STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
Engineering Division
Honolulu, Hawaii 96813

January 9, 2015

Chairperson and Members
Board of Land and Natural Resources
State of Hawaii
Honolulu, Hawaii

Land Board Members:

SUBJECT: REQUEST APPROVAL OF THE *WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN, KAWAINUI MARSH*; ACCEPTANCE OF THE FINAL ENVIRONMENTAL ASSESSMENT FOR THE SUBJECT PLAN; AND ISSUANCE OF A FINDING OF NO SIGNIFICANT IMPACT FOR THE PROPOSED PROJECT, TMKs (1) 4-2-013: PORTIONS OF 005 AND 022, KAILUA, OAHU.

BACKGROUND

The Division of Forestry and Wildlife (DOFAW) is proposing to restore a portion of Kawainui Marsh in the Kailua District of the island of Oahu in accordance with the *Wetland Restoration and Habitat Enhancement Plan, Kawainui Marsh*. Restoration will focus on an area of approximately 80 acres that consists of about 60 acres of wetland and 20 acres of adjacent upland riparian and forested slopes. See Exhibit A. The restoration plan identifies the following improvements:

1. Wetland restoration and erosion control;
2. Habitat restoration for native Hawaiian waterbirds, migratory shorebirds and waterfowl, and native fish species;
3. Improvements to support DOFAW's maintenance operations.

An Environmental Assessment (EA) was completed on the approximately 80 acre area, and the Final EA filed with OEQC and published in the September 23, 2012 issue of The Environmental Notice.

PROJECT DESCRIPTION

This project proposes to restore upland forest and wetland habitat, starting with a five acre area of the approximately 80-acre total area covered in the restoration plan, near the intersection of Kalanianaole Highway and Kapaa Quarry Road. See Exhibit A. The ingress and egress will be through Kapaa Quarry Road.

ITEM C-3

ALTERNATIVES CONSIDERED

The following five alternatives were evaluated:

1. No Action Alternative: Under this alternative, DOFAW would not proceed with any major wetland restoration improvements to Kawainui Marsh or implementing upland reforestation improvements.

2. Action Alternatives: The following four possible action alternatives are considered:

   Alternative A: Wetland Restoration and Habitat Enhancement Plan – includes both a wetland restoration and upland reforestation program involving removal of invasive species using a variety of methods, both mechanical and chemical, and utilizing an adaptive management approach to insure effect maintenance of restored areas; retaining existing native vegetation while replacing non-native plant species; utilizing a variety of native plants for re-vegetation efforts; implementing predator control and perimeter fencing; improving storm-water detention to reduce sediment flows into the wetland; providing access for DOFAW vehicles; and protecting historic and archeological sites.

   Alternative B: Wetland Restoration Via Excavation and Grading - wetland area would be restored by removing existing invasive vegetation primarily through excavation or grading areas using a tractor or other equipment.

   Alternative C: Upland area would be restored by direct removal of existing invasive vegetation and non-native trees through mass clearing, excavating, or grading with a tractor or other equipment.

   Alternative D: DOFAW would be provided a maintenance path for vehicles across the wetland and Kahanaiki Stream from the Kawainui Marsh headquarters. The purpose of this maintenance path was to support DOFAW operations by providing a direct access for transport of equipment and staff, and minimize disruptions to traffic along Kalanianaole Highway.

DOFAW selected Alternative A for implementation because restoration improvements and accessory improvements would best be implemented. The other alternatives were eliminated based on their limited scope and effectiveness in addressing project objectives, conflicts with the physical environment, or feasibility and practicability of implementation.

SUMMARY OF AFFECTED ENVIRONMENT

Soil and Climate

According to the Web Soil Survey, United States Department of Agricultural, Natural Resources Conservation Service, the wetland portion of the project site consists of poorly drained clay soils common to coastal plains, stream bottoms, and floodplains. The upland portion consists of well-drained clay soils weathered from basic igneous rock, or common to fans and terraces on the windward side of the island. Climate is mild year-round, with moderate annual rainfall and frequent trade wind showers.

Flood and Tsunami Hazards
The project site, according to the Flood Insurance Rate Map, Federal Emergency Management Agency, is located within Zones A (special flood hazard area subject to the 100-year flood) and D (unstudied areas where flood hazards are undetermined, but flooding is possible). Based on the City Department of Emergency Management's tsunami evacuation maps, the current tsunami evacuation zone does not extend up to the defined project area.

Archeological and Cultural
The only traditional artifact observed within the project site was a grinding stone, which is protected by DOFAW staff. There are no known archeological or cultural sites within the project site. An archaeological reconnaissance survey with limited subsurface testing was conducted by Cultural Surveys Hawaii, Inc.

Botanical, Faunal, and Aquatic Resources

Botanical Resources
The Kawainui wetland supports plant assemblages comprised of both non-native and native species. Native plant assemblages cover over 52 percent of the overall wetland area, with two indigenous species (Saw-grass and Neke fern) accounting for most of the native species component, according to a botanical survey performed by Oceanit Laboratories, Inc. However, the native plant component in the restoration area defined by this plan and environmental assessment is almost entirely comprised of non-native species

Upland area located mauka of the wetland was identified as an upland forest assemblage, with a variety of plants and large trees dominated by Monkeypod, African tulip, and Java plum.

Faunal Resources
Kawainui Marsh provides habitat for various migratory waterfowl, wintering shorebirds, and a variety of resident and introduced bird species. It is also provides important habitat for four endangered species of native Hawaiian water birds. The four species include the Hawaiian stilt, Hawaiian coot, Hawaiian moorhen, and Hawaiian duck.

Wide varieties of mammals live within Kawainui Marsh or access the marsh from surrounding areas, and serve as predators to waterbirds. They include rats, mongooses, feral dogs, and feral cats.

The waters of Kawainui Marsh are dominated by introduced aquatic wildlife. Native fish have been found in low densities. There are several introduced species of invertebrates such as Tahitian prawn, crayfish, damselfly, apple snail, and pond snails. Native species include native shrimp.

SUMMARY OF MAJOR IMPACTS

Short Term: Minor impacts to air quality and noise levels from restoration work and other construction related activities. Air quality would be predominantly associated with fugitive dust emissions and to a lesser extent exhaust emissions from on-site equipment.

Long Term: There will be no long-term negative impacts.

PROPOSED MITIGATION MEASURES

Provisions will be made in the project specifications to control and minimize dust within the project area from construction activities. A dust control plan will be prepared which may include implementing a watering program or use of wind screens, as appropriate.

ANTICIPATED DETERMINATION

Since no major impacts are anticipated, costly detailed studies are considered inappropriate. Consequently, an Environmental Impact Statement is not required.

FINDINGS AND REASONS SUPPORTING ANTICIPATED DETERMINATION

Evaluation of the effects of the proposed project on the environment indicates that there will be no significant adverse effects on the environment. The project will not:

1. Involve irrevocable commitment to loss or destruction of any natural or cultural resources, except for the labor and materials related to the expansion of the project.
2. Permanently curtail the beneficial uses of the environment.
3. Conflict with the State's long-term environmental policy goals or guidelines.
4. Permanently degrade the environmental quality.
5. Cause the displacement of any persons.

For the reasons above, it is anticipated that the proposed project will not have any significant effect in the context of Chapter 343, Hawaii Revised Statutes and Section 11-200-12 of the State Administrative Rules.

RECOMMENDATIONS

That the Board of Land and Natural Resources:

1. Approve the *Wetland Restoration and Habitat Enhancement Plan* as a guiding document for the management of the subject Kawainui Marsh.

2. Accept the Final Environmental Assessment for the plan.

3. Based on review of the Final Environmental Assessment and the comments received during the 30-day public comment period and the Division of Forestry and Wildlife's responses, find that the project will not have a significant effect on the environmental, economic and/or cultural resources of the area and approve the issuance of a finding of no significant impact for the proposed project.

4. Authorize the Chairperson to publish a finding of no significant impact for the proposed project in the Office of Environmental Quality Control's The Environmental Notice. Such other terms and conditions as may be prescribed by the Chairperson to best serve the interests of the State.

Respectfully submitted,

LISA J. HADWAY, Administrator
Division of Forestry and Wildlife

APPROVED FOR SUBMITTAL:

WILLIAM J. AILA, Jr., Chairperson
Board of Land and Natural Resources

Attachment: Exhibit A

Wetland Restoration And Habitat Enhancement Plan

Kawainui Marsh

Kailua, O'ahu

Final | August 2012

Wetland Restoration and Habitat Enhancement Plan

Kawainui Marsh

Kailua, O'ahu

Final | August 2012

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

Prepared by:
Helber Hastert & Fee
Planners, Inc.

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CHAPTER 1
INTRODUCTION AND BACKGROUND

The State of Hawai'i, Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW) has prepared the Kawainui Marsh Wetland Restoration and Habitat Enhancement Plan. The Plan identifies improvements planned for a portion of the Kawainui Marsh consisting of: 1) wetland restoration and erosion control for a portion of Kawainui Marsh; 2) habitat restoration for native Hawaiian waterbirds, migratory shorebirds and waterfowl, and native fish species; and 3) improvements to support DOFAW's maintenance operations. Funding for the plan and implementation of restoration improvements was obtained via a grant from the U.S. Fish and Wildlife Service, Harold K.L. Castle Foundation, the State of Hawai'i, and other private partners.

1.1 Purpose for Restoration Plan

The purpose for this conceptual restoration plan is to present the types of improvements and management activities that DOFAW plans to implement for the project area. Information in the plan was used in the preparation of an Environmental Assessment (EA) document complying with both State and Federal environmental review procedures prescribed under Chapter 343, Hawai'i Revised Statutes and the National Environmental Policy Act (NEPA). Necessary land use approvals and permits would also be obtained using the plan. This plan is intended to guide the design and phased implementation of restoration improvements for the project area by DOFAW over several years.

Restoration and habitat enhancement recommendation provided in this plan are part of an on-going progression of improvements being made to the Kawainui/Hāmākua Marsh complex beginning with the *Coastal Wetlands Acquisition, Planning, Development and Management of Hāmākua Wetlands* project in 1992. More recently, the U.S. Department of Army, Corps of Engineers (COE) is implementing the *Kawainui Marsh Environmental Restoration Project* adjacently *makai* (east) of the project area. Construction of the latter project is planned to be completed by the end of 2012. The success of ecosystem restoration improvements at Hāmākua Marsh has provided a framework for actions proposed in this plan for a portion of Kawainui Marsh.

1.2 Background on Kawainui Marsh

Kawainui Marsh was recognized as a Ramsar Wetland of International Importance in 2005 for its historical, biological, and cultural significance. The wetland encompasses about 830 acres of land and is the largest remaining wetland in the State of Hawai'i. Exhibit 1.1 provides an aerial oblique view of Kawainui Marsh, and Exhibit 1.2 provides a panoramic photo of the project area within the marsh.

Exhibit 1.1 – Oblique Aerial Photo of Kawainui Marsh (August 2012)

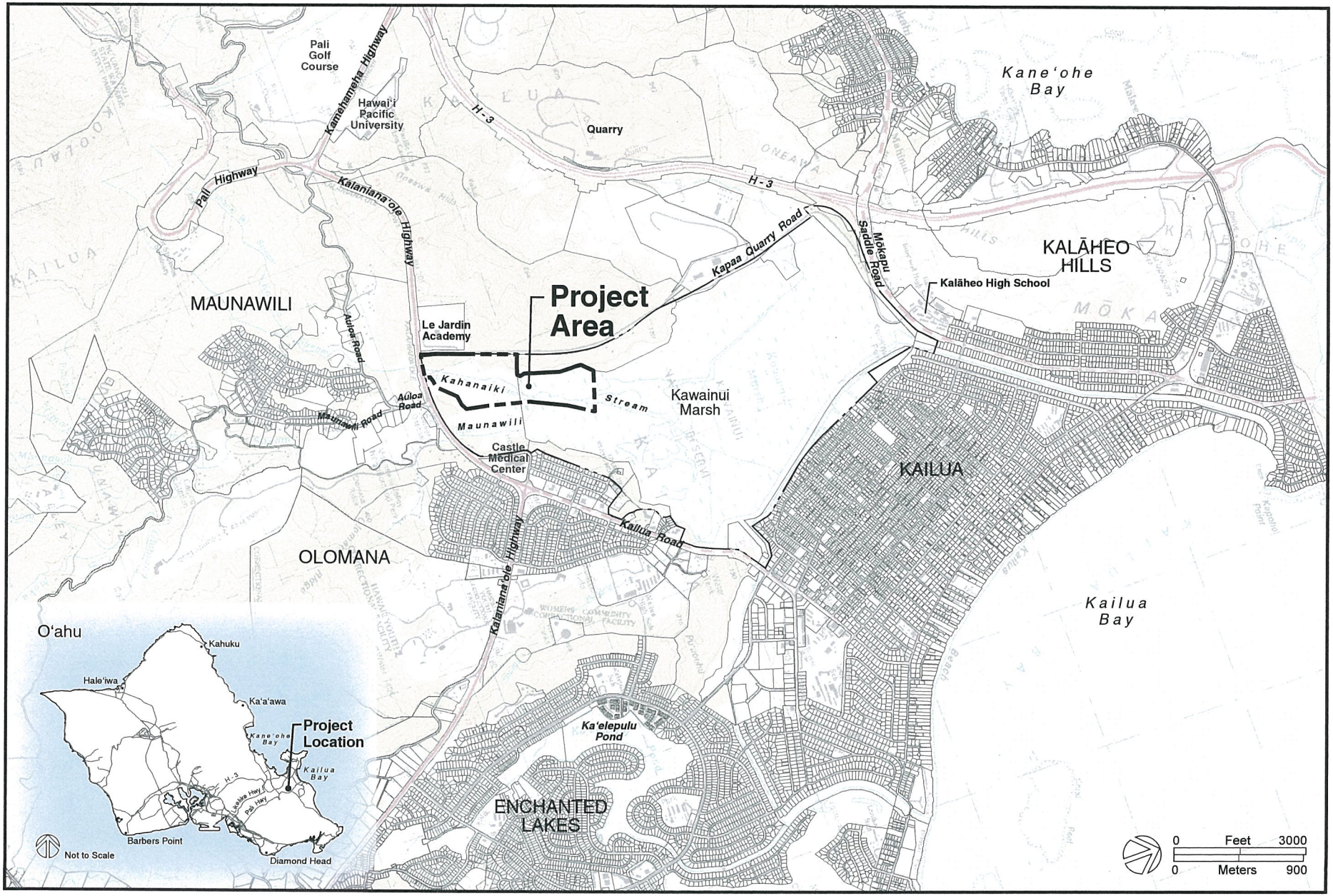
Exhibit 1.2 – Panoramic Photo of Kawainui Marsh Project Area

The marsh is located in the Kailua district of the island of O'ahu, and generally bordered by major roadways on each side including Kalaniana'ole Highway and Kailua Road, Mōkapu Saddle Road, Kapa'a Quarry Road, and Kīhāpai Street. Figure 1.1 identifies the location of the project area and entire marsh boundary in relation to Kailua.

Kawainui Marsh has been identified by the U.S. Fish and Wildlife Service (FWS) as a waterbird recovery area because it provides habitat for four endemic and endangered Hawaiian waterbirds. It also plays a unique role in the Ko'olau Poko region watershed as an important source of flood control and sediment filtration protecting urbanized areas of Kailua and the Kailua Bay ecosystem through ground water recharge and improved water quality.

1.3 Scope of Work

This plan serves as DOFAW's guide for implementing restoration improvements within this project area. Plan components were developed based upon information from the DOFAW grant application used in obtaining funds. Future funding outside of this grant would also be pursued by DOFAW to implement restoration efforts, drainage infrastructure, and accessory improvements under this plan. The scope of work for preparation of this plan includes work tasks summarized below.



Project Location Map

KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN

KAILUA, O'AHU

Figure 1.1

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

1. Research and collect information, maps, and other data associated with the Kawainui Marsh project area. Conduct field surveys of the project area to confirm information.
2. Consult with government agencies and identify permit and regulatory requirements, and issues to be addressed in the plan. Consult with the community through presentations and public informational meetings to solicit input and concerns.
3. Develop restoration plans for the wetland and upland areas based upon the information gathered and input received from agencies and the community.
4. Refine and finalize restoration plans based upon further agency and community input received as part of the environmental review process.

Chapter 2
Existing Conditions

CHAPTER 2
EXISTING CONDITIONS

2.1 Project Area

The wetland restoration project area involves a total of approximately 80 acres, which comprises about 10 percent of the entire Kawainui Marsh. Figure 2.1 shows the project boundary in relation to the entire marsh. Notable land uses surrounding the restoration area include Le Jardin Academy to the west (*mauka*) and the Castle Medical Center and Kukunono residential subdivision to the east (*makai*) as shown on the figure.

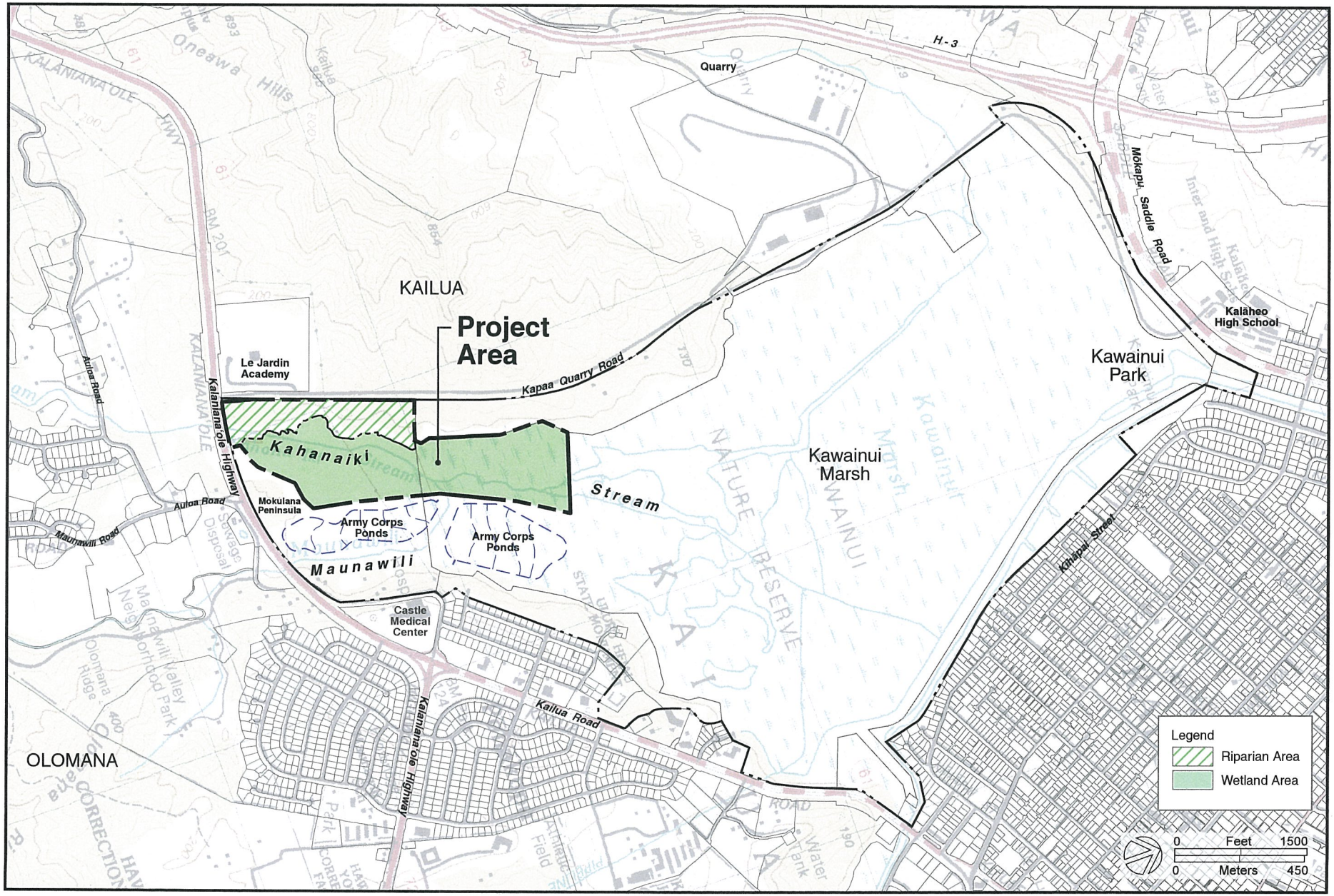
The project area is bounded on the west (*mauka* side) by Kapa'a Quarry Road which runs in a north-south direction from its intersection with Kalaniana'ole Highway. The highway forms the project's southern boundary generally running in an east-west direction. Remaining areas of the project area are bordered by the marsh. An area known as Mokulana peninsula is situated across the highway's intersection with Auloa Road. A portion of the marsh used for the creation of ponds by the COE is located adjacently *makai* (east) of the restoration project area.

The 80-acre project area can be characterized as consisting of approximately 60 acres of wetland with Kahanaiki Stream extending through the site in a north-south orientation. The remaining 20 acres consists of adjacent upland riparian and forested slopes situated above the wetland area and *makai* of Kapa'a Quarry Road. Figure 2.2 shows a southwest oriented oblique aerial view of the Kawainui Marsh project area.

2.2 Property Information and Land Use Designations

The project area is identified as Tax Map Key (TMK) No. (1) 4-02-013: portions of 005 and 022. These parcels are larger properties owned by the State of Hawai'i and under the jurisdiction of the DOFAW. Figure 2.3 shows the project area in relation to the parcel boundaries based upon the Tax Map. It should be noted that parcel 43 shown on the TMK map was previously created for the intended issuance of a revocable permit, but has not been officially subdivided as a parcel. That revocable permit is no longer applicable and subdivision not required. Therefore, the correct boundary for parcel 5 follows the project boundary up to Kapa'a Quarry Road based upon a State survey map dated July 2, 2007 prepared for Governor's Executive Order 4102.

Parcel 5 consists of 97.224 acres based upon the State's survey map. The Tax Map incorrectly identifies this parcel as being 80.0 acres. The Tax Map identifies parcel 22 as consisting of 89.0 acres. It was estimated that about 50 acres of the project area is situated within parcel 5 and 30 acres situated within parcel 22. A summary of this parcel information along with applicable land use designations for the project area is summarized on Table 1.



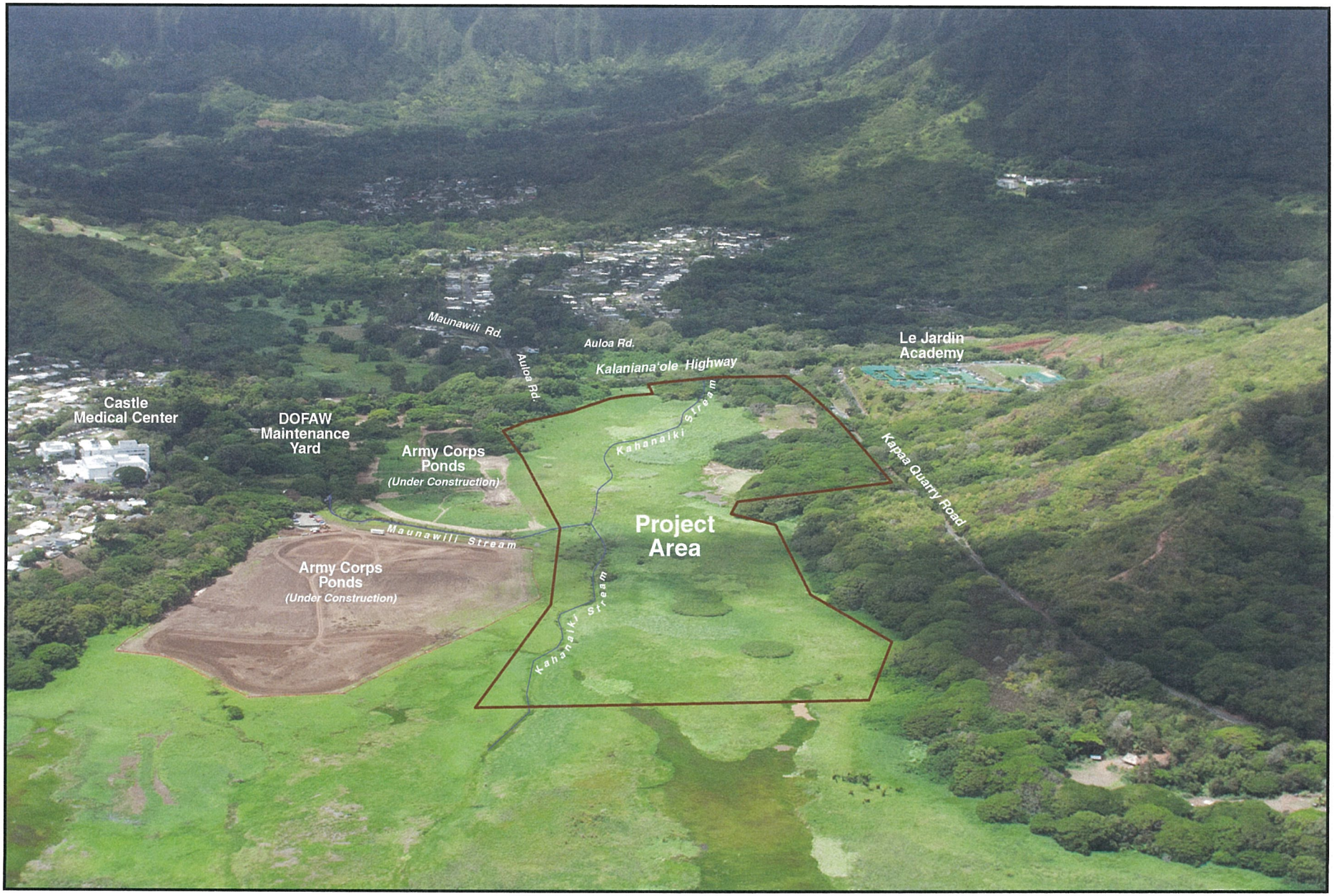
Project Vicinity Map

KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN

KAILUA, O'AHU

Figure 2.1

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

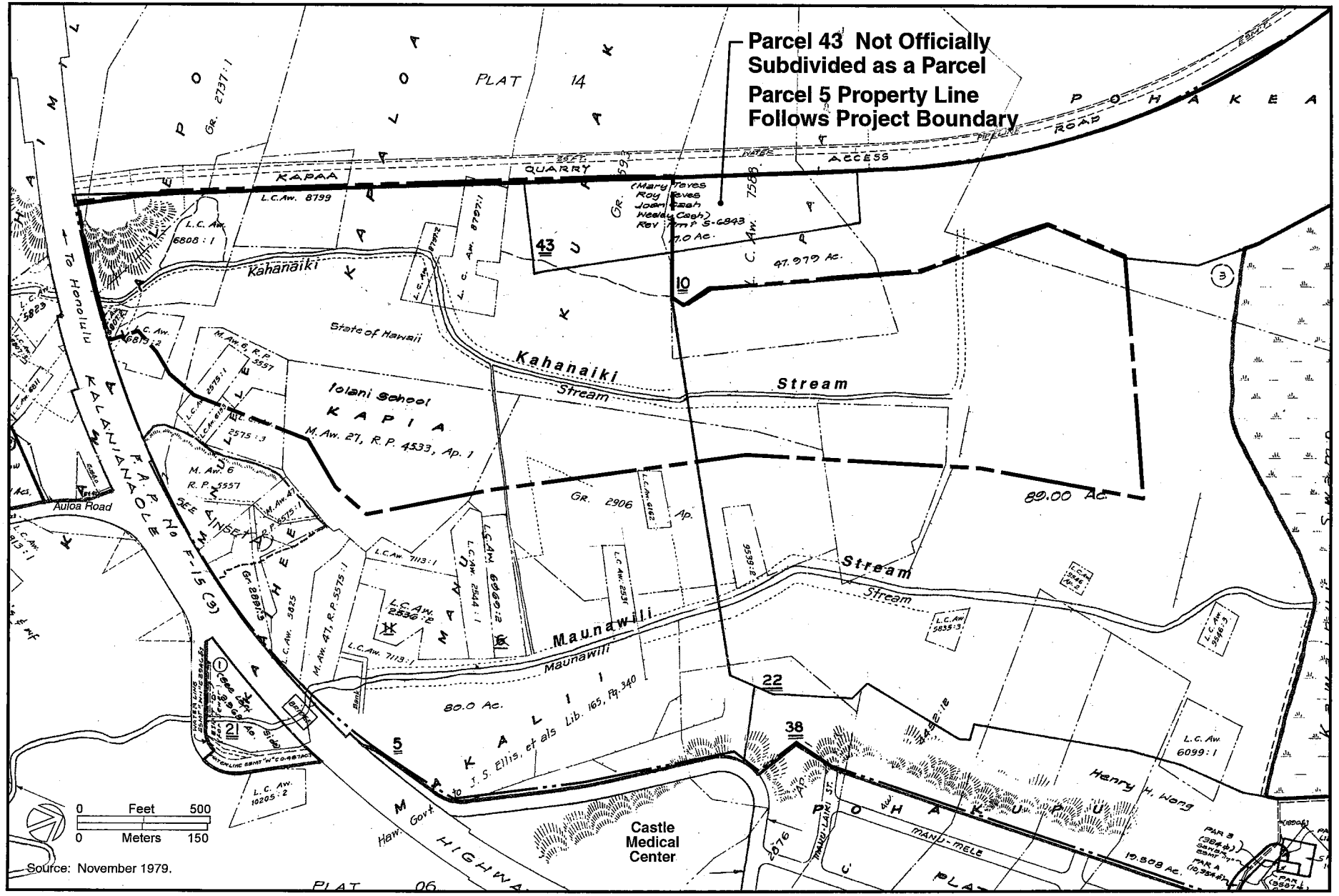


Oblique Aerial View of Project Area

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

Figure 2.2

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



Tax Map Key 4-02-013

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

Figure 2.3

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

Table 1 TMK Parcel Summary and Land Use Designations			
Tax Map Key Parcels: (1) 4-02-013:	Parcel 005 Parcel 022	97.22 acres 89.00 acres	(Project Area: 50 acres) (Project Area: 30 acres)
State Land Use District:	Urban District: Conservation District:	Primarily associated with upland area Primarily associated with wetland area	
Ko'olau Poko Sustainable Communities Plan Designation:	Open Space / Preservation Areas (entire project area)		
Special Management Area:	Entire project area is within the SMA boundary.		
City and County of Honolulu Zoning District:	P-1, Restricted Preservation District: P-2, General Preservation District:	Follows Conservation District Follows Urban District	

Parcel 5 is part of a larger area of 145 acres that was acquired by the State of Hawai'i using federal assistance from the Land and Water Conservation Fund (LWCF). The other portion of this LWCF area extends further north outside of the project site. As a result, the larger 145-acre area, of which the 80-acre project site is part of, is subject to Section 6(f) of the LWCF Act that requires it to be retained for use as public outdoor recreational.

