



CHAPTER 4
WETLAND RESTORATION PLAN

CHAPTER 4 RESTORATION PLAN FOR KAWAINUI MARSH

4.1 Kawainui Marsh Conceptual Restoration Plan

Restoration improvements will involve gradual removal of invasive vegetation covering most of the marsh in the project area and restoring it with native vegetation. This will allow Kahanaiki Stream to naturalize, open up surface water flows, and establish seasonal mud flats. A combination of mechanical methods and localized application of herbicide will be implemented to address removal of existing vegetation. Staging areas will be established as appropriate for temporary storage of biomass awaiting transport to a processing site.

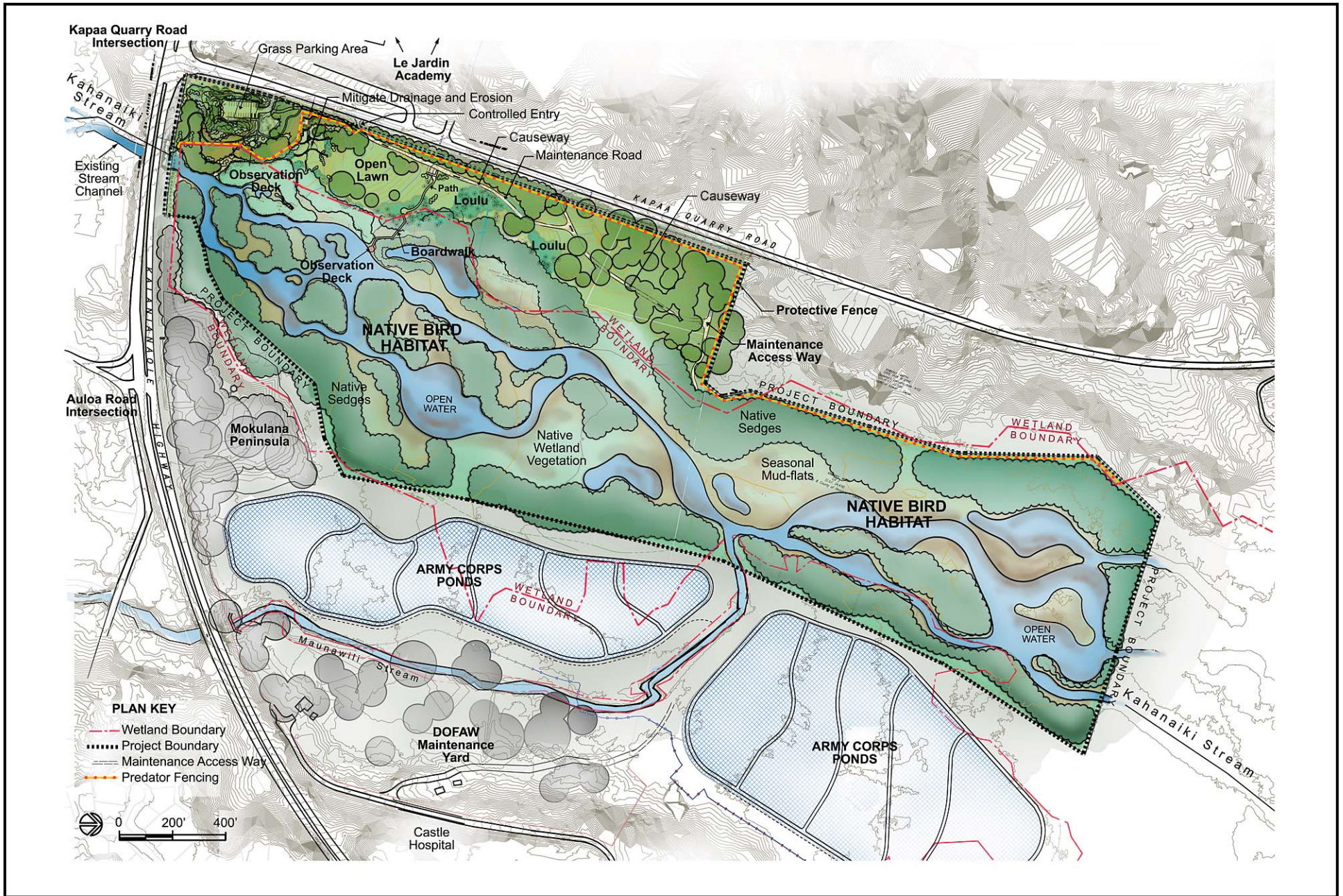
The conceptual restoration plan illustrated in Figure 4.1 provides an overview of major project improvements. This involves restoration of approximately 60 acres of natural wetland and 20 acres of upland riparian forest. The wetland boundary designated by the U.S. Corps of Engineers (dated July 17, 2008) is also identified and distinguishes the jurisdictional wetland area from the upland area. The figure also shows the location of the COE ponds on the makai (west) side of the project area. Construction of these bird habitat areas is intended to begin during the summer of 2011. The existing DOFAW Kawainui Marsh headquarters, which provides efficient access to both the project area and COE ponds to conduct maintenance activities, is also shown in the figure to highlight its proximity to the various

habitat sites that will require continued maintenance in the near future.

Restoring the wetland and naturalizing Kahanaiki Stream will enhance the natural habitat for endangered waterbirds, various species of migratory shorebirds, and waterfowl. Protective fencing will be installed around the project area and some adjacent lands to minimize intrusion by predators. The upland area near the intersection of Kapa'a Quarry Road with Kalaniana'ole Highway will be cleared of most vegetation to allow for re-shaping the area (the site consists of landfill spoils from previous construction in the area), landscaping with native vegetation, public access, and parking. Actions proposed for other upland areas include selective replacement of trees and vegetation with native vegetation. Re-establishing agricultural use (ex. taro *loi*) within the marsh is not included under this restoration plan.

Continuation of DOFAW maintenance operations will be provided by retaining efficient access to the restored wetland area and adjacent uplands for maintenance vehicles (pickup trucks or smaller) and equipment. Public access to the site is proposed for passive recreational use and educational opportunities. Related improvements include a parking area, pedestrian trails, viewing sites, and interpretive signage.


The following sections provide details regarding proposed improvements in the project area.



Kawainui Marsh Restoration Conceptual Plan
KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

Figure 4.1

Prepared for:
 State of Hawai'i
 Department of Land and Natural Resources
 Division on Forestry and Wildlife



4.2 Wetland Restoration Program

Wetland restoration actions will involve several phases over time based on seasonal conditions (wet and dry seasons), to allow Kahanaiki Stream and associated wetland areas to naturally re-establish within the project area. Figure 4.2 graphically illustrates the major components associated with specific actions to accomplish this objective. Restoration actions will incorporate an adaptive management process to allow DOFAW flexibility to adapt and modify activities depending upon the progress of restoration efforts in alignment with resource issues (e.g., funding, available staff, etc.). The adaptive management process includes assessing the situation, implementing improvements, monitoring and evaluating results, and adjusting methods.

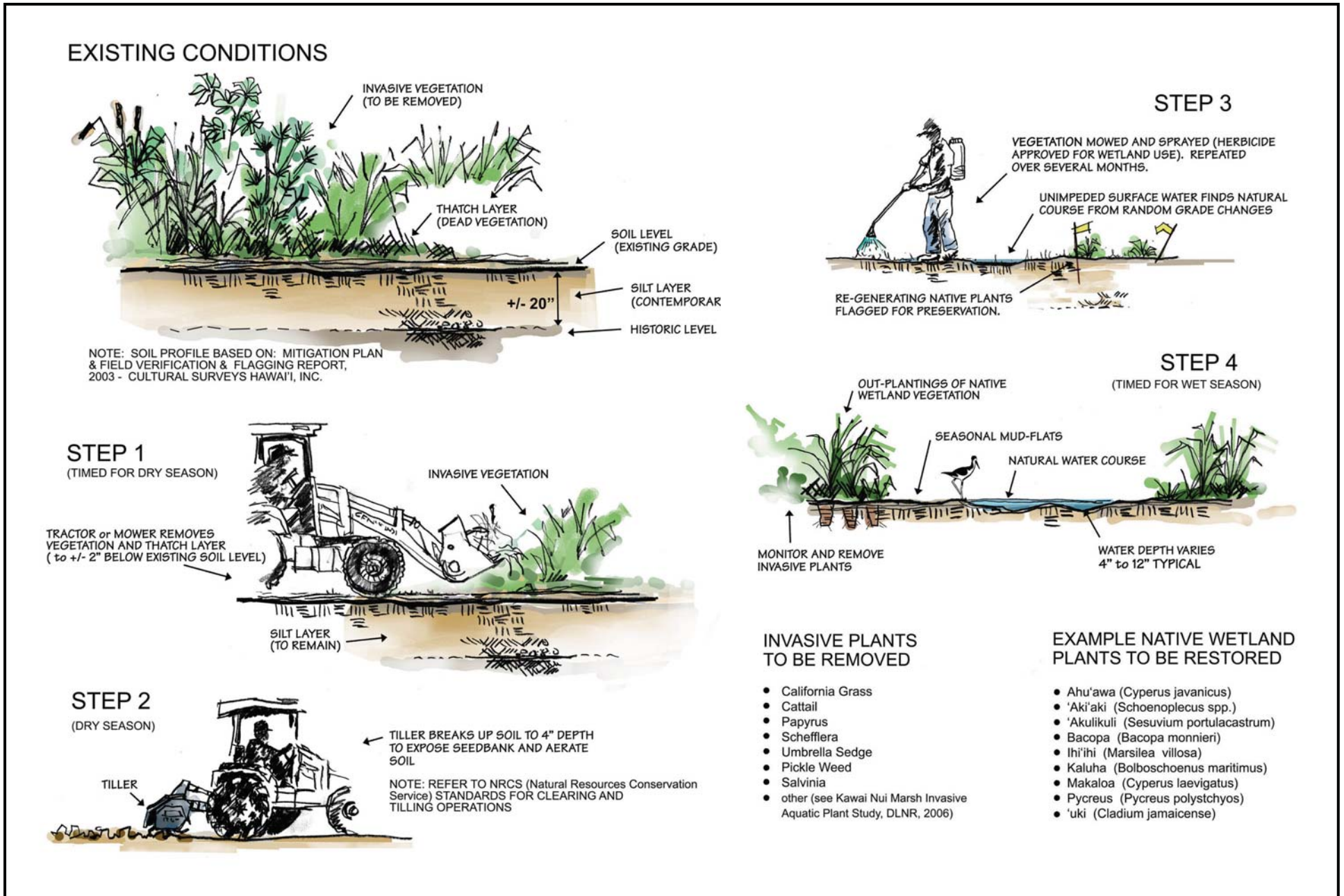
Existing invasive vegetation (e.g., California Grass, Cattail, etc.) will be removed along with dead vegetation that has formed a thatch layer. Based on prior test excavations, a contemporary soil layer about 20 inches deep is located below the existing vegetation. It is the result of sediment transported by storm water runoff into the marsh over many years. A tractor, mower, or floating excavator will be used to cut or grub the vegetation and thatch layer up to a few inches below the soil level.

