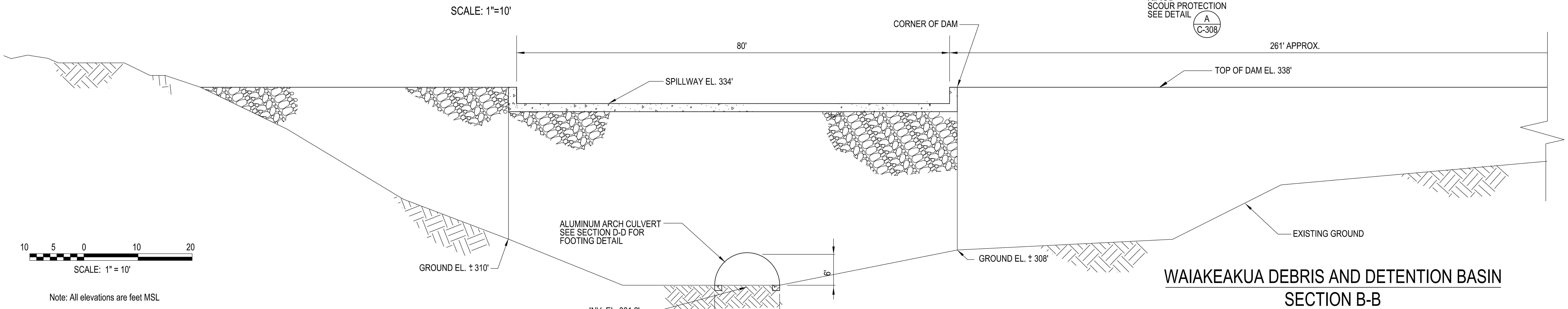
SCALE: 1" = 80'



WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.
3. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.



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SCALE: 1" = 10'