Kawainui Marsh is a State regulated wildlife sanctuary under Title 13, Chapter 126, HAR. As a result, public access under these regulations is restricted to perimeter marked trails and roads, or other marked trails or roads, and no motorized vehicles are allowed. In this 80-acre project area, there are currently no marked trails or roads designated for such public access. Access to the project area is restricted to DOFAW employees for management and maintenance operations. and contractors hired by DOFAW or other authorized personnel for support activities.

2.3 General Site Conditions

Kawainui Marsh serves as an important flood control basin protecting the low-lying urbanized areas of Kailua Town and Coconut Grove subdivision that experienced flooding in 1988 when floodwaters breached the levee. The levee was constructed in 1966 along the northernmost edge of the marsh to enhance its flood storage capacity. It was later modified by the COE and City and County of Honolulu (City) in 1997 raising its height and constructing a concrete floodwall to address the 100-year flood level estimated for Kawainui.

The marsh generally drains in a south to north direction from Kapa'a Quarry Road and Kalaniana'ole Highway toward the shoreline. In the project area, Maunawili Stream is the main source of surface water flowing into the marsh with Kahanaiki Stream providing most of the remaining flows. Exhibit 2.1 provides photos of Kahanaiki Stream. Other inflow to the marsh comes from peripheral drainages and smaller, non-perennial streams. Water from the marsh is discharged into the Kawainui Channel (also referred to as Oneawa Channel) which drains into Kailua Bay.

Figure 2.4 provides an aerial photo of the project area and shows the general location of relevant streams. Additional photo documentation of existing conditions in the project area is provided in Appendix A.

Previous studies have estimated inflow from all sources in the marsh ranging from a low of 6.8 million gallons per day (mgd) to as much as 13.1 mgd. A 1994 assessment of the Maunawili Stream and Kawainui Marsh system used stream flow data to estimate flow from Maunawili and Kahanaiki Streams into the marsh at 12.3 mgd and estimated 0.3 mgd from other sources. Outflow from the marsh was estimated at approximately 4.6 mgd by evapotranspiration and 8 mgd through surface outlets and groundwater seepage (U.S. Army Corps of Engineers, December 2008).

Northbound Photo of Stream

Southbound Photo of Stream

Exhibit 2.1 – Photos of Kahanaiki Stream within Restoration Project Area

Existing Conditions Aerial Map

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

Figure 2.4

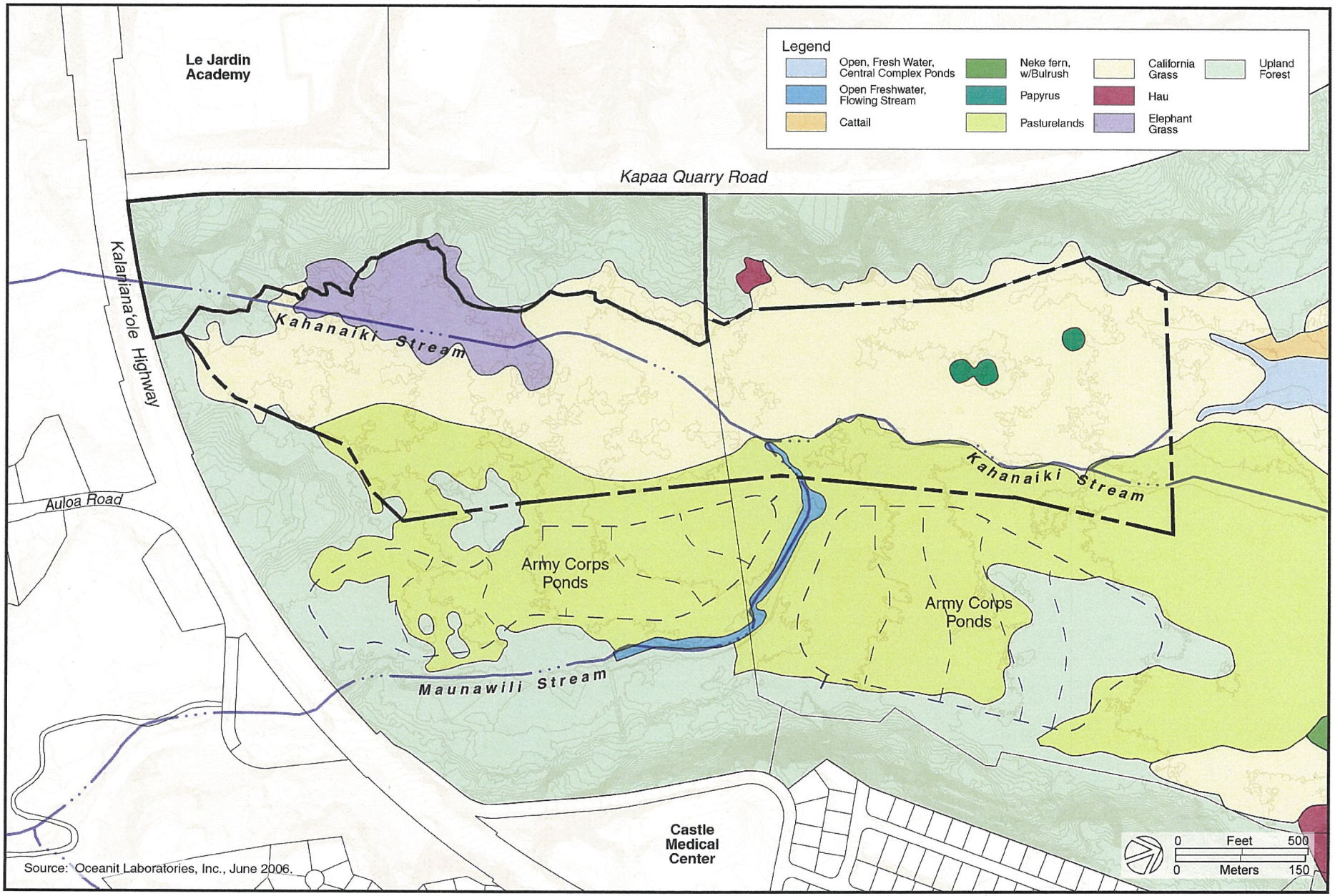
Prepared for:
State of Hawai'i
Department of Land and Natural Resources
Division on Forestry and Wildlife

Kahanaiki Stream is a perennial stream running through the project's 60-acre wetland restoration area characterized as generally consisting of a shallow (less than 1-foot deep) flow of water about four to seven feet wide. Existing invasive vegetation has been encroaching into the stream bank and the reducing open-water flows and shallow-water habitat. An abundant growth of this invasive vegetation has formed a very thick layer of peat (partially decomposed plant matter that is saturated with anoxic water) along the stream. The vegetation mat has also filled most of wetland area associated with Kawainui Marsh in this project area.

Vegetation in the wetland area can be characterized as consisting of a California grass (*Urochloa mutica*) community, Elephant grass (*Pennisetum purpureuma*) stands, and some pasture lands typically dominated by California grass. The California grass community is dominant, along with patches of cattail (*Typha latifolia*) and bulrush occur and terrestrial vines (ex. *Canavalia cathartica* and *Paederia scandens*) in some places. Figure 2.5 includes a map showing a summary of general vegetation assemblages (Oceanit Laboratories, Inc., June 2006).

The 20-acre upland riparian project area hosts a variety of plants and several large trees (monkeypods and java plum) associated with an upland forest as shown in Figure 2.5. The southern end near Kalaniana'ole Highway is overgrown with trees and other invasive vegetation. The northern section has been cleared by DOFAW to provide an open grassed area, and a row of hau trees is located along a portion of Kapa'a Quarry Road. The northern most portion of the area has a canopy of various trees. Exhibits 2.2, 2.3, and 2.4 illustrate existing conditions in the project area. Additional images are provided in Appendix A.

Exhibit 2.2 – Northbound Photo of Open Grass
and Trees Along Kapa'a Quarry Road



Vegetation Assemblages for Project Area

KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN

KAILUA, O'AHU

Figure 2.5

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

Exhibit 2.3 –Photo of Overgrown Southern Portion of Project Area

Avifauna and Aquatic Resources

Kawainui Marsh provides important habitat for four endangered species of native Hawaiian water birds and for migratory bird species. It was identified by the U.S. Fish and Wildlife Service as a "primary habitat" for the recovery of these water bird species. Its waters also support a variety of introduced and indigenous aquatic wildlife.

The project area provides habitat for various migratory waterfowl, wintering shorebirds and a variety of resident and introduced bird species. Standing ponds, wet pastures, and open water areas are attractive habitat for migratory waterfowl during the rainy season. Several migratory shorebirds identified in Kawainui Marsh include Pacific

Photo of Trail and Vegetation in Northern Portion

Photo of Canopy Forest in Northern Portion

Exhibit 2.4 –Photos of Northern Upland Forest Project Area

golden plovers (*Pluvialis dominica*), ruddy turnstones (*Arenaria interpres*), sanderlings (*Calidris alba*), and wandering tattlers (*Heteroscelus incanus*). Four species of endangered Hawaiian waterbirds found in Kawainui Marsh include the Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica alai*), Hawaiian moorhen (*Gallinule chloropus sandvicensis*), and Hawaiian duck (*Anas wyviliana*).

In the upper reaches of the marsh, Kahanaiki and Maunawili Streams are dominated by introduced species such as tilapia (*Oreochromis mossabmica* and *Sarothorodon melanotheron*), mosquito fish (*Gambusia affinis*), guppy (*Poecilia spp.*), carp (*Cyprinus carpio*), Chinese catfish (*Clarias fuscus*), swordtail (*Xiphophorus heller*), bronze catfish (*Corydoras aeneus*) and smallmouth bass (*Micorpterus dolomieui*). Native fish have been found in the marsh in low densities. These include the endemic goby (*Awaous guamensis*), an indigenous goby (*Stenobobius genivittatus*) and an endemic eleotrid (*Eleotris sandwicensis*).

There are several invertebrates within the marsh. Some of the introduced species include the Tahitian prawn (*Macrobrachium lar*), crayfish (*Procambarus clarkia*), damselfly (*Ischnura ranburii*), apple snail (*Pomacea sp.*), and pond snails (*Melanoides sp.*). Native invertebrates include the native shrimp (*Atyoida bisculata* and *Marcrobrachium grandimanus*) (U.S. Army COE, December 2008).

Kawainui Marsh Predators

A wide variety of waterbird predators, mammalian, avian and amphibian, live within Kawainui Marsh or access the marsh from the surrounding areas. The small Indian mongoose (*Herpestes auropunctatus* or *javanicus*) is the most pernicious of the predators in the marsh and a key predator to waterbirds. The roof rat (*Rattus rattus*) inhabits a wide range of environmental conditions, and has been identified as a predator of native birds. Feral dogs (*Canis familiaris*) may constitute a threat to ground-nesting birds to a limited degree although they seem to confine their foraging to rats, sheep, goats and pigs. Because of the proximity of urban communities, domesticated dogs may also pose a threat to the Kawainui Marsh waterbirds, particularly when dogs are walked through the marsh. Feral cats (*Felis catus)* pose a threat to both ground nesting and arboreal nesting birds.

Other species have been observed consuming or endangering native waterbirds and therefore constitute a threat to their recovery at the marsh. The cattle egret (*Bubulcus ibis*), introduced in Hawai'i in 1959 to control flies on cattle, is a predator on Hawaii's endangered waterbirds. Predation of waterbird chicks by the cattle egret and Black-Crowned Night Heron (*Nycticorax nycticorax*) has been documented at the Oahu National Wildlife Refuge (NWR).

Historic and Cultural Resources

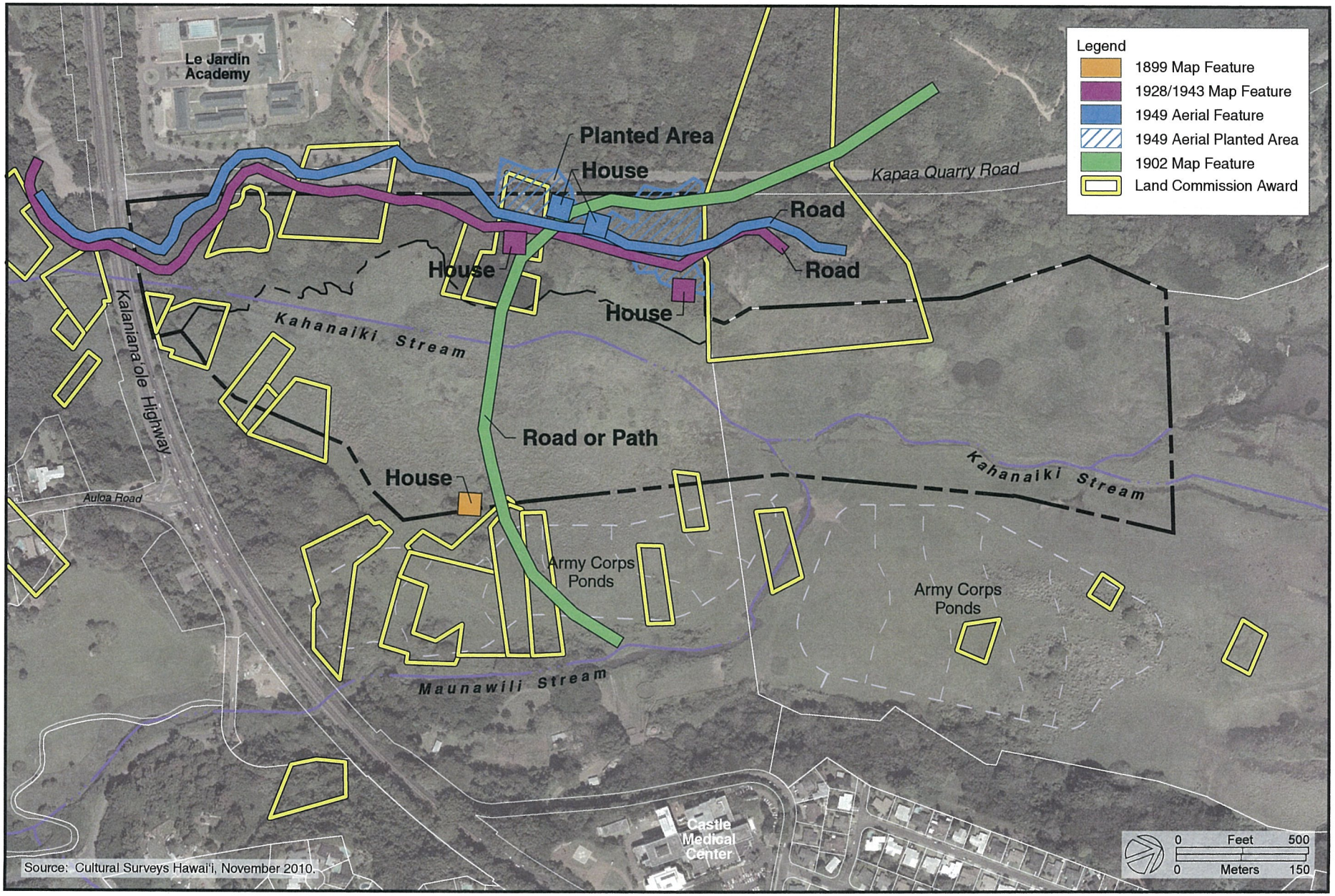
The project area lies within the Kawainui Marsh archaeological cultural-historical complex that was deemed eligible for listing on the National Register of Historic Places in 1979 (SIHP 50-80-11-2029). The historic and cultural significance associated with Kawainui Marsh as a whole has been well documented. There are three identified heiau distributed around the marsh including Pahukini Heiau (Site 359), Holomakani Heiau (Site 360) and Ulupō Heiau (Site 371).

Historic maps, aerial photographs, and Land Commission Award records all demonstrate the vitality of the marsh and describe the abundant *lo'i* cultivation during the *Māhele* of 1848. Within the project restoration area, there were over two dozen *lo'i* patches fed by *'auwai* and possibly Maunawili Stream. The *lo'i* patches were converted to rice cultivation within the marsh in the late 1800s and early 1900s. Modern sediment deposits from floods and cattle grazing have both affected the integrity of what may have been left in the way of archeology within the lowland areas of Kawainui Marsh.

A reconnaissance survey conducted by Cultural Surveys Hawai'i, Inc. (CSH) for the project area identified two historic properties: 1) components of the Kawainui Marsh archaeological-cultural-historical complex (SIHP# 50-80-11-2029); and 2) an in-use, early 20th century road remnant (SIHP# 50-80-11-7199). The only traditional artifact observed was a grinding stone lying at the base of a break in slope under a particularly large noni (*Morinda citrifolia*) tree near the corner of a former land commission award site. These grinding stones are somewhat characteristic traditional Hawaiian artifacts of the Kawainui slopes.

A long linear northeast/southwest trending break in slope ascending from the west (*mauka*) side of the marsh near the grindstone was identified. This probable terrace remnant is suggested to relate to two terraces previously identified by others (Ewart & Tuggle's 1977 "Site 7", Clark's 1980 "Cluster 12", and B. P. Bishop Museum Site # 50-Oa-G6-36). It appears these two sites may be the same but were shown as being 1,720 feet (550 meters) apart. However, it is probable that these two terrace sites both relate to road and house construction in the immediate area in the early twentieth century. This terrace is also believed to relate to extensive early twentieth century activity including grading for a road, agricultural field preparation, and possibly four houses. Figure 2.6 shows the locations of these post-contact features.

Limited subsurface testing within the project area identified a sparse amount of historic and traditional Hawaiian artifacts, some of which appear to be linked with habitation within the possible footprint of a house lot that appears on an 1899 map, and considered components of SIHP# 50-80-11-2029. Limited subsurface testing did not expose subsurface cultural deposits or modification within the project area. The documentation of



Post-Contact Features

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

Figure 2.6

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

backhoe test trenches that were excavated along LCA boundaries and within possible 20th century house lots failed to identify any associated rock or sediment walls (*lo'i* walls), foundations, or associated features.

No further archaeological work was recommended for the road remnant (SIHP# 50-80-11-7199). An archaeological monitoring program would be implemented to address the potential impact of subsurface disturbance within the project area. The monitoring plan would include provisions for the post-review of historic properties if any were encountered during construction activities. Preservation, in the form of avoidance and protection, will be implemented for the two components of SIHP# 50-80-11-2029 (grinding stone and habitation area) identified. A strand of bamboo about 12 feet wide present at the habitation site would also be avoided if possible from restoration activities.

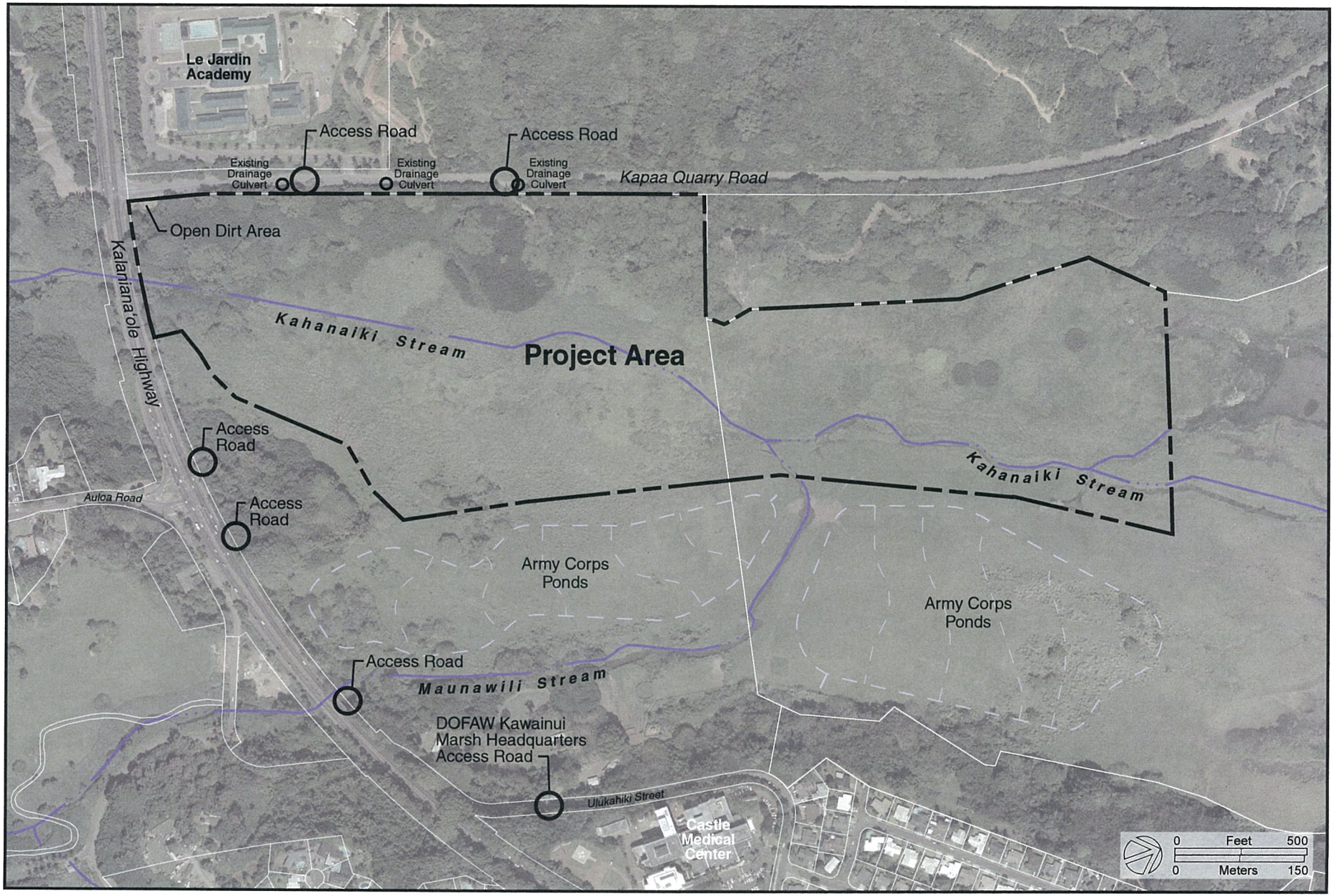
Access and Drainage Conditions

Currently, access to the project area is restricted to DOFAW employees for management and maintenance operations along with contractors hired by DOFAW for support activities. Kawainui Marsh is a State regulated wildlife sanctuary under Title 13, Chapter 126, HAR. As a result, it is prohibited for any person to enter the sanctuary unless authorized by DOFAW or by permit from the Board of Land and Natural Resources. Additional access could be permitted by perimeter marked trails or roads. However, no such access trails have been established.

DOFAW has six (6) vehicular access locations to the project area, which are shown on Figure 2.7. One access is from the DOFAW Kawainui Marsh Headquarters located behind Castle Medical Center along Ulakahiki Street. This location allows DOFAW to access the lower (*makai*) portion of the project area from their headquarters using the pasture area north of Maunawili Stream between the two ponds being developed by the COE.

There are three access driveway locations along the State Department of Transportation's (DOT) Kalaniana'ole Highway. One location is referred to as the "Mokulana" access across from Auloa Road, which used to serve a former residence on the site. The second access along the highway is situated slightly east of the Mokulana access as shown on the figure. A third access is located further east near the highway's bridge serving Maunawili Stream. All these access points are gated.