A tiller will be used to break up the soil up to roughly 4-inches in depth to expose the invasive vegetation seed bank being eliminated and to aerate the soil. These activities would predominantly be conducted during the dry season to allow

efficient movement of equipment within the marsh area. Areas will be worked in phases of about three to four acres in size. These methods minimize potential impacts on subsurface archaeological sites, such as an *'auwai*, since they occur within the contemporary silt layer.

Invasive vegetation re-appearing in cleared areas will be mowed or sprayed with an herbicide approved for wetland use. This process will be repeated over several months. Unimpeded surface water flowing into this area from Kahanaiki Stream should then be allowed to re-establish its natural course through the area based on random changes in ground conditions. During the wet season, increased water flowing through this area should establish seasonal mud flats along the stream's natural watercourse. The water depth would typically vary from about four inches up to one foot in depth. Figure 4.3 shows a typical sectional view of the restored stream, wetland, and seasonal mud flats, and Exhibit 7 has a representative photo.

Native plants will be re-established in the wetland along with transitional sections to upland areas. Plants will be initially flagged for identification to prevent accidental application of herbicide. Preservation of marked areas allows for their growth and can be monitored to support re-establishment and minimize reoccurrence of invasive plants. Appendix B provides a plant list and images of recommended wetland plants that will be used.



Wetland Restoration Process

KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU

Figure 4.2

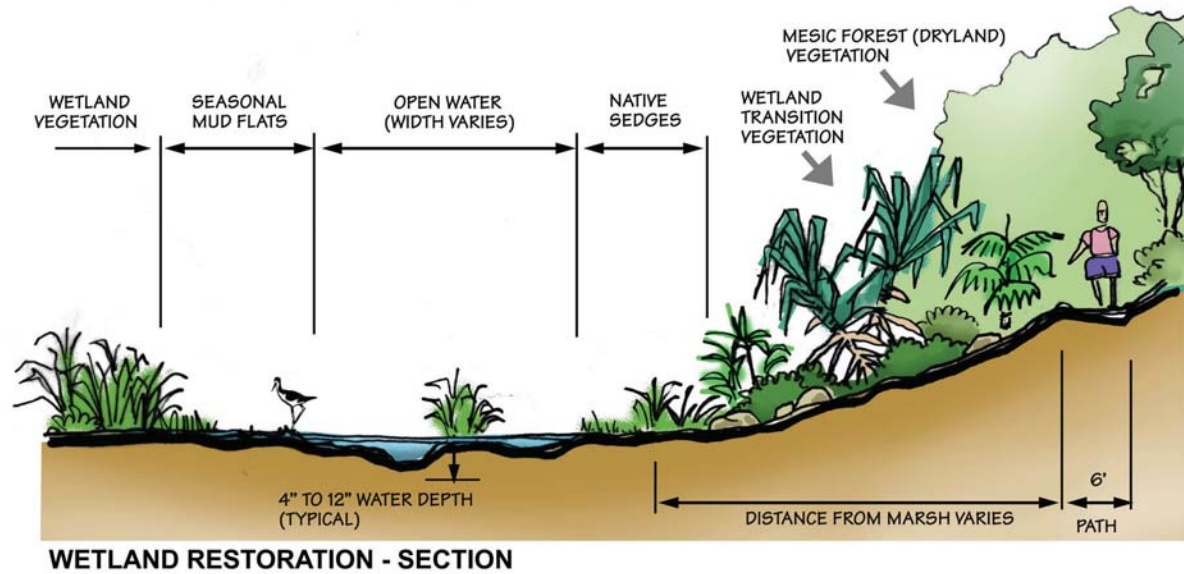




Boardwalk into Wetland



Variety of native wetland plants, open water, and mud-flats provides bird habitat.



Wetland Restoration Typical Section View
 KAWAINUI MARSH WETLAND RESTORATION
 AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

Figure 4.3



Exhibit 7 – Photo Representation of Restored Wetland

Vegetation mowed or grubbed will either be left on the site to decompose or temporarily stored in established staging areas within upland areas. Any top soil removed during clearing and grubbing operations would be dispersed on-site in areas above the wetland. This will aid retention of storm water, and it may also be mixed with vegetation to enhance decomposition. As a result, the amount of biomass needing to be removed from the site should be minimal. If required, vegetation will be moved to a holding site adjacent to the Model Airplane Park on Kapa‘a Quarry Road, then transported to the appropriate City refuse disposal site.

4.3 Upland Reforestation Concepts and Related Improvements

Restoration actions in the upland area along Kapa‘a Quarry Road will re-establish the area as a native upland forest area. DOFAW has begun clearing some trees and vegetation, resulting in an open grassed area. Proposed improvements will continue these efforts by reducing invasive vegetation and selectively removing trees. The upland area of the project site is divided into Area A and Area B; each having different natural conditions and types of vegetation. Improvement actions in these areas will focus on enhancing the natural characteristics of each area.

A hybrid ecosystem model for forest restoration illustrated in Figure 4.4 will be implemented to allow native and existing non-native species to mix in a transitional period. This benefits native biodiversity and aids the process of re-establishing a robust native forest. Since existing Hawaii forests have been heavily compromised by non-native invasive species, a restoration process using a direct approach of clearing non-native plants and replacing them with native species is not cost effective or even practical. By allowing some selective non-native plants to remain, particularly as over-story canopies, other aggressive invasive species can be contained while understory plantings of native species can grow and mature. Once an appropriate density of native vegetation has been restored, remaining non-native species (over-story canopies) can be removed without allowing invasive species to return.

Native Forest Restoration w/ Hybrid Ecosystem Model

EXISTING NON-NATIVE FOREST

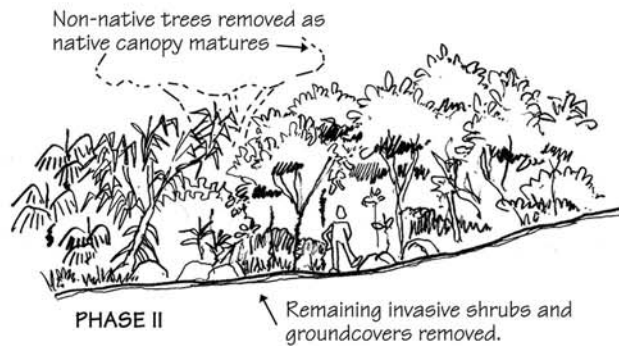
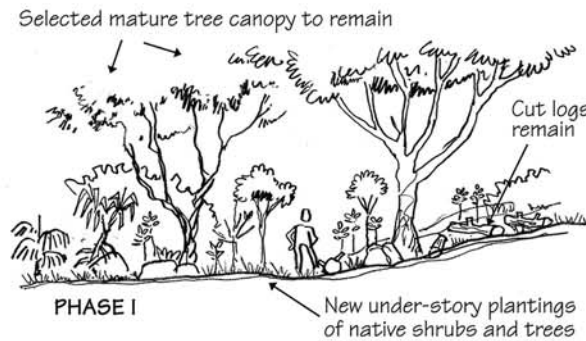
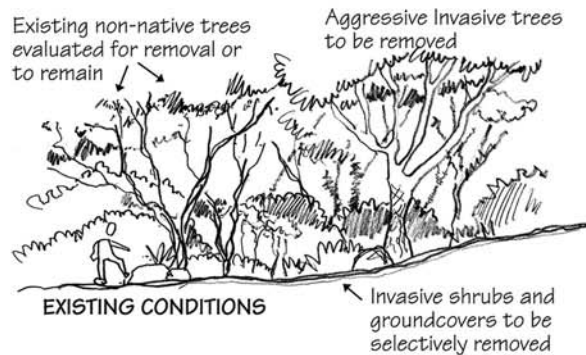
- Dominated by invasive species
- Complete removal of existing invasive plants is not practical

HYBRID ECOSYSTEM

- New native plantings co-exist with non-native over-story canopy
- Aggressive non-native plants are removed only around newly planted natives to allow good growth
- Existing non-native tree canopy helps to protect newly planted native under-story trees
- Non-aggressive weeds allowed to remain.
- Cut logs from removed trees are left in places to help cool soil, retain moisture, reduce erosion, and help encourage beneficial soil microbes and fungi.

NATIVE FOREST RESTORED

- Once maturity of native plants has been realized, remaining non-native plants are removed.
- Landscape is maintained to remove aggressive invasive plants as seedlings.



Invasive Plants to be Removed from Hybrid Ecosystem:

Java Plum
Albizia
Invasive vines
Strawberry Guava
Koa Haole
Brassaia
African Tulip Tree
Non-native Palms
All Non-native Seedling Trees

Mature Non-native Plants to Remain in Hybrid Ecosystem:

Monkeypod Tree
Banyan (selective removal)
Gun Powder Tree (selective removal)
Kukui
Hau (selective removal)
Opiuma
Mango
Kiawe (short thorn variety)

Native Forest Restoration with Hybrid Ecosystem Model

KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU

Figure 4.4

Prepared for:
State of Hawai'i
Department of Land and Natural Resources
Division on Forestry and Wildlife