Note: All elevations are feet MSL

WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

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ALA WAI CANAL PROJECT

WAIAKEAKUA DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

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C-302
SHEET 0 OF 31

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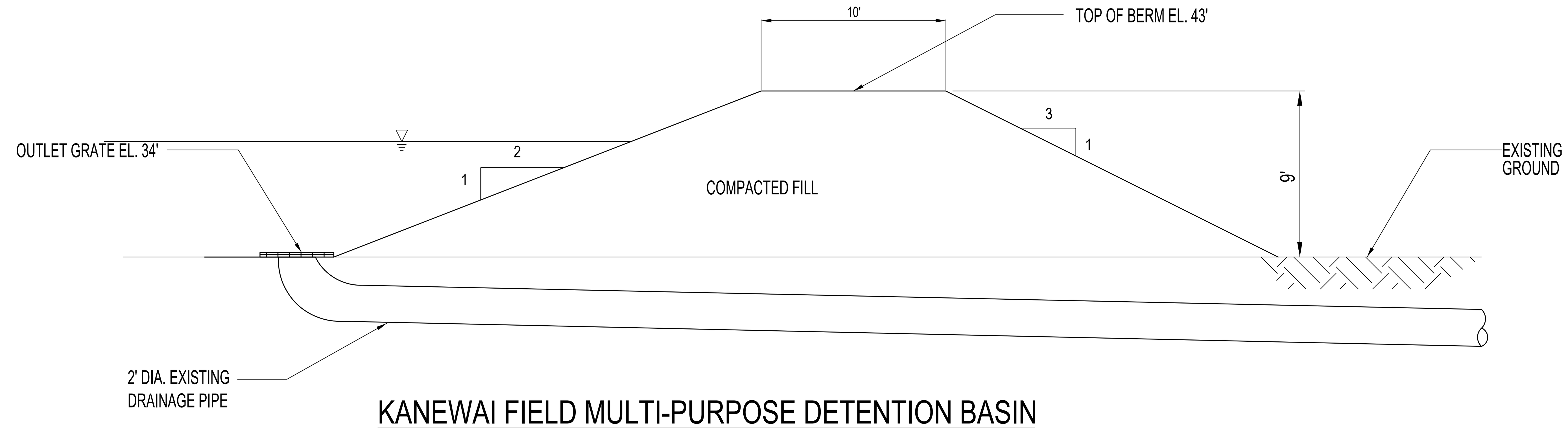
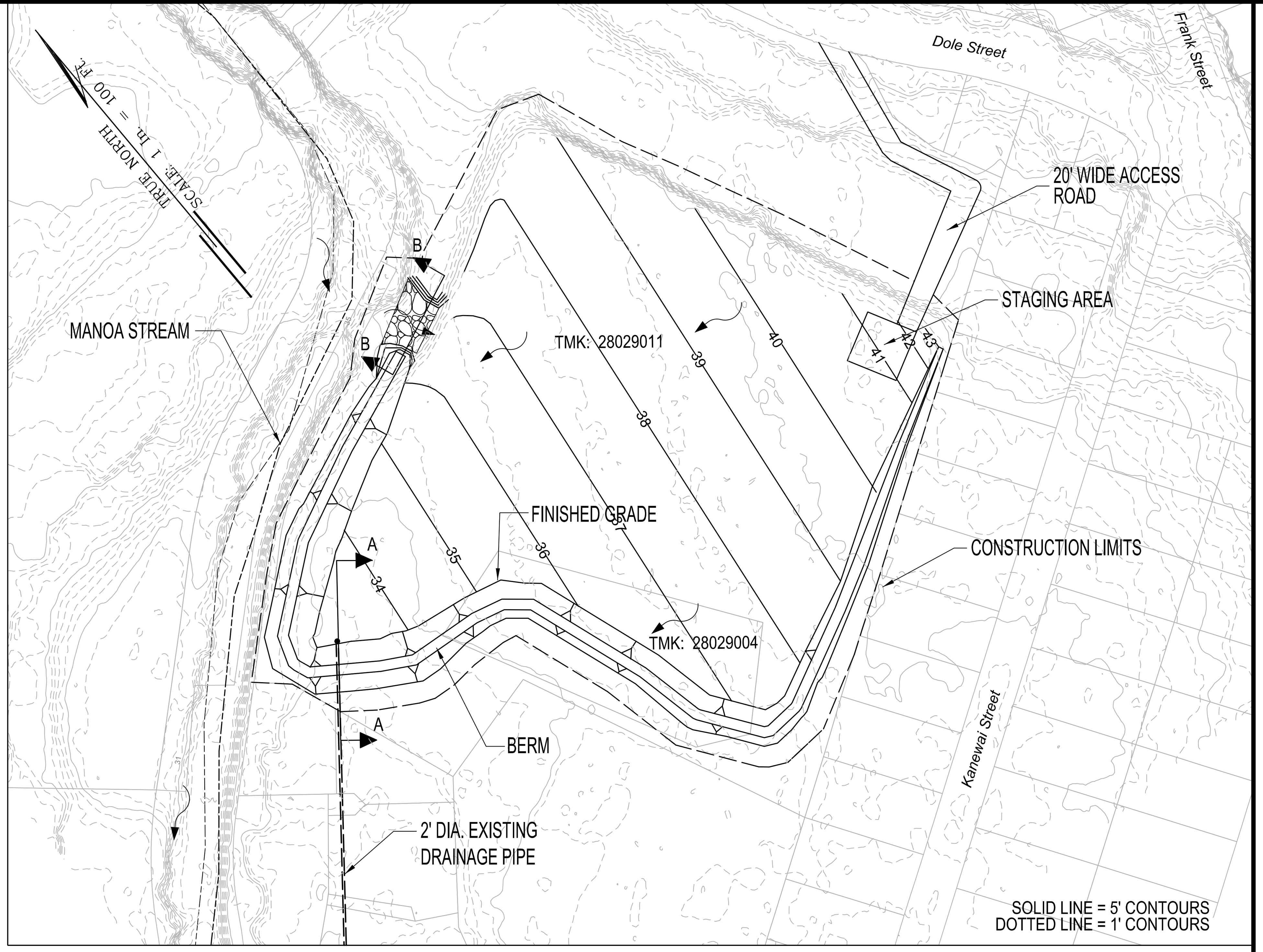


KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION A-A

SCALE: 1" = 5'



