Draft Environmental Assessment

Connection to Farrington Highway and Wastewater Treatment Plant Improvements Dillingham Ranch Agricultural Subdivision

Volume II: Appendices

Waialua, Island of O'ahu,
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Chapter 343, Hawaii Revised Statutes,
and Title 11, Chapter 200,
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Prepared for:

Dillingham Ranch 'Aina, LLC
9701 Wilshire Boulevard, Suite 700
Beverly Hills, California 90212

Prepared by:

Sherwood Design Engineers
58 Maiden Lane, Third Floor
San Francisco, CA 94108

Hart Howerton
1 Union Street, Third Floor
San Francisco, CA 94111

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Appendix A

Documentation Regarding Application for Subdivision,
Dillingham Ranch Agricultural Subdivision,
Mokule'ia, O'ahu, Hawai'i

Agricultural Subdivision Documentation to be Included with Final DEA

Appendix B

Report of Findings: Terrestrial Vegetation Surveys
Dillingham Ranch Agricultural Subdivision
Mokule'ia, O'ahu, Hawai'i

DRAFT

Report of Findings

Terrestrial Vegetation Surveys

Dillingham Ranch Agricultural Subdivision, Mokuleia, O‘ahu, Hawai‘i

Prepared for:
Dillingham Ranch Aina, LLC
9701 Wilshire Boulevard Suite 700
Beverly Hills CA 90212

Prepared by:
Maya LeGrande
LeGrande Biological Surveys, Inc.
68-569 Crozier Drive
Waialua HI 96791

July 2014

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1 INTRODUCTION

This report includes the findings of a plant and animal inventory conducted within the subject property for the proposed Dillingham Ranch Agricultural Subdivision located in Mokuleia on the Island of O‘ahu, Hawai‘i. The purpose of the survey was to inventory the plant species present within the project area, with special attention to Listed, Proposed, and Candidate Endangered Species, critical habitats, and Species of Special Concern.

2 SITE DESCRIPTION

The project area includes the current Dillingham Ranch Properties mauka of Farrington Highway from an elevation of a few feet above sea level up to approximately 400-foot elevation. The lower portion of the property is characterized by flat alluvial plains rising into sloping lands and terminating at the steep slope faces at the upper elevations. The majority of the planned subdivision and roadways are located in the upper areas of the property mauka of the managed land or areas that are currently utilized for plantation and ranching activities. At least four intermittent streams run through the project area. All have dry rocky streambeds and several have constructed channels for either flood control or road crossings. Photographs of the project area are found in Appendix A.

The Dillingham Ranch has been surveyed in the past numerous times for botanical resources. The most recent being a 1991 study by Whistler and the 2008 (Guinther) survey carried out by Aecos Inc. The survey areas were predominantly the same apart from both the 1991 survey and the present survey included an upland (mauka) section that was not included in the 2008 survey. Both Whistler and Guinther describe similar vegetation types. The differences mainly consist of the expansion of Guinea Grassland into the lower elevation areas, most likely due to the contraction of ranching into the lower managed lands of the ranch allowing the Guinea grass and other weedy species to expand into the historically open grazed areas observed by Whistler in 1991. The present study found much of the vegetation types similar in area to the 2008 study. Therefore, the main focus of the 2014 survey was to document any significant changes in vegetation types or areas of expansion and search for additional native or rare species that may still be extant within the ranch boundaries.

3 METHODS OF STUDY

The field study was conducted by biologist Maya LeGrande and a field assistant (LeGrande Biological Surveys). Prior to conducting fieldwork, the biologists reviewed existing scientific literature, older environmental impact assessments and statements, biological survey reports, topographic maps and images. Field data was collected on June 30 and July 1 & 7, 2014 between 6:15am and 5:00pm. Prior to conducting fieldwork, we reviewed the U.S. Fish and Wildlife database (USFWS 2014) in order to determine if any Threatened or Endangered taxa are known to reside within the study area or in close proximity.

Plants were inventoried during a pedestrian survey along the proposed alternative alignments as well as the proposed area of impact. Notes were collected on plant associations and plant distribution, disturbances, topography, substrate types, exposure, drainage, and related factors.

4 SURVEY RESULTS

4.1 Vegetation

We observed a total of 170 plant species within the survey area. These species are listed in Appendix B. One hundred and sixty-five (165) of the 170 species observed, or over 97%, are alien to Hawai‘i. Six taxa are native (four indigenous and two endemic). The majority of the study area is dominated by an overgrown forest of invasive tree species with a weedy understory. None of the plant species are listed as threatened and endangered species, or a species of concern (U.S. Fish and Wildlife Service, 2014) within the study area.

4.1.1 Managed Lands

The lower elevation areas of the subject property are currently utilized for ungulate (horse and cow) pastures as well as tree plantation and house lots. Pastures are dominated by grassy fields with various species of trees scattered throughout the area. Tree species include, Christmas berry (*Schinus terebinthifolius*), Chinese banyan (*Ficus macrocarpa*), monkey pod (*Samanea saman*), milo (*Thespesia populnea*), ironwood (*Casuarina oppositifolia*), coconut (*Cocos nucifera*), kiawe (*Prosopis pallida*), koa haole (*Leucaena leucocephala*), Java plum (*Syzygium cuminnii*), and autograph trees (*Clusia rosea*). Grass species include Guinea grass (*Panicum maximum*), kikiyu (*Pennisetum clandestinum*), buffelgrass (*Cenchrus ciliaris*), and swollen fingergrass (*Chloris barbata*). Other weedy species observed included Spanish needle (*Bidens pilosa*), Chinese violet (*Asystasia gangetica*), false ragweed (*Parthenium hysterophorus*). The indigenous *uhaloa* (*Waltheria indica*) was observed frequently along roadsides.

The tree plantation is dominated by coconut and other species of ornamental palms including; fish tail palm (*Caryota mitis*), royal palm (*Roystonia* sp.), and manila palm (*Veitchia merrillii*). Several overgrown areas are located near the Highway and project boundary mainly around the drainage canal areas. Guinea grass dominates the thick vegetation while species such as sourbush (*Pluchea carolinensis*), red mangrove (*Rhizophora mangle*), and milo were observed growing on the banks of the canals.

There are several water features on the property. The largest pond (presumably manmade) is located in the northwest corner of the property near the highway. The vegetation around the perimeter of the pond was surveyed. The vegetation growing on inaccessible islands within the pond were surveyed from afar. Large trees include ironwood, Java plum, monkey pod, Christmas berry, opiuma (*Pithecellobium dulce*), and kiawe (*Prosopis pallida*). Weedy species along the banks included; Guinea grass, *Sidastrum micranthum*, molasses grass (*Melinus minultiflora*), lion’s ear (*Leonotis nepetifolia*), spiny amaranth (*Amaranthus spinosus*), sourbush, indian fleabane (*Pluchea indica*), castor bean (*Ricinus communis*), and slender mimosa (*Desmanthus pernambucanus*).

4.1.2 Panicum Grassland

This vegetation type dominates the naturalized areas outside of the managed lands. Guinea grass is by far the most abundant species throughout the survey area. It grows in large clumps up to 12 feet in height. Other species mixed in with the thick bunch grass include castor bean, *Sidastrum micranthum*, cherry tomato (*Solanum lycopersicum* var. *cerasiforme*), lion’s ear, spiny amaranth, cocklebur (*Xanthium strumarium* var. *canadense*), and glycine (*Neonotonia whightii*). The

grassland extends into bordering vegetation types especially into Kiawe woodland, Koa Haole Scrub, and Riparian forest becoming more of an understory with shorter grass heights and sparser distribution of grass bunches.

In areas where there is active grazing by cattle, especially in the upper elevations of the south-eastern corner of the property, weedy species such as klu (*Acacia farnesiana*), lion's ear, silver oak, and bunches of grazed Guinea grass are dominant. A few short statured wiliwili (*Erythrina sandwicensis*) trees were also located in the same area.

4.1.3 Kiawe woodland

Sections of the upper western portion of the property are dominated by kiawe trees with juvenile kiawe plants mixed with the guinea grass understory. Other plants in the understory include false mallow (*Malvastrum coromandelianum*), *S. micranthum*, *popolo* (*Solanum americanum*), and ivy gourd (*Coccinea grandis*). Other tree species observed growing in this vegetation type were; silver oak (*Grevillea robusta*), Java plum, African tulip (*Spathodea campanulata*), and monkey pod. Clusters of macadamia (*Macadamia ternifolia*) trees were observed growing in the kiawe woodland scattered around the lower elevation sections of this vegetation type. Several native wiliwili trees were also observed.

4.1.4 Koa Haole Forest

The species are consistent throughout this vegetation type with the dominant tree species including, koa haole, autograph, monkeypod (*Samanea saman*), kiawe, Chinese banyan, Java plum, and Christmas berry. Understory plants include, Guinea grass, mock orange (*Murraya paniculata*), *Achyranthes aspera*, and khaki weed (*Alternanthera pungens*). In the western section of the project area in the upper elevations, this vegetation type also harbors a few remnant native plants including a handful of alahee (*Psydrax ordorata*) and a few wiliwili trees.