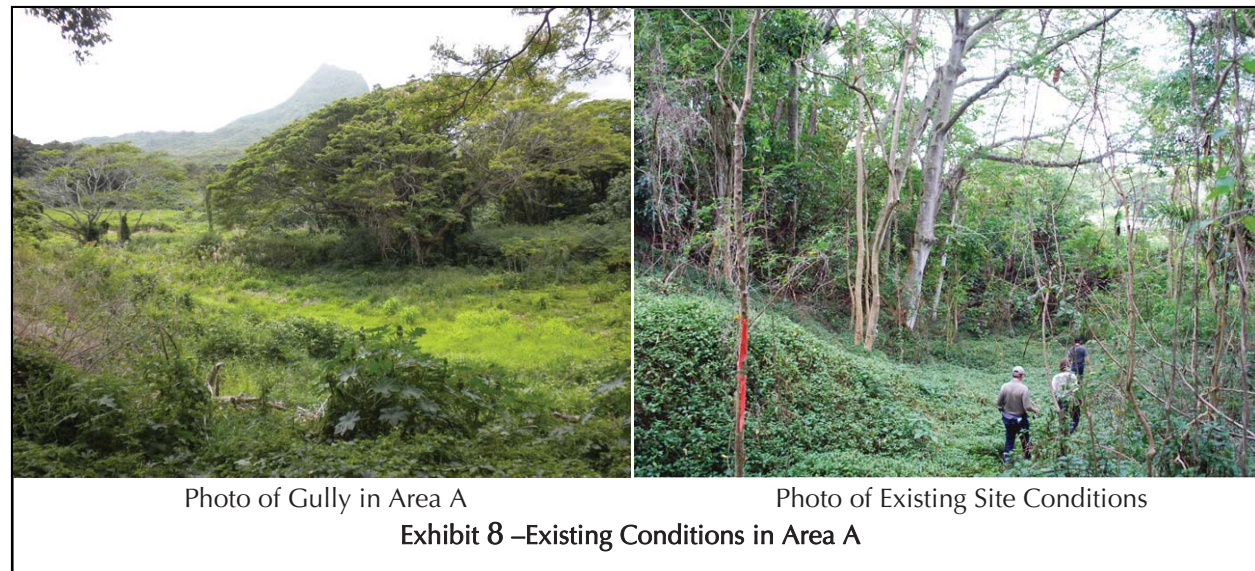


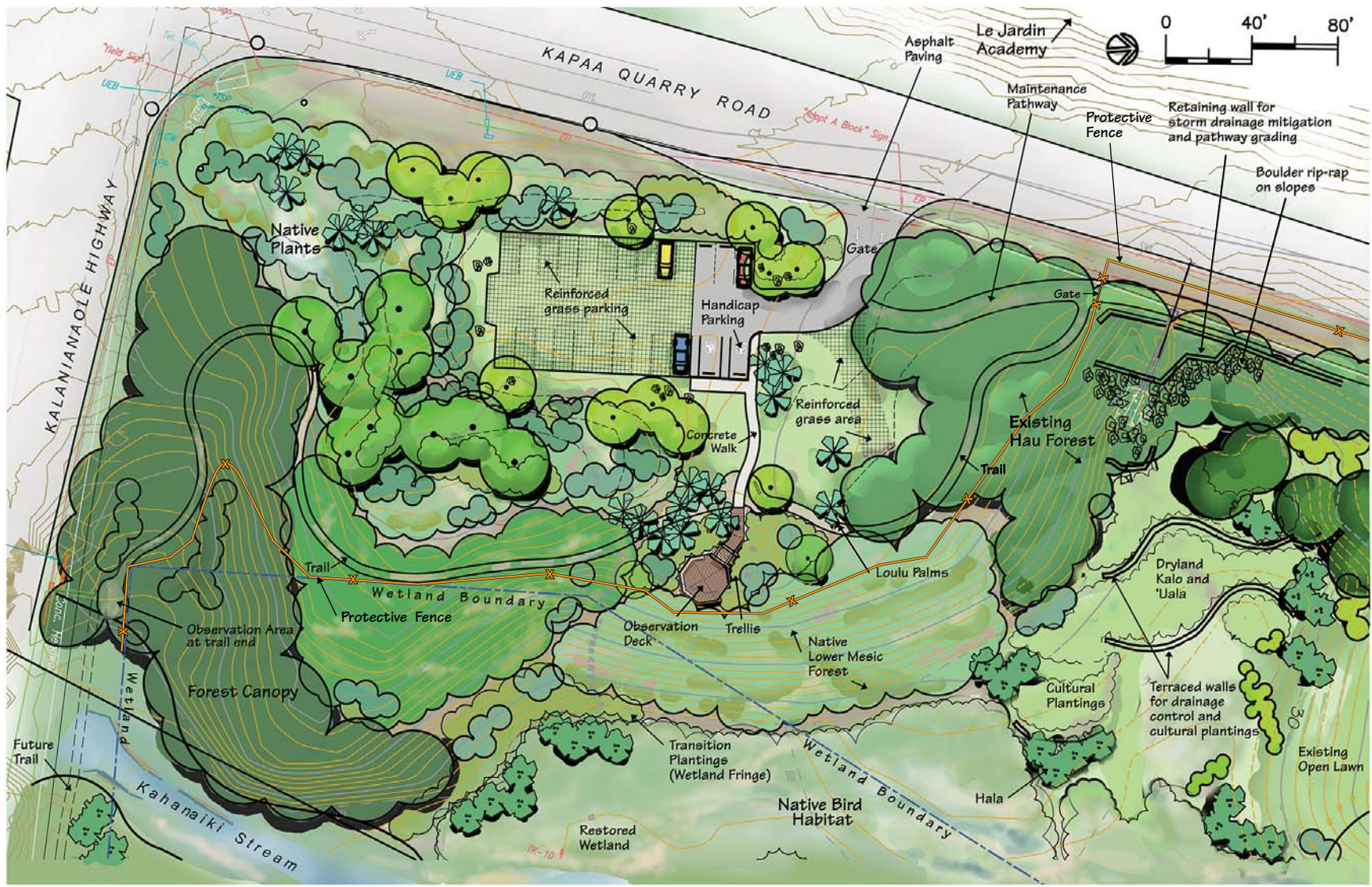
Existing non-native tree canopies can provide wind protection and reduce desiccation, and can slow water run-off that reduces erosion and increases water infiltration. Leaf litter from mature tree canopies provide useful organic mulch helping suppress weed growth and greatly benefits establishment of critical mycorrhizal fungi that many native plants require for growth. This also supports erosion control, reduces dislocation of existing forest birds, and reduces the potential of wildfires by reducing the density of grasses. Once native trees have reached maturity, non-native trees can be removed and additional native shrubs and groundcovers planted.

Upland Area A Improvements

Area A comprises of the upland area in the southwest corner of the project area, extending about 650 feet north from the intersection of Kapa'a Quarry Road and Kalaniana'ole Highway. The area has dryland characteristics heavily vegetated with invasive vegetation and trees that will be replaced with native vegetation. A large gully is also part of this area as shown in Exhibit 8.

Figure 4.5 illustrates detailed restoration improvements planned for Area A. Improvements include a parking area, maintenance pathway, observation areas, and pedestrian trails (design details are provided in following pages). Invasive vegetation and trees will be cleared starting in the area where a parking lot is planned. Figure 4.6 provides a sectional view of reforestation concepts supporting a low mesic forest along with sample images. Appendix B includes a list of plants and trees to be used for low mesic forest restoration along with sample photographs. The appendix also has a listing of cultural plants that should be used.






Conceptual Landscape Plan - Southwest Corner (Area A)
 KAWAINUI MARSH WETLAND RESTORATION
 AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

Figure 4.5

Prepared for:
 State of Hawai'i
 Department of Land and Natural Resources
 Division on Forestry and Wildlife





Dryland Forest contains wide diversity of species



Within diversity of plantings are strong massings of similar plants to create themes and to reinforce plant associations.

SCREENING PLANTS REMAIN ALONG ROADWAYS WITH SELECTIVE VIEW "WINDOWS" OPENED TO MARSH.

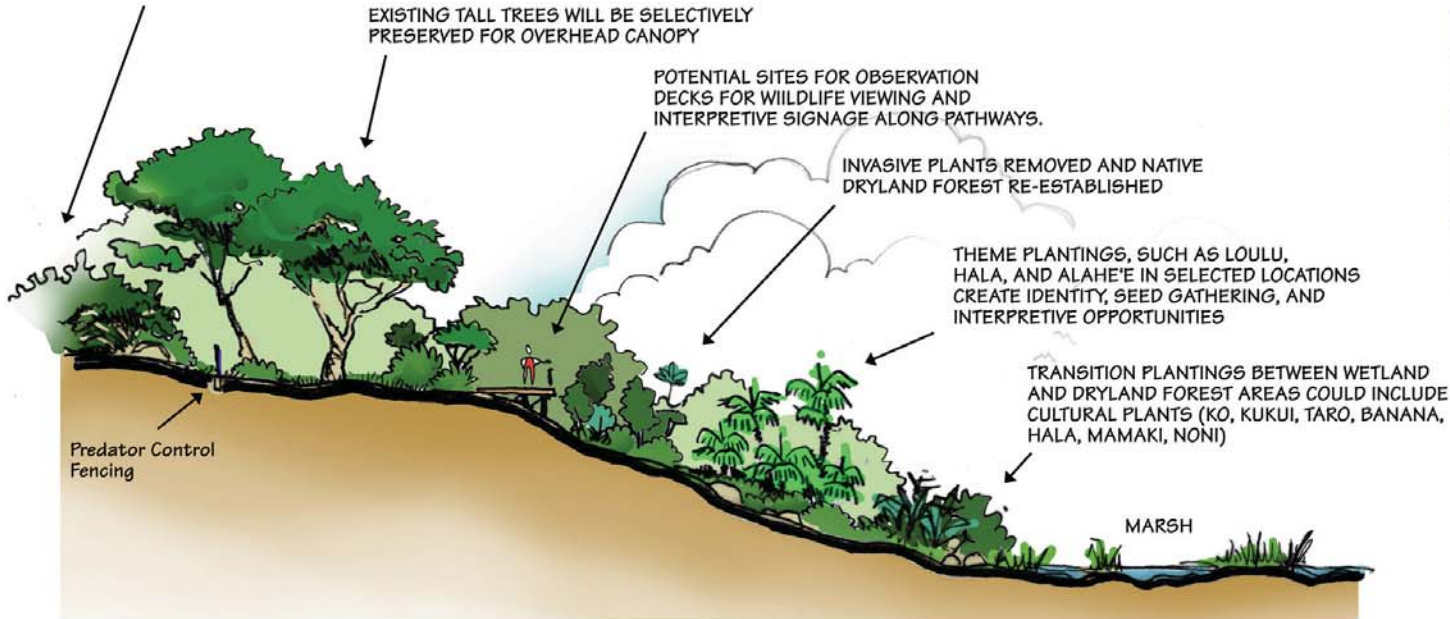
EXISTING TALL TREES WILL BE SELECTIVELY PRESERVED FOR OVERHEAD CANOPY

POTENTIAL SITES FOR OBSERVATION DECKS FOR WILDLIFE VIEWING AND INTERPRETIVE SIGNAGE ALONG PATHWAYS.

INVASIVE PLANTS REMOVED AND NATIVE DRYLAND FOREST RE-ESTABLISHED

THEME PLANTINGS, SUCH AS LOULU, HALA, AND ALAHE'E IN SELECTED LOCATIONS CREATE IDENTITY, SEED GATHERING, AND INTERPRETIVE OPPORTUNITIES

TRANSITION PLANTINGS BETWEEN WETLAND AND DRYLAND FOREST AREAS COULD INCLUDE CULTURAL PLANTS (KO, KUKUI, TARO, BANANA, HALA, MAMAKI, NONI)



Sparse groundcovers during dry season. Heavy application of mulch for organic humus layer and soil erosion control.



Transition plants between dryland forest and wetland areas could include Hala, Loulu Palm, and cultural plantings.