PLAN

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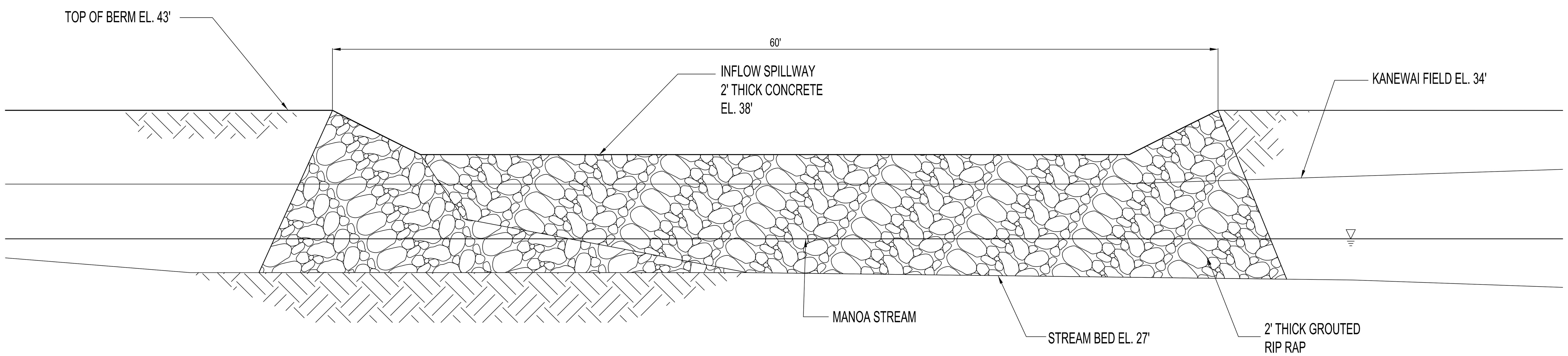

KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION B-B

SCALE: 1" = 5'

5' 2.5' 0 5' 10'

SCALE: 1" = 5'

Note: All elevations are feet MSL

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KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-306

SHEET 0 OF 31

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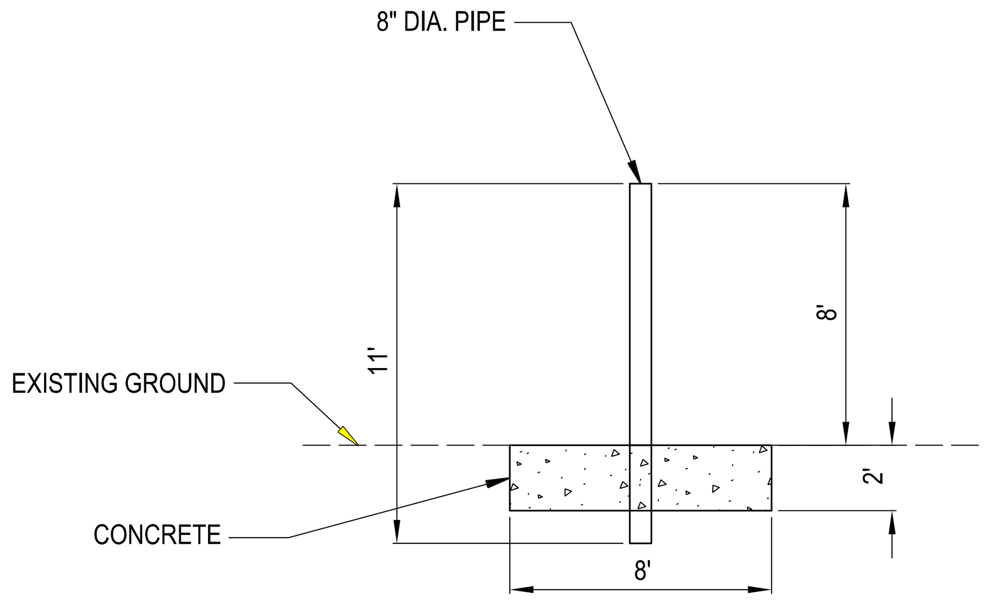
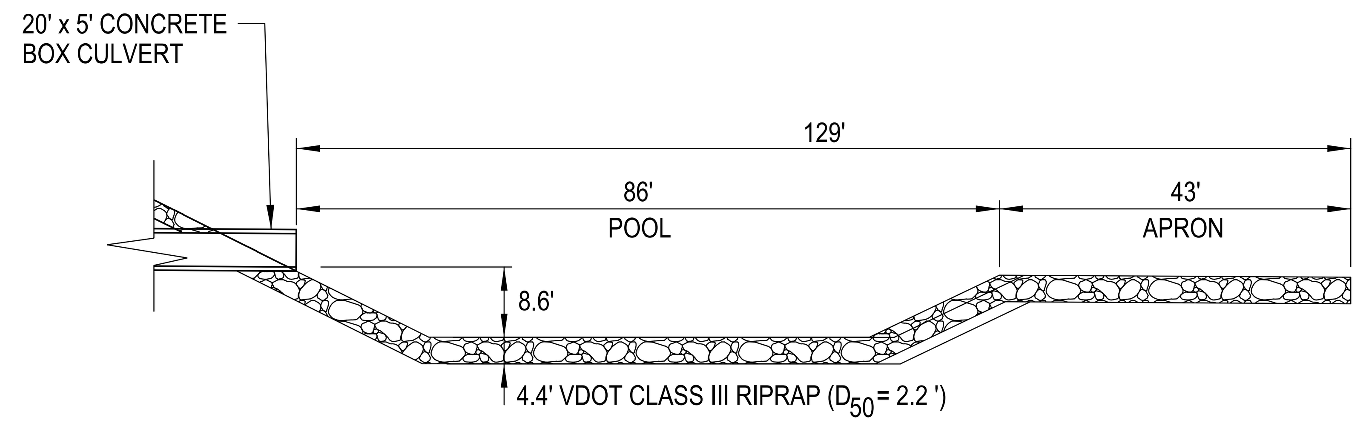