4.1.5 Riparian Forest

The forests surrounding the intermittent streams appear to have shrunk since both the 1991 survey as well as the 2008 survey. Most of the vegetation along the banks of the streams and gulches in the project area are barely discernable from the previously mentioned vegetation types. A few areas where denser stands of Java plum, kiawe, koa haole, and *Kukui* (*Aleurites moluccana*) trees are apparent along the stream banks characterize the riparian causeway. Guinea grass is the predominant understory plant. In areas where bare boulders are exposed a few plants of the native '*ilie'e* (*Plumbago zeylanica*) were observed.

5 DISCUSSION & RECOMMENDATIONS

The results of our fieldwork represent a one-time snapshot of the plants inhabiting the survey area. However, when considered together with the results of historical surveys, we can compile a reasonably accurate description of the environment and vegetation of the project area.

Native plant habitat within the proposed project area has been highly modified by human activities, such as agricultural activities, road building, residential construction, and the intentional and accidental introduction of alien species. The overwhelming abundance of non-native plant species throughout the project area is in direct correlation to disturbance over the last several hundred years. A concerted effort was made to locate native plants within the survey

area. Whistler reported finding *Lipochaeta lobata* (no variety distinction was noted) during his 1991 survey of the Dillingham Ranch. We searched extensively for this taxa, especially in areas whith rocky outcroppings, but no individuals were located. The only other endemic taxa observed during the survey besides wiliwili was a few dried vines of kupala (*Sicyos pachycarpus*). The liana is more abundant after the rainy season when new growth is apparent festooning stands of koa haole.

Wetland areas are all located near the highway either in constructed ponds or drainage canals. The areas around the current ponds are not expected to be modified by the proposed development. If the plan changes to include areas around the wetlands (ponds/canals), a wetland delineation may be needed.

We have the following recommendations in regards to the flora of the Dillingham Ranch Agricultural Subdivision:

- During construction, clearing of vegetation should be mitigated by controlling erosion and runoff, especially during rainy season by implementing known engineering practices.
- The remaining native wiliwili trees should be preserved as much as possible within the development areas. Encouraging use of the species, as ornamentals in the subdivision would help to encourage this now rare dryland tree species to persist in one of its native habitats.
- Management/eradication of the false ragweed (*Parthenium hysterophorus*) may be in the best interest of the ranch as it can reduce carrying capacity of pastures by 90% and can cause allergic reactions in humans and livestock, especially horses, due to its allelopathic compounds (Smith, 2002).

6 LITERATURE REVIEWED

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APPENDIX A – SITE PHOTOGRAPHS

Fig 1. Pastureland to west of main entrance road looking mauka towards upper portion of project area in foothills. Patch of False ragweed (*Parthenium hysterophorus*) characterized by light green foliage in center of picture.

Fig 2. Portions of the managed land are landscaped with large tree species such as kiawe, banyan, and monkey pod with expansive mowed lawns.

Fig 3. Pond in north-west corner of property is dominated by large ironwood trees and weedy shrub species along the banks.

Fig 4. Typical Guinea grassland in previously managed lands with Koa Haole scrub forest at margins.

Fig 5. Kiawe woodland in the upper western section of project area with scattered monkey pod and silk oak trees.

Fig 6. Koa Haole Forest mixed with Guinea grassland in the upper west of the project area. The dense line of trees, mainly Java plum, designate a section of Riparian forest.

Fig 7. Upper property, south-east of the Mokuleia Forest Reserve Access Road, located on a slope dominated by non native species such as Guinea grass, koa haole, and silver oak.

APPENDIX B: PLANT SPECIES LIST

The following checklist is an inventory of all the plant species observed within the 900 acres of survey land of Dillingham Ranch. The plant names are arranged alphabetically by family and then by species into each of four groups: Pteridophytes, Gymnosperms, Monocots, and Dicots. The taxonomy and nomenclature of the flowering plants (Monocots and Dicots) are in accordance with Wagner *et al*. (1990), Wagner and Herbst (1999) and Staples and Herbst (2005). Recent name changes are those recorded in the Hawaii Biological Survey series (Evenhuis and Eldredge, eds., 1999-2002). For each species, the following name is provided:

1. Scientific name with author citation.
2. Common English and/or Hawaiian name(s), when known.
3. Biogeographic status. The following symbols are used:

   E = endemic= native only to the Hawaiian Islands.

   I = indigenous= native to the Hawaiian Islands and elsewhere.

   X = introduced or alien = all those plants brought to the Hawaiian Islands by humans, intentionally or accidentally, after Western contact, that is Cook's arrival in the islands in 1778

SCIENTIFIC NAME	COMMON NAME	STATUS
PTERIDOPHYTES		
POLYPODIACEAE		
Phymatosorus grossus (Langsd.&Fisch.) Brownlie	*lauae*	X
GYMNOSPERMS		
ARAUCARIACEAE		
Araucaria columnaris (G.Forst) D.Hooker	Cook island pine	X
MONOCOTS		
AGAVACEAE		
Cordyline fruticosa (L.) A.Chev.	ti, ki	X
ALOEACEAE		
Aloe vera (L.) N.L.Burm.	aloe	X
ARECACEAE		
Caryota mitis L.	fish tail palm	X
Cocos nucifera L.	coconut	X
Phoenix dactylifera L.	date palm	X
Roystonia sp.	royal palm	X
Veitchia merrillii (Beccari) H.E.Moore	Manila palm	X
COMMELINACEAE		
Commelina benghalensis L.	hairy dayflower	X
Commelina diffusa N.L. Burm	dayflower	X

SCIENTIFIC NAME	COMMON NAME	STATUS
CYPERACEAE		
Cyperus involucratus Rottb.	umbrella sedge	X
Cyperus rotundus L.	kili o'opu	X
POACEAE		
Brachiaria mutica (Forssk.) Stapf	California grass	X
Cenchrus ciliaris L.	buffelgrass	X
Cenchrus echinatus L.	common sandbur	X
Chloris radiate (L.) Sw.	radiate fingergrass	X
Chloris barbata (L.) Sw.	swollen fingergrass	X
Cynodon dactylon (L.) Pers	manienie	X
Digitaria insularis (L.) Mez ex Ekman	sourgrass	X
Eleusine indica (L.) Gaertn.	beach wiregrass	X
Eragrostis amabilis (L.) Wight&Arnott	lovegrass	X
Eragrostis tenella (L.) P.Beauv. Ex Roem.&Schult.		X
Melinus minutiflora P.Beauv.	molasses grass	X
Melinus repens (Willd.) Zizka	natal redtop	X
Panicum maximum L.	Guinea grass	X
Panicum repens L.	torpedo grass	X
Paspalum dilatatum Poir.	dallis grass	X
Paspalum urvillei Steud.	vasey grass	X
Pennisetum clandestinum Hochst. Ex Chiov.	kikuyu grass	X
Pennisetum purpureum Schumach.	elephant grass	X
Setaria verticillata (L.) P.Beauv.	bristly foxtail	X
Urochloa mutica (Forsk.) Webster	para grass	X
TYPHACEAE		
Typha latifolia L.	cattail	X
DICOTS		
ACANTHACEAE		
Asystasia gangetica (L.) T. Anderson	Chinese violet	X
Dicliptera chinensis		X
Justicia betonica	white shrimp plant	X
AIZOACEAE		
Tetragonia tetragonioides (Pall.) Kuntze	New Zealand spinach	X
AMARANTHACEAE		
Achyranthes aspera L.		X
Alternanthera pungens Kunth	khaki weed	X
Amaranthus spinosus L.	spiny amaranth	X
Amaranthus viridis L.	slender amaranth	X
ANACARDIACEAE		
Mangifera indica L.	mango	X
Schinus terebinthifolius Raddi	Christmas berry	X
APIACEAE		
Ciclospermum leptophyllum (Endl.) Sprague	fir-leaved celery	X