Reforestation Concepts - Sectional View (Low Mesic Forest)

KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU

Figure 4.6

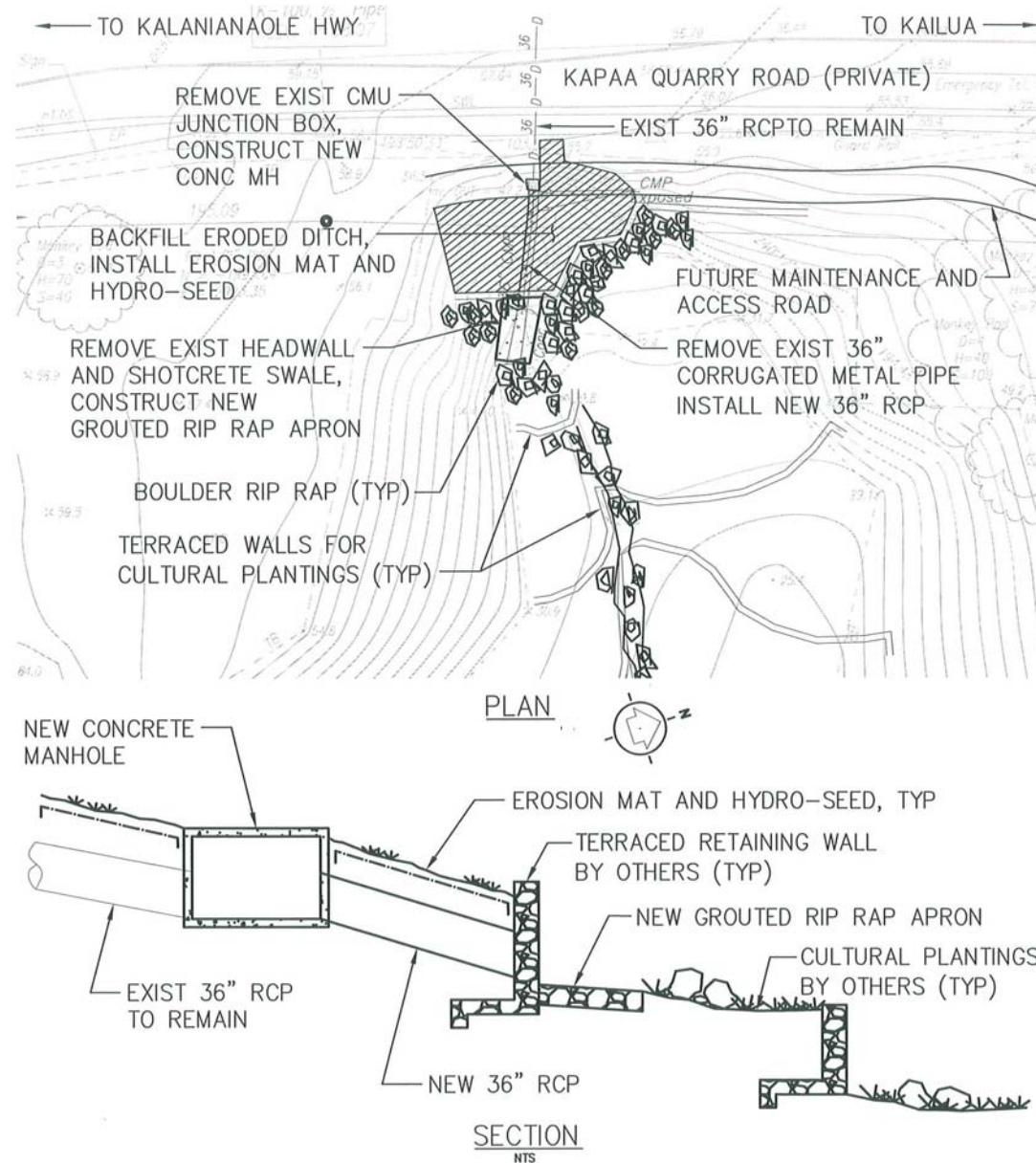
Trees and vegetation along Kapa‘a Quarry Road will be selectively removed to retain a visual screen between the roadway and the marsh. Existing trees within the upland forest will be selectively removed to continue the overhead canopy in this area, and other restoration efforts will be implemented using the hybrid ecosystem model. Various types of native vegetation will be used for the area similar to those being planted at Nā Pōhaku o Hauwahine north of the project area. Transitional plantings using cultural plants along with theme plantings will be incorporated between the wetland and low mesic forest areas. The forest canopy present along the highway will be retained during the initial phases of the restoration work. Future phases will involve replacement of this forest area with native vegetation following the hybrid ecosystem model.

The gully at the northern end of Area A will be modified to mitigate storm water runoff. The existing drainage culvert (Culvert 1) should be improved by replacing the existing junction box with a concrete drop manhole structure, installing a new 36-inch reinforced concrete pipe (RCP), and providing grouted rip rap protection downstream of this pipe. Figure 4.7 illustrates a notional design for these culvert improvements. Terraced walls *makai* of this area are recommended to detain runoff discharging from the culvert into the marsh. Open areas created between these walls could be used for cultural plantings such as dryland *Kalo* and *‘Uala*. Figure 4.8 provides a section view of these terraced walls.

The southern corner area near the roadway intersection will be graded to create a level area for vehicle parking. Figure 4.9 provides a conceptual grading and hardscape plan for the area. The parking lot is planned to provide 25 parking stalls including 2 handicap stalls. A separate reinforced grassed area extending from the driveway will be provided for DOFAW maintenance vehicles, trucks, a bus, or other large vehicles to park. The driveway and a portion of the parking lot will be paved with asphalt. The remaining parking area will be reinforced grass or gravel. This design should minimize the amount of new impervious areas and reduce storm water discharge. It also provides flexibility to accommodate improvements that may be proposed for this area during future planning studies.

Vehicular access to the parking area will be from Kapa‘a Quarry Road, about 320 feet from the intersection with Kalaniana‘ole Highway. A right-turn storage lane is planned to transition cars turning into the driveway from Kapa‘a Quarry Road and minimize traffic delays.

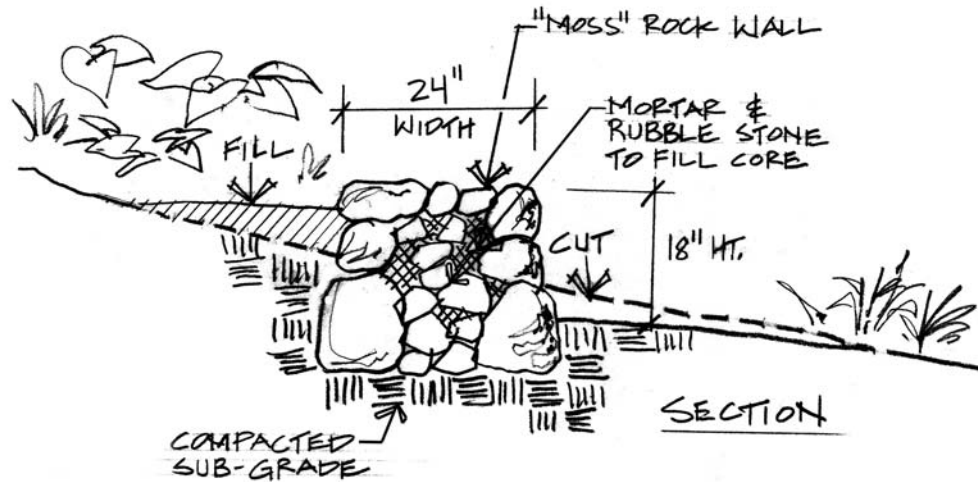
A proposed concrete pathway from the parking lot will extend to the edge of a bluff overlooking the marsh where an observation deck is recommended. A pedestrian trail made of crushed basalt rock will be routed within this area supporting the concept of a system of pathways that circle the marsh. The southern end of this area is planned to have another observation area overlooking Kahanaiki Stream. Directional and informational signage, information kiosks, and interpretive signage should be installed



Drainage Culvert 1 Improvements
 KAWAINUI MARSH WETLAND RESTORATION
 AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

Figure 4.7

"Moss Rock" Terrace Wall



TERRACE RETAINING WALL DETAIL
NO SCALE

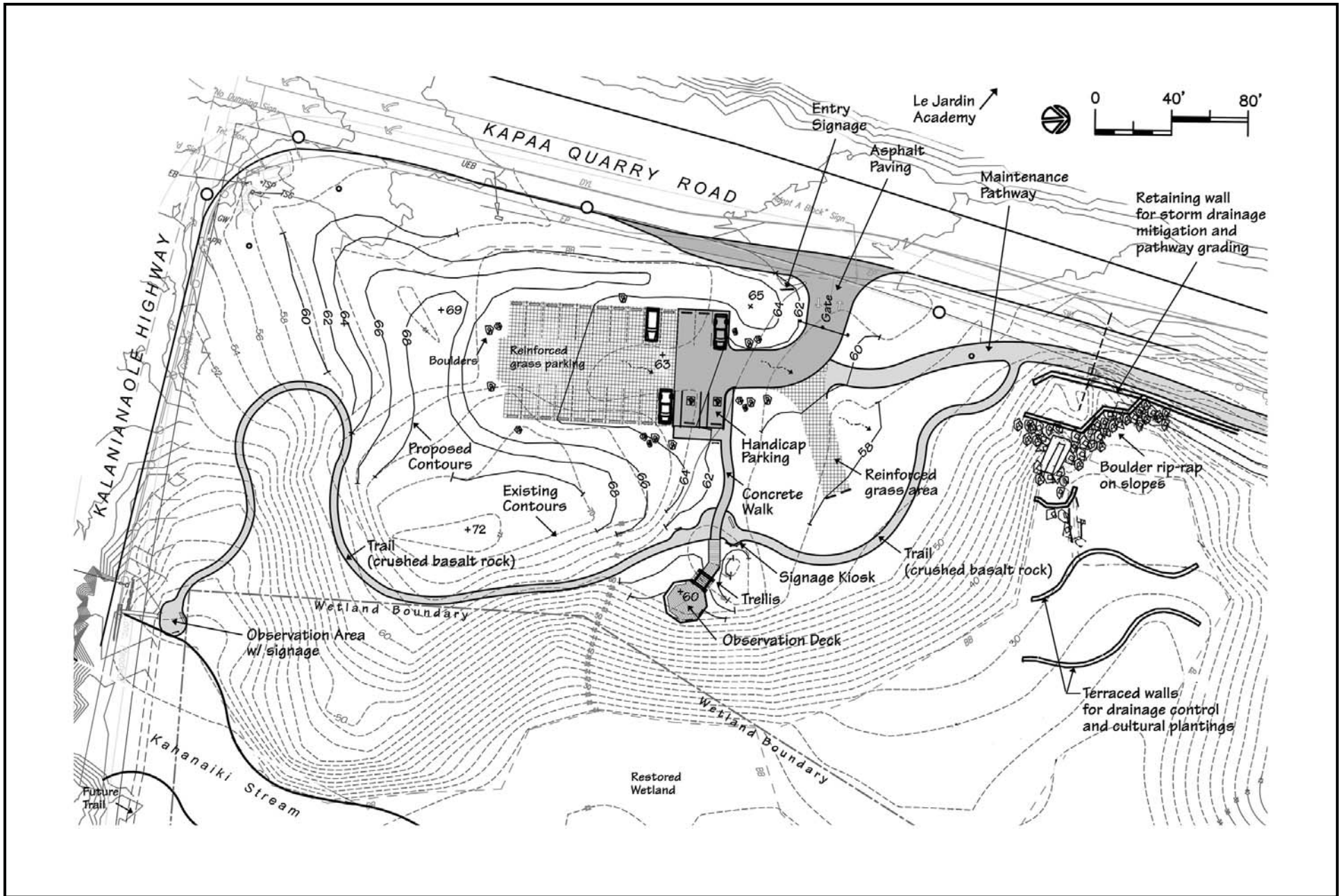
Notes:

1. Low retaining wall slows storm water run-off, creating terraced settling basins.
2. Terraces act as areas for cultural plantings for dryland Kalo, sweet potato, Hawaiian sugar cane, or banana.
3. Wall should have the appearance of traditional "dry stack" technique.