WAIOMAO DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



A
C-308
RIPRAP DISSIPATION & SCOUR PROTECTION DETAIL
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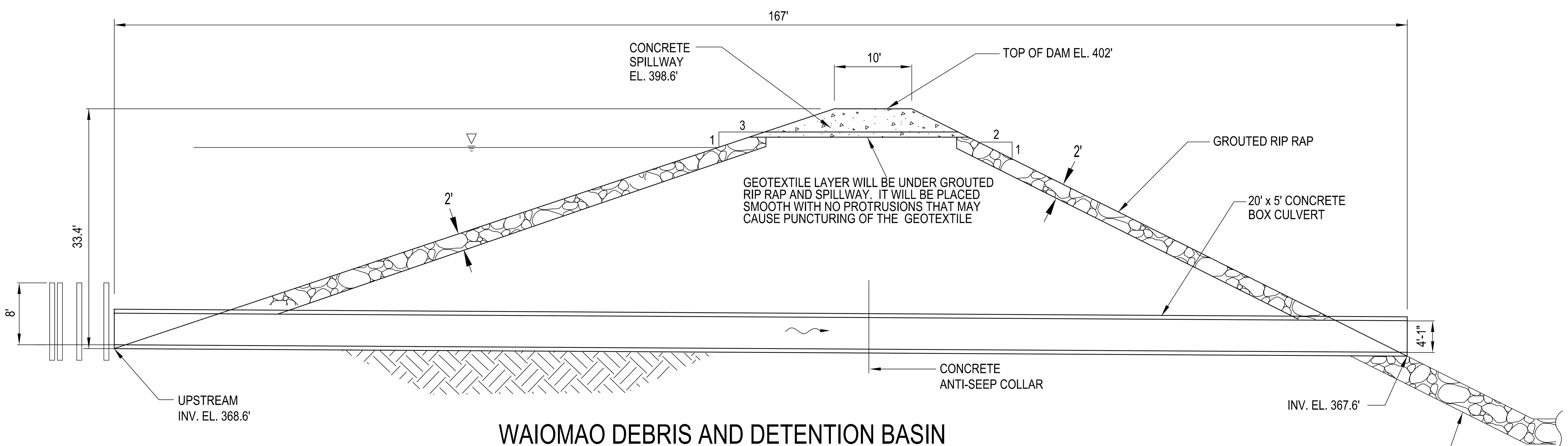
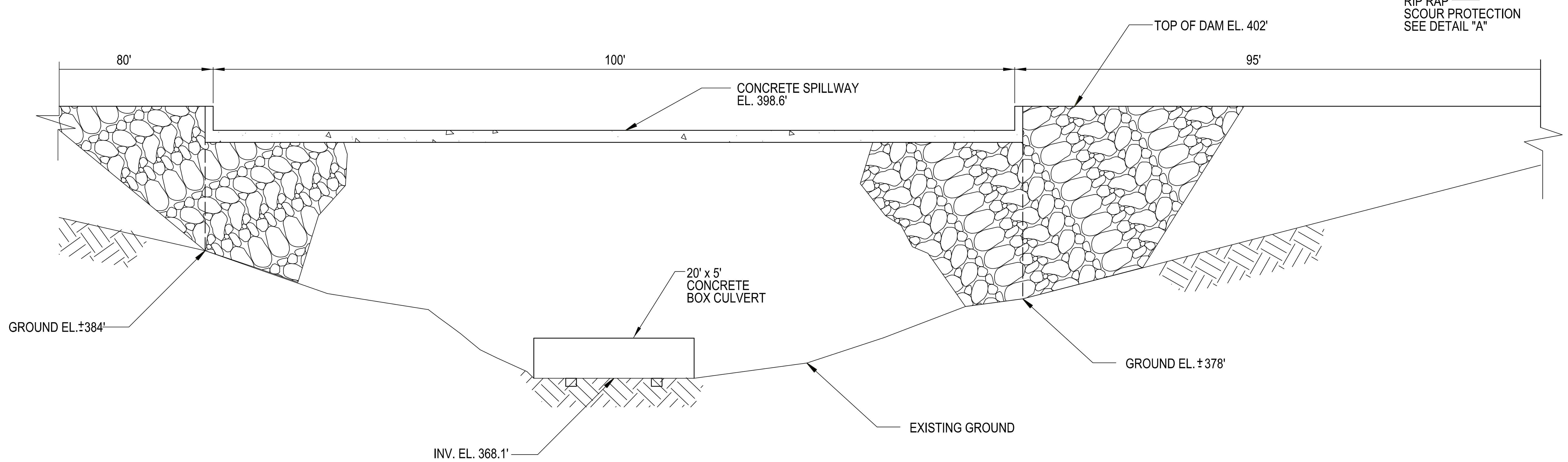