SCIENTIFIC NAME	COMMON NAME	STATUS
APOCYNACEAE		
Thevetia peruviana (Pers.) K.Schum.	be-still tree	X
Plumeria rubra L.	plumeria	X
ARALIACEAE		
Schefflera actinophylla (Endl.) Harms	octopus tree	X
ASCLEPIADACEAE		
Calotropis gigantea (L.) W.T. Aiton	crown flower	X
ASTERACEAE		
Ageratum conyzoides L.	ageratum	X
Bidens alba (L.) DC. var. radiata Ballard ex Melchert	beggar tick	X
Bidens pilosa L.	Spanish needle	X
Conyza bonariensis (L.) Cronq.	hairy horseweed	X
Crassocephalum crepidioides (Benth.) S.Moore	crassocephalum	X
Emilia fosbergii Nicolson	red pualele	X
Lactuca serriola L.	prickly lettuce	X
Parthenium hysterophorus L.	false ragweed	X
Pluchea carolinensis (Jacq.) G. Don	sourbush	X
Pluchea indica (L.) Less.	Indian fleabane	X
Pluchea x fosbergii Cooperr. & Galang	pluchea hybrid	X
Sigisbeckia orientalis L.	small yellow crownbeard	X
Sonchus oleraceus L.	pualele	X
Sphagneticola trilobata (L.) Pruski	wedelia	X
Synedrella nodiflora (L.) Gaertn.	nodeweed	X
Tridax procumbens (L.)	coat buttons	X
Verbesina encelioides (Cav.) Benth. & Hook	golden crown-beard	X
Xanthium strumarium var. canadense Mill.	cocklebur	X
BIGNONIACEAE		
Spathodea campanulata P. Beauv.	African tulip	X
BORAGINACEAE		
Heliotropium procumbens Mill. var. depressum		X
BRASSICACEAE		
Capsella rubella Reut.	shepherd's purse	X
Cardamine flexuosa With.	bittercress	X
Coronopus didymus (L.) Small	swinecress	X
Lepidium virginicum L.	pepperwort	X
CACTACEAE		
Hylocereus undatus (Haw.) Britton&Rose	night blooming cereus	X
CARICACEAE		
Carica papaya L.	papaya	X
CASUARINACEAE		
Casuarina equisetifolia L.	ironwood	X

SCIENTIFIC NAME	COMMON NAME	STATUS
CHENOPODIACEAE		
Atriplex semibaccata R.Br.	Australian saltbush	X
Chenopodium murale L.	aheahea	X
CLUSIACEAE		
Clusia rosea Jacq.	autograph tree	X
COMBRETACEAE		
Terminalia cattapa L.	tropical almond	X
CONVOLVULACEAE		
Ipomoea cairica (L.) Sweet	ivy leaved morning glory	X
Ipomoea obscura (L.) Ker Gawl.		X
Ipomoea triloba L.	little bell	X
Merremia aegyptia (L.) Urb.	hairy merremia	X
CUCURBITACEAE		
Coccinea grandis (L.) Voigt	ivy gourd	X
Cucumis dispaceus Ehrenb. Ex Spach	hedgehog gourd	X
Momordica charantia L.	balsam pear	X
Sicyos pachycarpus Hook.&Arnott.	kupala	E
EUPHORBIACEAE		
Aleurites moluccana (L.) Willd.	kukui	X
Chamaesyce hirta (L.) Millsp.	hairy spurge	X
Chamaesyce hypercifolia (L.) Millsp.	graceful spurge	X
Chamaesyce prostrata (Aiton) Small	prostrate spurge	X
Codiaem variegatum	croton	X
Euphorbia heterophylla L.	kaliko	X
Ricinus communis L.	castor bean	X
FABACEAE		
Acacia confusa Merr.	formosan koa	X
Acacia farnesiana (L.) Willd.	klu, aroma, kolu	X
Bauhina x blakeana	Hong Kong orchid tree	X
Cassia sp.	shower tree	X
Chamaecrista nictitans (L.) Moench	partridge pea	X
Crotalaria incana L.	fuzzy rattlepod	X
Crotalaria pallida Aiton	smooth rattlepod	X
Desmanthus pernambucanus (L.) Thell.	slender or virgate mimosa	X
Desmodium tortuosum (Sw.) DC	Florida beggarweed	X
Enterolobium cyclocarpum	elephants earpod	X
Erythrina sandwicensis Deg.	wiliwili	E
Indigofera hendecaphylla Jacq.	creeping indigo	X
Indigofera suffritocosa Mill.	iniko	X
Leucaena leucocephala (Lam.) de Wit	koa haole	X
Macroptilium atropurpureum (DC) Urb.		X
Macroptilium lathyroides (L.) Urb.	wild bean	X
Medicago polymorpha L.	bur clover	X
Mimosa pudica L.	sensitive plant	X

SCIENTIFIC NAME	COMMON NAME	STATUS
Neonotonia whightii (Whight&Arnott) Lackey		X
Pithecellobium dulce (Roxb.) Benth.	opiuma	X
Prosopis pallida (Humb. & Bonpl. Ex Willd.) Kunth	kiawe, algaroba	X
Samanea saman (Jacq.) Merr.	monkeypod	X
Senna surattensis (Burm.f.)	kolomona	X
Tamarindus indica L.	tamarind	X
LAMIACEAE		
Hyptis pectinata (L.) Poit.	comb hyptis	X
Leonotis nepetifolia (L.) R.Br.	lion's ear	X
Ocimum gratissumum L.	wild basil	X
LAURACEAE		
Persea americana Mill.	avocado	X
MALVACEAE		
Abutilon grandifolium (Willd.) Sweet	hairy abutilon	X
Hibiscus sp.	hibiscus	X
Malva parviflora L.	cheese weed	X
Malvastrum coromandelianum (L.) Garcke	false mallow	X
Sida acuta subsp. carpinifolia (L.f.) Borss.Walk.		X
Sida ciliaris L.		X
Sida rhombifolia L.		X
Sida spinosa L.	prickly sida	X
Sidastrum micranthum (St.Hil.) Fryx.		X
Thespesia populnea (L.) Sol. Ex Correa	milo	X
MELIACEAE		
Khaya sengalensis L.	mahogany	X
Melia azerdarach L.	chinaberry	X
MORACEAE		
Artocarpus atilis (Z) Fosberg	breadfruit	X
Ficus benghalensis L.	Indian banyan	X
Ficus microcarpa L.f.	Chinese banyan	X
Ficus religiosa	Bo tree	X
Ficus rubiginosa	Port Jackson fig	X
MYRTACEAE		
Eucalyptus citriodora Hook.	lemon gum	X
Eucalyptus crebra F.v. Muell.	narrow leaved ironbark	X
Psidium guajava L.	guava	X
Syzygium cuminii(L.) Skeels	Java plum	X
NYCTAGINACEAE		
Boerhavia coccinea Mill.		X
Bougainvillea sp. A.L. Jussieu	bougainvillea	X
OXALIDACEAE		
Oxalis corniculata L.	yellow wood sorrel	X

SCIENTIFIC NAME	COMMON NAME	STATUS
PASSIFLORACEAE		
Passiflora foetida L.	love-in-a-mist	X
PHYTOLACCACEAE		
Rivina humilis L.	coral berry	X
PLANTAGINACEAE		
Plantago major L.	common plantain	X
PLUMBAGINACEAE		
Plumbago zeylanica L.	`ilie`e	I
POLYGONACEAE		
Antigonon leptopus Hook&Arnott	Mexican creeper	X
Coccoloba uvifera	sea grape	X
PORTULACACEAE		
Portulaca oleracea L.	pigweed	X
PROTEACEAE		
Grevillea robusta A.Cunn. Ex R.Br.	silk oak	X
Macadamia ternifolia F. Muell	macadamia	X
RHIZOPHORACEAE		
Rhizophora mangle L.	red mangrove	X
RUBIACEAE		
Psydrax odorata (G.Forst) A.C.Sm.&S.P.Darwin	alahee	I
Spermacoce assurgens Ruiz&Pavon	buttonweed	X
RUTACEAE		
Citrus sp.	orange/pummel	X
Murraya paniculata (L.) Jack	mock orange	X
SOLANACEAE		
Nicotiana glauca Graham	tree tobacco	X
Nicandra physalodes (L.) Gaertn.	apple of Peru	X
Solanum americanum Mill.	glossy nightshade, popolo	I
Solanum lycopersicum L. var. cerasiforme (Dunal)	cherry tomato	X
Spooner, G.J. Anderson & R.K. Jansen		
Solanum seaforthianum Andrews		X
STERCULIACEAE		
Waltheria indica L.	uhaloa	I
VERBENACEAE		
Lantana camara L.	lantana	X
Stachytarpheta australis Moldenke		X
Stachytarpheta jamaicensis (L.) Vahl	Jamaican vervain	X

Appendix C

Avifaunal and Feral Mammal Field Survey of the
2014 Proposed Dillingham Ranch Agricultural Subdivision
Mokule'ia, O'ahu

AVIFAUNAL AND FERAL MAMMAL FIELD SURVEY OF THE 2014

PROPOSED DILLINGHAM RANCH SUBDIVISION,

MOKULE'IA, OAHU

Prepared for:

Hart Howerton

One Union Street

San Francisco, CA 94111

Prepared by:

Phillip L. Bruner

Environmental Consultant

Faunal (Bird & Mammal) Surveys

Box 1775

BYU-Hawaii

55-220 Kulanui Street

Laie, HI 96762

11 July 2014

INTRODUCTION

The purpose of this report is to present the findings of a two day (30 June, 7 July 2014) field survey of the birds and mammals recorded on Dillingham Ranch, Mokule'ia, Oahu property including the 2008 and 2014 proposed subdivision sites. In addition, pertinent published and unpublished sources of information on the fauna in this region of Oahu are also provided to supplement the field data. The goals of the field survey were:

1- To document what species of birds and mammals currently occur on and near the property, with special attention to any native or migratory species.
2- Note any natural resources important to native and migratory species.