The fifth access is from Kapa'a Quarry Road about 620 feet north from the intersection with the highway. This access has been closed and is blocked off from use at this time. The sixth access is about 350 feet north of the entrance to Le Jardin Academy. This gated location provides access to a dirt road that runs through the northern upland area of the project.



DOFAW Access Locations and Drainage Culverts

KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN

KAILUA, O'AHU

Figure 2.7

Prepared for:
State of Hawai'i
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Division on Forestry and Wildlife

Kapa'a Quarry Road is a privately owned road in the vicinity of this project area (part of TMK 4-02-014: 002). There are no designated parking areas along Kapa'a Quarry Road for vehicles within this area. The posted speed limit along this road is 25 mph, however, vehicles frequently travel at higher speeds. An open dirt area along Kapa'a Quarry Road near the intersection with Kalaniana'ole Highway is frequently used for parking (photo of area included in Appendix A).

The portion of Kapa'a Quarry Road along the project area has a history of individuals dumping rubbish or bulky items along the roadside. This problem is periodically addressed through community clean-up events. There is no fencing or barriers around the perimeter of the marsh separating it from the highway and roadway, but vegetative buffers do form a visual barrier as indicated in photos in Appendix A.

Surface water runoff in the project area enters the marsh primarily from Kahanaiki and Maunawili Streams. Runoff from the highway also sheet flows into drainage culverts eventually discharging into these streams. A State DOT drainage ditch runs along the northern side of the highway from the intersection of Kapa'a Quarry Road discharging into Kahanaiki Stream at the bridge crossing. The drainage ditch is within the State DOT's highway right-of-way and outside of the project area.

There are three drainage culverts along Kapa'a Quarry Road collecting runoff from Le Jardin Academy and *mauka* areas before discharging into Kawainui Marsh. There is also one drainage location collecting overland sheet flow from Le Jardin Academy's access road and discharging runoff across Kapa'a Quarry Road and into the marsh. These culverts are in poor condition, filled with sediment, or in complete disrepair (see Exhibit 2.5).

Exhibit 2.5 –Photo of Existing Drainage Culvert

As a result, runoff discharging into the marsh from these general areas have contributed to erosion of the marsh's upland areas and may have begun to undermine the structural stability of some portions of Kapa'a Quarry Road. Runoff from Le Jardin Academy's access driveway also concentrates some flows from the campus across the road and into the marsh.

DOFAW Maintenance Operations

DOFAW maintenance operations at Kawainui Marsh are limited due to a shortage of available assigned staff. Three full-time positions were initially established for maintenance of the area. However, three existing positions were subsequently cut due to the State's fiscal circumstances. This forced DOFAW to increase the responsibilities of existing personnel making it more difficult to achieve maintenance objectives for the marsh. Recent maintenance operations have focused on reducing the amount of invasive vegetation in the wetland and upland areas. Vegetation is mowed or cut, and herbicide is applied periodically to control weeds as necessary.

DOFAW maintenance operations in the project area average approximately 12 man-days per month depending on weather conditions. Consequently, most work takes place during dry summer months. Some staff utilizes excavators or other mechanical equipment for larger maintenance activities, while others, including prisoners from the State's work furlough program, use weed whackers.

Equipment maintenance is also a factor that affects the availability of staff and their ability to maintain the environment at Kawainui Marsh. Machinery needs to be serviced, oiled, and frequently parts are ordered for replacement. These activities reduce the amount of time actually spent clearing and removing invasive vegetation by DOFAW staff.

DOFAW implements a predator control program as part of their maintenance operations since 2008. DOFAW currently has a contract with the U.S. Department of Agriculture to implement a trapping program. Cage traps are placed around the perimeter of the upper reaches of the project area, as well as in other areas of the marsh. Cage traps are the primary tool for controlling mongoose and feral cats.

Chapter 3
Planning Framework

CHAPTER 3
PLANNING FRAMEWORK

Wetland restoration conceptual improvements were developed based upon a planning framework established for this 80-acre project. The intent of the framework is to ensure DOFAW's requirements for the USFW grant are addressed, and are consistent with their mission and objectives for the larger Kawainui Marsh area. Guiding principles were developed based on best use practices for the site, the specific elements of the grant application, existing references and studies published for Kawainui Marsh, consultations with government agencies and the community, and evaluation of existing site conditions. A summary of these factors contributing to the planning framework is provided below.

3.1 Project Need and Objectives

DOFAW's mission is to enhance, protect, conserve and manage Hawaii's unique and limited natural, cultural and historic resources held in public trust for current and future generations. This includes the people of Hawai'i and visitors acting in partnership with others from the public and private sectors. In fulfilling this mission, DOFAW obtained a grant to implement improvements to a portion of Kawainui Marsh. Therefore, the goal for this project supported by grant funds is to restore habitat for native Hawaiian water birds, migratory shorebirds and waterfowl, and native fish species within the study area at Kawainui Marsh. DOFAW's three primary management objectives for this area include: 1) controlling invasive vegetation; 2) controlling water flow into the marsh; and 3) managing public access.

Objectives also involve local organizations, businesses, schools and City, State and Federal agencies in the process in order to integrate the wildlife sanctuary into the community. By including a broad spectrum of community organizations, businesses, schools and government agencies, the project is intended to instill a sense of ownership by local citizens, educate residents and visitors, and encourage further habitat restoration at this internationally recognized marsh.

Today, over 30 percent of Hawaii's natural lowland wetlands have been filled or converted to other land uses such as agriculture and urban expansion. Oahu's windward coast wetlands are mostly small and isolated by topography and urban expansion. Long-term protection of the remaining wetlands is essential to ensure protection of native Hawaiian water birds, flood control, ground water recharge, and aesthetic values.

Kawainui Marsh is the largest remaining freshwater wetland in the State of Hawai'i and provides flood control and sediment filtration that protect urbanized areas of Kailua and the Kailua Bay ecosystem. It also accommodates important habitat for endangered endemic waterbirds and several species of migratory shorebirds and waterfowl, and contains numerous cultural and

historical resources. Kawainui Marsh's intrinsic values therefore make it a critical location for wildlife protection, watershed interpretation and education, and an area rich in cultural and historical resources.

Despite its rich environmental and cultural resources, challenges with management and maintenance have resulted in an overgrowth of alien and invasive vegetation contributing to limited wetland habitat suitable to support endangered Hawaiian waterbirds. Currently, California grass, water hyacinth, Kariba weed and cattail are choking waterways and native emergent vegetation. This has severely curtailed habitat for endemic Hawaiian waterbirds foraging and nesting.

Storm water runoff from Kapa'a Quarry Road is causing erosion of upland areas contributing to increased discharges of sediment and other materials into the marsh. There are also challenges with predator control. Improved access within the upland section of the project area is needed for DOFAW to effectively conduct maintenance activities. Presently, there is limited access to most areas due to existing overgrowth of vegetation and absence of access for vehicles and staff.

DOFAW is committed to the preservation, protection, and enhancement of the natural and cultural resources of Kawainui Marsh. As a result, this project represents a first step to restore the marsh and enhance its habitat. The primary project objectives addressed by restoration plan actions include:

- Restore native wetland habitat and naturalize Kahanaiki Stream. After gradual removal of invasive vegetation, various types of native plants would be used to re-vegetate the wetland area and the upland slope along Kapa'a Quarry Road.
- Restore native bird habitat and effectively control predation of native birds.
- Mitigate drainage failure and reduce erosion entering the marsh by addressing existing storm water runoff from Kapa'a Quarry Road.
- Ensure efficient DOFAW maintenance operations and improve their maintenance capabilities to sustain a remediated native ecosystem.

Increasing public access within the marsh would support development of interpretative and educational programs with schools and various organizations interested in Kawainui Marsh. Passive outdoor recreational amenities (e.g. pedestrian trails, viewing platforms, etc.) would also support such programs and LWCF objectives. Initial project plans included limited public access and passive outdoor recreational amenities. However, concerns with having such amenities and increased public access within this project area were raised by some community organizations during the review of a Draft EA. As a result, increased public access and outdoor recreational amenities were eliminated from this particular project. Such amenities and public access would be better evaluated within the context of the entire Kawainui-Hāmākua Marsh Complex under a separate

project to update the master plan for the complex. Project improvements would thus focus on wetland restoration and habitat enhancement.

3.2 DOFAW Grant Application

The grant application prepared by DOFAW to fund the wetland restoration project focused on restoring habitat for native Hawaiian water birds, migratory shorebirds and waterfowl, and native fish species in Kawainui Marsh. It also included community outreach efforts to local organizations, businesses, schools and government agencies in order to integrate the wildlife sanctuary into the fabric of the community. Improvements would expand endangered water bird habitat by restoring and enhancing wetland and stream areas currently choked with a heavy growth of invasive vegetation. Restoration plans would also improve the hydrologic function of the wetland and stream areas benefiting a wide range of native species and improving the educational attributes of the site.

The grant application proposed restoration of about 60 acres of wetland and stream-bank habitat to support endangered Hawaiian stilts, gallinules, coots and ducks, as well as numerous species of migratory shorebirds and waterfowl. Stilt use is projected to increase from four birds and no nests to 60 birds and 20 nests; gallinules should increase from two birds and one nest to 40 birds and 20 nests; and coots should increase from no birds to 12 birds and 6 nests. Koloa and migratory shorebirds and waterfowl should increase from no birds to a multi-species complex utilizing the wetland on a seasonal basis.

Numerous (approximately 1,000) native sedges and other native species would be planted in the 60-acre wetland portion of the project area in accordance with the grant application. Upland slopes will be graded to address surface runoff discharging into the marsh, reduce erosion, and increase runoff detention prior to entry into the wetland area. DOFAW's access within the area would be increased to improve maintenance and management operations.

Native trees (approximately 1,000) will be planted on the upland slopes and riparian areas as part of erosion control efforts and replacing invasive vegetation. The project area would be fenced (about 8,500 linear feet) for predator control and other control efforts implemented to bring the number of rats, mongooses and feral cats down to remnant levels. In the future, coordination with Le Jardin Academy, other schools, and educational and cultural organizations would assist with programs and other research activities conducted at Kawainui Marsh.

3.3 Existing Planning References and Documents

Several studies have been prepared for Kawainui Marsh over the years that create a baseline of information and guidance for future improvements and are important considerations for this restoration project. A summary of pertinent guidelines is provided below.

1. State DLNR Kawai Nui Marsh Master Plan; Report R-100 (July 1994).

   The State DLNR, DOFAW published this master plan as an update to the Kawai Nui Heritage Plan prepared in October 1982. Figure 3.1 illustrates proposed improvements from the 1994 plan that are relevant to the study area for this report. Improvements included:

   - A waterbird enhancement area generally corresponding to the current restoration project area. A buffer zone between upland areas and the waterbird habitat was also recommended.
   - A 20-acre area for wetland agricultural use of the marsh generally surrounding the Mokulana peninsula situated along Kalaniana'ole Highway.
   - A visitor center and ethnobotanical garden at the intersection of Kalaniana'ole Highway with Kapa'a Quarry Road. A trail was shown extending northbound paralleling Kapa'a Quarry Road from the visitor center generally situated within the project's upland area.

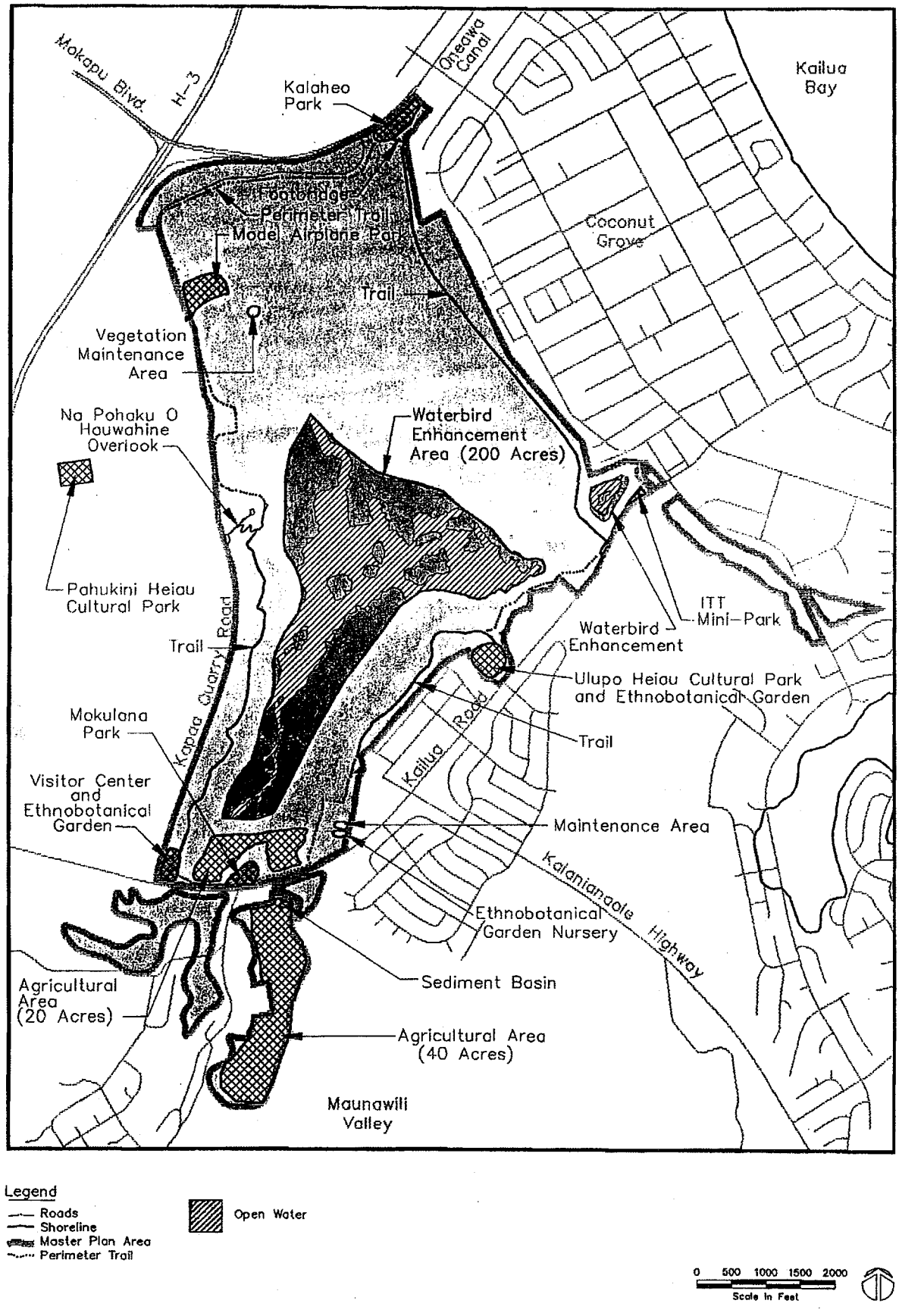
2. State DLNR Management Plan for Kawai Nui Marsh (March 2000).

   The State DLNR, Land Division published a management plan for the marsh under a Final Environmental Assessment that was part of their acquisition of property from the City and to continue implementation of the 1994 master plan recommendations. Figure 3.2 highlights recommendations from the DLNR management plan. These include:

   - Provide for long-term maintenance activities to assure the protection and enhancement of the marsh's flood control capabilities.
   - Provide a maintenance facility and a vegetation processing area south of the existing model airplane park to augment existing operations,
   - Restore wildlife habitats in the marsh.
   - Create about 70 acres of mudflats and shallow ponds in three areas in the southern portion of the marsh in coordination with the COE.
   - Restore riparian wetland habitat along Maunawili and Kahanaiki Streams, vegetation clearing, and installation of fencing was proposed.

3. Kawai Nui Marsh Pathway Plan (May 2001).

   The Kailua Community Vision Team funded a study to plan a pathway around the marsh in accordance with recommendations from the 1994 master plan. Figure 3.3 graphically shows proposed improvements from this pathway plan associated with the wetland restoration project area. Elements include:



Source: Wilson Okamoto & Assoc., Inc. July 1994.

Figure 3.1

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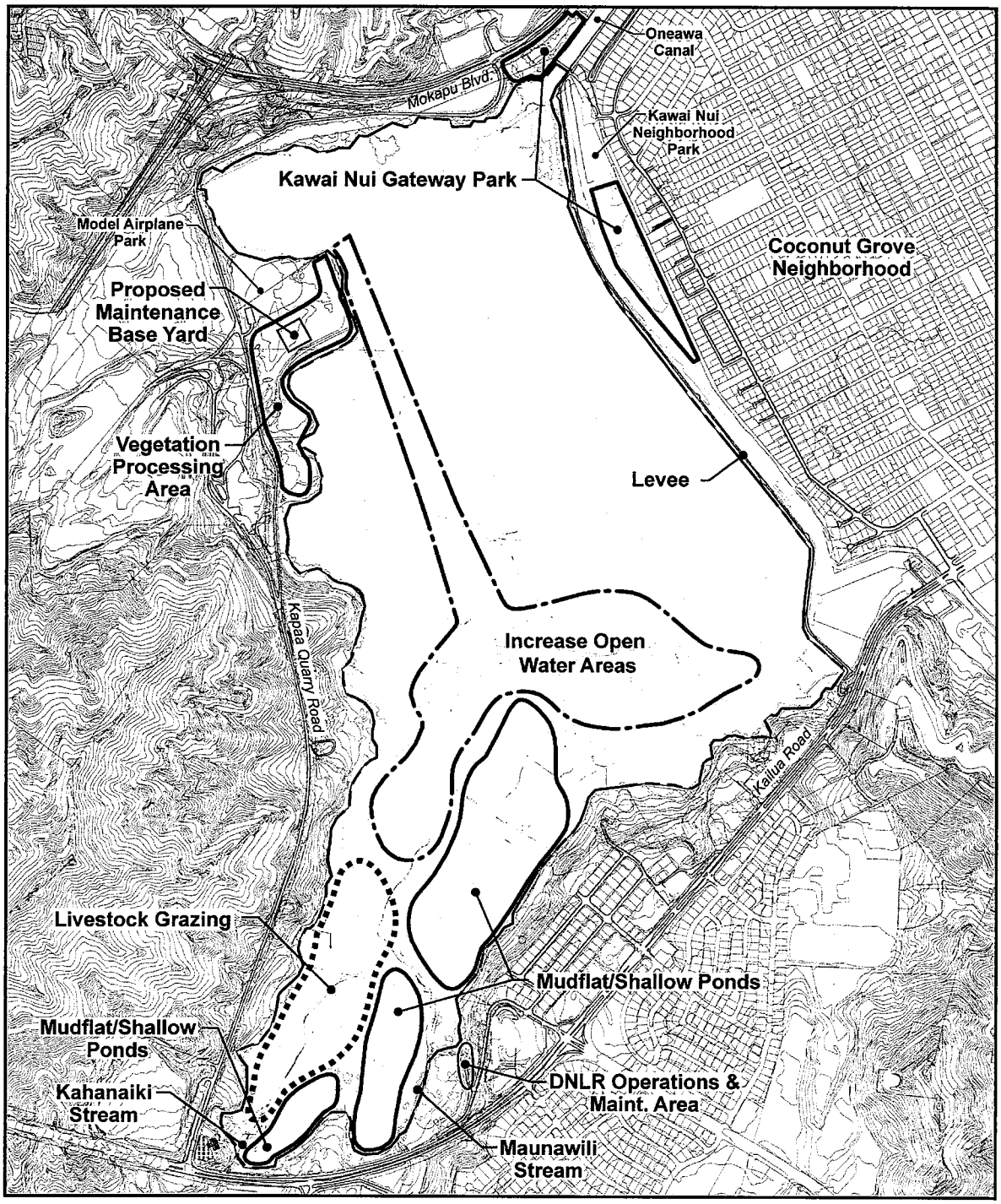
Division on Forestry and Wildlife

DLNR Kawainui Master Plan (July 1994)

KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN

KAILUA, O'AHU



Proposed Improvements

Kawainui Nui Pathway
Kailua, Koolaupoko, Oahu

0 Feet 1300
0 Meters 400

Figure 4

Source: Helber Hastert & Fee, Planners, March 2000.

Figure 3.2

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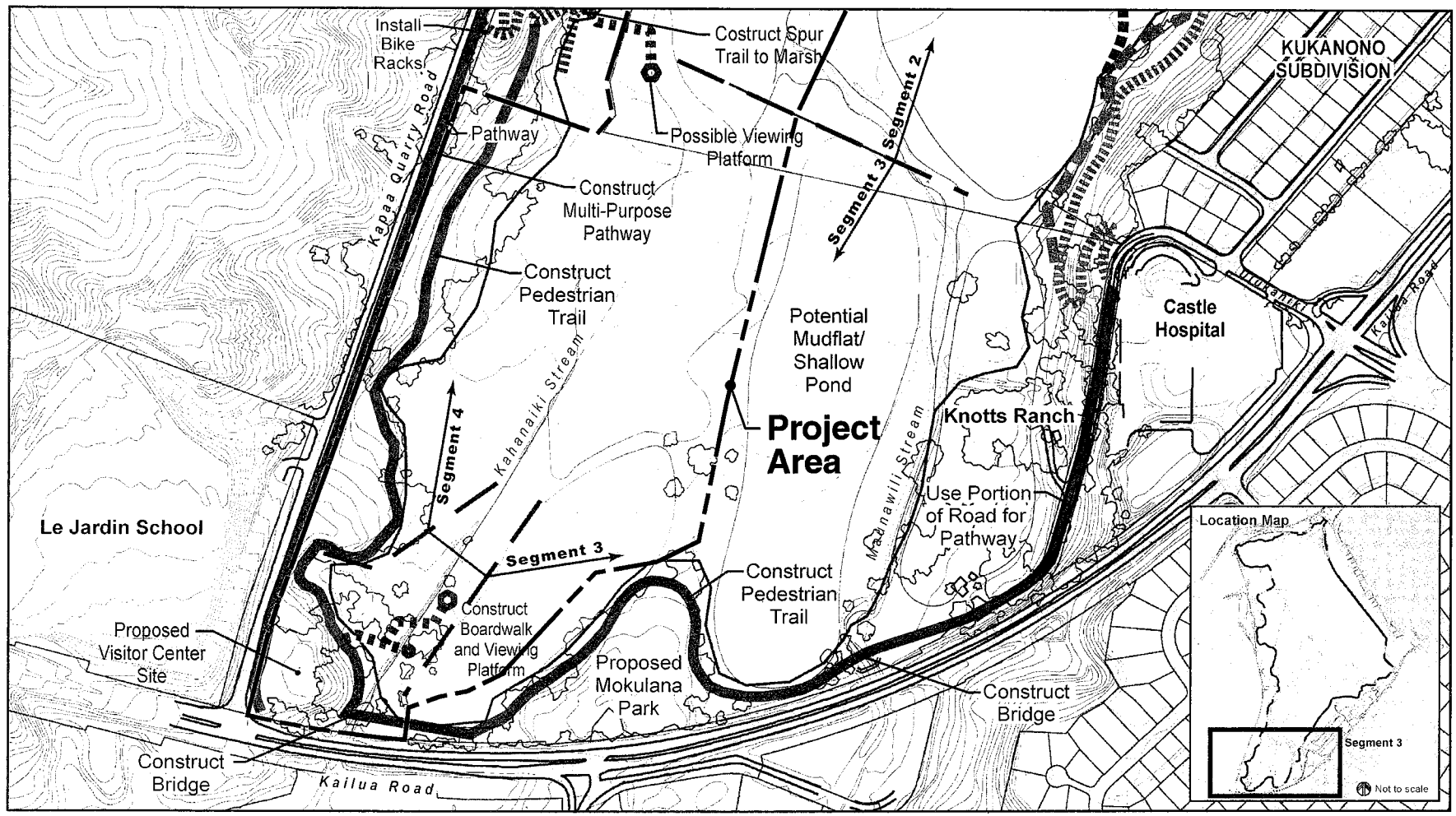
Department of Land and Natural Resources
Division on Forestry and Wildlife

DLNR Management Plan Improvements (March 2000)
KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU



Source: Helber Hastert & Fee, Planners, May 2001.

Kawainui Pathway Plan (May 2001)

KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN

KAILUA, O'AHU

Figure 3.3

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

- A multi-purpose pathway for pedestrians and bicyclists along Kapa'a Quarry Road.
- A pedestrian trail within the upland area below Kapa'a Quarry Road extending from a visitor center site (as proposed in the 1994 plan). The trail extended along the highway and around the Mokulana Peninsula toward Castle Medical Center.
- A boardwalk and viewing platform extending into the marsh from the visitor center site.

4. Second Draft Revised Recovery Plan for Hawaiian Waterbirds (May 2005).

The latest draft of the U.S. Fish and Wildlife Service recovery plan addresses four species of Hawaiian waterbirds listed as endangered. Key findings include:

- Kawainui Marsh is listed as a "Core Wetland" which is an area providing habitat essential for supporting larger populations of Hawaiian waterbirds.
- Expansion of open water areas would facilitate use by all four endangered waterbird species, which now use the area only in small numbers.
- Recommended recovery actions included implementing management plans, securing water sources and managing water levels, managing vegetation, reducing and monitoring predator populations, minimizing human disturbances, monitoring and controlling avian disease, monitoring populations, and removing the threat of mallard-Hawaiian duck hybridization.

5. DOFAW Hawai'i's Comprehensive Wildlife Conservation Strategy (October 2005).

The DOFAW plan comprehensively reviewed the status of a full range of the State's native terrestrial and aquatic species. It presented strategies for the long-term conservation of species and their habitats. Management actions and future needs for Kawainui Marsh identified include:

- Current Management Needs: Hydrologic studies, habitat restoration, including invasive plant removal, native wetland planting, and predator control.
- Future Needs: Continue existing management, secure adequate funding to support expanded management (increased predator control, invasive weed removal, habitat restoration, educational opportunities).

6. State Comprehensive Outdoor Recreation Plan 2008 Update (April 2009).

The State DLNR published this update of the plan as part of Federal LWCF program requirements. The technical reference document serves as a tool for statewide outdoor recreational planning, leadership, and action. Relevant parts of the plan include:

- Recognition of Kawainui Marsh as a State wetland of importance and popular for outdoor recreation (walking, jogging, biking). It notes that the marsh has potential for further recreational value based on recommendations from the 1994 master plan.

- 'Ahahui Mālama I Ka Lōkahi was identified as an organization that has taken the lead in developing educational activities and service learning projects at the marsh.

3.4 Consultations with Agencies and Community

Consultations with several government agencies and community organizations were conducted to solicit public input and comments on restoration improvements proposed at Kawainui Marsh. Community consultations included two public informational meetings, presentations to the Kailua Neighborhood Board, meetings with Ho'olaulima Iā Kawainui and other community organizations, presentations at community sponsored events (e.g. World Wetlands Day, Envisioning Kawainui community meetings), and briefings of elected officials.. A summary of major issues or requirements contributing to the planning framework are listed below.