WAIOMAO DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



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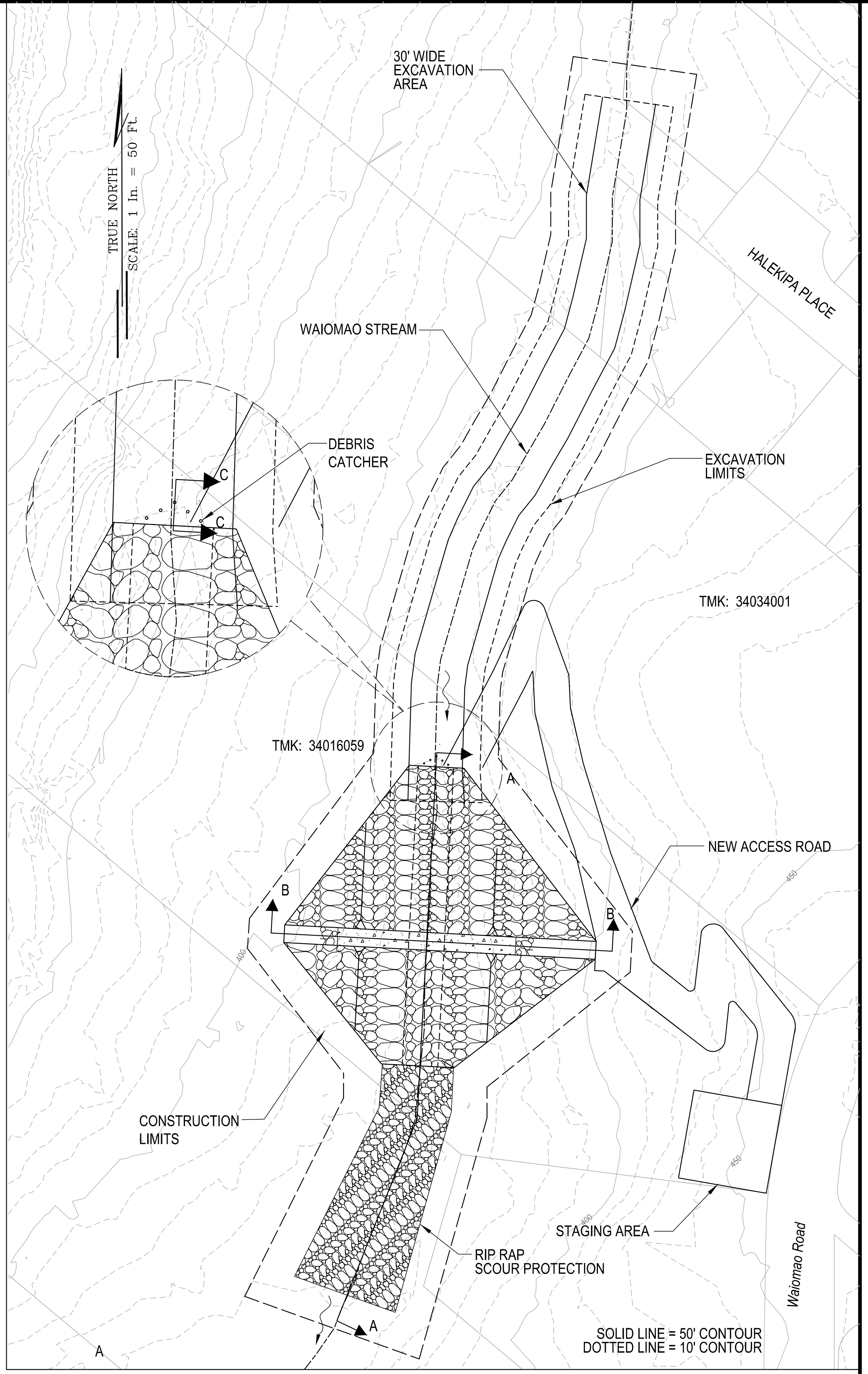
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