SITE DESCRIPTION

The following habitats occur on this property: pasture/ranch land, residential, second growth alien forest, ephemeral stream drainages/irrigation ditches, and ponds. The topography is relatively flat except for the upper (mauka) portions of the property.

SURVEY METHODS

The property was surveyed for birds and mammals by driving and walking. All species seen or heard were noted. Observations of feral mammals were restricted to visual sightings and tracks. Scientific names used in this report follow Pyle (2002) and Honacki et al. (1982).

RESULTS AND DISCUSSION

Native Land Birds:

No native land birds were observed on the field survey. The only possible species that might on occasion forage in this area is the Short-eared Owl or Hawaiian Owl known as Pueo in Hawaiian (*Asio flammeus sandwichensis*). This species is listed as endangered by the State of Hawaii on the island of Oahu. They range over a wide variety of habitats including forest (both native and second growth) as well as agricultural/ranch lands. They nest on the ground in areas of tall grass (Pratt et al. 1987, Hawaii Audubon Society 2005). The introduced Barn Owl (*Tyto alba*) is often mistakenly reported as a Pueo by those unfamiliar with the difference in appearance between these two species. Barn Owls forage at night whereas Pueo are active at dawn or dusk and occasionally at midday.

Native Waterbirds:

Five Black-crowned Night Heron or `Auku'u (*Nycticorax nycticorax hoactli*) were seen foraging around the edge of the large pond near the entry road to the property. `Auku'u are the only native waterbird that is not listed as endangered or threatened. The endangered Hawaiian Coot or `Alae Ke'oke'o (*Fulica alai*), Common Moorhen or `Alae `ula (*Gallinula chloropus sanvicensis*), Hawaiian Duck or Koloa (*Anas wyvilliana*), and Black-necked Stilt or Ae'o (*Himantopus mexicanus knudseni*) were recorded on the survey. Forty three Coot including both adults and juveniles were observed on the large pond. Three active Coot nests with incubating adults were also seen. Seven Common Moorhen were observed foraging along with one adult incubating eggs. Five of the seven Moorhen were using the small pond closer to the ranch office. One pair of Black-necked Stilt were observed foraging on the edge of the large pond. This species was not recorded on the 2008 avifaunal survey (Bruner 2008). Three Hawaiian Duck were observed on the large pond. This endangered species was extripated from Oahu and subsequently reintroduced from Kauai. Since its reintroduction to Oahu, feral Mallard Ducks (*Anas platyrhynchos*) have bred with Koloa so that today most if not all Koloa are hybrids of these two species. A Northern Pintail Duck (*Anas acuta*) was recorded on the 1992 survey but not in 2008 or 2014. This is a common winter migrant to Hawaii. It breeds in Alaska and Canada. Domestic ducks of mixed parentage were common around both ponds.

Seabirds:

No seabirds were observed on this survey. The Great Frigatebird or `Iwa (*Fregata minor palmerstoni*) and White-tailed Tropicbird or Koa'ekea (*Phaethon lepturus dorotheae*) were recorded on the 2008 avifaunal survey. Wedge-tailed Shearwater (*Puffinus pacificus*) and Laysan Albatross (*Phoebastria immutabilis*) nest at the nearby Kaena Point Natural Area Reserve.

Migratory Shorebirds:

No migratory shorebirds were recorded on this survey due to the fact that they depart Hawaii for their arctic/subarctic nesting grounds at the end of April and don't return until August/September. The 2008 avifaunal survey was conducted in January and recorded the three most common migratory shorebirds that come to Hawaii: Pacific Golden-Plover or Kolea (*Pluvialis fulva*), Ruddy Turnstone or Akekeke (*Arenaria interpres*) and Wandering Tattler or Ulili (*Heteroscelus incanus*). All of these migratory shorebirds are protected by the Migratory Bird Treaty Act. They are not listed as threatened or endangered.

Alien (Introduced) Birds:

A total of 22 alien species were recorded on this survey compared with 26 species in 2008 and 17 species in 1992. Table One gives the names of these species and their occurance on each of the three (1992, 2008, 2014) surveys. The array of alien birds are typical of this type of habitat, in this region of Oahu (Bruner 1982, 1986, 1991, 1992, 1993, 2003, 2008, Pratt et al. 1987, Hawaii Audubon Society 2005).

Feral Mammals:

The only feral mammals observed on the survey were pigs (*Sus scrofa*), cats (*Felis catus*), and Small Indian Mongoose (*Herpestes auropunctatus*). Roof Rat (*Rattus rattus*) and House Mouse (*Mus musculus*) likely occur in this area. The endangered Hawaiian Hoary Bat or Ope'ape'a (*Lasiurus cinereus semotus*) was not observed. Ope'ape'a are infrequently reported on Oahu. They are not restricted to native forest but can be seen foraging for flying insects in

urban and agricultural areas as well as over bays and ponds. They roost solitarily in trees (Tomich 1986, Kepler and Scott 1990).

EXECUTIVE SUMMARY

This property has been altered from its natural state by years of agricultural and ranching activity. Four endangered waterbirds (Hawaiian Coot, Common Moorhen, Hawaiian Duck) and one non-endangered waterbird (Black-crowned Night Heron) were found on this survey. No indigenous seabirds were observed. The endangered Hawaiian Owl was not seen but could occur in this area. The number of alien (introduced) birds (22 species) was similar to the list acquired in 2008. Feral mammals recorded, included cats and pigs. The endangered Hawaiian Hoary Bat was not observed. This species is infrequently seen on Oahu. The grazed pastures are important foraging habitat for migratory shorebirds (Pacific Golden-Plovers and Ruddy Turnstones) during the months of late August through early May. None were seen on this survey due to the time of year. The three surveys of this property (1992, 2008, 2014) reflect little change in the array of birds and mammals at this location. The most important habitat feature on the property, are the ponds. The four endangered waterbirds are endangered because of the loss of wetlands statewide. Even relatively small ponds, such as those on this property are important to the continual existence of these unique Hawaiian waterbirds. The proposed development should have little or no significant effect on the current alien bird populations.

TABLE 1

Alien (introduced) birds recorded at Mokuleia, Oahu. (1992, 2008, 2014). A plus (+) notes recorded on that survey, a minus (-) not recorded.

Common Name	Scientific Name	1992	2008	2014
Cattle Egret	*Bubulcus ibis*	+	+	+
Domestic Duck	Spp. (Hybrids)	+	+	+
Gray Francolin	*Francolinus pondicerianus*	-	+	+
Black Francolin	*Francolinus francolinus*	-	+	+
Erckel's Francolin	*Francolinus erckelii*	-	+	+
Red Jungle Fowl	*Gallus gallus*	-	+	+
Ring-necked Pheasant	*Phasianus colchicus*	+	+	+
Common Peafowl	*Pavo cristatus*	+	+	+
Spotted Dove	*Streptopelia chinensis*	+	+	+
Zebra Dove	*Geopelia striata*	+	+	+
Barn Owl	*Tyto Alba*	-	+	-
Red-vented Bulbul	*Pycnonotus pycnonotus*	+	+	+
Japanese Bushwarbler	*Cettia diphone*	+	+	+
White rumped Shama	*Copsychus malabaricus*	+	+	+
Japanese White-eye	*Zosterops japonicas*	+	+	+
Common Myna	*Acridotheres tristis*	+	+	+
Saffron Finch	*Sicalis flaveola*	-	+	+
Red-crested Cardinal	*Paroaria coronate*	+	+	+

Common Name	Scientific Name	1992	2008	2014
Norther Cardinal	*Cardinalis cardinalis*	+	+	+
House Finch	*Carpodacus mexicanus*	+	+	+
House Sparrow	*Passer domesticus*	+	+	+
Common Waxbill	*Estrilda astrild*	+	+	+
Red Avadavat	*Amandava amandava*	+	-	-
Nutmeg Mannikin	*Lonchura puntulata*	+	+	+
Chestnut Munia	*Lonchura atricapilla*	-	+	-
Java Sparrow	*Padda oryzivora*	-	+	-

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Appendix D

Archaeological Inventory Survey of the Mauka Lands
Dillingham Ranch Agricultural Subdivision
Kawaihapai, Kikahi, Auku'u and Mokule'ia
Ahupua'a, O'ahu, Hawai'i

— DRAFT —

Archaeological Inventory Survey of the *Mauka* Lands, Dillingham Ranch Agricultural Subdivision, Kawaihāpai, Kikahi, Aukuʻu, and Mokulēʻia 2 Ahupuaʻa, Oʻahu, Hawaiʻi

Tax Map Key (1) 6-8-002:006 (portion), 6-8-003:005 (portion), 006 (portion)

Prepared for:
Dillingham Ranch Aina, LLC
68-540 Farrington Highway
Waialua, Hawaiʻi 96791

Under Contract to:

Belt Collins Hawaii LLC
2153 North King St., Suite 200
Honolulu, HI 96819-4554

INTERNATIONAL ARCHAEOLOGY, LLC.
JUNE 2014

— Draft —

ARCHAEOLOGICAL INVENTORY SURVEY OF THE *MAUKA* LANDS, DILLINGHAM RANCH AGRICULTURAL SUBDIVISION, KAWAIHĀPAI, KIKAHI, AUKUʻU, AND MOKULĒʻIA 2 AHUPUAʻA, WAIALUA DISTRICT, OʻAHU, HAWAIʻI

TMK (1) 6-8-002:006 (portion), 6-8-003:005 (portion), 006 (portion)

by

Adam J. Lauer, M.A.
Timothy M. Rieth, M.A.