Terrace Retaining Wall Detail
KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU


Figure 4.8



Conceptual Grading and Hardscape Plan
KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

Figure 4.9

Prepared for:
 State of Hawai'i
 Department of Land and Natural Resources
 Division on Forestry and Wildlife



at selected locations. Figures 4.10 and 4.11 provide example images of an observation deck, typical pathways, and informational signage.

A DOFAW maintenance pathway about 10-feet-wide made of crushed basalt rock will extend from the parking lot northbound along Kapa‘a Quarry Road. This pathway is intended for DOFAW maintenance vehicle use only. Access will be restricted (chained) at the parking lot, but could be used for public pedestrian use.

Upland Area B Improvements

Area B comprises the remaining upland area extending north from Area A. This section includes an open lawn area and canopy forest area. Since this area has already been improved by DOFAW, most of the restoration improvements focus on continued removal of invasive plants, implementing the hybrid ecosystem model, and enhancing conditions. Figure 4.12 shows a conceptual landscape plan for a portion of this area that includes the existing the open lawn.

A hau forest along Kapa‘a Quarry Road will be retained to provide a visual screen from the roadway. The open lawn and large canopy trees will be retained, and certain trees selectively removed to open views of the marsh. Plants such as *Hala* and *Loulu* palms should be used as transitional vegetation separating the wetland from the low mesic forest area.

An existing driveway connection with Kapa‘a Quarry Road will be improved with a controlled entry. This will connect to the access road (dirt road) running parallel to Kapa‘a Quarry Road to provide DOFAW with more efficient access within the area. The existing hau forest covers most of the dirt road. Therefore, minor grading would be required to re-establish the alignment of the road while maintaining the existing forest. The access road (maintenance pathway) connects to the parking lot and extends north to the canopy forest area.

An existing culvert (Culvert 2) and another drainage discharge point are located in Area B. To mitigate runoff, a grassed drainage swale will be provided along the *mauka* (west) side of the access road to direct runoff into lower areas used as detention sites. A gravel causeway about 60 feet long is planned along the low point section of the access road. The causeway provides a stable surface allowing vehicle passage during wet conditions. It will normally be dry, but allows storm water to sheet flow over it during larger storm events. This measure slows and widely disperses runoff, reduces its velocity, and increases retention and infiltration before entering the wetland. Figure 4.13 shows a sectional view of a typical causeway and proposed locations.



Signage and Kiosks

KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU

4-16

Figure 4.10

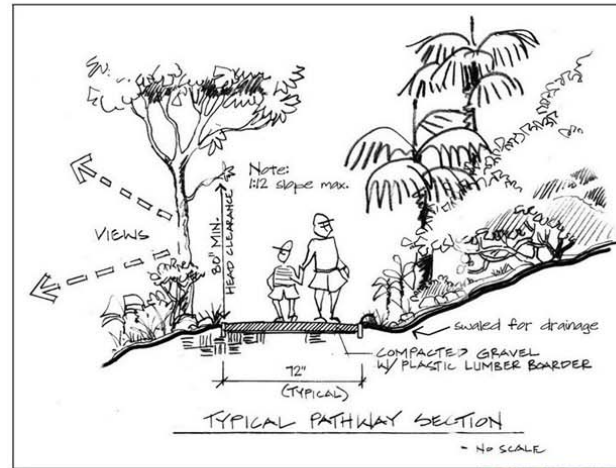
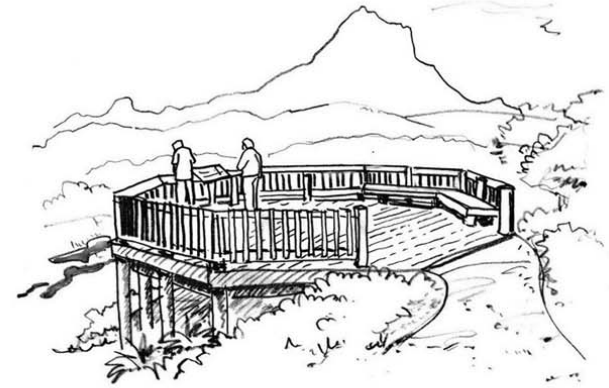
Prepared for:
State of Hawai'i
Department of Land and Natural Resources
Division on Forestry and Wildlife



Trail through Hau Forest



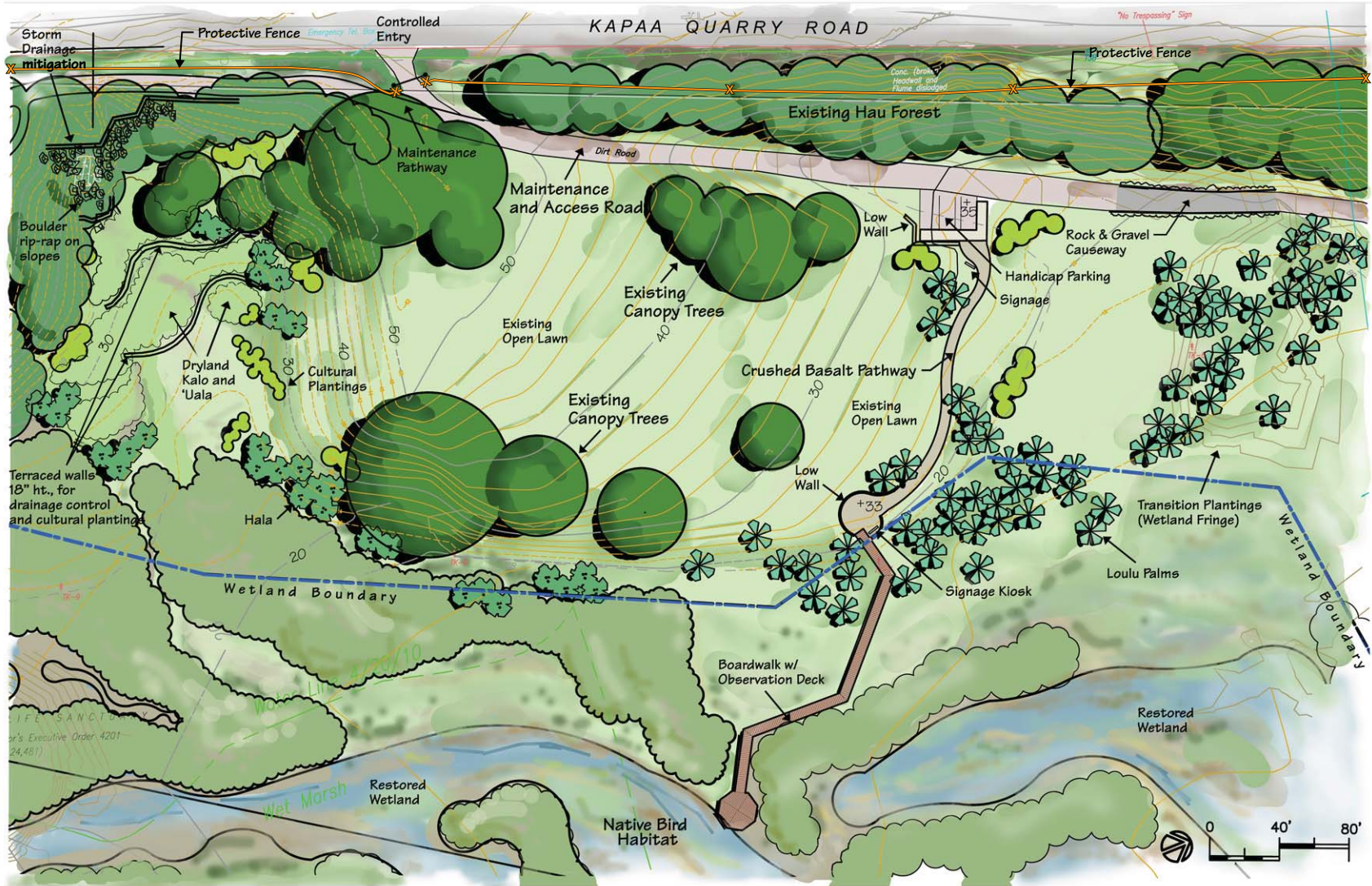
OBSERVATION DECK



TYPICAL PATHWAYS

Observation Deck and Pathways
KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU

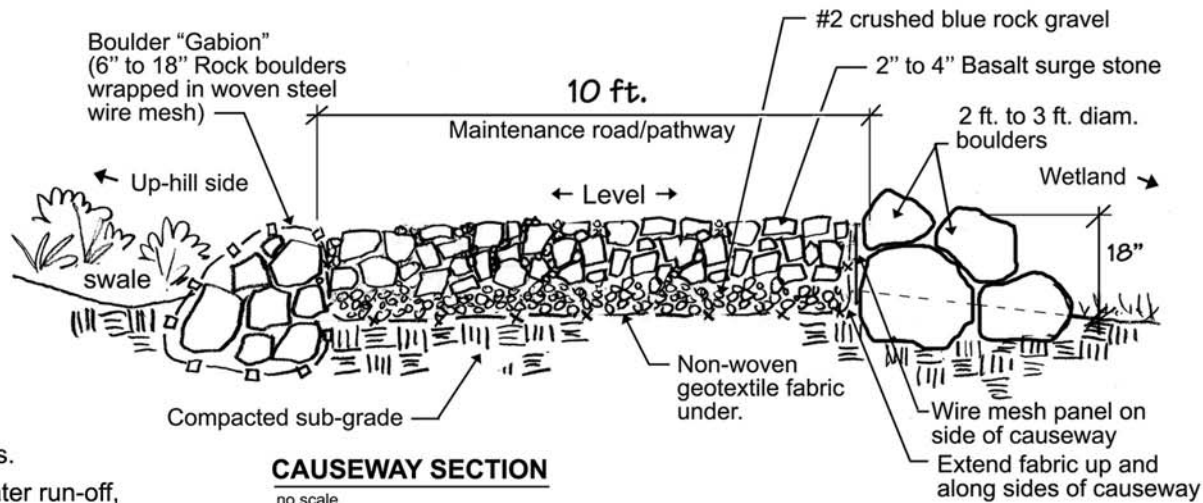
Figure 4.11



Conceptual Landscape Plan - Open Lawn (Area B)
 KAWAINUI MARSH WETLAND RESTORATION
 AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