Note: All elevations are feet MSL



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50 25 0 50 100

SCALE: 1" = 50'

NOTES:

1. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

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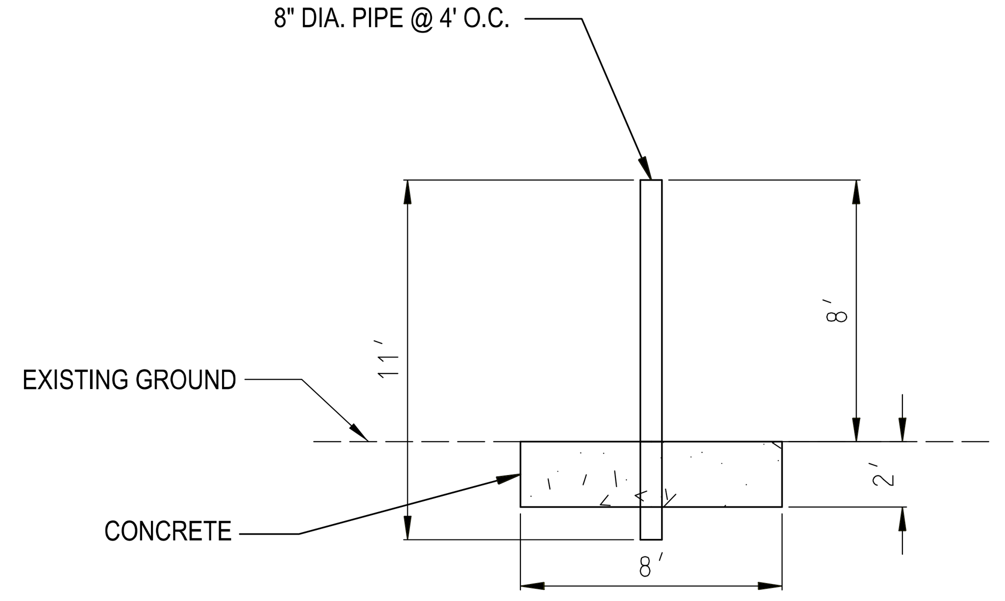
ALA WAI CANAL PROJECT