Prepared for

Dillingham Ranch Aina, LLC
68-540 Farrington Highway
Waialua, Hawaiʻi 96791

International Archaeology, LLC
2081 Young Street
Honolulu, Hawaiʻi 96826

June 2014

ABSTRACT

International Archaeology, LLC, (IA) completed an archaeological inventory survey of approximately 85.3 acres (34.5 hectares) for the proposed Dillingham Ranch Agricultural Subdivision. The project was conducted in compliance with Hawaii Revised Statute (HRS) 6E-42 and Hawaii Administrative Rules (HAR) §13-276 and 13-284. Fieldwork included a pedestrian survey; feature/site recording with text descriptions, photography, and detailed tape-and-compass mapping, along recording of feature locations using a Global Positioning System (GPS) unit; and, subsurface testing.

One archaeological site composed of four discontinuous historical ranching walls was documented as Site 50-80-03-7653. The dry-stacked stone walls in places incorporate large colluvial boulders and bedrock exposures. Wall segments may parallel the slope contours (generally east-west) or run cross contour (generally north-south). Slope erosion and collapse has affected numerous portions of these walls, but the remaining segments are consistent with the extensive 19th/early 20th century ranching infrastructure in this area. These walls, and the components of the previously recorded Site 6884, likely once formed an integrated enclosure/exclosure system for the ranch. In addition to Site 7653, two unmodified seeps were noted within the western survey parcel.

Site 50-80-03-7653 is recommended to be significant under Criterion d of the Hawai‘i Register of Historic Places: the distribution and characteristics of the various historical walls provide information about ranching activities and land divisions. The site features have been recorded in detail and no further work is recommended prior to the initiation of development activities.

Although the springs noted during the survey are not culturally modified features, their potential correlation with the “Hidden Waters” recorded in oral history and by McAllister (1933) suggest that they should be protected from any adverse future effects from development.

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I. INTRODUCTION

At the request of Dillingham Ranch Aina, LLC, International Archaeology, LLC, (IA) completed an archaeological inventory survey of 85.3 acres (34.5 hectares) for the proposed Dillingham Ranch Agricultural Subdivision. The project acreage is divided between three areas that will largely be used for pasturage but also residential development: an eastern parcel (30.1 acres), a central parcel (38.2 acres), and a western parcel (17 acres) (Fig. 1). The large approximately 390-acre southern extension of the subdivision (immediately south of the eastern survey parcel) will not be subject to development, but will continue to be used to graze cattle. This survey supplements an earlier survey for the subdivision completed by Tulchin and Hammatt (2007), which in turn followed up on a survey conducted by Drolet and Schilz (1992a, 1992b). The project was conducted in compliance with Hawaii Revised Statute (HRS) 6E-42 and Hawaii Administrative Rules (HAR) §13-276 and 13-284.

PROJECT LOCATION

Dillingham Ranch is a large active horse and cattle ranch located in Waialua District on the North Shore of O‘ahu. The ranch is located on the south (*mauka* [inland]) side of Highway 930, between Mokulē‘ia and Kawaihāpai Airfield (formerly known as Dillingham Airfield). The proposed Dillingham Ranch Agricultural Subdivision will include approximately 938 acres, encompassing more than half of the ranch property. The project area includes three discontinuous areas of the foothills and cliffs towards the southern end of the ranch, collectively termed “*mauka* lands.” The eastern survey parcel runs roughly 875 meters (m) along the east and south sides of a Department of Land and Natural Resources (DLNR) access road leading to Peacock Flats; the central survey parcel extends roughly 1,000 m east-west along the south-central portion of the ranch, directly upslope from the horse stables; and the western survey area extends for 860 m along the slope and cliffs behind the eastern portion of Kawaihāpai Airfield. The terrain consists of a section of sloping foothills with the majority of the project areas located on the cliffs overlooking the coastal plain. The center and western survey areas are dissected by four deep gullies.

PROJECT PERSONNEL AND DATES OF FIELDWORK

Timothy Rieth, M.A., was the Principal Investigator for this project. Adam Lauer, M.A., served as the Project Director. Robert Dinapoli, B.A., Chris Filimoehala, M.A., Simon Howard, B.A., Rona Ikehara-Quebral, Ph.D., Brian Lane, M.A., Thomas Leppard, Ph.D., Robert Pacheco, M.A., and Damion Sailors, B.A., assisted at various times as Field Technicians. The inventory survey was conducted May 7-9, 13-15, June 9, and July 22, 2014.

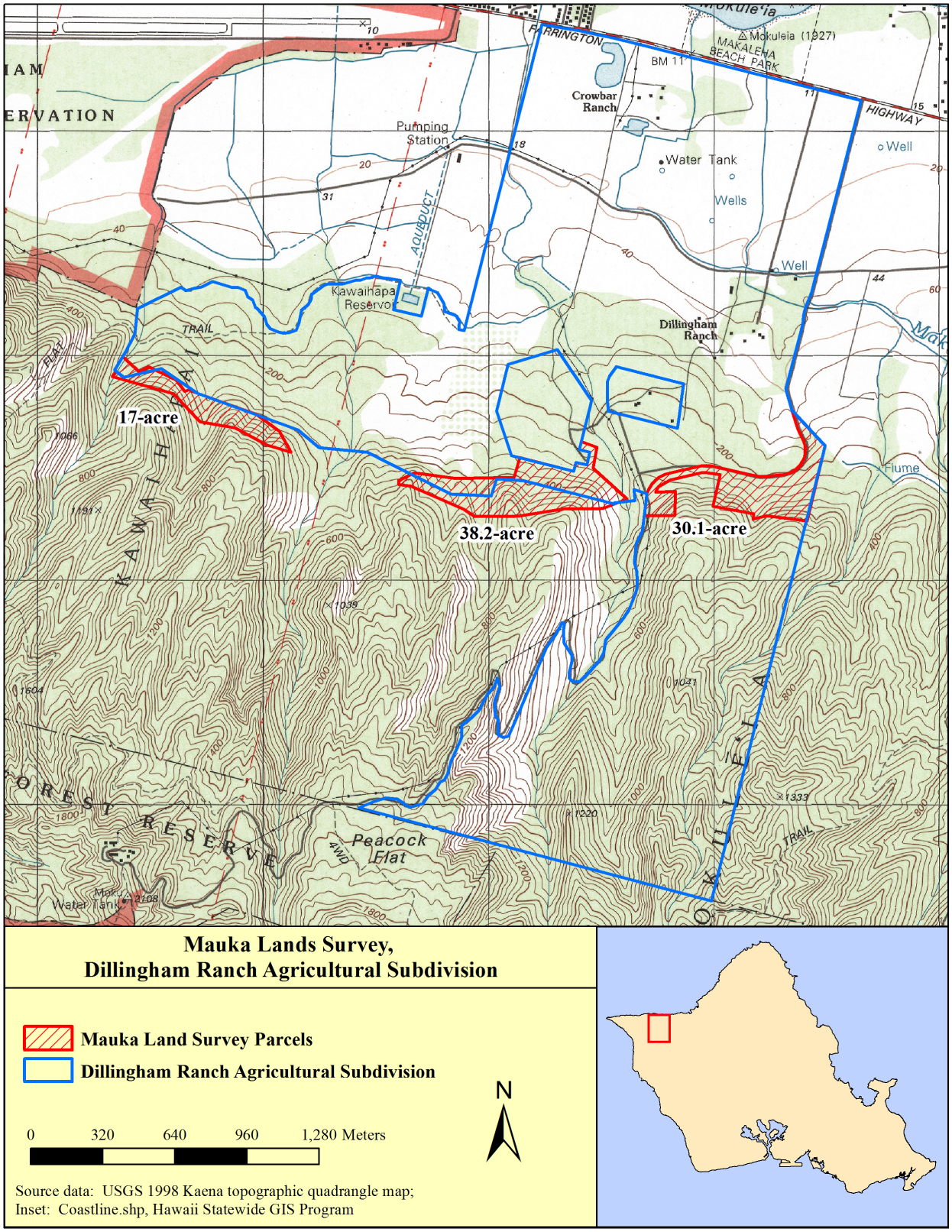

Figure 1. The locations of the three *mauka* survey parcels and the proposed Dillingham Ranch Agricultural Subdivision.