1. Identified various agency permits triggered by restoration efforts in the wetland along with crossing streams which may be required for maintenance operations.
   - Plans for invasive vegetation removal methods along with re-vegetation using native plants were modified based on permit requirements trigged by such actions.
   - Information on a delineated wetland boundary is necessary so that jurisdictional boundaries can be determined when evaluating project improvements.
2. Outdoor recreation amenities and public access, initially included in restoration plans to support LWCF requirements, will be evaluated in the context of master plan update for the entire Kawainui-Hāmākua Marsh Complex. This change was in response to concerns expressed by community organizations.
3. Other components that should be included or addressed as part of the restoration plans include: 1) a resource management component addressing staffing and funding to maintain the natural resource; 2) the concept of adaptive management should be incorporated to maintain flexibility with operations over time; and 3) culvert improvements along Kapa'a Quarry Road should serve as best management practices to reduce discharges into the marsh.
4. A Memorandum of Agreement between the Board of Land and Natural Resources and 'Ahahui Mālama I Ka Lōkahi establishes a cooperative effort to provide educational and interpretive opportunities for the public about the natural and cultural resources of Kawainui Marsh. Such opportunities will be addressed as part of the master plan update of the Kawainui-Hāmākua Marsh Complex.
5. Information on DOFAW's management and operation of the marsh should be included.
6. Re-establishing taro *loi* within the marsh for use by cultural practitioners was suggested for consideration. Such opportunities will be addressed as part of the master plan update of the Kawainui-Hāmākua Marsh Complex.

7. Potential historic sites associated with former *'auwai* may be present in the wetland. Therefore, consideration should be given to minimizing impacts from restoration activities. Archaeological testing did not encounter subsurface sites, and archeological monitoring will be implemented to mitigate potential effects.

Other various comments received are documented in a Final EA prepared for this project.

3.5 Conceptual Restoration Plan Guiding Principles

A number of guiding principles were developed to guide preparation of the restoration plan for Kawainui Marsh. These principles were established based upon the planning references and documents, community and agency consultations, and evaluation of existing site conditions. These principles are listed below.

1. Removal of invasive vegetation within the wetland will be implemented in phases due to the size of the area and available DOFAW staffing.
2. Adaptive management concepts should be incorporated into the plan to provide DOFAW with options and flexibility to modify restoration activities.
3. Resource management information should be incorporated to support DOFAW efforts to maintain the study area after restoration activities are completed.
4. An extensive row of vegetation (hau trees) along Kapa'a Quarry Road should be retained and enhanced with native vegetation to retain the visual buffer from the marsh. The northern section of upland area improved by DOFAW provides a canopy of trees that should be enhanced with selective tree removal and planting of native vegetation.
5. A variety of native plants should be identified as part of restoration plan for DOFAW's consideration and implementation of re-vegetation efforts.
6. A gully at the southern end of the study area that receives storm water runoff from the roadway should be improved to allow for detention of water flow and to reduce sediment and other materials from entering the wetland.
7. Re-evaluation of the drainage conditions along Kapa'a Quarry Road should be conducted to identify improvements needed to improve storm water runoff discharging into the marsh since existing drainage culverts are structurally deteriorated.
8. Accessible paths for DOFAW maintenance vehicles should be provided along the upland area.
9. Provisions should be incorporated into the plan to minimize potential impacts on historic sites.
10. Restoration improvements should not preclude future implementation of recommendations from previous studies or plans.

Chapter 4
Wetland Restoration Plan

CHAPTER 4
RESTORATION PLAN FOR KAWAINUI MARSH

4.1 Kawainui Marsh Conceptual Restoration Plan

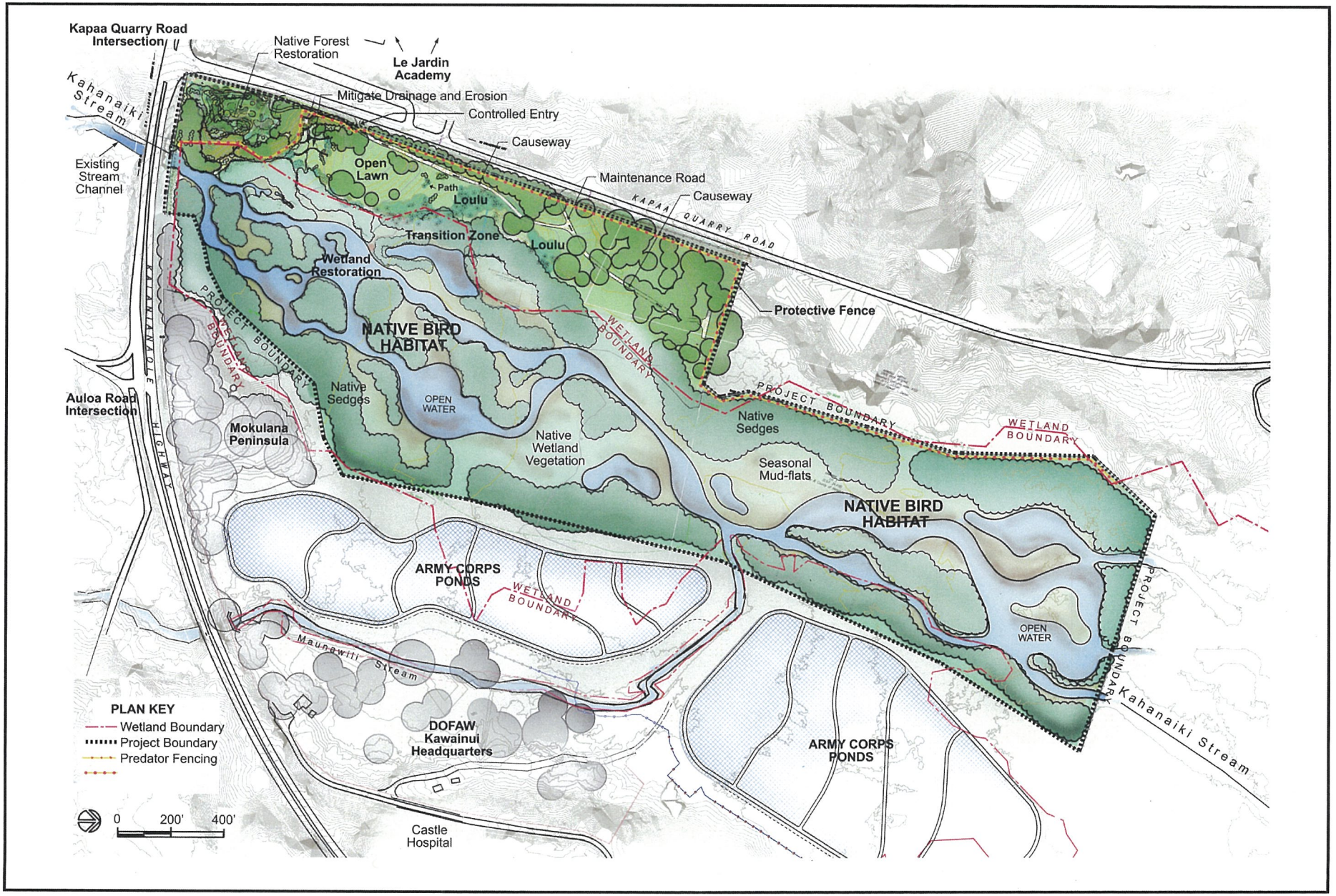
Restoration improvements will involve gradual removal of invasive vegetation covering most of the marsh in the project area and restoring it with native vegetation. This will allow Kahanaiki Stream to naturalize, open up surface water flows, and establish seasonal mud flats. A combination of mechanical 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 COE (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 2012. 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. Predator fencing will be installed around the wetland area and some adjacent upland areas 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.

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



Kawainui Marsh Restoration Conceptual Plan

Figure 4.1

KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN

KAILUA, O'AHU

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.

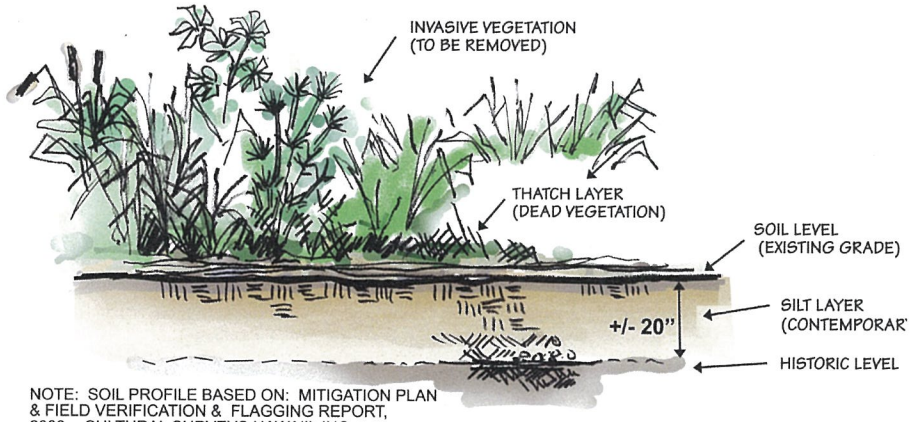
Existing invasive vegetation (e.g., California Grass, Cattail, etc.) will be removed along with dead vegetation that has formed a thatch layer. Based on prior test excavations, a contemporary soil layer about 20 inches deep is located below the existing vegetation. It is the result of sediment transported 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 4.1 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.

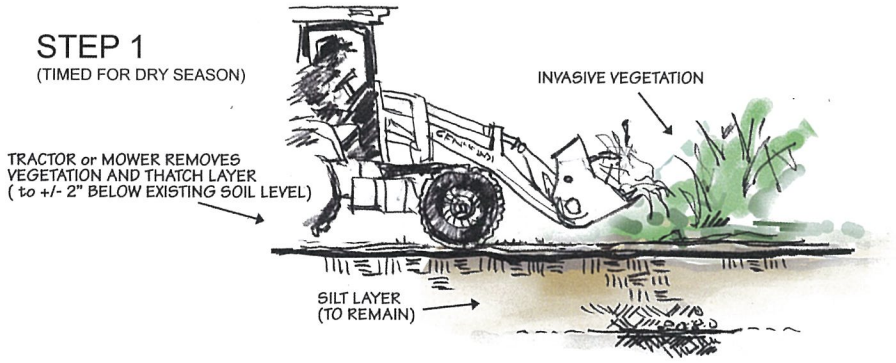
EXISTING CONDITIONS



NOTE: SOIL PROFILE BASED ON: MITIGATION PLAN & FIELD VERIFICATION & FLAGGING REPORT, 2003 - CULTURAL SURVEYS HAWAI'I, INC.

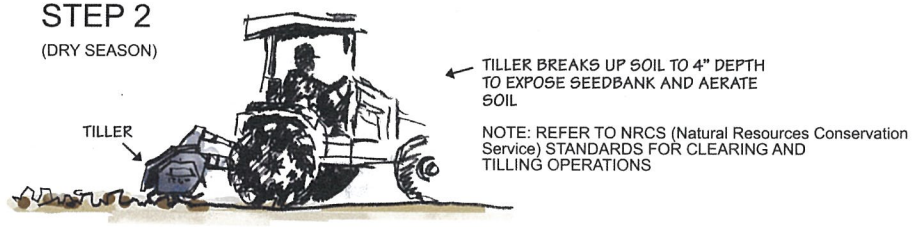
STEP 1

(TIMED FOR DRY SEASON)



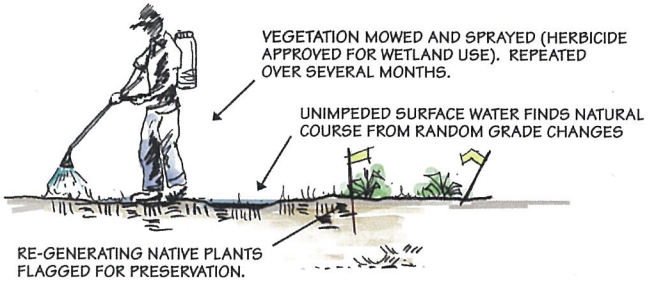
STEP 2

(DRY SEASON)



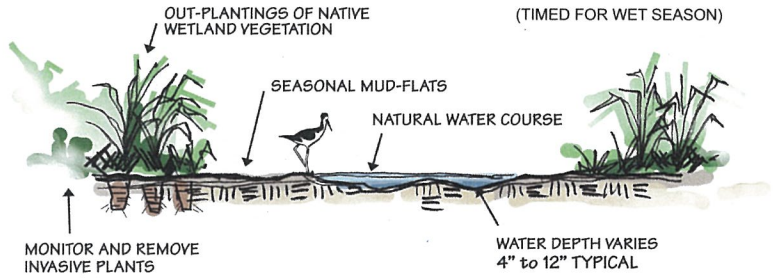
NOTE: REFER TO NRCS (Natural Resources Conservation Service) STANDARDS FOR CLEARING AND TILLING OPERATIONS

STEP 3



STEP 4

(TIMED FOR WET SEASON)



INVASIVE PLANTS TO BE REMOVED

- California Grass
- Cattail
- Papyrus
- Schefflera
- Umbrella Sedge
- Pickle Weed
- Salvinia
- other (see Kawai Nui Marsh Invasive Aquatic Plant Study, DLNR, 2006)

EXAMPLE NATIVE WETLAND PLANTS TO BE RESTORED

- Ahu'awa (Cyperus javanicus)
- 'Aki'aki (Schoenoplecus spp.)
- 'Akulikuli (Sesuvium portulacastrum)
- Bacopa (Bacopa monnieri)
- Ihi'ihi (Marsilea villosa)
- Kaluha (Bolboschoenus maritimus)
- Makaloa (Cyperus laevigatus)
- Pycreus (Pycreus polystchyos)
- 'uki (Cladium jamaicense)

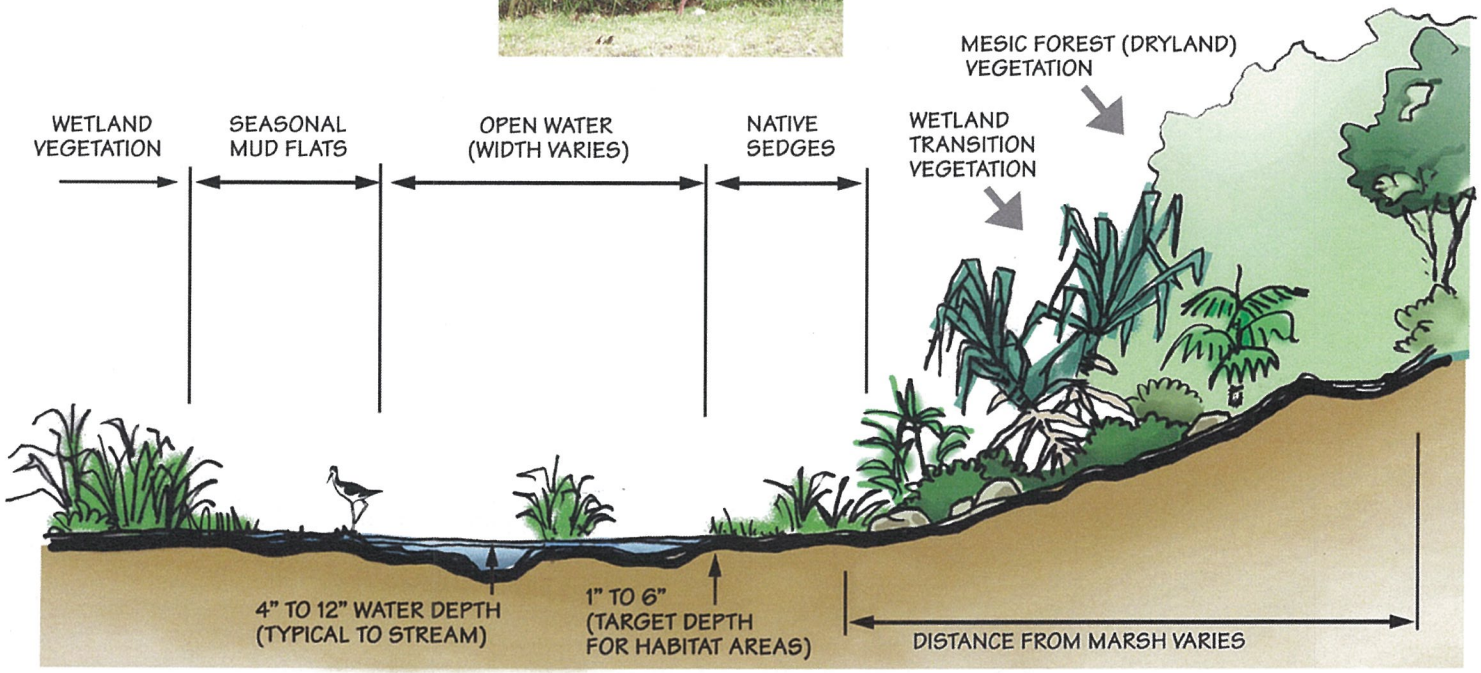
Wetland Restoration Process

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

Figure 4.2

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

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



WETLAND RESTORATION - SECTION

Wetland Restoration Typical Section View

Kawainui Marsh Wetland Restoration and Habitat Enhancement Plan

Kailua, O'ahu

Figure 4.3

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

Exhibit 4.1 – 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 be mixed with vegetation to enhance decomposition. Thus, the amount of biomass needing to be removed from the site should be minor.

If required, vegetation will be transported to an existing vegetation processing site adjacent (south) to the City's Model Airplane Park on Kapa'a Quarry Road. It will then be transported to the appropriate City refuse disposal site. The vegetation processing site of over 20 acres was previously established and used by the City in 1992 for this same type of activity as part of their efforts in completing an open waterway project for the marsh to increase flood storage capacity. The site consisted of areas for the processing of vegetation and sediment along with drying beds. Accessory facilities planned consisted of roadways around this processing area, a maintenance facility, and barge launch and off-loading area (M&E Pacific, Inc., June 1990). The vegetation processing site was also designated for similar use in the 1994 master plan developed for Kawainui Marsh.

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.

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 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 4.2.

Photo of Gully in Area A

Photo of Existing Site Conditions

Exhibit 4.2 –Existing Conditions in Area A

Native Forest Restoration w/ Hybrid Ecosystem Model

EXISTING NON-NATIVE FOREST

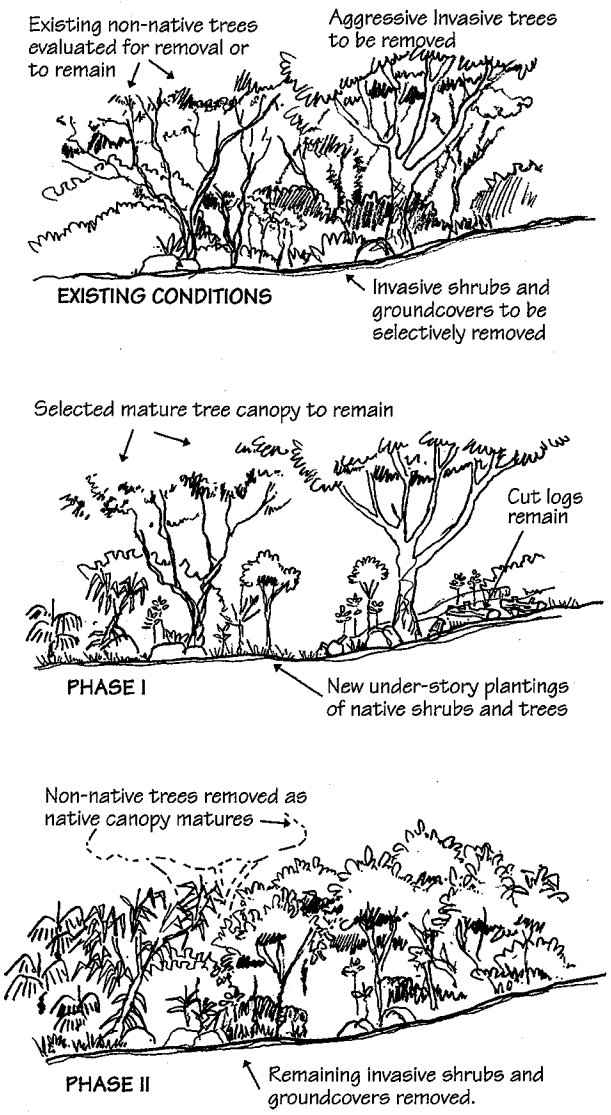
- Dominated by invasive species
- Complete removal of existing invasive plants is not practical

HYBRID ECOSYSTEM

- New native plantings co-exist with non-native over-story canopy
- Aggresive 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

Figure 4.5 illustrates detailed restoration improvements planned for Area A. Invasive vegetation and trees will be cleared in the area in phases as determined by DOFAW. 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.

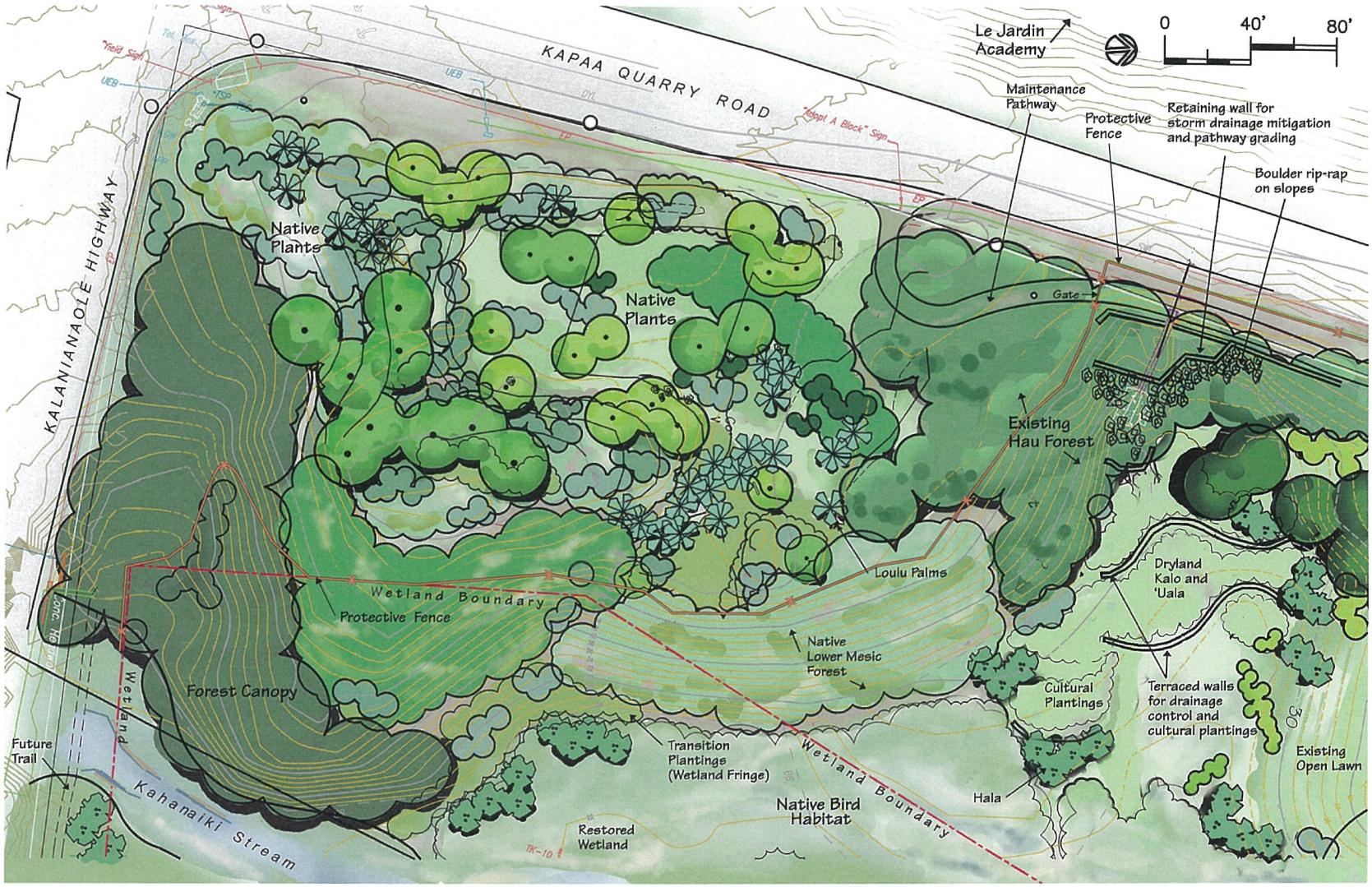
Trees and vegetation along Kapa'a Quarry Road will be selectively removed to retain a visual screen between the roadway and the marsh. Existing trees within the upland forest will be selectively removed to continue the overhead canopy in this area, and other restoration efforts will be implemented using 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) will 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 is planned 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.

A DOFAW maintenance pathway about 10-feet-wide made of crushed basalt rock or dirt will extend northbound along Kapa'a Quarry Road. This pathway is intended for DOFAW authorized maintenance vehicle use only.

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 4.9 shows a conceptual landscape plan for a portion of this area that includes the existing open lawn.



Conceptual Landscape Plan - Southwest Corner (Area A)

Figure 4.5

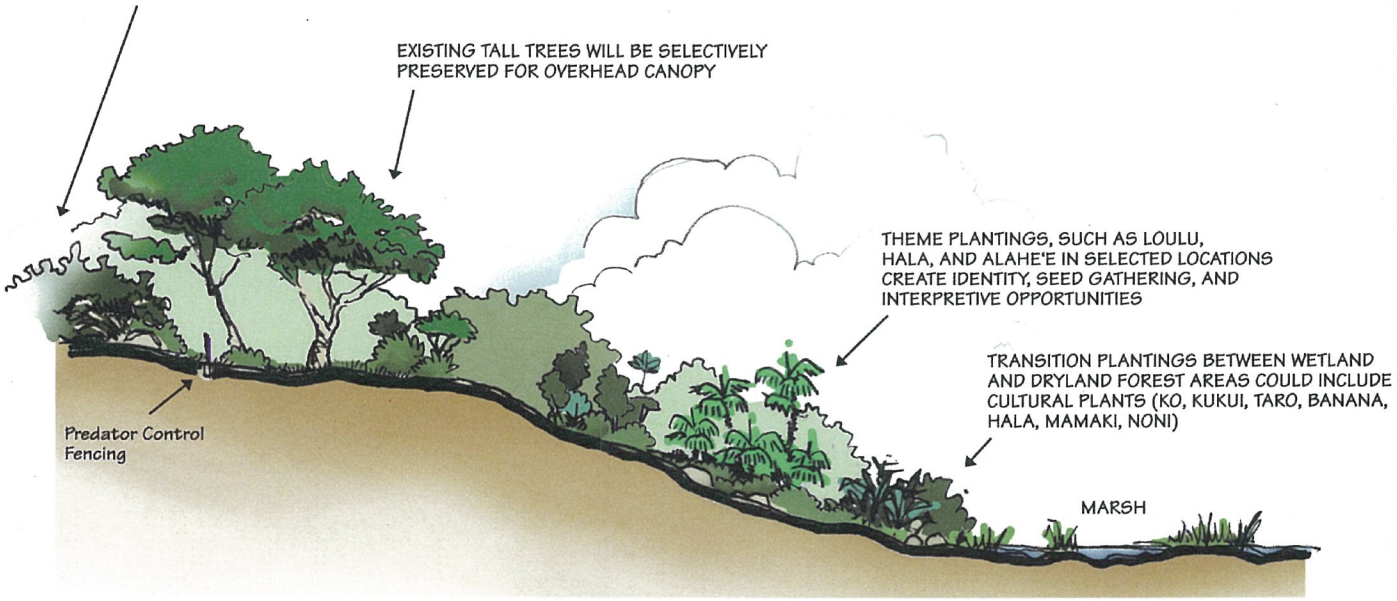
KAWAINUI MARSH WETLAND RESTORATION AND HABITAT ENHANCEMENT PLAN
KAILUA, O'AHU

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.