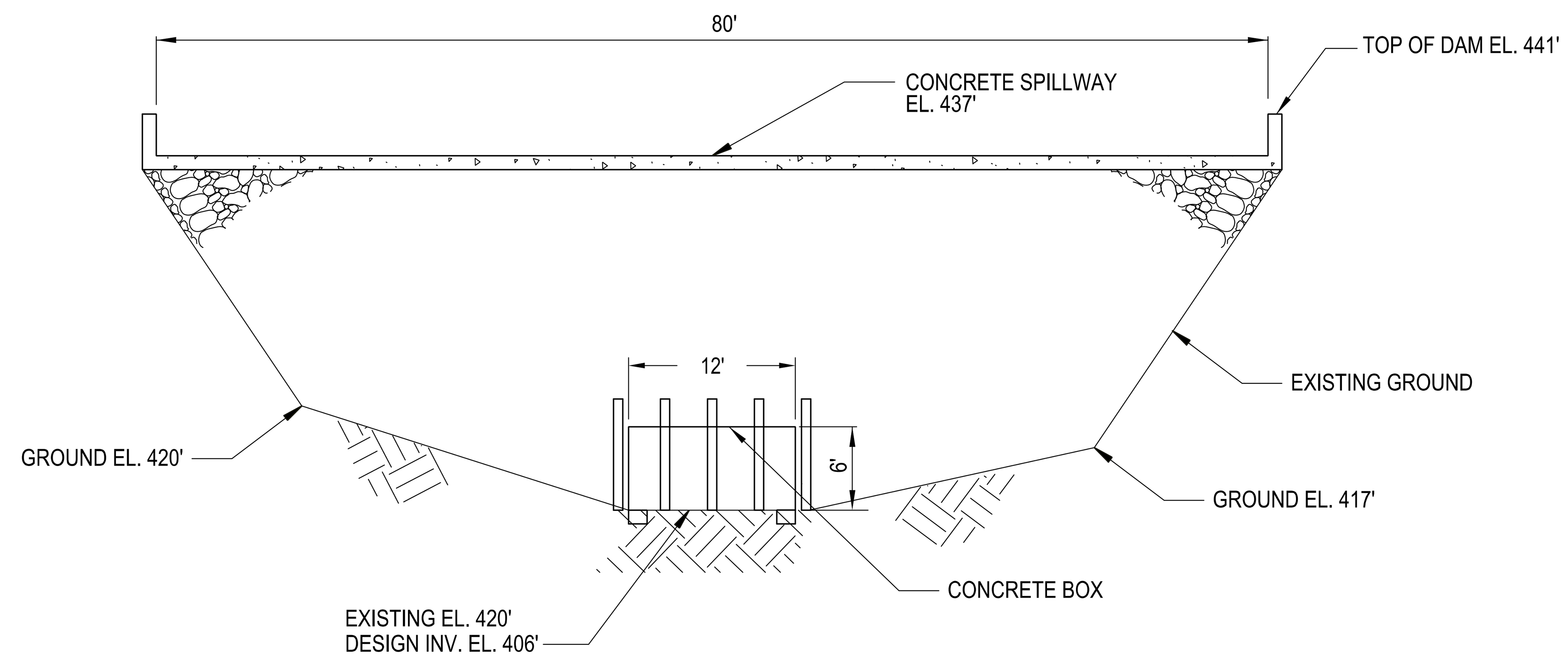
WAIOMAO DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET
IDENTIFICATION
C-308
SHEET 0 OF 31



PUKELE DEBRIS AND DETENTION BASIN SECTION A-A

SCALE: 1"=5'



PUKELE DEBRIS AND DETENTION BASIN SECTION C-C

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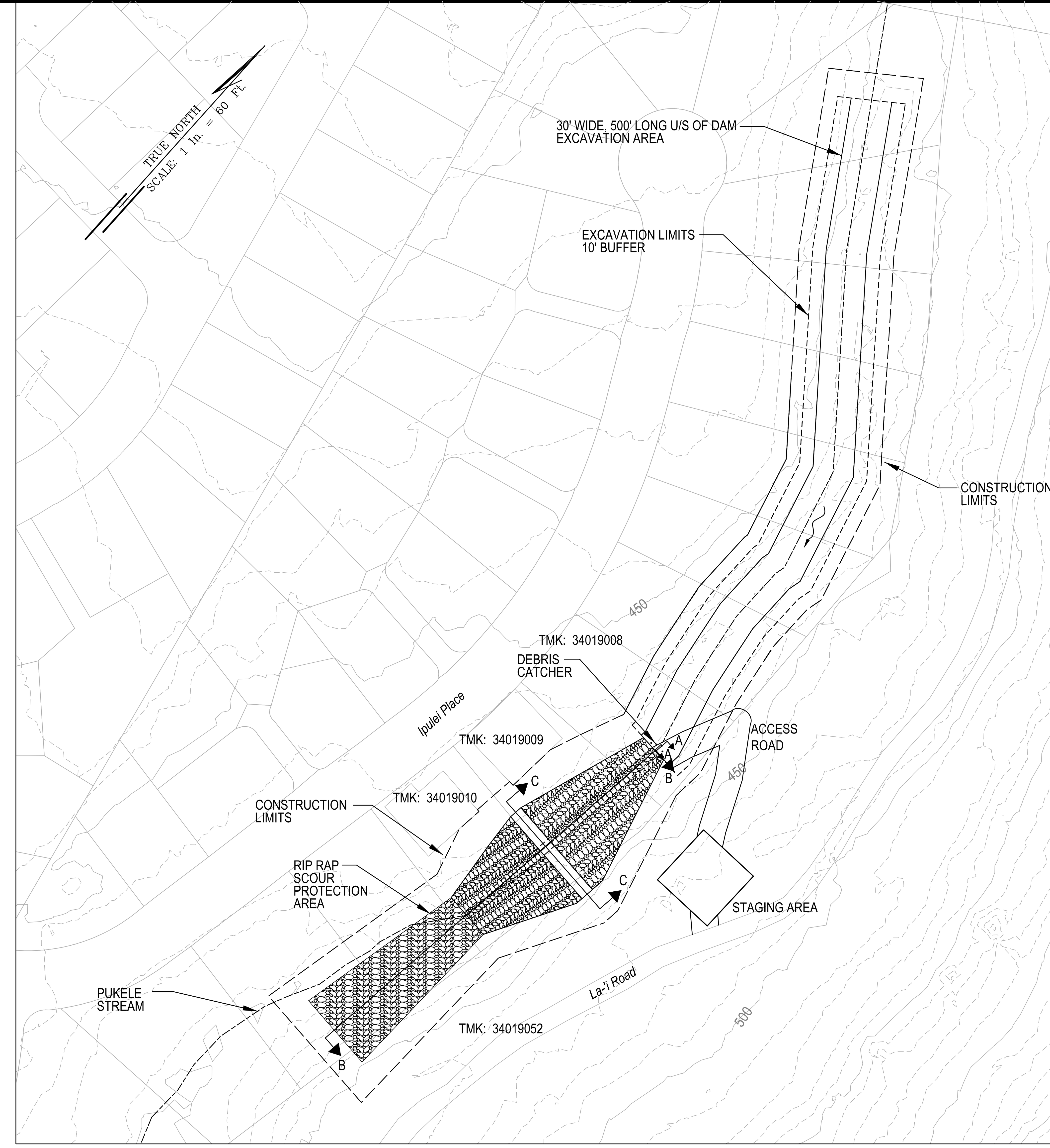