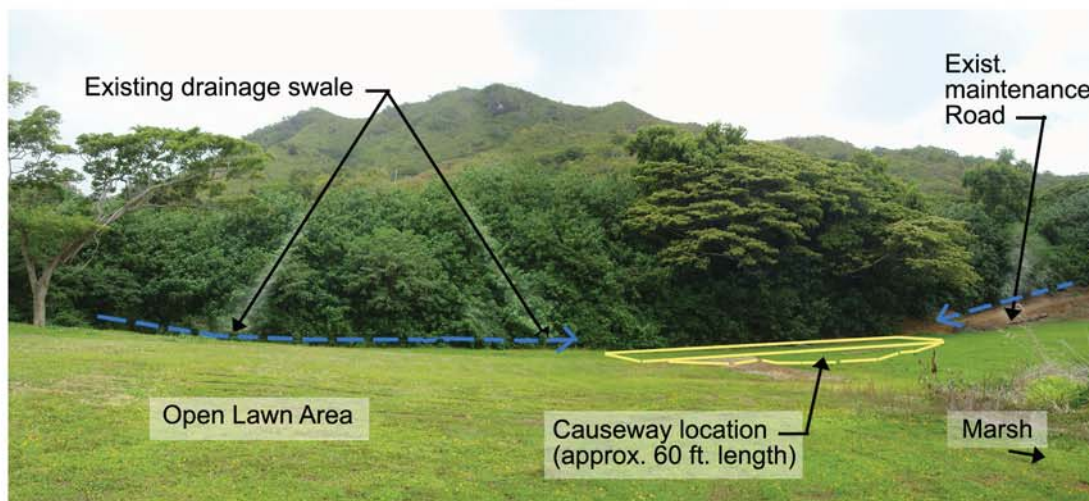
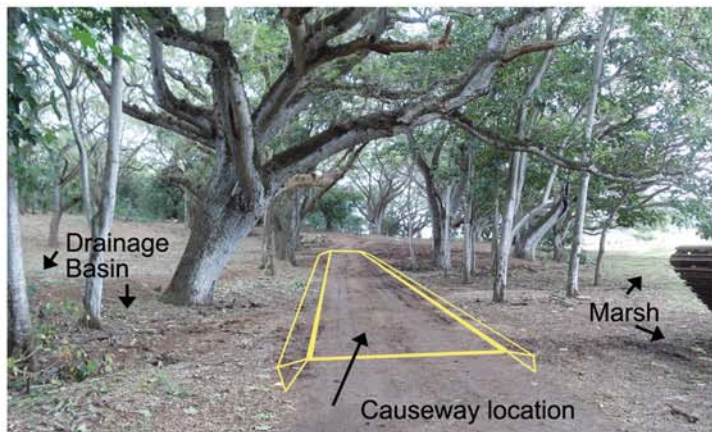
Figure 4.12

Gravel/Boulder Causeway



Notes:

1. Provides a stable surface, allowing vehicle passage during wet conditions.
2. Slows and widely disperses storm water run-off, reducing velocity and increasing retention and settling prior to entry into wetland
3. Causeway is normally dry, but allows storm water to sheet flow over roadway during storm events.



Gravel/Boulder Causeway Typical Section
KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU

Figure 4.13

Culvert 2 will be reconstructed and connected to a new 18-inch reinforced concrete pipe and concrete headwall. A grouted rip rap apron will be provided from the pipe and connect to the grassed drainage swale along the access road. Runoff overflowing the causeway would settle in the open grassed lawn area. Figure 4.14 shows proposed Culvert 2 improvements.

Another drainage area discharging into the marsh from Le Jardin Academy's driveway is eroding the area by Kapa'a Quarry Road. This drainage will be improved with grouted rip rap for slope protection, an erosion mat installed, and adjacent slope areas grassed. Surface runoff from this area will then be intercepted by the grassed drainage swale along the access road. Figure 4.15 shows proposed drainage area improvements.

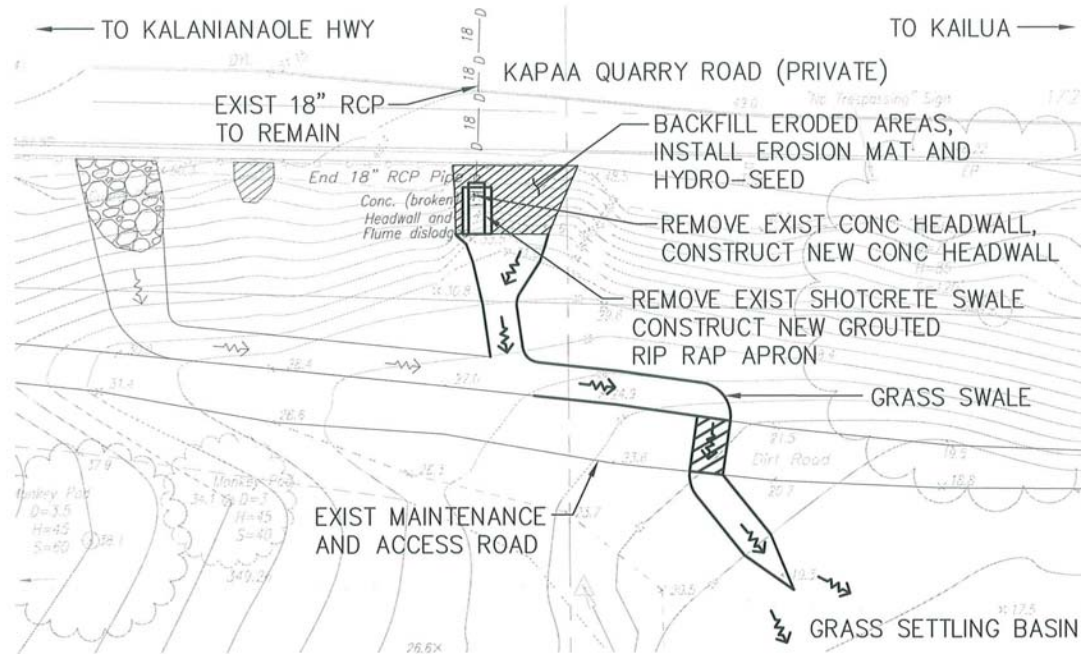
A small parking area for three vehicles will be provided along the dirt road within the open lawn area as previously shown on the Area B landscape plan (Figure 4.12). A pathway comprised of crushed basalt is proposed to extend from this parking area to the edge of the wetland where another observation area can be established. Signage kiosks should be provided as shown on the landscape plan. In the future, a boardwalk can be extended from this area into the wetland to an observation deck. Figure 4.16 includes a sketch of this boardwalk along with typical section drawings.

For the northern most section of Area B, the existing dirt road that extends to the area characterized by the canopy forest will be

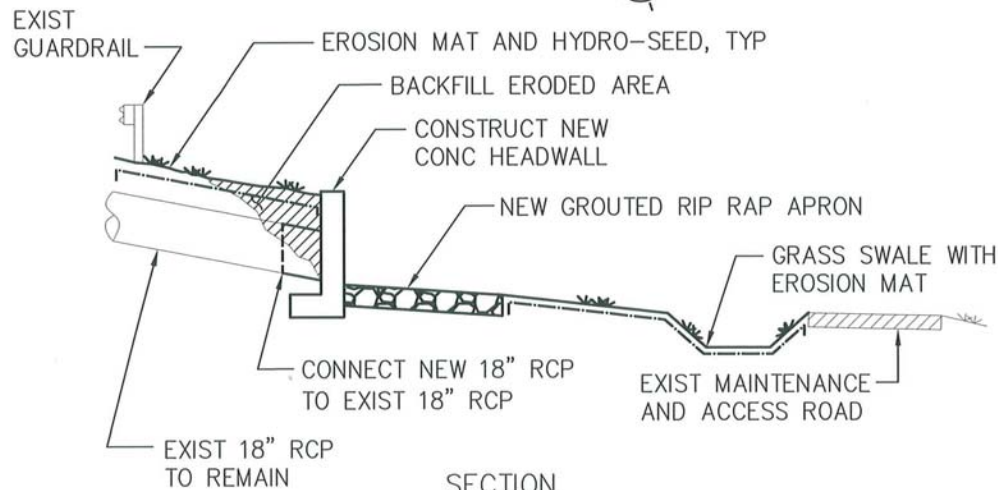
retained for continued use by DOFAW. An existing gated driveway along Kapa'a Quarry Road that connects to the dirt road will be retained. Improvements in this area will consist of implementing the hybrid ecosystem model for native forest reforestation. Figure 4.17 shows a conceptual landscape plan for this section.

The northern most upland area has been improved by DOFAW to create a canopy forest that will be retained. Additional trees may be selectively removed to open views or increase sunlight in the area. DOFAW will determine which trees may be removed or trimmed as restoration work progresses. Invasive plants will be replaced with native vegetation. A variety of choices is provided in Appendix B. Transition plantings can be added along the fringe of the wetland. There are existing large piles of debris and old asphalt present in the area that will be removed.

Existing Culvert 3 located north of the existing gated driveway will be improved as shown in Figure 4.18. A grouted rip rap apron, erosion mat, and grass will be installed on the downstream end of this culvert. Discharges from the culvert should follow an existing grass ditch toward an open area along the dirt access road used for detention and infiltration. A causeway will be created along the section of the access road.



PLAN

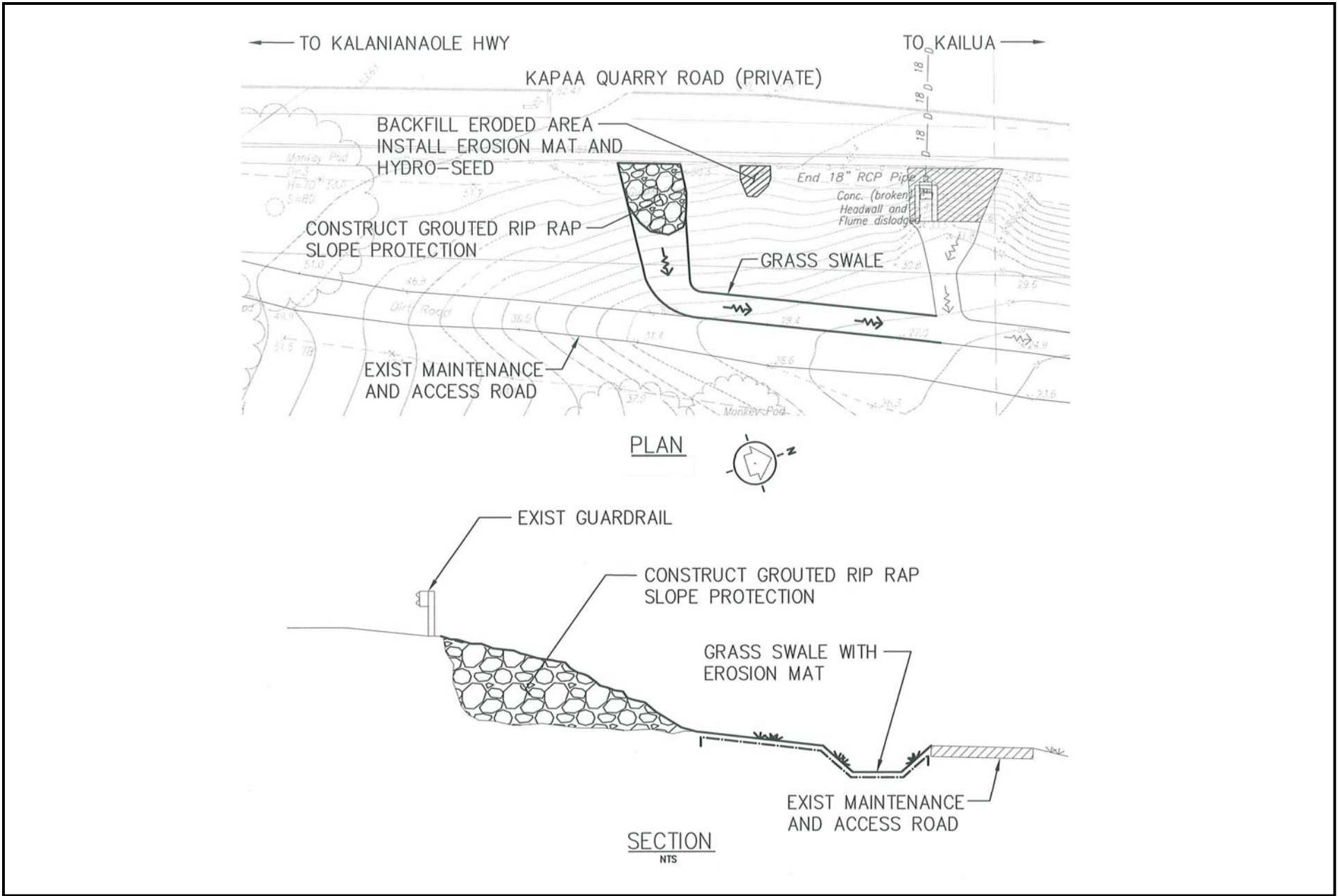


SECTION

NTS

Drainage Culvert 2 Improvements
 KAWAINUI MARSH WETLAND RESTORATION
 AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