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



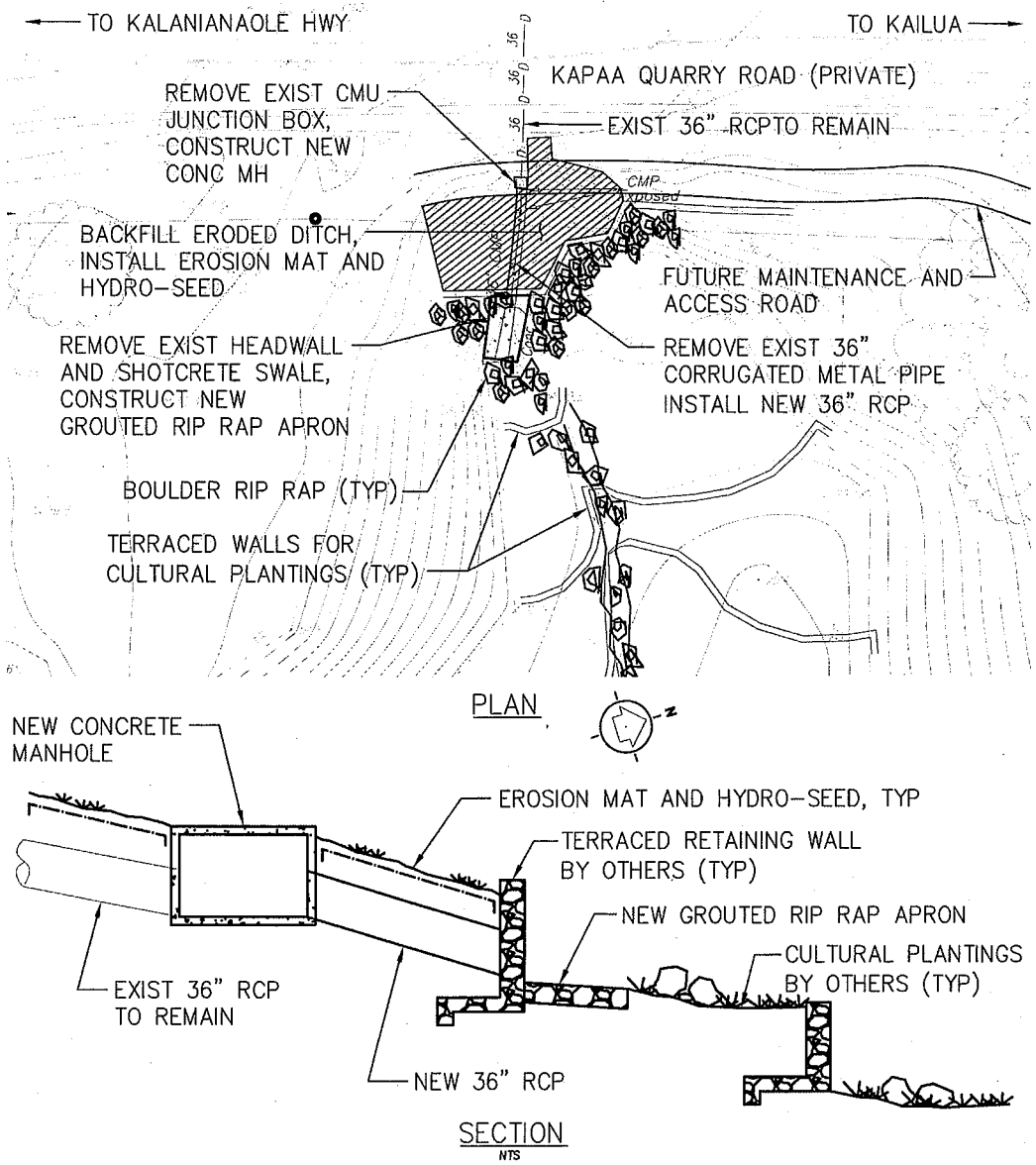
Transition plants between dryland forest and wetland areas could include Hala, Loulu Palm, and cultural plantings.

Reforestation Concepts – Sectional View (Low Mesic Forest)

Figure 4.6

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

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



Drainage Culvert 1 Improvements

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

Figure 4.7

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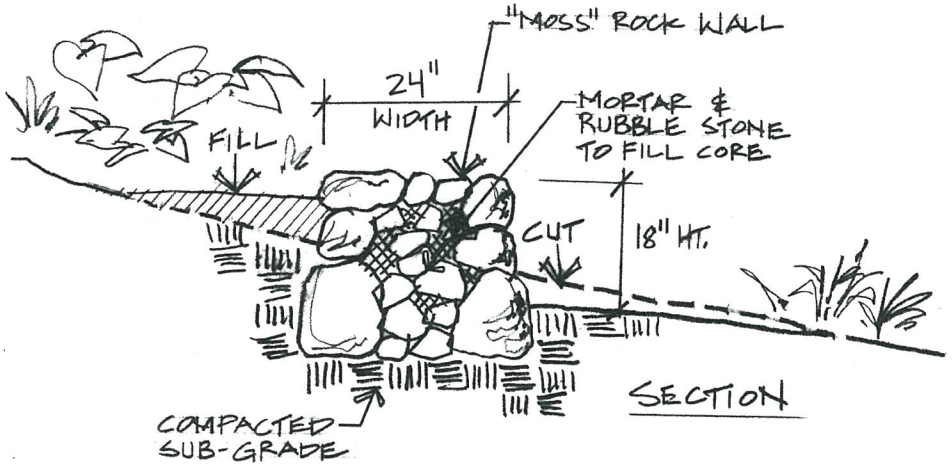
"Moss Rock" Terrace Wall



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

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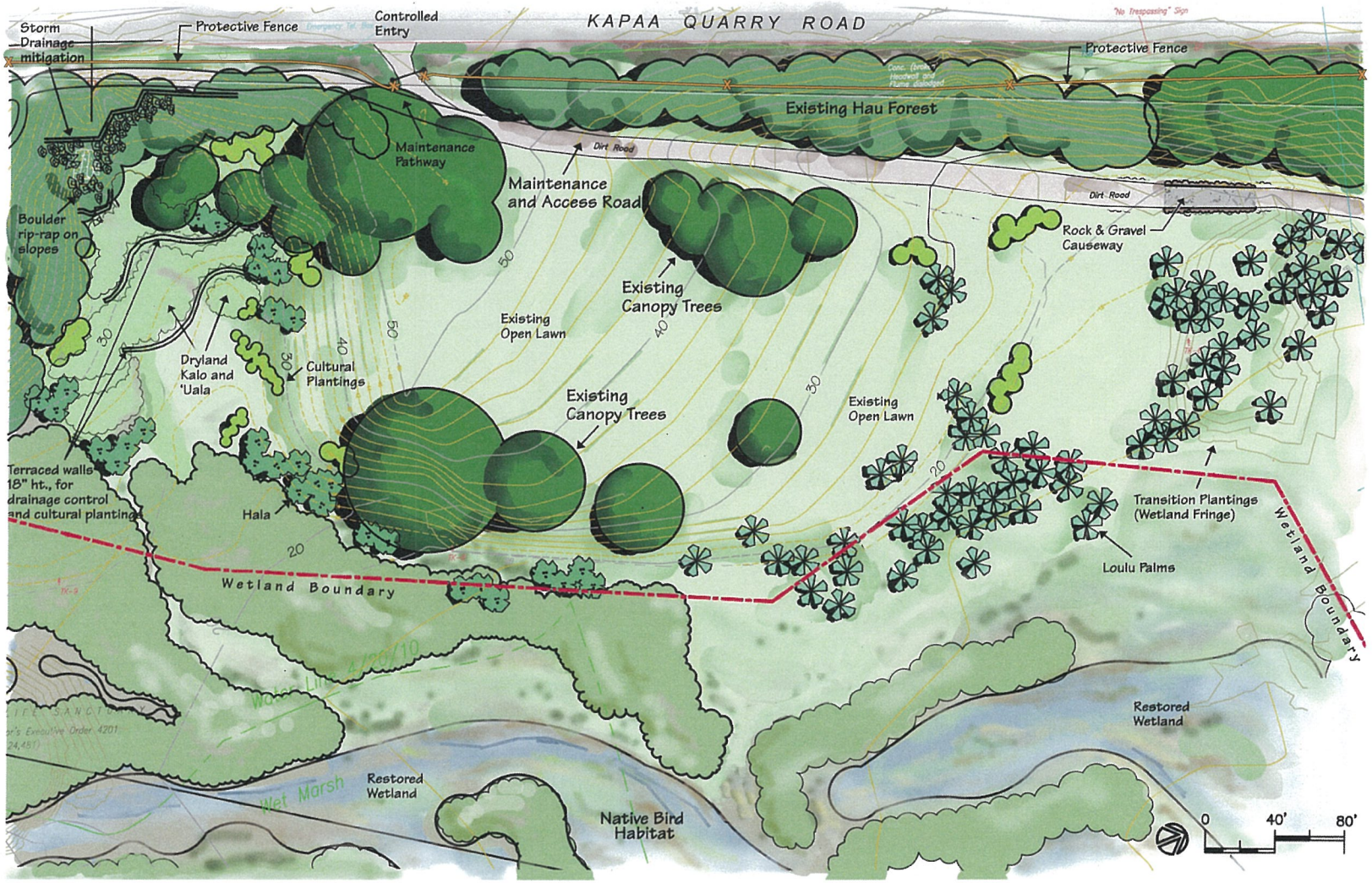
Division on Forestry and Wildlife



Conceptual Landscape Plan – Open Lawn (Area B)

Figure 4.9

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

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

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 for DOFAW authorized use. This will connect to the maintenance access road (dirt or gravel 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 existing dirt road. Therefore, minor grading would be required to re-establish the alignment of the road while maintaining the existing forest.

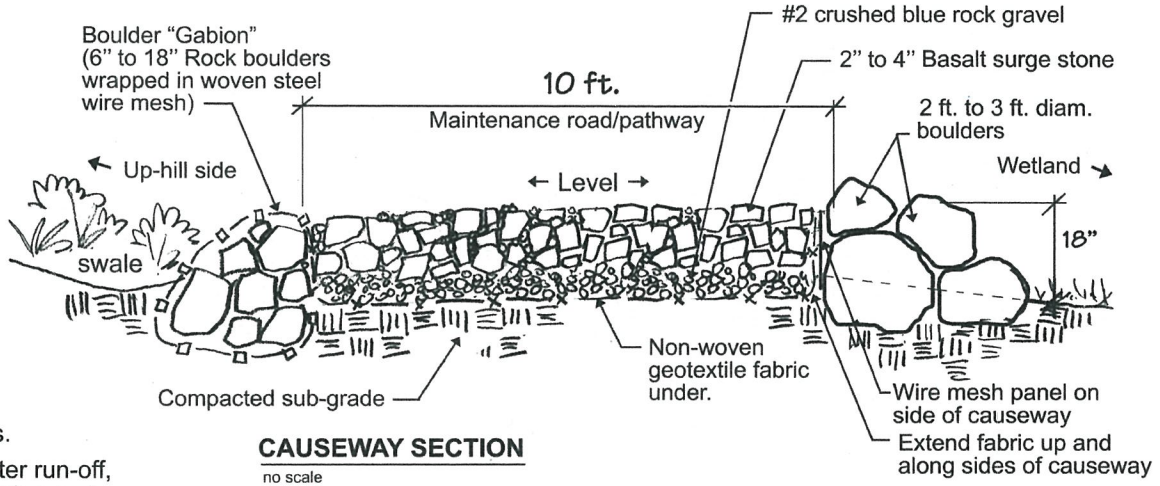
An existing culvert (Culvert 2) and another drainage discharge point are located in Area B. To mitigate runoff, a grassed drainage swale will be provided along the *mauka* (west) side of the access road to direct runoff into lower areas used as detention sites. A gravel causeway about 60 feet long is 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 4.10 shows a sectional view of a typical causeway and proposed locations.

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 4.11 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 4.12 shows proposed drainage area improvements.

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 4.13 shows a conceptual landscape plan for this section.

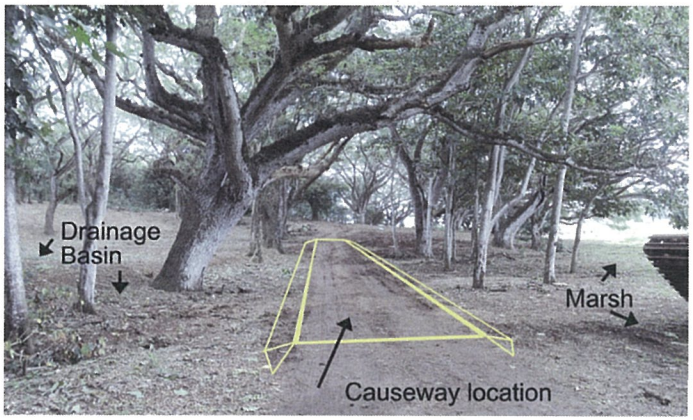
Gravel/Boulder Causeway

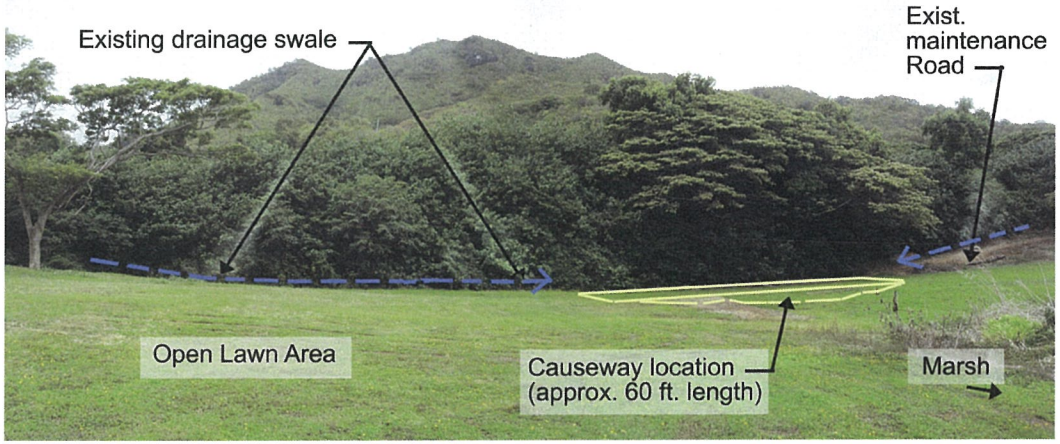


CAUSEWAY SECTION
no scale

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

Figure 4.10

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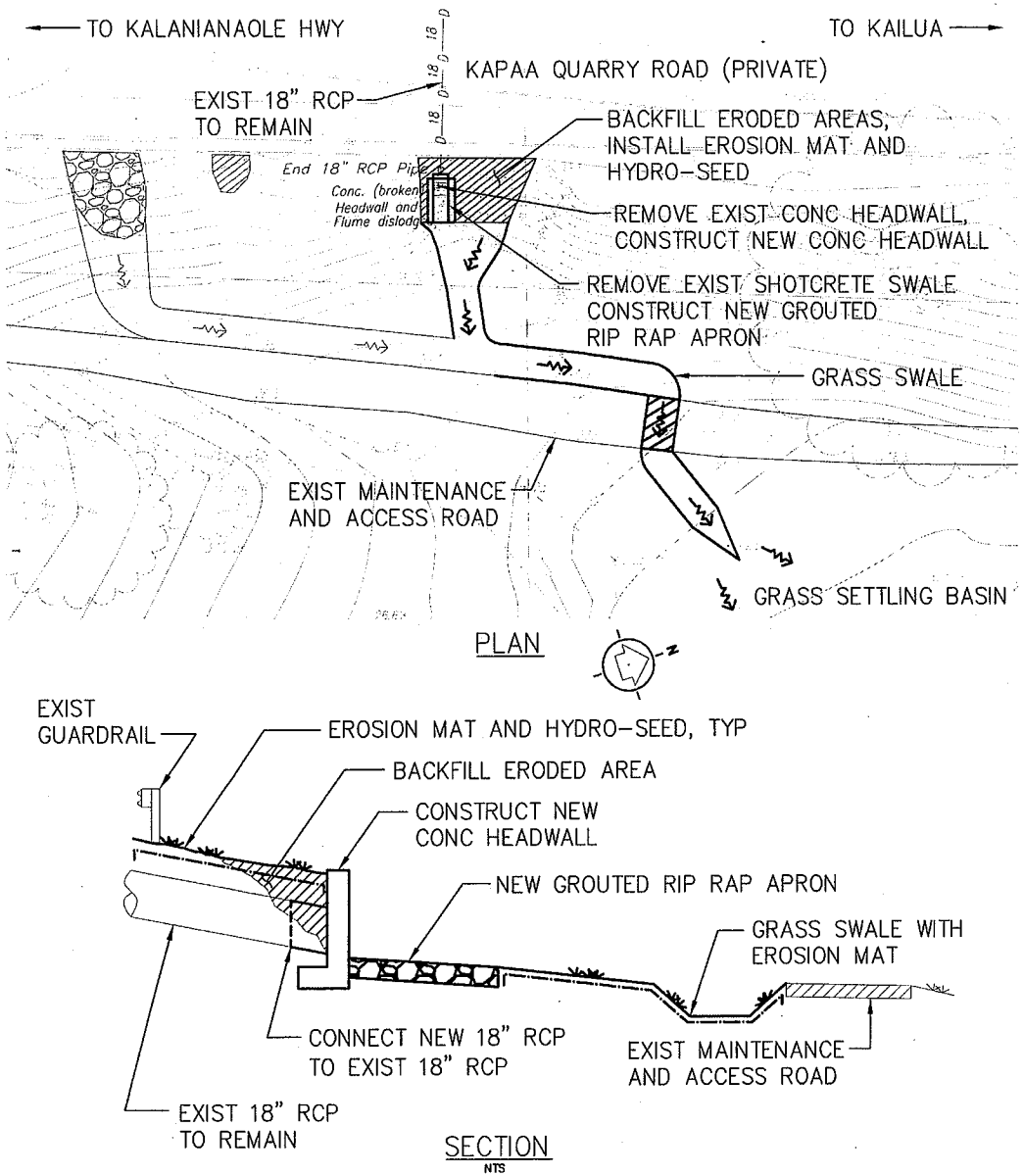

Drainage Culvert 2 Improvements

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

Figure 4.11

Prepared for:
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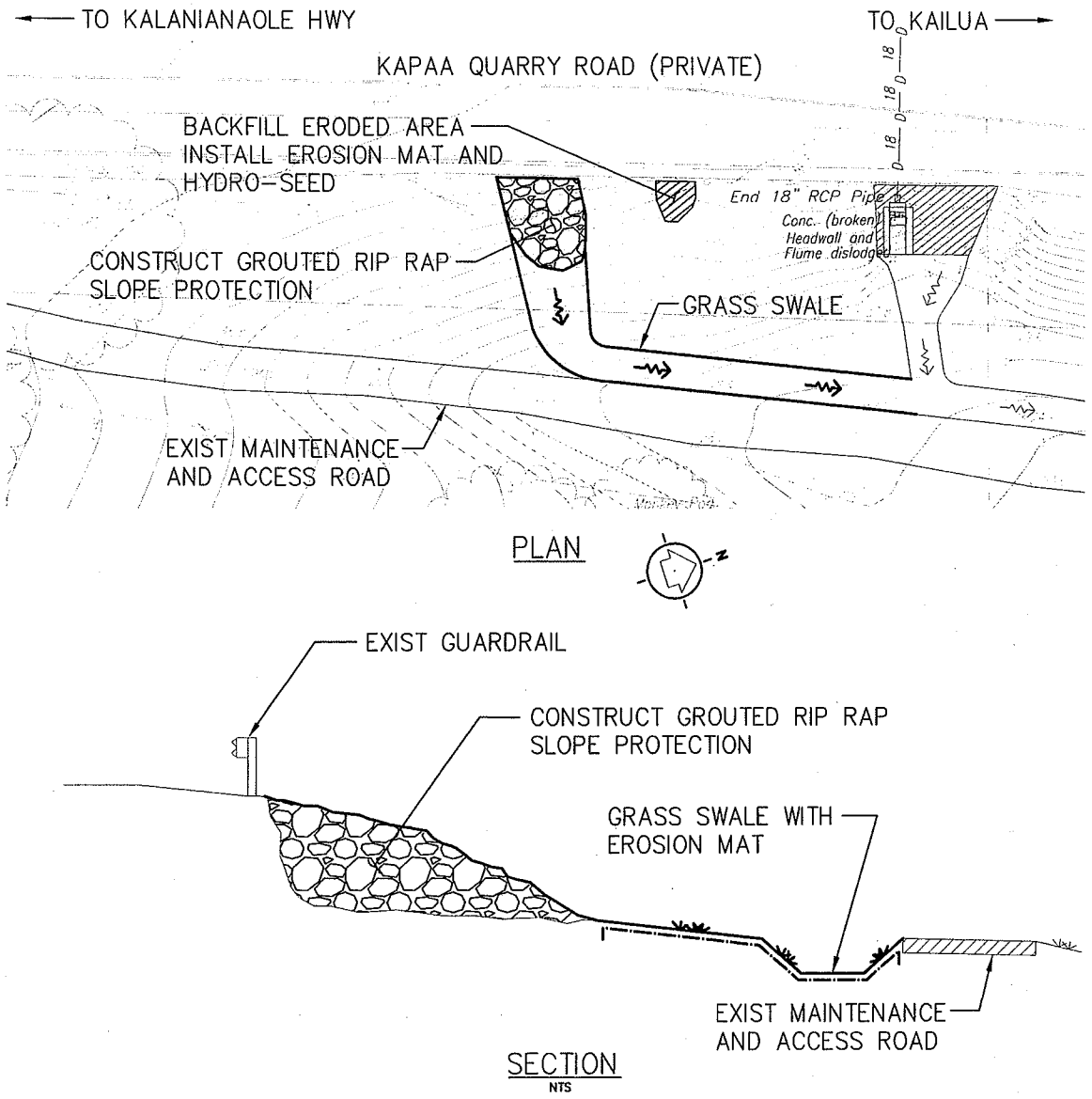

Drainage Area Improvements

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

Figure 4.12

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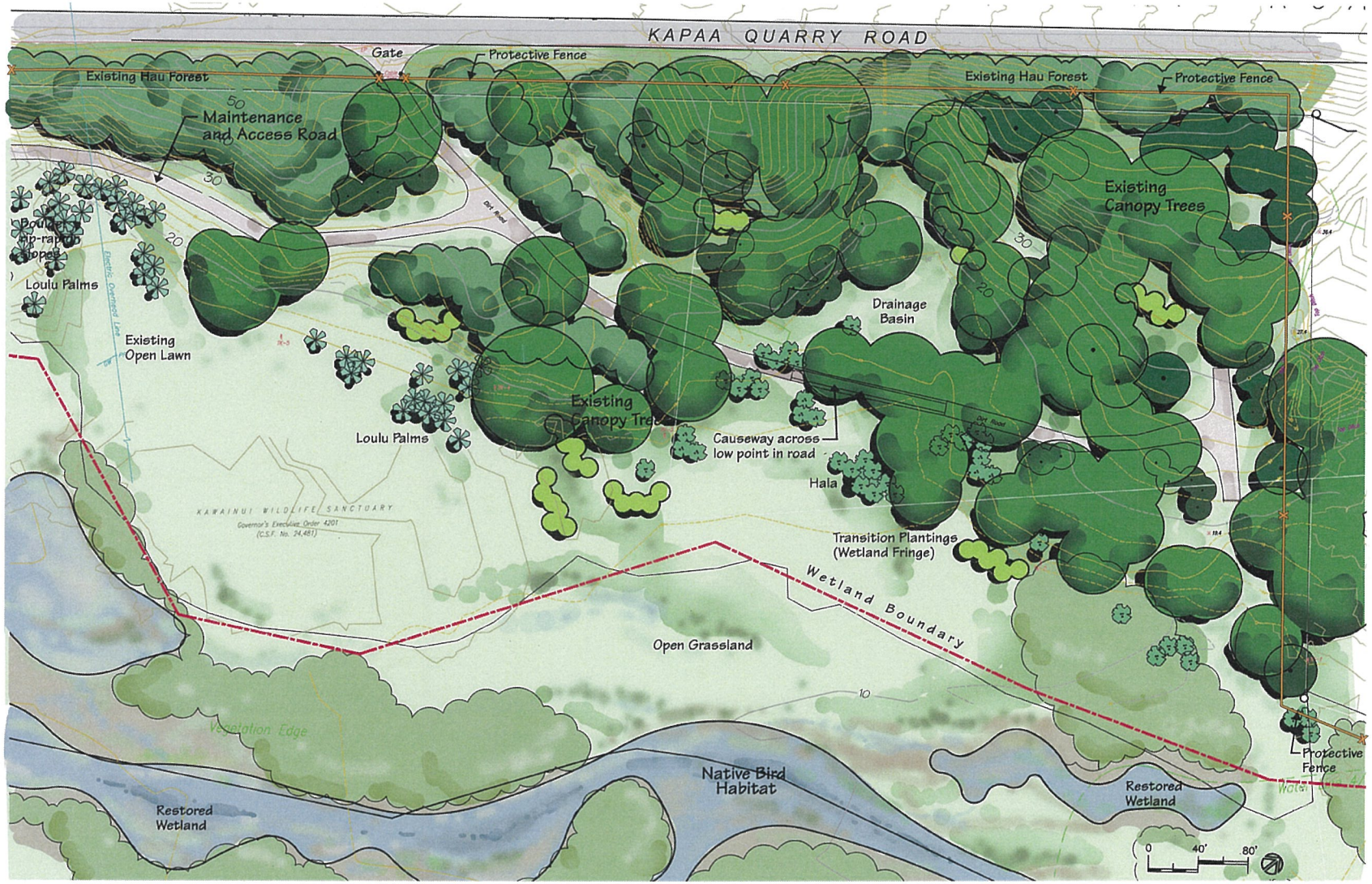


Conceptual Landscape Plan – Canopy Forest (Area B)

Figure 4.13

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

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

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.