II. BACKGROUND

The Dillingham Ranch is located in northwest Oʻahu, with the planned Dillingham Ranch Agricultural Subdivision covering approximately 938 acres towards the center of the ranch's property. The current project parcels fall within four *ahupuaʻa* (traditional subdistrict land division) of the *moku* (island district) of Waialua. The eastern parcel is largely within Mokulēʻia 2 Ahupuaʻa with the western portion extending into Aukuʻu Ahupuaʻa; the central parcel crosses Aukuʻu and Kikahi Ahupuaʻa[1]; and, the western parcel is within Kawaihāpai Ahupuaʻa (Fig. 2).

PHYSICAL SETTING

The project area is located in the foothills of the Waiʻanae Mountain Range (see Fig. 1). The eastern parcel is 30.1 acres at an altitude ranging from 28-171 m above sea level (asl) (92-560 feet). The topography of this area includes gentle slopes (0-15%) at the lower elevations with steep grades (50-90%) along the upper, southern portion (Photo 1). Construction and maintenance of a single track dirt road has created multiple stone push piles in this area. The central parcel is separated from the eastern parcel by Polipoli Stream and a distance of 380 m. This 38.2-acre survey parcel has an altitude of 67-198 m asl (220-650 feet). The lower portion of this area is gently sloping (10-15%) while the southern upland portion rises abruptly with 50-80% slopes and many small cliffs and exposed rock faces (Photo 2). The 17-acre western parcel has an altitude of 86-186 m asl (282-610 feet). The lower elevations of this parcel are found within deeply incised drainages, and the majority of the survey area is between 125-180 m asl (410-590 feet). This parcel consists of steep (>40%) slopes, large cliffs (10-15 m) and exposed rock faces (Photo 3, Photo 4).

Soils across the three project areas are variable and diverse (Fig. 3). The eastern parcel includes six soil types: Kawaihapai[2] clay loam, 0-2 percent slopes (KlA); Kawaihapai very stony clay loam, 0-15 percent slopes (KlbC); Kaena stony clay, 12-20 percent slopes (KaeD); Kaena very stony clay, 10-35 percent slopes (KanE); Helemano silty clay, 30-90 percent slopes (HLMG); and, Kemoo silty clay, 35-70 percent slopes (KpF) (Foote et al. 1972). The central parcel has five soil types, with the most common being Kemoo silty clay, 35-70 percent slopes (KpF). The other soils are: Helemano silty clay, 30-90 percent slopes (HLMG); Kaena stony clay, 2-6 percent slopes (KaeB); Kaena very stony clay, 10-35 percent slopes (KanE); and, stony steep land (rSY) (Foote et al. 1972). The western parcel is characterized as rockland (rRK)—"areas where exposed rock covers 25 to 90 percent of the surface" (Foote et al. 1972:119). These soils are characteristic of the foothill terrain with moderate to steep slopes and drainages.

With the exception of the Kemoo series soils (which are poorly drained), the soils in the project area are well-drained. All are derived from alluvium and/or colluvium (including talus and masses of boulders and smaller stones). Slopes vary from gentle to very steep. Most of the land is classified as suitable for pasture, with sugarcane and truck crop cultivation possible in less stony and steep soils.

---

[1] Aukuʻu and Kikahi Ahupuaʻa are represented on certain modern maps, whereas these land areas fall within the U.S. Geological Survey's (USGS) larger Mokulēʻia Ahupuaʻa. Aukuʻu and Kikahi are not included in Pukui et al. (1974).

[2] The Hawaiian soil names are presented without diacritical marks following the standardized designations provided by Foote et al. (1972).

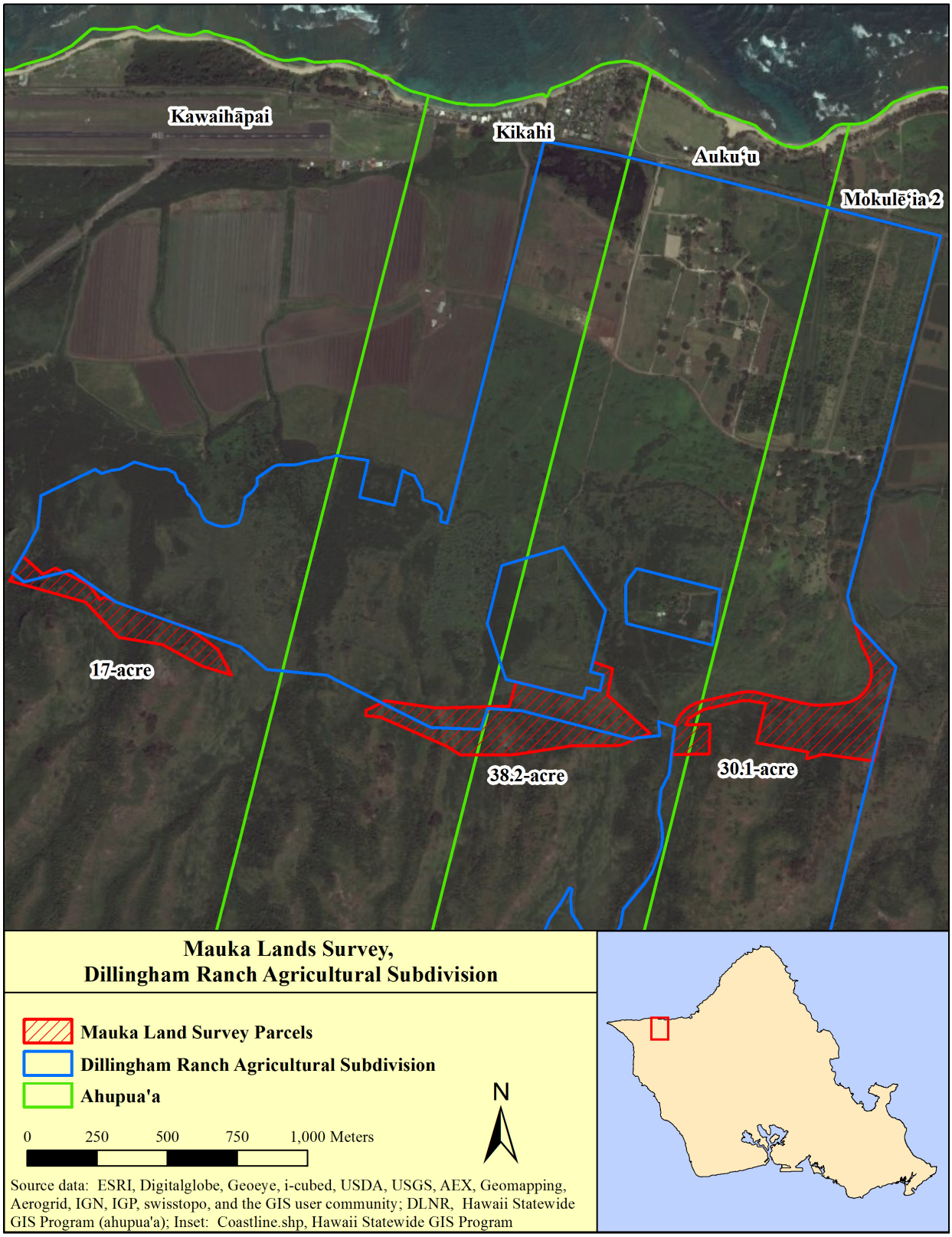

Figure 2. Overlay of the survey parcels and *ahupuaʻa* boundaries on a current orthophotograph.