PLAN

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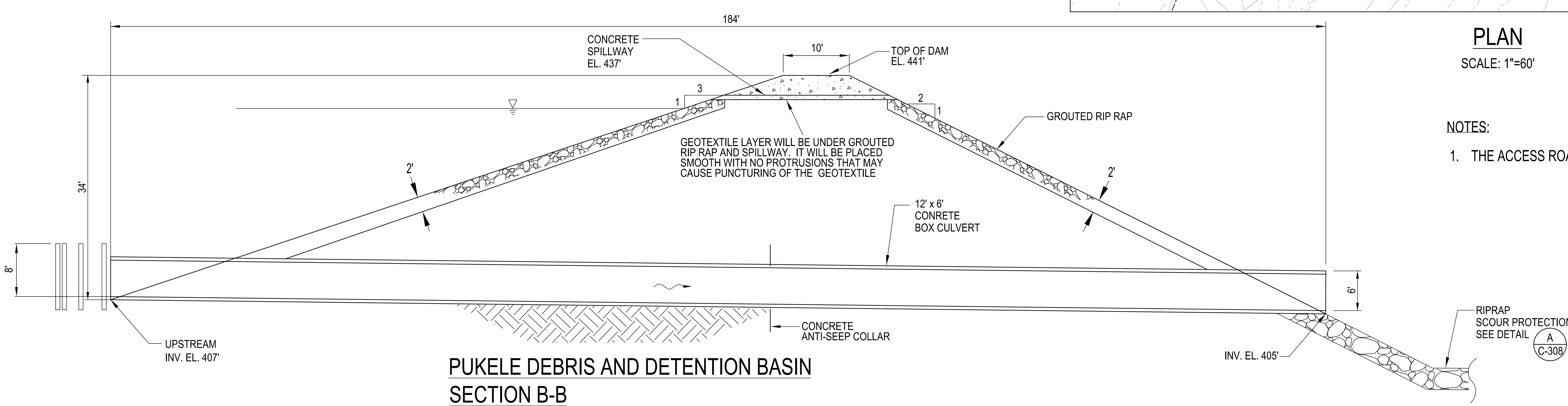
DOTTED LINE = 10' CONTOURS



PUKELE DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=5'

NOTES:

1. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

5 2.5' 0 5 10

SCALE: 1" = 5'

Note: All elevations are feet MSL

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PUKELE DEBRIS AND DETENTION BASIN PLAN AND SECTIONS

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C-313

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