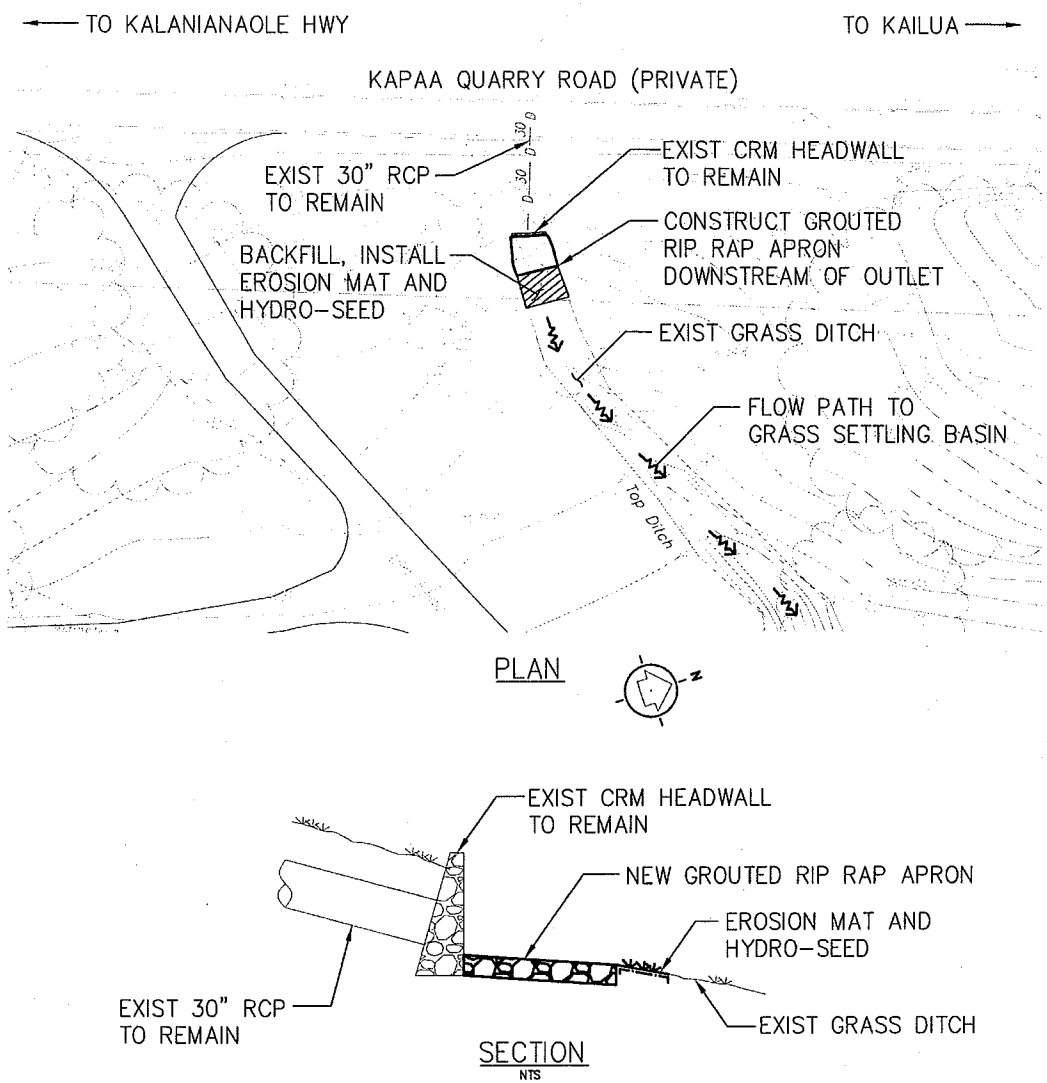
Existing Culvert 3 located north of the existing gated driveway will be improved as shown in Figure 4.14. A grouted rip rap apron, erosion mat, and grass will be installed on the downstream end of this culvert. Discharges from the culvert should follow an existing grass ditch toward an open area along the dirt access road used for detention and infiltration. A causeway will be created along the section of the access road.

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 Grasspave[2] or Gravelpave[2] can be installed at appropriate locations along the maintenance path to minimize impacts from DOFAW vehicles. Exhibit 4.3 shows an example of the type of material under consideration. A product brochure is provided in Appendix C.

Exhibit 4.3 –Grasspave Product Sample



Drainage Culvert 3 Improvements

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

Figure 4.14

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This type of "porous paving" is recognized by the Environmental Protection Agency (EPA) and 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 will continue 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) identified 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 4.4 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 4.4 –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 and Maunawili Streams and upland areas, and waterbird nesting 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 constructed 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.)	$100,000
Subtotal	$370,000
Contingency Factor (10%)	$37,000
Total Budget	$407,000

The estimated costs for equipment, restoration activities, and construction of project improvements is about an additional $3.9 million. Funding from the grant obtained by DOFAW is available to implement basic wetland restoration and upland reforestation improvements. However, additional funding would be acquired to complete all restoration improvements, and DOFAW would pursue such funding from Federal, State, and private sources.

Restoration improvements are anticipated to begin in early 2013. Restoration improvements would be implemented in phases over time, and will be subject to availability of additional funding. Primary wetland restoration and upland reforestation improvements will likely be implemented by both DOFAW staff along with contractors hired to implement certain work tasks or phases of improvements. Certain improvements could also involve participation by community organizations or volunteer efforts. Wetland restoration and upland reforestation improvements are planned to be completed within five (5) years or by the end of 2018. However, improvements could extend out to about 10 years dependent upon availability of funding (year 2023).

Chapter 5
References

CHAPTER 5
REFERENCES

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Appendices

Appendix A
Photos Of Existing Conditions

Photo 1: Panoramic East View of Kawainui Marsh Restoration Project Area.

Photo 2: Panoramic Southeast View of Kawainui Marsh Restoration Project Area.

Photo 1: Northeast view of southern corner of project site at Kalanianaole Highway with Kapaa Quarry Road intersection.

Photo 2: Northeast view of Area A vegetation along Kapaa Quarry Road.

Photo 3: East view of Kahanaiki Stream Bridge along Kalanianaole Highway.

Photo 4: South view of Kahanaiki Stream under highway bridge.

Photo 5: North view of Kahanaiki Stream under highway bridge leading into Kawainui Marsh.

Photo 1: South view of Area A site conditions along Kapaa Quarry Road.

Photo 2: North view of Area A site conditions along Kapaa Quarry Road (near Le Jardin driveway).

Photo 3: South view of Area B site conditions along Kapaa Quarry Road.

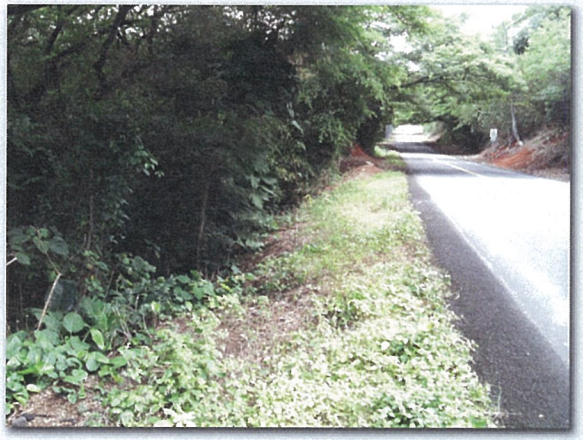


Photo 4: South view of Area B site conditions along Kapaa Quarry Road at northern end of project site.

Photo 5: West view of Area A site conditions (southern end near highway).

Photo 6: North view of Area A site conditions.

Photo 1: Southeast view of gully in Area A.

Photo 2: Northeast view of lawn and marsh in Area B.

Photo 3: Northwest view of open lawn area and vegetation along Kapaa Quarry Road in Area B.

Photo 4: Southeast view of open lawn and marsh before start of canopy forest portion of Area B.

Photo 1: South view of Area A site conditions along Kapaa Quarry Road.

Photo 2: North view of Area A site conditions along Kapaa Quarry Road (near Le Jardin driveway).

Photo 3: South view of Area B site conditions along Kapaa Quarry Road.

Photo 4: South view of Area B site conditions along Kapaa Quarry Road at northern end of project site.

Photo 5: West view of Area A site conditions (southern end near highway).

Photo 6: North view of Area A site conditions.

Photo 1: East view of marsh site conditions from northern end of Area B.

Photo 2: East view of marsh site conditions from northern end of Area B.

Photo 3: West view of pasture area and DOFAW path located below (makai) project area by the COE ponds project.

Photo 4: West view of Maunawili Stream area located below project area by COE ponds project.

Photo 5: South view of existing dirt road in Area B leading to canopy forest area north of open lawn area.

Photo 6: East view of existing DOFAW driveway at Kapaa Quarry Road in Area B.

Photo 1: West view of dirt road and site conditions in Area B.

Photo 2: Northeast view of dirt road and canopy forest site conditions in northern end of Area B.

Photo 3: North view of canopy forest site conditions in northern end of Area B.

Photo 4: South view of canopy forest site conditions in northern end of Area B.

Photo 5: South view of transition area from canopy forest toward marsh.

Photo 6: South view of existing large pile of construction debris in Area B.

Photo 1: North view of Culvert 1 location in Area A.

Photo 2: Northeast view of Culvert 1 condition.

Photo 3: South view of Culvert 2 location in Area A.

Photo 4: East view of Culvert 2 condition and erosion.

Photo 5: Northeast view of Culvert 3 location near Le Jardin Academy driveway.

Photo 6: East view of Culvert 3 condition.

Appendix B
Plant Listing And Representative Photos

Wetland Plants

ʻAeʻae	Bacopa monnieri
Nehe	Bidens pilosa
Kaluhā	Bolboschoenus maritimus
ʻUki	Cladium jamaicense
ʻAhuʻawa	Cyperus javanicus
Makaloa	Cyperus laevigatus
Kohehohe	Eleocharis obtusa
ʻAkiohala	Hibiscus furcellatus
ʻIhiʻihi	Marsilea villosa
Pycreus	Pycreus polystachyos
Bulrush	Schoenoplectus spp.
Neki	Schoenoplectus lacustris
ʻAkaʻakai	Schoenoplectus spp.
ʻĀkulikuli	Sesuvium portulacastrum

Cultural Plants

Kukui	Aleurites moluccana
Kī	Cordyline fruticosa
Noni	Morinda citrifolia
ʻAwa	Piper methysticum
Kō	Saccharum officinarum
Kalo	Colocasia esculenta
ʻUala	Ipomea batatas

ʻIhiʻihi

ʻĀkulikuli

ʻAeʻae

ʻAkaʻakai

ʻAhuʻawa

ʻUki

ʻAkiohala

Kukui

Kō (and other cultural plantings)

Dryland Plants

Koʻoloaʻula	Abutilon menziesii
Koaiʻa	Acacia koaia
Hame	Antidesma spp.
Maiapilo	Capparis sandwichiana
Carex	Carex wahuensis
ʻAkoko	Chamaesyce spp.
Pāpala	Charpentiera spp.
ʻĀnapanapa	Colubrina asiatica
ʻAʻaliʻi	Dodonaea viscosa
Wiliwili	Erythrina sandwicensis
Nāʻū	Gardenia brighamii
Maʻo	Gossypium totemtosum
Kokiʻo/Pualoalo	Hibiscus spp.
Naio	Myoporum sandwicense
Kuluʻī	Nototrichium spp.
ʻŪlei	Osteomeles anthylidifolia
ʻIlieʻe	Plumbago zeylanica
Naupaka kauhiwi	Scaevola gaudichaudiana


ʻĀnapanapa


Maʻo


Kuluʻī


ʻAʻaliʻi


ʻIlieʻe


Maʻo


Naio


Koʻoloaʻula


Nāʻū


ʻAkoko


Kokiʻo


Pualoalo


Naupaka kauhiwi


ʻŪlei

'Iliahi

Lonomea

Hao

Kou

Alahe'e

Hala

Hō'awa

Loulu

'Ohe makai

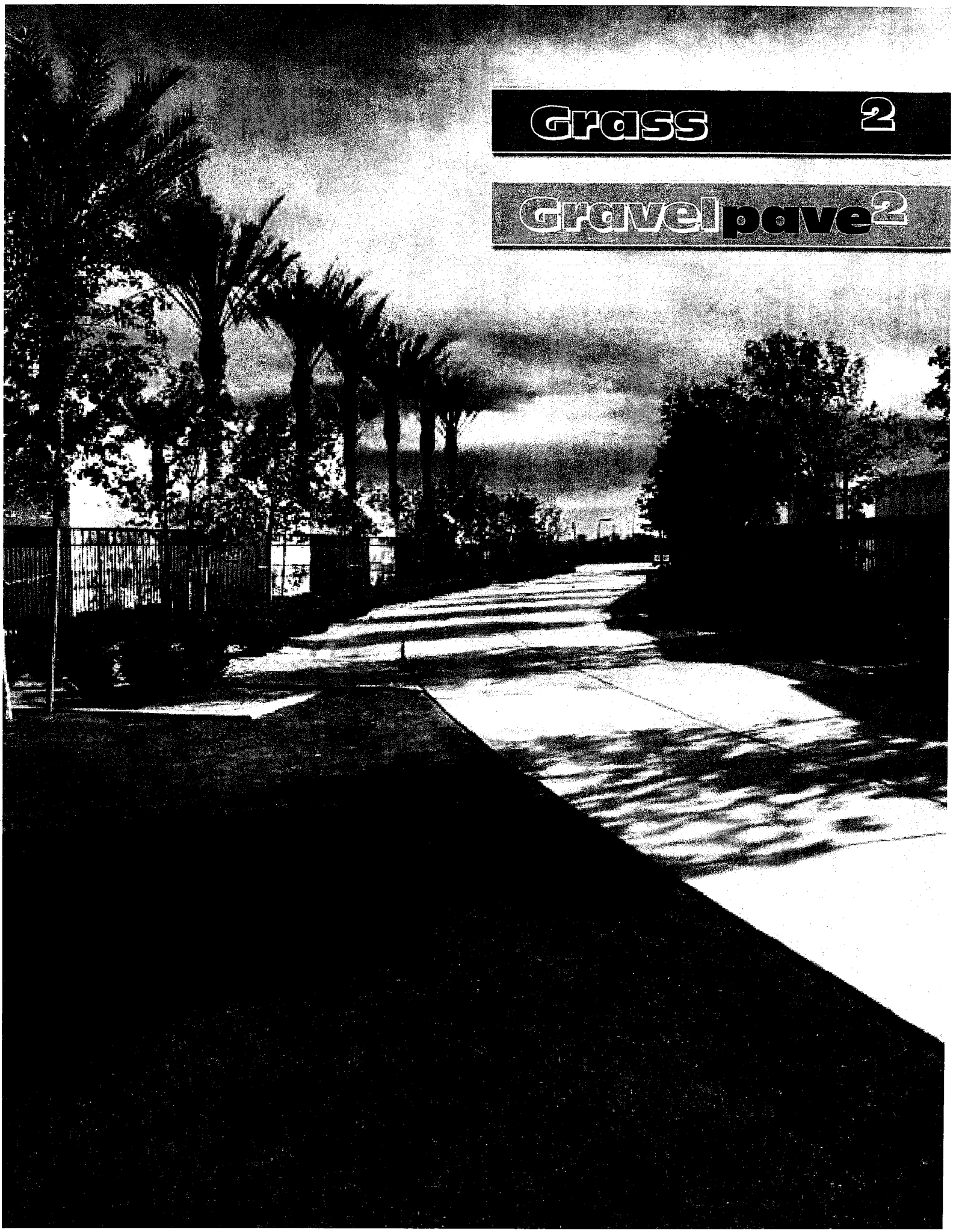
Lama

Koai'a

Dryland Plants

Koai'a	Acacia Koaia	Hō'awa	Pittosporum spp.	'Ohe makai	Reynoldsia sandwicensis
Kou	Cordia subcordata	Loulu	Pritchardia martii	'Iliahi	Santalum spp.
Lama	Diospyros sandwicensis	Alahe'e	Psydrax odorata	Lonomea	Sapindus oahuensis
Hala	Pandanus spp.	Hao	Rauvolfia sandwicensis		

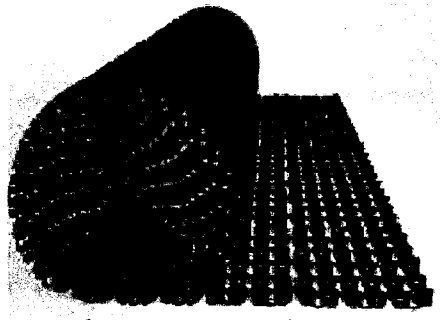
Appendix C
GrassPave Manufacturer Brochure


Grass 2
Gravelpave2

Introduction

History of Porous Paving

Pebbles, cobblestones, and wood decking structures have been used since the dawn of civilization to reinforce where we walk and the roads we use. Little did we realize that these methods had benefits over the modern trends of sealing up the ground with asphalt and concrete. Porous, permeable or pervious paving—whatever you prefer—became a method for addressing stormwater issues in the early 20th century. Concrete turfblock for grass paving began in the mid-1940s and plastic versions were invented in the late '70s and early '80s. Great advancements have occurred in pervious concrete, pervious asphalt, and other permeable surfaces. We introduced Grasspave^2 in 1982, improving upon these earlier concepts. In 1993, Gravelpave^2 was unveiled, the only product specifically developed for gravel porous paving. Fast forward to this millennium, and Grasspave^2 and Gravelpave^2 are considered by most, the finest porous pavers developed.



Grasspave^2 large rolls and Gravelpave^2 large rolls (not shown) install quickly and conform to the contours of the ground.

Infiltration

Porous paving allows rainwater to percolate through the pavement's surface and back into the ground (infiltrating), where the water is cleaned and returned to ground water supplies. Porous paving improves upon impermeable surfaces, such as concrete or asphalt, which do not allow for this natural filtration. Rain collects airborne and surface pollutants such as sediment, brake dust, chemicals, vehicle exhaust, oil, salts, fertilizers, bacteria, and animal waste. On impermeable surfaces the polluted rainwater runoff (non-point source pollution) is collected, concentrated, and discharged to downstream waters such as streams, reservoirs, and lakes—our drinking water. This runoff also harms vegetation and wildlife with increased water volumes, velocities, and higher temperatures. The Grasspave^2 and Gravelpave^2 systems protect against this dangerous runoff by processing and cleaning the water, thus safeguarding the natural water cycle.

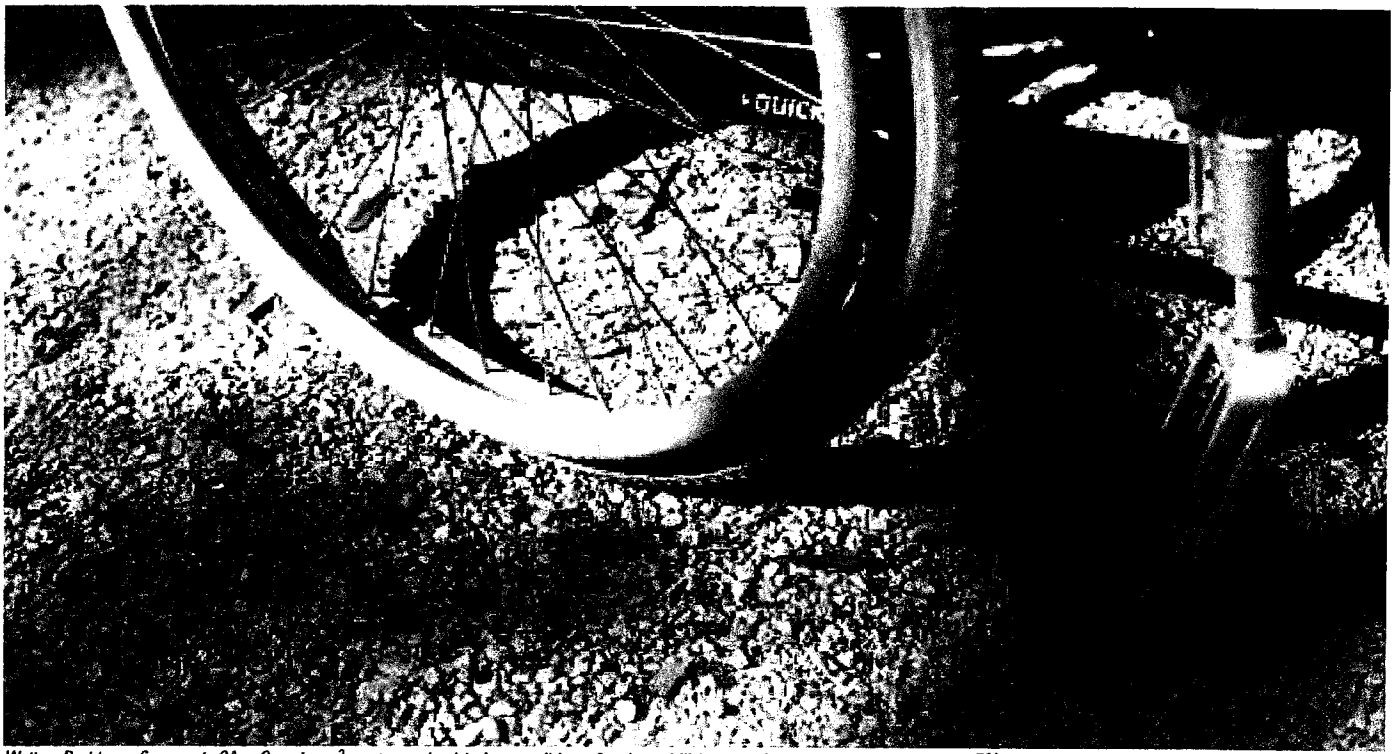
State of the Earth

Invisible Structures, Inc. has developed an entire line of products to address stormwater and environmental concerns. Rainstore^3, Slopetame^2, Draincore^2, and Beachrings^2 can work in addition to, or in conjunction with, Grasspave^2 and Gravelpave^2 to provide your site, home, or office with stormwater and environmental enhancements. Our products can store and collect rain, provide erosion and sediment control, efficiently convey and deliver water, and protect natural areas.

Advanced Technology

The Grasspave^2 and Gravelpave^2 systems are based on a simple, but impressive technology—a series of rings (cylinders) connected on a flexible grid system. The cylinders are engineered to withstand significant structural loads and the grid provides stability, flexibility, and continuity for large areas. The grid system also has the unique ability to be rolled up for easy shipping, handling and installation.

This engineered design allows for any street-legal vehicle (and sometimes larger) to park or drive on our Grasspave^2 or Gravelpave^2 surfaces. The point load pressure is transferred from the top of the ring, through the fill material and cylinders, to the engineered base course.



Wallace Residence, Savannah, GA—Gravelpave^2 creates a wheelchair-accessible surface by stabilizing gravel and supporting tire pressure. 7% dry cement was mixed with gravel before filling rings. Cover photo: Westin Kierland Resort and Spa, Scottsdale, Arizona—Grasspave^2 fire lane and Gravelpave^2 fire lane (concrete widening).

The ring and grid structure is 92 percent void space allowing for the healthiest root zone for grass (in Grasspave²) and more decorative gravel (in Gravelpave²) for some of the most attractive paved surfaces around. Less plastic means more natural looking surfaces. This technology also makes for better runoff coefficients and better percolation rates.

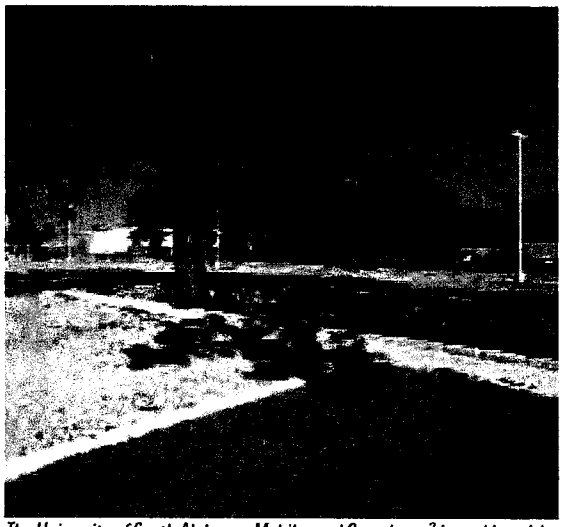
120 psi Maximum on Public Highways!

Even empty, Grasspave² and Gravelpave² will support 2,100 psi (14,470 kPa)—well over the 120 psi highest truck tire pressure allowed on public highways. This is a safety factor of 17 times. When Grasspave² is filled with sand for part of the root zone medium, the strength increases to 5,700 psi (39,273 kPa). The safety factor increases from 17 to 47 times. The heavier a vehicle, the more axles and tires it needs to support the load being carried. Grasspave² and Gravelpave² will meet and exceed all loading criteria.

Vehicle Loading Examples:

Auto tires: 40 psi
Truck tires: 110 psi
DC-10 tires: 250 psi
F-16 tires: 350 psi
Fire truck with outriggers: 78psi
(An 85,000 lb. truck distributed to four outrigger pads is equal to 21,250 lbs. for each outrigger pad with 12" × 18" surface contact with Grasspave².)

All these vehicles are well within our 5,700 psi loading capability. With a sturdy base course design, our rings will easily perform under all conditions. It's also a good design practice to strengthen concrete sidewalks and curbing that will be mounted by fire trucks.



The University of South Alabama, Mobile used Gravelpave² in parking aisles and Grasspave² in the spaces.

CSI 32 12 43 Flexible Porous Pavers

In 1997 The Construction Specifiers Institute (CSI) came out with a generalized listing (02795) for all porous paving products. However, since performance and application is varied even in the porous paving industry, the 2004 CSI MasterFormat™ has adopted a new number *32 12 43 Flexible Porous Paving*, to recognize that Grasspave² and Gravelpave² are in a class by themselves.

Best Management Practice

Porous paving is recognized as a Best Management Practice (BMP) by the Environmental Protection Agency, the Center for Watershed Protection, the U.S. Army Corp of Engineers, and countless other federal, state, regional and local authorities. In addition, Grasspave² and Gravelpave² are often mentioned by name, as the product of choice for many of these agencies.

Applications

Stormwater Management

The Grasspave² and Gravelpave² systems can easily handle storm water from an intense storm dropping three inches of rain in less than thirty minutes! In one square meter (40" × 40") there are 144 rings, two inches in diameter by one inch high. With one inch of fill in the rings and a standard road base of sandy gravel six

Bowditch Point Regional Park, Fort Myers Beach, Florida—Gravelpave² parking bays blend in with the natural surroundings.

inches thick, our porous systems will percolate approximately ½ inch of rain per hour! A seven-inch section can store 2.4 inches of water (about 20 percent void after compaction). Alternatively, hard surfaces, such as asphalt and concrete, shed 95 percent of storm water.

Aesthetics

As a designer, engineer, contractor, or homeowner, you can be sure Grasspave² and Gravelpave² can deliver a more beautiful surface and add a unique look to a site. Grass simply looks better than asphalt and decorative gravel has been used for centuries in landscaping. Space constraints can be dealt with by combining the beauty of grass or gravel with the utility of paving.

Trees and other vegetation not only survive, they thrive with Grasspave² and Gravelpave². Porous paving has the ability to deliver water, oxygen and carbon dioxide through the cross section—all essential to root survival. Concrete and asphalt suffocate and starve the root zones of water and air. With Grasspave² and Gravelpave², you can now design in as many trees and plants as your site will allow. Grasspave² and Gravelpave² prevent compaction while allowing for ample amounts of water and air. Cars can then drive and park below tree canopies. Saving existing, mature trees is also possible with our products—our structures can come within inches of the mature tree trunk without damage. Our mats have the ability to flex with the tree root growth that would otherwise damage and crack hard surfaces.