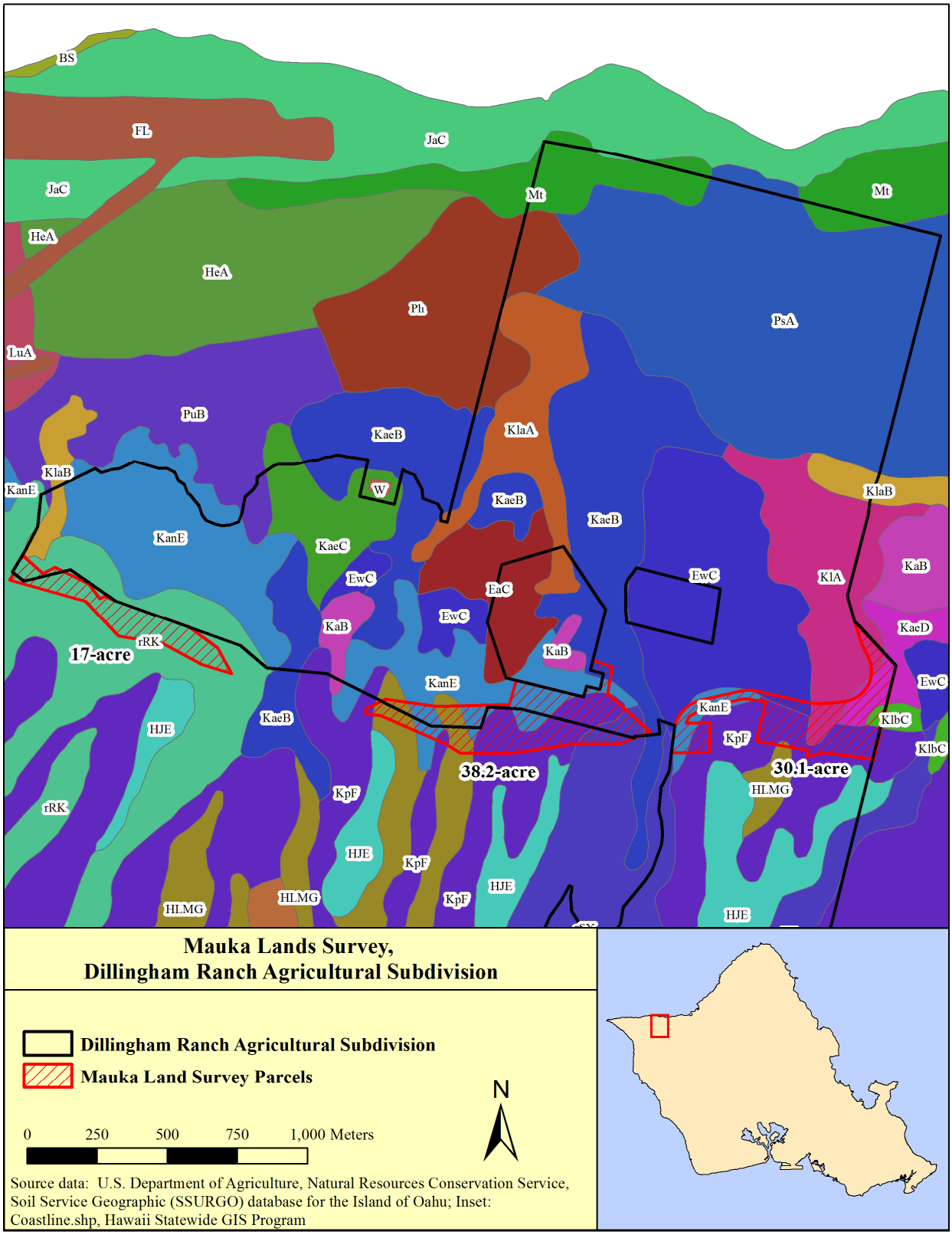

Figure 3. Soil types present within the project areas and surrounding land.

Photo 1. Portion of the eastern survey parcel with low slopes rising to steep slopes and small cliffs. View south.

Photo 2. Moderate slopes of the central survey parcel. View north with Dillingham Ranch stables at the top left.

Photo 3. Steep slopes and cliffs of the western survey parcel. View west.

Photo 4. The western survey parcel from the coastal plain (Kawaihāpai/Dillingham Airport). View to the southeast, survey parcel to the left of Kapuhi Valley.

Mean annual rainfall in this area is 904.5 millimeters (mm) (35.6 inches) with an annual range of 136.5 (January) to 21.5 (June) mm (5.4 to 0.8 inches) (based on Station Kawaihapai [20]) (Giambelluca et al. 2013). To the south and upland in the Waiʻanae Range, rainfall averages 1,304.2 mm (51.3 inches), with an annual range of 184.6 (January) to 42.6 (June) mm (7.3 to 1.7 inches) (Station Makua Ridge) (Giambelluca et al. 2013).

Vegetation in the project areas is generally exotic grasses, weeds, and trees, predominantly California grass (*Brachiara mutica)*, Guinea grass (*Panicum maximum*), Hilo grass (*Paspalum conjugatum*), with *lilikoi* (*Passiflora edulis*), *koa haole* (*Leucaena leucocephala*), *kiawe* (*Prosopis pallida*), Java plum *(Syzygium cumini*), *klu* (*Acacia farnesiana*), guava (*Psidium guajava*), strawberry guava (*Psidium cattleianum*), and Christmas berry (*Schinus terebinthifolius*). Other species noted include *kukui* (*Aleurites moluccana*), *wiliwili* (*Erythrina sandwicensis*), silk oak (*Grevillea robusta*), and *niu* (coconut, *Cocos nucifera*). These observations are similar to those documented by Drolet and Schliz (1992a) and Tulchin and Hammatt (2007).

PRE-MODERN CULTURAL BACKGROUND

The boundary between the traditional Hawaiian districts of Waialua and Waiʻanae straddles Kuaokalā Ridge and extends to the tip of Kaʻena Point. Kawaihāpai Ahupuaʻa in Waialua, which includes the westernmost survey parcel, extends north to the coast and south to the boundary with Kahanahaiki Ahupuaʻa in Waiʻanae District. Keālia and Kikahi Ahupuaʻa adjoin Kawaihāpai to the west and east, respectively. Kikahi and Aukuʻu Ahupuaʻa, which include the central survey area, extend north to the coast and south to Mākua Ahupuaʻa in Waiʻanae District. Aukuʻu Ahupuaʻa is bounded on the east

by Mokulēʻia 2 Ahupuaʻa and on the west by Kikahi Ahupuaʻa. Mokulēʻia 2 Ahupuaʻa, which includes the eastern survey parcel, extends north to the coast and south to Mākua and Mākaha Ahupuaʻa in Waiʻanae District. Mokulēʻia 2 Ahupuaʻa is bounded by Mokulēʻia 1 Ahupuaʻa to the east.

PLACE NAMES

Numerous traditional place names are associated with the larger area surrounding the survey parcels. During this discussion of place names, it will become apparent that Hawaiian words frequently have multiple meanings, and that Hawaiian place names often operate as puns that can convey complementary meanings simultaneously (Tuggle and Hommon 1986:16). The name Waialua has at least two possible interpretations. One translation, "two (*ʻalua*) streams (*wai*)," may refer to the two large stream drainages (Anahulu and Helemano-Poamoho-Kaukonahua) that once irrigated the district (Handy and Handy 1972:466). Another translation, "doubly (*lua*) disgraced (*waia*)," alludes to a traditional story of a hated *aliʻi* (chief) who purportedly lived in the area (Handy and Handy 1972:466). According to Handy and Handy (1972:466), citing a Hoku o Hawaii article from April 16, 1929:

> Waia, the grandson of Wakea, was said to be a cruel chief. He cared nothing for the gods or for doing good. He had men and women killed for the fun of killing them. When he saw a maiden with shapely legs, he ordered them cut off, and if a man or woman had beautiful tattooing, he was put to death. Because of this he was driven away by the people. In the legend of Hiʻiaka, it was said that Waia lived and practised [sic] his evil deeds at Waialua. The people suffered so much there that the place was named for him Waia-lua (Doubly disgraceful).

The name of the *ahupuaʻa* in which the western portion of the project area is located, Kawaihāpai, means "the carried water" (Pukui et al. 1974:97-98). Historical sources explain that Kawaihāpai took its name from the stream that provided water for several irrigated taro fields in the area (Handy and Handy 1972:467). Oral traditions describe the origin of the name as stemming from a drought during which two old priests offered prayers that were answered in the form of a cloud that passed over the cliffs, producing a splashing sound and a new source of water flowing from the mountainside (Alameida 1996; Sterling and Summers 1978). This spring, known as "water without source on the cliff," was a well-known feature into the post-Contact era (McGerty and Spear 2001:10).

Kikahi and Aukuʻu Ahupuaʻa do not have clear meanings and do not appear in Pukui et al (1974). Aukuʻu may have referred in some manner to the water sources of this area, considering some of the meanings of *au* (current; to flow, as a current [Pukui and Elbert 1986:30]) and *kuʻu* (to diminish, as stream water [Pukui and Elbert 1986:186]). These two *ahupuaʻa* are not depicted on the U.S. Geological Service (USGS) "Kaena" quadrangle map, but rather would fall within the single large Mokulēʻia Ahupuaʻa that is presented.

Mokulēʻia means "isle of abundance" (Pukui et al 1974). The area had a large expanse of flat land for agriculture and abundant water. Pukui (1953, cited by Sterling and Summers 1978:101) identified a second, possibly more recent (1880s), translation. Mokulēʻia may be from the saying "*Moena pāwehe o Mokulēʻia,*" meaning "the patterned mat of Mokulēʻia". In this case, the name may be *moku leia*, or "encircled island" due to the patterns of cultivation on the land looking like a woven mat (Sterling and Summers 1978:101, citing Pukui 1953). In a third alternative, Andrews and Parker (1922:437) and Pukui and Elbert (1986:252) define *mokulēʻia* as one of several Hawaiian names for the greater amberjack (*Seriola dumerili*) (see below).

Pacheco discusses the discrepancies surrounding the multiple meanings of Mokulēʻia, suggesting that this resulted from the varying meanings of both *moku* and *leʻia* (Pacheco 2013). According to

Andrews and Parker (1922:437) and Pukui and Elbert (1986:252), *moku* can refer to either "an island" or "[island] district," or "[a state of being] divided in two" or "cut, severed, amputated, broken in two." Further, while Pukui and Elbert (1986:200) define *leʻia* as meaning "abundance" or "full," the word also seems to be a cognate of the nearly-identical word *lei*, which refers to an encircling garland or wreath (Andrews and Parker 1922:364-365; Pukui and Elbert 1986). In fact, the word *leia* (without an *ʻokina*) is defined by Sterling and Summers (1973:101) as "encircled," and by Pukui and Elbert (1986:200) as a passive or imperative form of *lei*. Bringing all of these competing definitions into consideration, the seemingly contradictory translations of "*mokulēʻia*" can be explained in the following manner: while "encircled island" and "isle [of] abundance" are self-explanatory, *mokulēʻia* as applied to the greater amberjack may refer to the distinctive amber stripe that "encircles" the fish from the head to the base of the tail fin, "dividing" it in two parts (Tinker 1982:256-257).