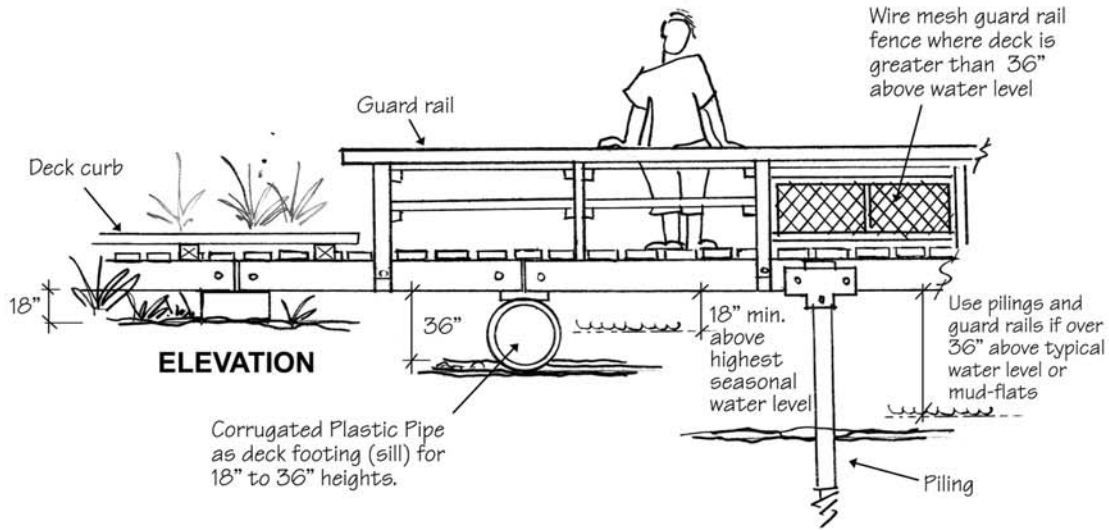
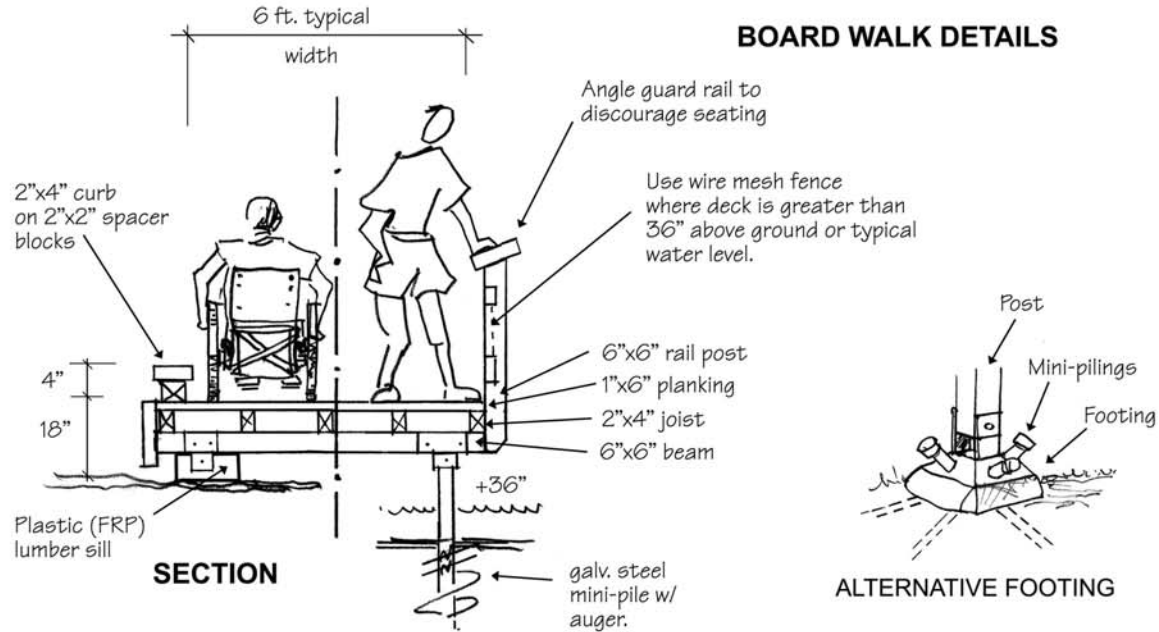
Figure 4.14



Drainage Area Improvements
 KAWAINUI MARSH WETLAND RESTORATION
 AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

Figure 4.15

BOARD WALK DETAILS




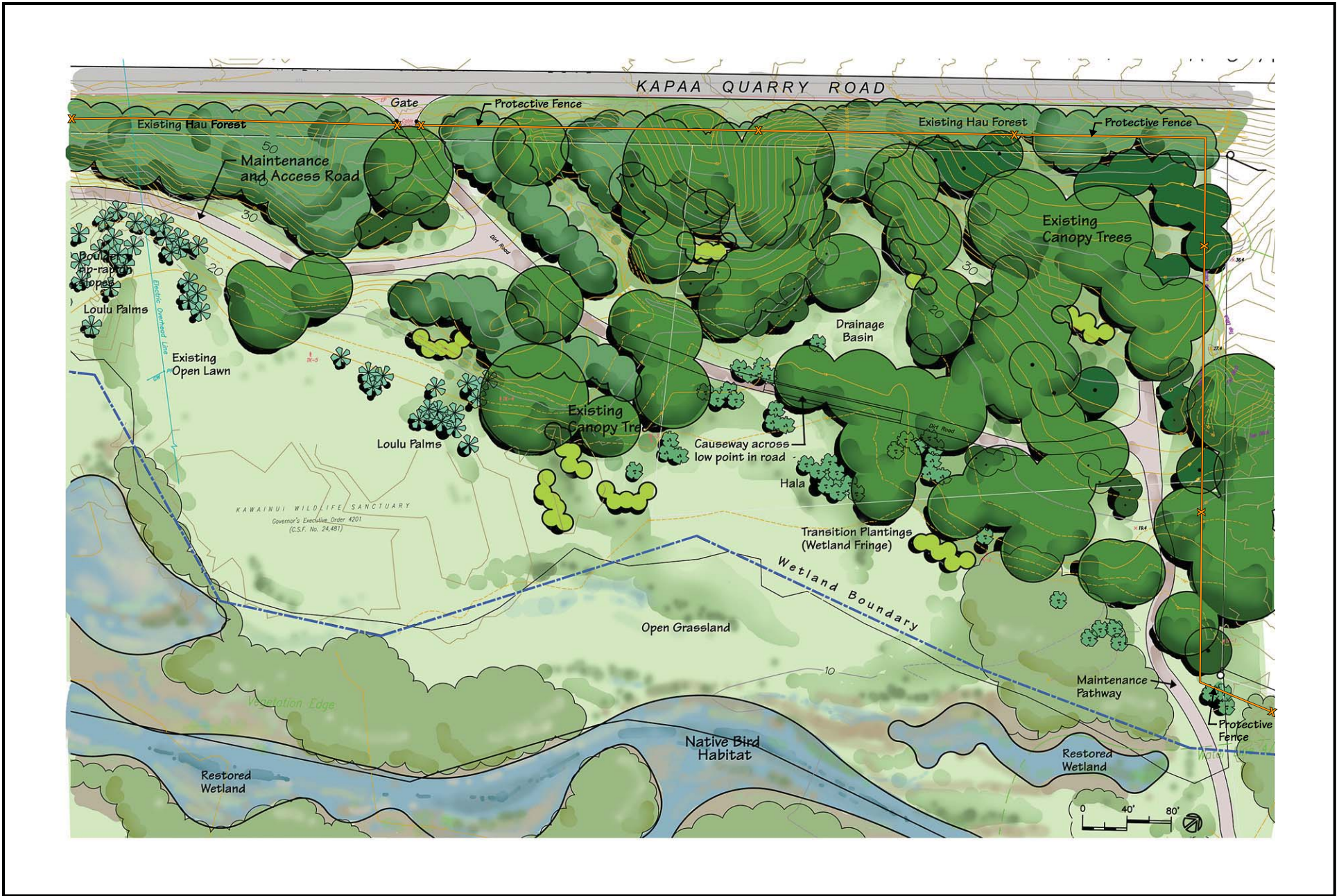
- NOTES:**
1. Use only environmentally safe pressure treated wood or fiberglass reinforced plastic (FRP) lumber for deck framing and planking.
 2. Use 4" high curbing along edges where boardwalk is no more than 18" above ground level.
 3. Use guard rails where boardwalk is greater than 18" above ground or water levels. Use wire mesh screen under guardrail, with openings no greater than 4", where boardwalk is greater than 36" above ground or water level.