Environmental Benefits

Grasspave² and Gravelpave² not only protect the environment, they enhance it. All of our products are made from 100 percent recycled plastic—plastic that goes into improving the environment and not into a landfill. Through bioremediation, porous pavers have the ability to clean pollutants (heavy metals, 96–99 percent; suspended solids, 95 percent; phosphorous, 65 percent; nitrogen, 82 percent, hydrocarbons, up to 100 percent) out of stormwater. Our products also reduce erosion and soil migration, reduce site disturbance, and contribute to airborne dust capture and retention.

Cooling the atmosphere and reducing the "urban heat island effect" (cities being up to 10 degrees hotter than undeveloped land) are added benefits of Grasspave² and Gravelpave². Both products can mitigate these increased temperatures. In addition, Grasspave² promotes the conversion of carbon dioxide (greenhouse gas) into oxygen and has an "air-conditioning effect."

Driveways

Environmental, economic, and aesthetic enhancements are drawing homeowners and designers to use Grasspave² and Gravelpave² in driveways. Most residential driveways are good candidates for our porous duo because of the reduced speed and limited frequency of traffic. Our products can add beauty to residential and commercial driveways.

Parking Lots

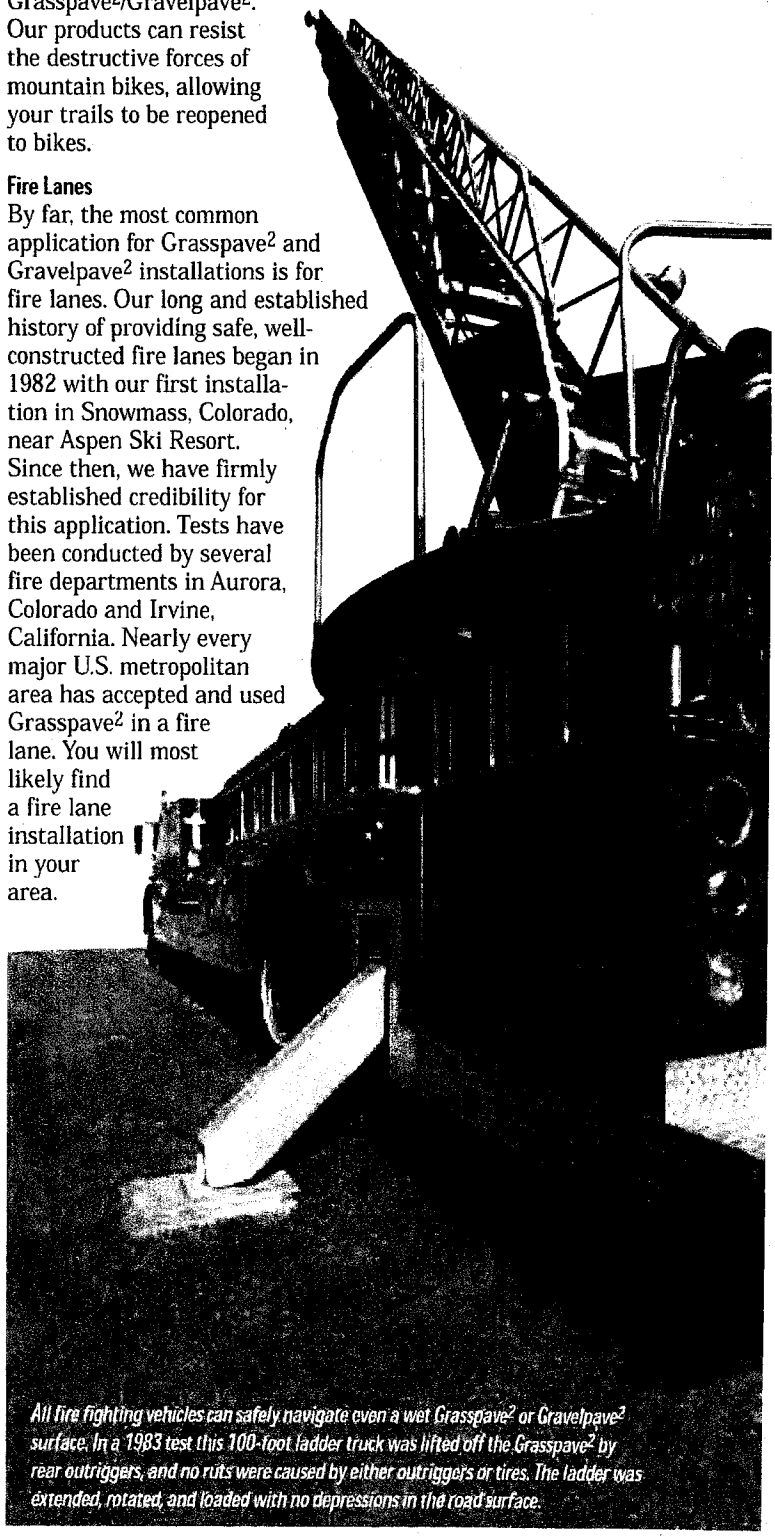
Parking for churches and synagogues, stadiums, arenas, and overflow at shopping centers, campuses, parks and more are ideal for Grasspave² and Gravelpave². These sites generally support large numbers of vehicles but only on periodic basis. Stormwater management and green space can be combined with parking, reducing maintenance, real estate, and development costs. A great design idea is combining durable Gravelpave² drive aisles with attractive Grasspave² parking bays.

Pedestrian, Horse Trails and Bicycle Paths

Garden paths, greenhouse aisles, sidewalks, park paths, and wilderness trails paved with Grasspave²/Gravelpave² provide a stable surface for strollers, bicycles, wheelchairs, and horses. There are no puddles or mud and traction is very good. Tree roots break up hard surface sidewalks, but our mats flex to accommodate such shifts and gradient changes. Plus, with the high proportion of air, roots are discouraged from moving upward. Mountain bikers will not be able to tear up paths reinforced with Grasspave²/Gravelpave². Our products can resist the destructive forces of mountain bikes, allowing your trails to be reopened to bikes.

Fire Lanes

By far, the most common application for Grasspave² and Gravelpave² installations is for fire lanes. Our long and established history of providing safe, well-constructed fire lanes began in 1982 with our first installation in Snowmass, Colorado, near Aspen Ski Resort. Since then, we have firmly established credibility for this application. Tests have been conducted by several fire departments in Aurora, Colorado and Irvine, California. Nearly every major U.S. metropolitan area has accepted and used Grasspave² in a fire lane. You will most likely find a fire lane installation in your area.



All fire fighting vehicles can safely navigate even a wet Grasspave² or Gravelpave² surface. In a 1983 test this 100-foot ladder truck was lifted off the Grasspave² by rear outriggers, and no ruts were caused by either outriggers or tires. The ladder was extended, rotated, and loaded with no depressions in the road surface.

Grasspave² Installation Procedures

This installation section is only intended as an overview. Please review our Grasspave² Technical Specifications (available at www.invisiblestructures.com or call 800-233-1510) for comprehensive installation instructions.

Excavate a space for the base course as determined by site soils and loading requirements. Place and compact sandy gravel which should be a mixture of clean sharp sand and gravel varying in size but not exceeding 3/4 of an inch. To check porosity, use a hose to see that water flows into the base and drains away. Add subsurface drainage as necessary to low spots or locations with poor draining soils. Install irrigation lines and sprinkler heads if necessary.

Apply the Hydrogrow mixture that is included free with your order. Hydrogrow is a mixture of polymer and fertilizer designed especially for our Grasspave² system.

Roll out Grasspave², aligning the side hole fasteners over the side pegs. The warmth of the sun will relax the plastic so it lays flat. Cut the grid between rings using pruning shears. Incorporate the cut pieces in other areas, as needed, keeping the distance between the rings uniform.

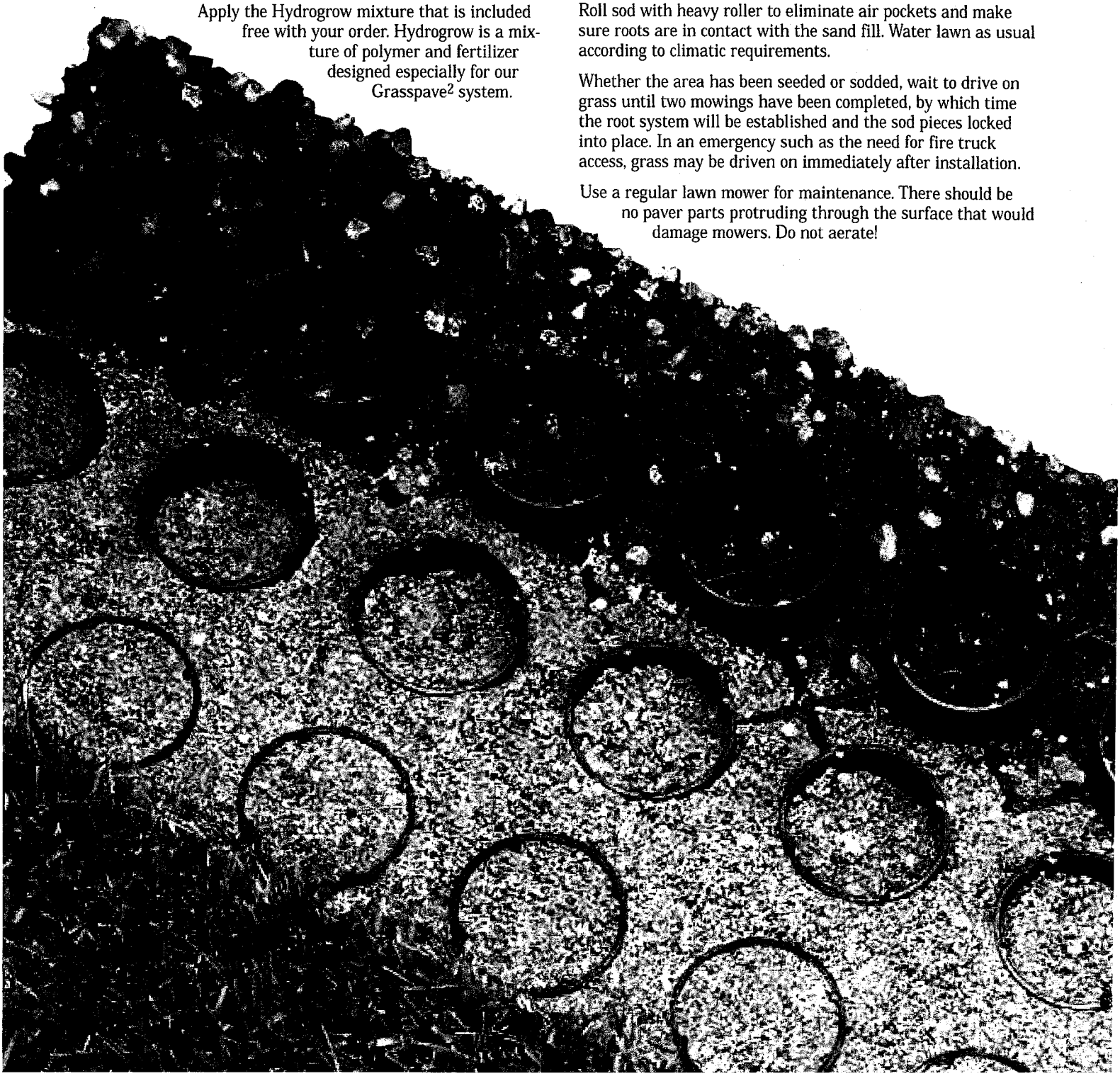
Fill rings with clean sharp concrete sand (AASHTO M6 or ASTM C-33) using large rakes and brooms so that the tops of the rings show when done.

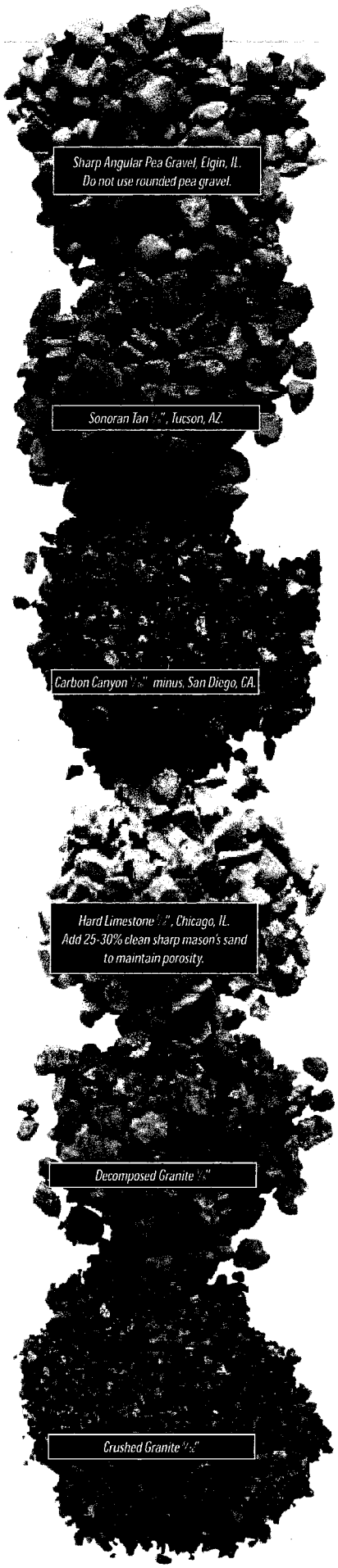
Lay turf over the rings. On warm days, wet the sand first to lower sand temperature and provide moisture for grass roots. Seeding and hydromulching is also an accepted vegetating method at this stage. Repeated hydromulching/seeding may be necessary.

Roll sod with heavy roller to eliminate air pockets and make sure roots are in contact with the sand fill. Water lawn as usual according to climatic requirements.

Whether the area has been seeded or sodded, wait to drive on grass until two mowings have been completed, by which time the root system will be established and the sod pieces locked into place. In an emergency such as the need for fire truck access, grass may be driven on immediately after installation.

Use a regular lawn mower for maintenance. There should be no paver parts protruding through the surface that would damage mowers. Do not aerate!

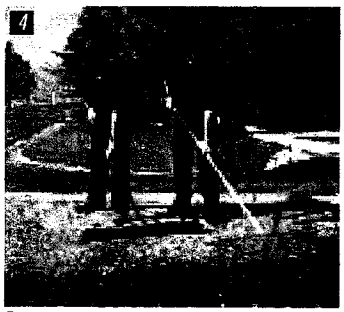





1
Place and compact sand and gravel road base.


2
Roll out Gravelpave², aligning the snap fit fasteners.


3
Secure mats with anchors provided (size and type may vary).


4
Fill rings with clean gravel.


5
Compact gravel with vibrator roller or flat plate compactor (not shown).

Gravelpave² Installation—

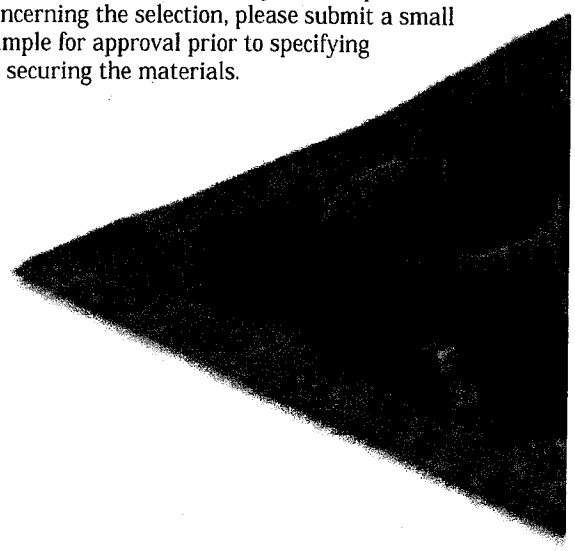
Gravelpave² Size/Shape Fill Requirements

You will need 1" of gravel fill, compacted. Be careful to order enough for the compaction process and choose a gravel size that will nest well into the rings. We have found that 3/16" minus crushed stone and sometime 3/8" with limited small sharp screenings (#40 to #100 screen) works well. Washed gravel will roll within the rings and will also "roll about." For this reason, we do not recommend pea gravel, even though it is often very attractive. A visit to your local quarry is suggested. We have found that some geological areas of the United States have limited types of sharp gravel available. It has been necessary to import gravel from a neighboring state, but remember the amounts are relatively small—the top one-and-a-quarter inch of the cross section. Gravel should be as free of fines as possible. To maintain porosity, avoid soft stone materials with low durability that will break easily.

Other Fill Materials for Gravelpave²

Please ask our staff for assistance with this category since it is use-specific and often experimental. Ground rubber, crushed glass, crushed brick, and many other materials can be useful as attractive fill materials for various applications. Thermoset (epoxy, polyurethane, etc.) binders may be cost prohibitive for most projects, but offer unique design possibilities, including clarity, color enhancement (wet look), flexibility, and durability.

Our technical support staff will assist with selection of gravel sources. The photographic samples shown on this page will help you narrow your gravel choices. Should you have questions concerning the selection, please submit a small sample for approval prior to specifying or securing the materials.



Mats can be rolled out in minutes!

Gravelpave² Installation Procedure

This installation section is only intended as an overview. Please review our Gravelpave² Technical Specifications (available at www.invisiblestructures.com or call 800-233-1510) for comprehensive installation instructions.

Prepare sandy gravel base course to a depth as determined by a soils engineer. Compact with a vibrating plate compactor or use a heavy motorized roller for large jobs. To test porosity, water with a hose and check to see that water drains readily through the base course before installing the Gravelpave² mats.

Roll out mats with the grain (in the same direction) so that the snap fit fasteners can be used with neighboring mats. To fit around boxes and curbs, cut the grid between the rings with pruning shears and scissors or a small portable electric hand saw.

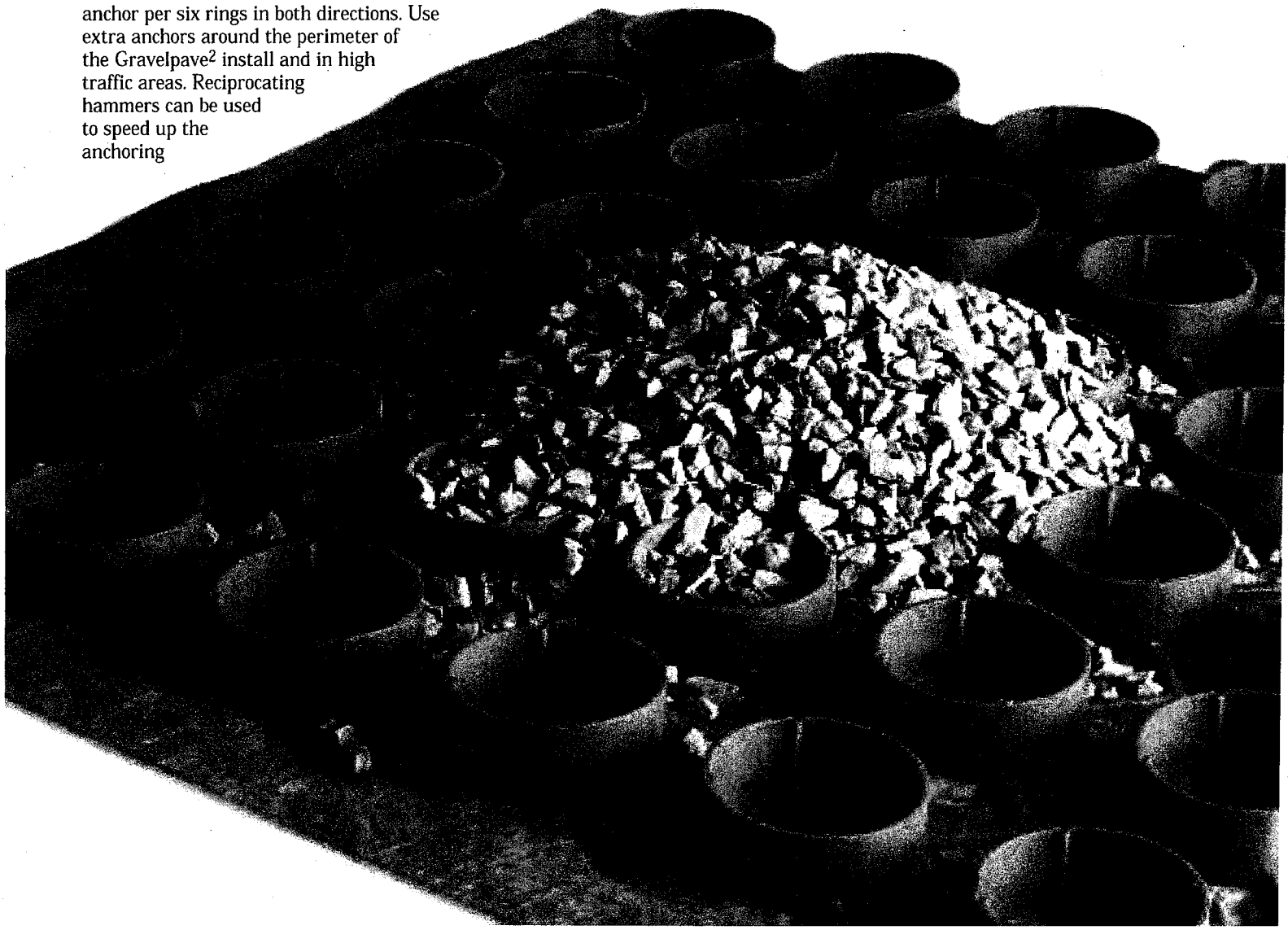
Fasten the mats together using the snap fit fasteners that are molded into the product inserting the prongs into the rectangular openings. Tuck the fabric underneath the fasteners to keep joints closed. A quarter-inch nut driver head (6 mm) fits nicely over the fastener to compress the pieces together. A piece of lumber placed under the Gravelpave² mat will provide stability to aid in fastening.

Supplied anchors must be used to secure the mats to the base. Hammer anchors with washers at a rate of one anchor per six rings in both directions. Use extra anchors around the perimeter of the Gravelpave² install and in high traffic areas. Reciprocating hammers can be used to speed up the anchoring process. Anchors should be placed inside the rings as close to the center as possible. Begin anchoring from one corner in a radial pattern.

Gradually place gravel fill (see suggested fill material on facing page) into rings by using a front-end loader and shaking out the fill as the machine drives forward. Carefully lower the bucket when empty and back up while dragging it *above* the rings to smooth out the gravel, finishing with a stiff broom. Wheel barrow and shovel works well for small jobs. Contractor tip—you can store excess material for future maintenance, top dressing as may be necessary. Use rakes and/or push brooms to distribute the gravel fill to a level slightly above rings so that compacting the fill will not uncover the rings.

Use a vibrating plate compactor or large driving roller again to compact the gravel fill. Additional gravel may be necessary to finish filling the rings. Compact again until the material appears solid in the rings. Wetting the gravel may help it to interlock.

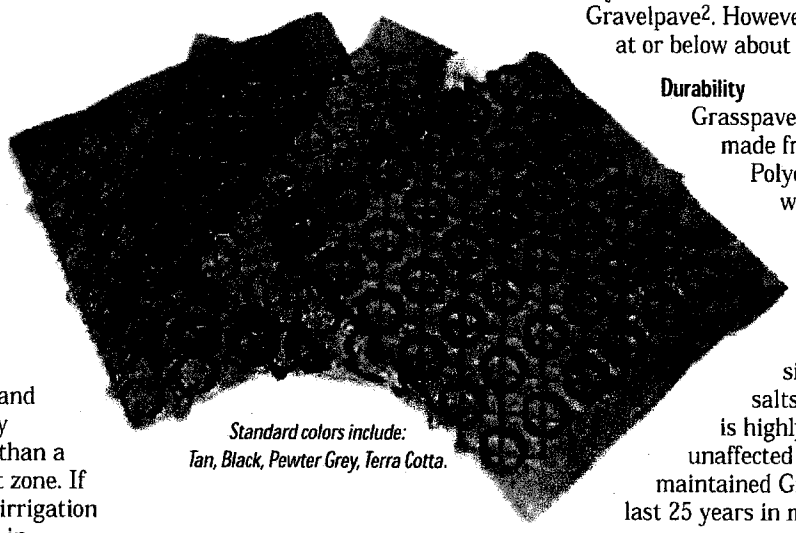
Drive on the installation when finished. If car tires make a pattern, there may be too much gravel or it may need additional compaction. It is expected that tops of the rings may be visible. If sides of the rings show, then add more fill material and repeat the compaction process.



Traffic Frequency
Grass as a surface material can withstand from two to six (varies with grass species and environmental conditions) trips daily over the same spot. This suggests that most parking applications we pave with asphalt today could be paved with Grasspave² instead. Vehicles can remain parked on grass for extended periods of time, provided some relief can be given for a few days for the grass to recover.

Lifespan
Grasspave² has a projected lifespan of 60 years. Compared to asphalt with a lifespan of 15 years; and concrete with a lifespan of 25 years, Grasspave² will save you money on replacement costs.

Irrigation
Grass needs water and you may need to have irrigation installed. Grasspave² has a sand based root zone which usually requires slightly more water than a normal topsoil or organic root zone. If golf courses in your area use irrigation systems, you probably should in your Grassapave² installation.



Standard colors include: Tan, Black, Pewter Grey, Terra Cotta.

Gravelpave² Characteristics

Fabric, Ring and Grid
When we developed Gravelpave² in 1993, our goal was to provide designers a second option for a porous pavement that can tolerate high frequency and low-speed traffic. By molding our ring and grid structure onto a non-woven polyester filter fabric, we were able to create a new product that contains gravel and prevents particle migration and rutting.

Invisible Structures—Standard Product Roll Sizes

	Width		Length		Diameter		Area		Weight	
Model	m	ft	m	ft	m	ft	m²	ft²	kg	lbs
1010	1	3.3	10	32.8	0.5	1.7	10	108	22	48
1020	1	3.3	20	65.6	0.8	2.7	20	215	44	96
1520	1.5	4.9	20	65.6	0.8	2.7	30	323	65	144
2020	2	6.6	20	65.6	0.8	2.7	40	430	87	192
2520	2.5	8.2	20	65.6	0.8	2.7	50	538	109	240

Rolls can be installed manually (2 people advised). Rolls apply to Grasspave², Gravelpave², Draincore², and Slopetame².

Gravelpave² is the only system specifically designed for aggregate containment porous paving. The cylinders displace the load onto an engineered base course and hold the decorative gravel in place. The fabric keeps the top-dress gravel from compacting into the road base, acts as a weed and vegetation barrier, and suppresses dust.

Traditional pavements, including gravel roads, are designed to shed water and keep it away from the pavement's cross-section. Gravelpave² is designed to do the opposite—welcoming water down through the system. Plus, Gravelpave² will not rut, washboard, or puddle like traditional gravel roads.

Snap-Fit Fasteners
Designed into Gravelpave² is a snap-fit fastener, a two-pronged arrow that fits into a rectangular slot. Simply push the slot over the prongs to easily snap together panels of Grasspave². To take them apart, just squeeze the prongs together and lift off the slot. Should the fasteners of one mat not align over the distance of another mat, then anchor pins (or eight inch ring shank nails and large washers) can be used to secure the mats along the seam. Forcing the alignment can cause the mats to ripple and not lay down evenly.

Traffic Frequency
Gravelpave² has no limits on frequency or duration of traffic on the system. Park or drive as often as you like on Gravelpave². However, speeds should be kept at or below about 20 mph (30 km/h).

Durability
Grasspave² and Gravelpave² are made from flexible High Density Polyethylene (HDPE) plastic with UV inhibitors, which withstands repeated freeze-thaw cycles and continuous subzero temperatures without cracking. HDPE resists aggressive chemicals such as road salts, motor oils and fuels. HDPE is highly abrasion-resistant and is unaffected by extremes in pH. A well-maintained Gravelpave² installation will last 25 years in most climates.

Aesthetics
Part of what draws many designers to use Gravelpave² is the ability to have an area maintain a natural look. Many times native soils or gravel can be used as fill material, complementing surrounding areas. Gravelpave² is available in four standard colors—black, tan, gray, and terra cotta (custom colors are available at additional cost). Ring colors are intended to blend with the gravel color so they will be less visible should some portion of the rings show. A small amount of excess stone fill should be left above the top of the rings to provide visual cover and additional UV protection. This excess will migrate, but usually not very far.

Size and Shape Requirements for Gravel Fill
You will need one and a quarter inch (3.2 cm) of gravel fill, before compaction. After compaction the gravel should be only be slightly higher than the rings (⅛ inch, 3 mm above). The following criteria for gravel fill will make the most of the systems performance:

- Hard—resistant to breaking, crushing or crumbling
- Sharp and angular (do not use rounded pea gravel)
- Clean, washed (free of fines)
- Size 3/16 to ⅜ inch (5 mm to 1 cm)

Other fill material may be used in certain situations, but may be considered use-specific or experimental. Please consult with our technical support staff regarding fill material not meeting the above criteria or for installations requiring "binders."

Dust Suppression

Dirt and gravel roads have the potential to kick up dust and dirt when traversed. Many communities have regulations limiting or eliminating gravel surfaces from new construction. Rest assured, if you design a Gravelpave^2 surface you will be getting a virtually dust-free surface. The clean and washed fill material required to fill the rings will not have any more dust than an asphalt-paved surface. Gravelpave^2's geotextile fabric will prevent the dust-sized particles contained within the base material (existing gravel surface or dirt), from being displaced by moving tire or wind forces.

Oakdale Nature Preserve, Freeport, Illinois—Gravelpave^2 reduces erosion and rutting in this ADA accessible trail.

Industry Advantages

Economic Advantages

Whether you are an engineer, architect, landscape architect, contractor or homeowner you will be concerned with the cost of you project. Grasspave^2 and Gravepave^2 will save you money. Our products will save on design costs, installation costs, component materials, maintenance/operations expenses and lifecycle costs. We can find a way to reduce your site expenses with our porous pavers.

When designing, you may be able to eliminate or reduce stormwater filters, detention basins, conveyance lines, modifying grading requirements, or many other "necessities" associated with asphalt or concrete. A great deal of your stormwater mitigation plan can be built into Grasspave^2 and Gravelpave^2.

Installers have been astounded by the speed and efficiency for which large areas can be accommodated by our large rolls. Unrolling our mats, snap fitting, and cutting is easy and requires no special machinery. Please view our technical specifications (from www.invisiblestructures.com, call 800-233-1510, or available through our partner network) for the installation procedure. A brief installation overview is also on pages 8 and 10).

In addition to cost savings in the design phase, you may be able to eliminate other components during installation such as root protection for trees, grates, manholes, curbing, and tree and vegetation removal costs.

Maintenance and operations costs are significantly reduced over asphalt and concrete surfaces. A. (Andy) E. Lindsey, Director of Grounds Maintenance, University of South Alabama, in his written analysis dated February 18, 1999, compared the cost of our porous systems to asphalt pavement using historical data from university records. The conclusion was a $56,000 savings over 20 years, by using Grasspave^2 and Gravelpave^2.

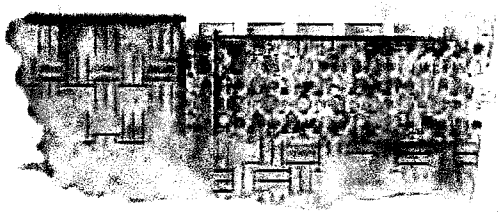
Our products can save you the most money by combining your surfaces' uses into one area. Multiple surface use means savings on real estate, design costs, maintenance, insurance and more. You can have a fire lane that doubles as "green space" for employees or visitors, combine a parking lot with a bio-swale and stormwater mitigation system, and expand your lawn into the driveway. The Grasspave^2 and Gravelpave^2 installations at Reliant Stadium, Houston, Texas, pull quadruple duty, providing over seven acres of parking, stormwater mitigation, required "green space," and an outdoor festival site which generate additional income.

As mentioned above, Grasspave^2 and Gravelpave^2 have a longer lifespan than asphalt. Compound the above savings with the longer lifespan, and you can have a lifecycle cost which can save thousand of dollars on even moderately sized installations.

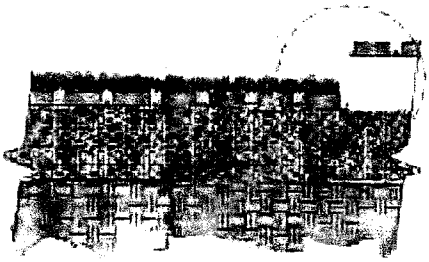
Competitive Advantages

Our porous pavers not only have advantages over impervious surfaces, we are proud to compete with any other plastic porous pavers manufactured. Our products are the strongest on the market 5,721 psi installed (39,273 kPa, 823,844 psf or 7,414,416 psy), or 2,100 psi empty. Grasspave^2 and Gravelpave^2 have

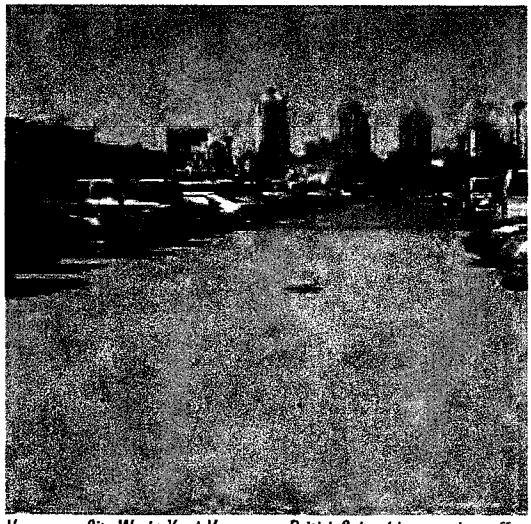
Compacted sandy gravel road base placed above compacted subgrade, 95% modified Proctor density. Gravelpave^2 rolls are laid, pinned, and filled with clean, sharp gravel.



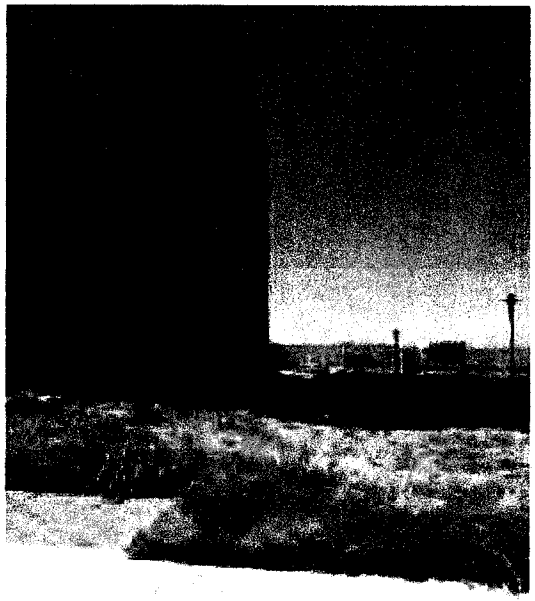
For Grasspave^2: Compacted sandy gravel road base placed above compacted subgrade, 95% modified.



92 percent void space for the best root development and grass coverage (Grasspave²) and the most volume available for desired fill (Gravelpave²). Most other plastic pavers come in rigid unit blocks, which are cumbersome to install and difficult to cut and shape. Grasspave² and Gravelpave² rolls are considered the favorite to work with by installers, for the flexibility, continuity, and speed of installations. Grasspave² is the only product on the market specifying sand infill for the grass roots. Sand is recommended as the infill of choice for grass pavers by Professor Bruce K. Ferguson, Univ. of Georgia, author of the book, "Porous Pavements."



Vancouver City Works Yard, Vancouver, British Columbia—main staff parking lot, done in Gravelpave².



Fire lane, San Mateo, CA—Many native grasses and other attractive vegetation can be grown in Grasspave².

Competing Technologies

Porous paving technology has made great strides not only in flexible plastic pavers but in other areas as well. Permeable asphalt, permeable concrete, interlocking unit blocks, reinforcement mats, and concrete grid pavements, have all improved and advanced to meet the growing demand for environmentally friendly technologies. It is Invisible Structures' firm belief that you should use porous paving, even if it is not our product line, whenever possible. The more you use these technologies, the better accepted they become: If you have to pave, porous pave!

Invisible Structures also contends that while these competing technologies have their place, in most instances, our Grasspave² and Gravelpave² systems outperform, last longer, require less maintenance, look better, and are easier to install. Check with our technical specialists at 800-233-1510 for the latest data.

Designing for Grasspave² and Gravelpave²

Design for Use

There is an area in your development, site, or home that will most likely benefit from Grasspave² and Gravelpave². We advise that you take a look at proper use patterns, site conditions, and other specifications to get full advantage and long life out of our products. *Invisible Structures, 800-233-1510, is available for preliminary design assistance and consultation. Please note that other porous paving systems are NOT interchangeable with Grasspave² or Gravelpave², consult our technical specifications for full installation instructions.*

Considerations for Design:

- High use, low speed, and unlimited traffic volume is optimal for Gravelpave²
- Low to moderate use, low speed, with recovery time is perfect for Grasspave² or Gravelpave²
- Keep the porous paving area free of sediment and erosion from adjacent areas as they can cause drainage and aesthetic issues. Extra care should be taking for use in swales or berms.
- Slope should be considered. Grasspave² and Gravelpave² perform the best for all vehicles when the slope is no greater than 8 percent. Light vehicles (golf carts), bicycles, and pedestrian areas can have up to a 20 percent slope. Grasspave² in fire lanes should not exceed five percent (consult your local fire departments).
- Check the permeability of existing underlying soils. Percolation rates should be .64 cm to 1.3 cm of water per hour (EPA guidelines).
- The water table should be about three feet (approx. 1 m) below base course in most instances.
- Bedrock should not be closer than two feet (0.6 m) below base course.
- Avoid use of Grasspave² and Gravelpave² in areas where high-speed acceleration or braking and turning occur. Examples are entrances and exits to parking lots that connect to higher speed roads.

If your site varies from these conditions, please consult ISI directly, 800-233-1510, as some conditions can be overcome with design and component adjustments.

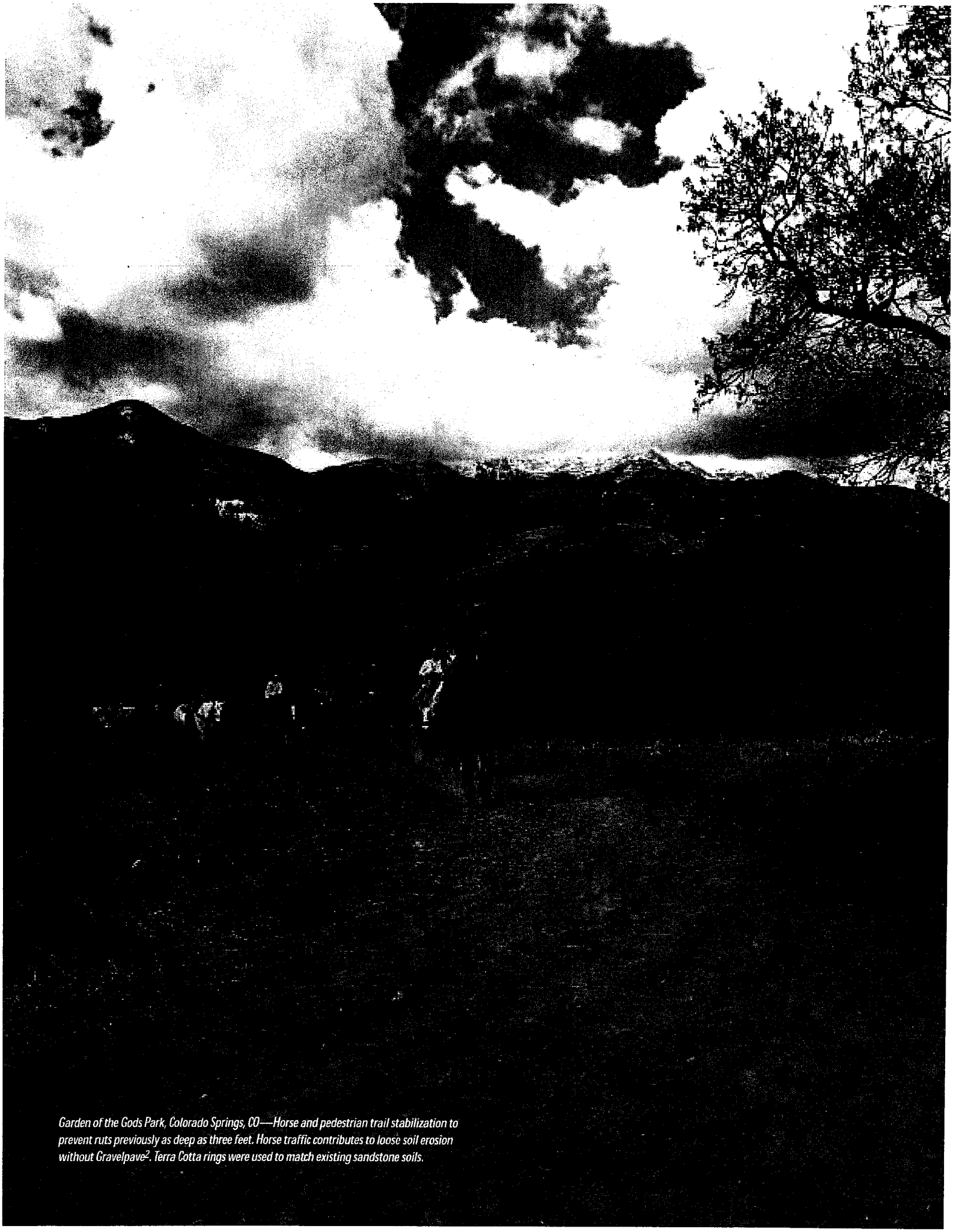
Base Course Design

Calculating the depth and composition of materials for the base course incorporates the same design criteria as for other pavements:

- Load-bearing capacity of native (or fill) subsoil,
- Plasticity or impact of moisture on strength and longevity,
- Frostheave potential, and
- Traffic load, frequency and/or duration.

Sample Base Course Depths

Please consult with a soils engineer for site-specific base requirements. Generally, the depth that is used under asphalt will be the requirement under Grasspave²/Gravelpave². Golf carts and pedestrian traffic may require nothing over sandy gravel soils, and just two to four inches of base course (5–10 cm) over very weak soils. Cars usually need a six- to eight-inch base course (15–20 cm). Buses, trucks, and fire engines can easily require eight to 12 inches (20–30 cm) or more. The use of geotextiles, below the base is not required, but will prevent integration with subsoils and is strongly advised in areas of clay or silt soils and frost heave. *Do not use 100 percent limestone base as limestone will compact and become impervious—If limestone must be used, mix with 25–30 percent sand (AASTO M6 or equal).*



Garden of the Gods Park, Colorado Springs, CO—Horse and pedestrian trail stabilization to prevent ruts previously as deep as three feet. Horse traffic contributes to loose soil erosion without Gravelpave^2. Terra Cotta rings were used to match existing sandstone soils.

Bedding Sand Not Necessary

Do not use a sand setting base with our products. Unlike concrete pavers, bricks, and other rigid pavers—our Grasspave² and Gravelpave² are flexible and do not require sand to level.

Edge Protection

For aesthetic and maintenance considerations, you may want to design in a durable edging material to separate our porous pavers from adjacent areas of turf or to simply delineate a fire lane or path. With Gravelpave², an edging can prevent vegetation from encroaching onto the system and can prevent the gravel fill from migrating at the edge. Steel, aluminum, wood, brick, or concrete are all acceptable edging materials. Keep the edging flush or slightly higher than the porous paver grade.

Maintenance and Operation

Grasspave² Maintenance

Irrigation is required in dry climates. Any popular pop-up system can be used. Simply cut out rings to reveal the irrigation head. If golf courses in your area use irrigation systems, you probably should in your Grasspave² installation. Be careful not to overwater as this will encourage shallow root development.

Fertilize once a year with an NPK slow-release fertilizer that contains trace elements. There are many brands on the market. Do not aerate! You'll end up with product damage. When installed using sand in the rings, there will not be a compaction problem. Be careful not to use clay-based sods in pedestrian or vehicular traffic areas—use sandy soil sod, or seed and mulch. There seems to be no problem with sod selection for fire lanes. If the Grasspave² area has just been seeded or sodded, drive on it only in an emergency.

Gravelpave² Maintenance

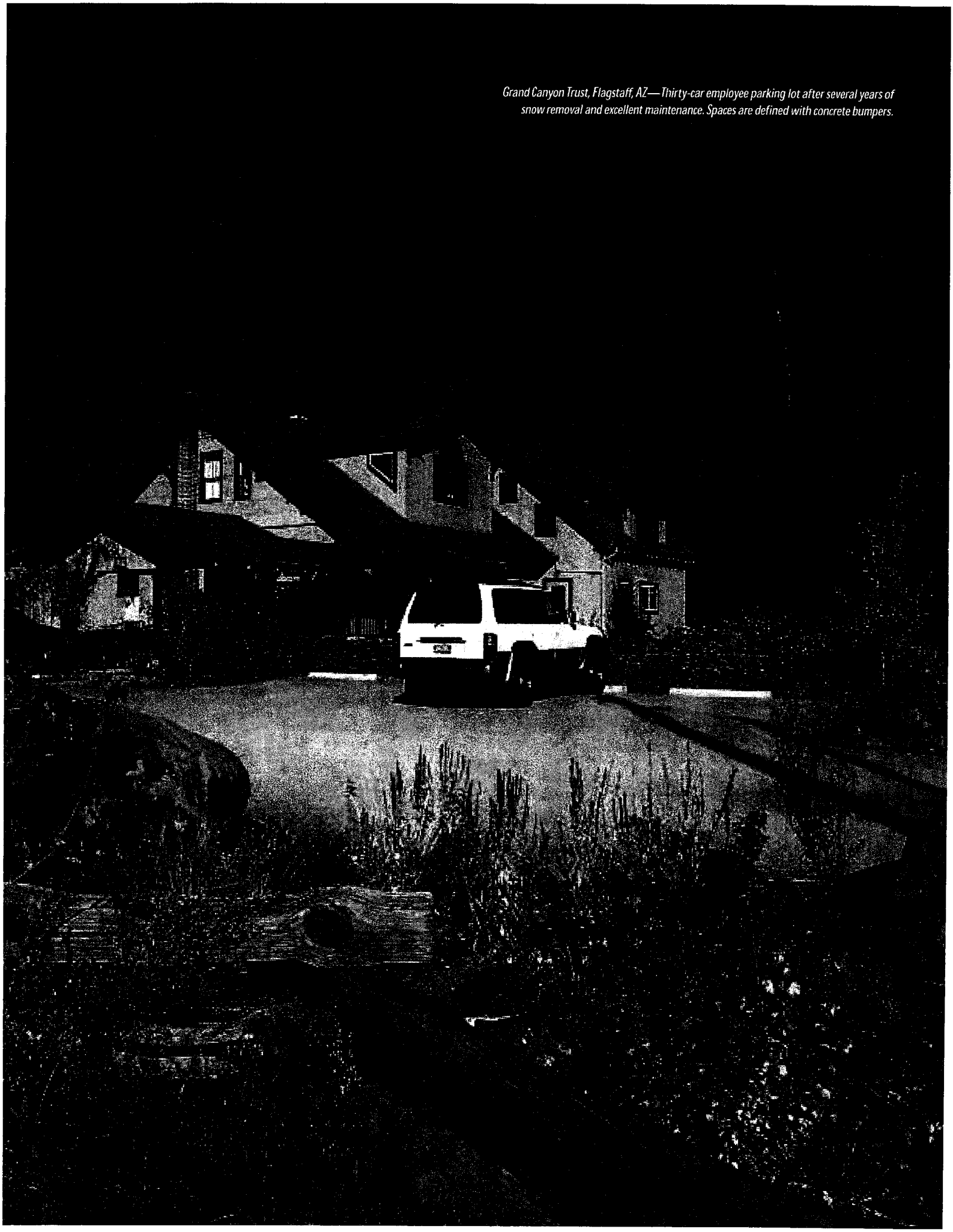
Potholes will only appear if the base course has not been compacted properly before laying the rings or if the base material is allowed to mix into clay soils below (use nonwoven fabric to keep separate). Should this occur, remove a section by vacuuming the gravel from the rings, unfasten the snap fit fastener, bring the base course to the proper grade and compaction, put the Gravelpave² square back in place, anchor, and fill to the top of the rings. Seasonally check the rings in high-traffic areas and entrance lanes for lower levels of fill and replace by sweeping gravel from other areas to bring it level again. Leaves should be raked or vacuumed and not allowed to decay. Organic matter will stimulate weed growth and reduce porosity. To attack any occasional weeds that may locate within the Gravelpave² installation, simply spray them with a weed killer (such as Roundup™) and remove them when dead.

Cold Climate Concerns

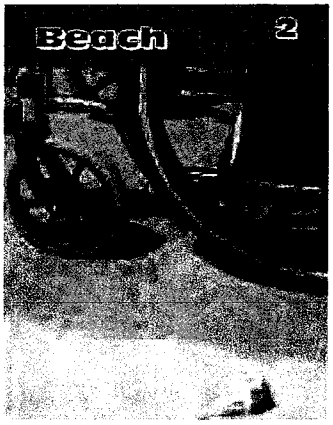
Porous pavement thaws faster than conventional pavements because it allows melted water to flow directly through the pavement, increasing the temperature in the cross-section.

Grasspave² and Gravelpave² are made from flexible High Density Polyethylene (HDPE) plastic with UV inhibitors, which withstands repeated freeze-thaw cycles and continuous subzero temperatures without cracking.

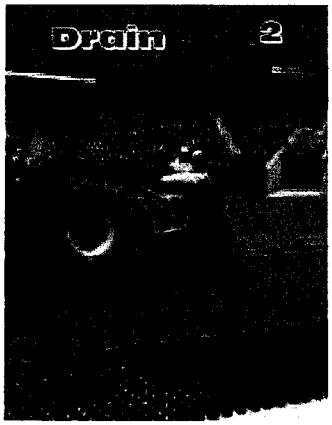
Private Residence, Houston, TX—Grasspave² supported grass sections in this custom home driveway.



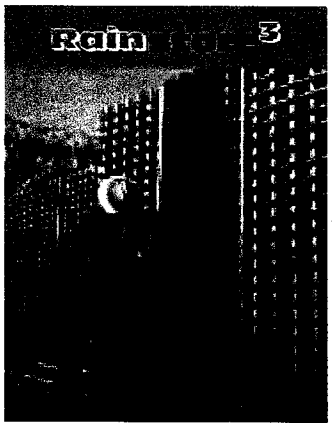
Grand Canyon Trust, Flagstaff, AZ—Thirty-car employee parking lot after several years of snow removal and excellent maintenance. Spaces are defined with concrete bumpers.



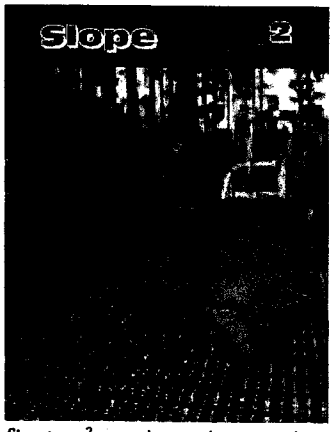
Beachrings², a portable and re-usable plastic boardwalk system, provides an attractive, comfortable, and slip resistant surface for equal access to beaches. Beachrings² also works well for temporary vehicle access over mud and sand.



Draincore² conveyance layer is used for advanced subsurface and green-roof applications. A replacement for antiquated French drains, Draincore² can maximize drainage (58 gpm per foot width) and minimize costs.



Rainstore³ is the new standard in efficient sub-surface stormwater storage. Rainstore³ is modular and stackable for versatile site design. Rainstore³ is 94% void space and can be designed for detention, retention, or water harvesting for re-use.



Slopetame²—much more than an erosion control blanket or mat—a completely integrated system of rings, grid, fabric, anchors, and vegetation to control erosion on some of the toughest slopes, channels, swales and more.

Quick Reference Guide for Grasspave² and Gravelpave²

	Grass 2	Gravelpave 2
Description	Connectable ring and grid system	Connectable ring, grid, and integrated fabric
Also Included	Hydrogrow polymer—exclusively for Grasspave²	Geotextile fabric molded to grid (exclusive to Gravelpave²) and anchors
Available in Large, Flexible Rolls	Yes, various sizes—see roll chart page 14	Yes, various sizes—see roll chart page 14
Colors	Black	Black, gray, tan, terra cotta, custom colors extra
Components Needed for System	Base course, sand, labor, sod or seed (irrigation is recommended)	Base course, 1¼" (3.2cm) of 3/16" to 3/8" decorative gravel, and labor
Traffic	Low speed, intermittent to moderate use	Low speed, unlimited use
Compressive System Strength	Filled: 5,721 psi (39,273 kPa); Empty: 2,100 psi (14,470 kPa)	Filled: to 5,721 psi (39,273 kPa) Empty: 2,100 psi (14,470 kPa)
Life Span	60 years	25 years
Recommended Maximum Slope	5% fire lanes, 8% car/light truck, 15-20% golf carts, pedestrian use, and trails	5% fire lanes, 8% car/light truck, 15-20% golf carts, pedestrian use, and trails
Stormwater Storage	Yes	Yes
Clean Pollutants through Bioremediation	Excellent	Good
Air-Conditioning Effect	Yes	No
Heat Island Mitigation	Yes—thermal conductivity, heat storage capacity, density, albedo (.40) and emissivity	Yes–thermal conductivity, heat storage capacity, density, albedo (varies) and emissivity
Reduces Runoff and Non-Point Source Pollution	Yes	Yes
Recycled Content	100% recycled HDPE plastic	100% recycled HDPE plastic, remnant fabric
Erosion Control	Yes	Yes
Airborne Dust Capture and Retention	Excellent	Good
Promotes and Retains Tree Growth	Yes	Yes
Recharges Groundwater	Yes	Yes

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