Board Walk Details
 KAWAINUI MARSH WETLAND RESTORATION
 AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

Figure 4.16

Prepared for:
 State of Hawai'i
 Department of Land and Natural Resources
 Division on Forestry and Wildlife





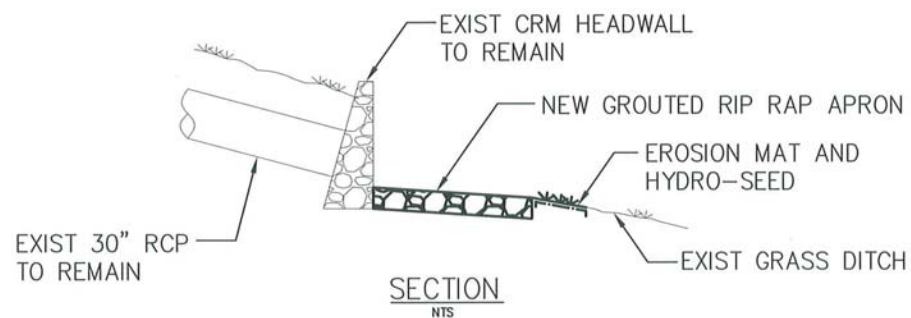
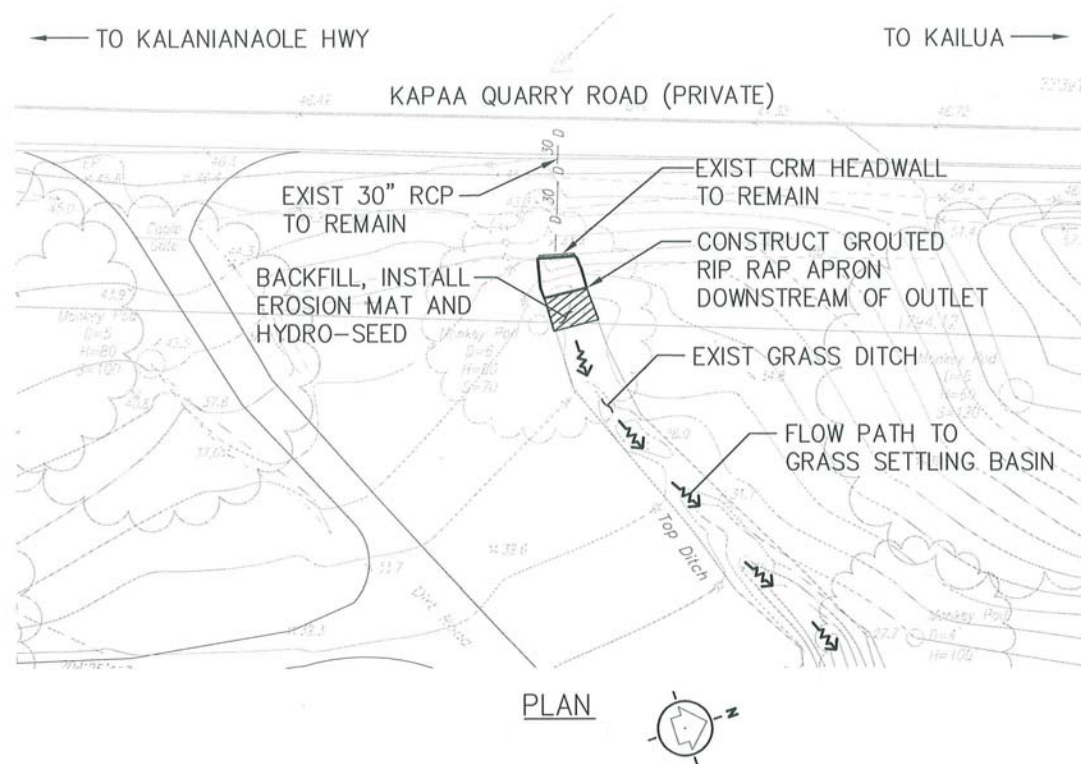
Conceptual Landscape Plan - Canopy Forest (Area B)

KAWAINUI MARSH WETLAND RESTORATION
AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU

Figure 4.17

Prepared for:
State of Hawai'i
Department of Land and Natural Resources
Division on Forestry and Wildlife





Drainage Culvert 3 Improvements
 KAWAINUI MARSH WETLAND RESTORATION
 AND HABITAT ENHANCEMENT PLAN
 KAILUA, O'AHU

Figure 4.18

4.4 Improvements Supporting DOFAW Maintenance

Improvements supporting DOFAW maintenance activities include providing a maintenance pathway for vehicles and equipment transport along the upland project area. The objective is to allow DOFAW to conduct efficient maintenance operations within the project area. Given the organization’s limited personnel, plus the extent of continued maintenance that will be required once the area is restored, the capability to perform regular maintenance in an efficient manner is critical to keep the area cleared of invasive plants. The maintenance path will predominantly consist of reinforced grass, gravel, or dirt.

Plans for the upland areas designate a maintenance pathway that generally runs parallel from the southern section to the north end of the forested area. The northern half of the maintenance pathway would typically follow existing dirt paths. A type of porous material such as Grasspave² or Gravelpave² can be installed at appropriate locations along the maintenance path to minimize impacts from DOFAW vehicles. Exhibit 9 shows an example of the type of material under consideration. A product brochure is provided in Appendix C.

This type of “porous paving” is recognized by the Environmental Protection Agency (EPA) and Corps of Engineers (COE) as a form of best management practices. The material could be installed along the maintenance path and then filled with gravel, dirt, or sand. The material allows for the growth of grass thru it

along with water percolation. It also provides a reinforced surface able to withstand structural loads to support maintenance vehicles such as a flat bed truck.



Predator Control Program and Perimeter Fencing

The predator control program initiated by DOFAW in 2008 will be continued during and after restoration improvements. The importance of this program will increase due to improved waterbird habitat that promotes nesting activity and use. At this time, DOFAW plans to continue contracting this program to the USDA for implementation. In the future, DOFAW may implement the predator control program on their own or in cooperation with another government agency or organization.

Traps will continue to be the primary predator control method utilized during the initial stages of restoration work to control mongoose and feral cats. Traps will generally be established around the perimeter of the upper reaches of the wetland and extend inland within the upland area. Traps are generally spaced between 160 to 200 feet apart.

In the future, additional predator control methods could be implemented by DOFAW as habitats and waterbird activities increase within the project area. Monitoring by DOFAW should determine the appropriate timing and implementation of additional control methods. DOFAW will implement predator control methods in conformance with applicable management policies, guidelines, and manufacturer requirements.

A protective fence will be installed around the project area and marsh as applicable to keep out larger predators such as dogs and

feral pigs. Figure 4-1 (Restoration Conceptual Plan) identifies the general location for the fence planned at this time. However, the actual location of fence will be determined based upon site conditions, effectiveness of predator control, and other factors considered by DOFAW in their evaluation and monitoring of restoration progress and habitat enhancement. The fence route may also connect to a similar fence installed around the COE ponds, if practicable. Exhibit 10 provides an example of the type of fence that may be used for the project area. However, DOFAW may install alternative types of protective fence if determined more feasible and practicable in meeting their management objectives.



Exhibit 10 –Protective Fence Example

4.5 Adaptive Management and Monitoring

The long-term management of the project area will require monitoring of vegetation growth, water flow into the wetland from Kahanaiki Stream and upland areas, and waterbird nesting and activities. Kawainui Marsh is a natural resource influenced by various environmental conditions that change over time and result in the need for adaptive management by DOFAW.

Adaptive management involves developing measureable objectives, monitoring to determine the effectiveness of management practices, evaluation to determine if the objectives are being reached, and adaptation in decisions based on the results. Therefore, resource managers must maintain flexibility in their decisions, knowing that uncertainties exist and management actions could change. This will improve DOFAW's understanding of the marsh's ecological system and help future decision-making to improve restoration progress and effectiveness.

Restoration accomplishments can be documented through biological surveys of areas before and after implementation of restoration improvements. DOFAW will consider implementing such surveys and other forms of data collection to support monitoring and evaluation of site conditions subject to available funding and staffing. The feasibility of implementing such activities will be evaluated in relation to their resource management responsibilities.

Success can be measured by various factors such as the numbers of birds utilizing the marsh, the number of native plants that become established, and the number of native aquatic species present. Aquatic species could also be surveyed to understand community dynamics in a restored wetland.

Physical components such as water quality may also be monitored before and after restoration efforts. Parameters such as dissolved oxygen, pH, temperature, conductivity and oxidation/reduction potential can be monitored to document links between restoration and water quality within the marsh. All monitoring data should be added to the existing Geographic Information System database for the site.

Under a FWS Biological Opinion issued to the COE for the construction of the ponds, a Kawainui Marsh Restoration Area Management Plan must be developed by DOFAW in coordination with the FWS and COE. Therefore, components developed under the management plan will provide a framework applicable to the management and monitoring of both the COE ponds and proposed wetland restoration improvements. The management plan includes the following:

1. A predator control program with Best Management Practices (BMPs) to minimize interactions with listed waterbirds and other environmental impacts.
2. A program to survey for and eradicate feral mallards and Hawaiian duck-mallard hybrids.

3. A revision of the *Management Plan for the Control of Avian Botulism at Kawainui Marsh, Oahu, Hawaii August 1997* to include surveillance for botulism outbreaks, response measures such as removal of carcasses, and post-outbreak population monitoring.
4. Waterbird population and breeding productivity monitoring.
5. Adaptive management recommendations to address habitat requirements for Hawaiian waterbirds.
6. Commitment of dedicated State biologists to manage, monitor and implement the Kawainui Marsh Restoration Area Management Plan.

4.6 Resource Management Principles

Future management and maintenance of restored areas at Kawainui Marsh will require dedicated staff to maintain the natural resources in the area. At least five (5) full-time staff will be required as follows:

- A wildlife biologist;
- An equipment operator;
- Two forestry and wildlife workers; and
- An outreach coordinator.

This level of staffing only allows DOFAW to maintain about four (4) acres a month of marsh and upland area.

The wildlife biologist will manage DOFAW's maintenance and monitoring operations of the marsh and coordinate activities of the equipment operator and wildlife workers. The equipment operator will operate larger machinery such as a tractor, tiller, or floatable excavator. Forestry and wildlife staff will control vegetation by weed whacking, spraying herbicide, and other daily maintenance activities. These efforts generally involve removal of re-occurring invasive vegetation, re-establishing native vegetation, trimming trees and other vegetation, and monitoring wildlife activities and public access in the project area.

The outreach coordinator oversees community projects and volunteers wanting to help maintain the marsh. DOFAW receives requests throughout the year from organizations and individuals wanting to volunteer for projects associated with the marsh. The coordinator will support establishing a formal volunteer program, coordinating activities, coordinating prisoner furlough activities, and assisting staff with other maintenance activities. Such projects cannot be accomplished now because of the existing conditions within the marsh and lack of available staff to coordinate volunteer efforts.

DOFAW requires semi-aquatic machines such as a small excavator to allow staff easy access in the wetland for regular maintenance. Additional costs will be associated with periodic repairs and maintenance of equipment, fuel, tools, herbicides, and predator control activities.

DOFAW will continue to contract with the USDA to implement a trapping program at Kawainui Marsh. The annual cost of this program is approximately \$75,000, and involves work by a full-time USDA staff to monitor traps and process predators that have been caught.

The preliminary annual cost for resource personnel and operating costs is estimated to be approximately \$407,000 (in 2011 dollars). This cost is broken down as follows:

Personnel Description	Total Annual Cost
1. Wildlife Biologist	\$45,000
2. Equipment Operator	\$40,000
3. Forestry and Wildlife Workers (2 @ \$35,000)	\$70,000
4. Outreach Coordinator	\$40,000
5. Predator Control Program	\$75,000
6. Operating Costs (parts, repair, etc.)	<u>\$100,000</u>
Subtotal	\$370,000
Contingency Factor (10%)	<u>\$37,000</u>
Total Budget	\$407,000