Emerson's (1896; Registered Map 1881) map of the greater Mokulēʻia area includes multiple place names. Four of these—Kapuhi Valley, Kaapahu, Waikoekoe Valley, and Mookaha—fall within or adjacent to the western survey parcel; no place names are recorded for the other project areas. Kapuhi Valley translates as "the eel" valley (Pukui and Elbert 1986:349) (alternatively, *kāpuhi* means a "master of an animal; nurse or caretaker of a child; provider in general" [Pukui and Elbert 1986:133). "Kaapahu" is applied to a stone escarpment or face (as depicted on Emerson's map and visible on current orthophotographs) and thus is likely *kaʻāpahu* meaning "to cut off squarely or crosswise" (Pukui and Elbert 1986:108). The meanings of Waikoekoe and Mookaha are unclear.

HISTORICAL SUMMARY

The history of Kawaihāpai and Mokulēʻia Ahupuaʻa (and by default the smaller *ahupuaʻa* of Aukuʻu and Kikahi) and the surrounding area is summarized in reports including Pacheco (2013), McGerty and Spear (2001), Moblo (1991), O'Hare et al. (2003), Tulchin and Hammatt (2007), and Wilson and Spear (2008), among others. Certain details are discussed here in order to establish a cultural and historical framework for the current project.

Waialua was famous for its extensive taro (*kalo*; *Colocasia esculenta*) fields, however, the western portions, including Mokulēʻia, Kikahi, Aukuʻu, and Kawaihāpai, were more arid. These areas were still famed for marine resources and extensive taro fields. Mokulēʻia was explicitly mentioned for its fishpond in the chant, or *mele*, of Kūaliʻi, the 18th century chief who united Oʻahu (Fornander 1986 [IV-II]:374). Other fishing resources mentioned in the *mele* of Kūaliʻi include the *kahala* (amberjack [*Seriola dumerili*]) (Fornander 1986 IV-II:374). This fish was closely associated with the area and is (rarely) also called the *mokulēʻia* (Pukui and Elbert 1986).

The legend of the Hinalea Fish Basket also suggests that Mokulēʻia was a fertile area with sweet potato (*ʻuala*; *Ipomoea batatas*), *kihi* and *lapa* varieties of taro, *ʻawa* (*Piper methysticum*), and bananas (*maiʻa*; *Musa* sp.) harvested from the fields and marine resources such as the *kūmū* (white saddle goatfish [*Parupeneus porphyreus*]), *uhu* (lobster), and *hīnālea* (wrasses) from the ocean (Kamakau 1870, cited in Sterling and Summers 1978:101). Tulchin and Hammatt (2008:33) suggest that the four fishing shrines (*koʻa*) found along the coasts of Mokulēʻia and Kawaihāpai attest to the great amount and variety of fish found in the area.

Historic references corroborate the legendary accounts of the fertile lands of Mokulēʻia. Kamehameha worked the extensive fields stretching from Mokulēʻia to Waimea for three or four days in 1806 (Alameida 1993:39). Handy and Handy (1972:467) also noted two areas of extensive *loʻi* near the ocean with wild taro growing in the Makaleha stream valley in 1935. A "sizable *loʻi* area," small terraces, and wild taro were documented at the same time in Kawaihāpai, with the *loʻi* continuing into

neighboring Keālia Ahupuaʻa (this agricultural complex has been designated Site 50-80-03-0461, see below) (Handy and Handy 1972:467).

After Western contact the population of the district began to fall despite the fertile agricultural lands and rich marine resources. Sahlins (1992:20) estimated a pre-Contact population of 6,000-8,000 people for Waialua District. The population of the district fell quickly after Western contact due to introduced sexually transmitted diseases, typhus, and smallpox (Schmitt 1968). By 1831-1832 a missionary census found the population of Oʻahu was half if its population at contact (Schmitt 1977). Sahlins, using this information and church attendance numbers, estimates the population of Waialua fell from 6,000-8,000 persons to 2,640 persons by the early 1830s (Sahlins 1992:144). The first official, well-constructed census of the Hawaiian Islands in 1853 enumerated 1,126 persons in the district, and this number fell to a low of 851 persons in 1852 (Schmitt 1968:71). These impacts were magnified by changes in land tenure, commercial agriculture, and increase in contact with Western economic spheres (e.g., Sahlins 1992:143).

Western contact brought more than disease; it also introduced Western economic models, land tenure, and commercial agriculture. The Waialua district was heavily impacted by the sandalwood trade and, later, the need to supply food to passing trade vessels and distant *aliʻi* (Sahlins 1992:87). Substantial harvesting of sandalwood led to the deforestation of the slopes of the district between 1812 and 1830. Major sandalwood gathering operations, sometimes lasting several months, were common during the period (Kamakau 1961:206).

Following shortly on the collapse of the sandalwood trade, commercial sugarcane, rice, and ranching became common in the district. Sugarcane was introduced in 1836 and expanded greatly, persisting for the next 160 years (Condé and Best 1973:340). Sugarcane became a profitable crop in Hawaiʻi by the second half of the 19th century, and the drilling of wells allowed the establishment of sugarcane cultivation in northern Oʻahu. Similar expansions of cattle pasture lands after the 1840s and rice farming after the 1850s took place, while traditional *loʻi* were reclaimed for rice or pastureland (Alameida 1993).

In 1897 B.F. Dillingham began purchasing or leasing land in Mokulēʻia for use as a cattle ranch, and later for sugarcane. These ranch lands were also seen as an investment to sell or sublease when irrigation and transportation infrastructure were improved (Yardley 1981). Much of Kawaihāpai was incorporated into Dillingham Ranch at this time, where low-lying areas between the mountains and coast were used for sugar or cattle grazing (Coulter and Chun 1937). The newly-established sugar economy necessitated the extension of rail lines into the area, and a new settlement grew up around the railroad station at Kawaihāpai (Moblo 1991:4).

The Waialua Agricultural Company (WAC), formed by J.B. Atherton, E.D. Tenney, B.F. Dillingham, W.A. Bowen, H. Waterhouse, and M.R. Robinson, led to more changes to the area (Moblo 1991). The Oahu Railway and Land Company (OR&L) railway provided access to Honolulu for sugar and cattle allowing Dillingham to lease or sell several lands he had acquired for a profit (Yardley 1981). The lands included several properties in Kawaihāpai and the greater Mokulēʻia area including the Dole Estate, Gaspar Silva Ranch, the James Gay Estate, the Kawailoa Ranch and many small plots owed by Hawaiians (Yardley 1981). Dillingham sold most of this land by 1900 but kept a portion of land that formed the modern Dillingham Ranch (Yardley 1981:206). The WAC developed extensive sugarcane fields and irrigation systems on either side of the Dillingham Ranch (U.S. Army Corps of Engineers 1922). Sugarcane cultivation was concentrated on the coastal plain, while cattle ranching activities were focused on the adjacent slopes.

Modern military use of the area began in 1922 at the north end of Kawaihāpai (U.S. Army Corps of Engineers 1922). It was mainly used for housing and agriculture before World War II (WWII), after which it was developed into a large active airfield. Following the war, the airfield was renamed Dillingham Air Force Base and was used primarily for defensive training purposes and as a missile launch site. It was transferred from the Department of the Air Force to the Department of the Army in 1974 and is currently used for small private planes and tourism (Hawaii Aviation n.d.).

KAWAIHĀPAI *AHUPUA'A* LAND OWNERSHIP

Records of traditional land use for the area are sparse before the Mahele of 1848, which initiated private land ownership in the Hawaiian Kingdom. Kahekili Ke'eaumoku was the *ali'i 'ai moku* (district-level chief) of Waialua after the conquest of O'ahu by Kamehameha (Alameida 1996:84). His sister, Kekuapi'ia Nāmāhana, assumed this position in 1829 (Kame'eleihiwa 1992:106). The district remained in the hands of *ali'i* up to the Mahele, when Victoria Kamāmalu, granddaughter of Kamehameha, was forced to give up the lands, after which unclaimed parcels became government lands available for public sale (Kame'eleihiwa 1992). The lands surrendered by Victoria Kamāmalu include the *ahupua'a* of Kawaihāpai, Kikahi, Auku'u, and Mokulē'ia 2.

Following the advice of their land agent, Reverend John S. Emerson, many Kawaihāpai residents purchased lands outright rather than claiming them based on traditional use and occupation. Through purchase they could acquire pasturage and forest lands that were not usually included in *kuleana* claims (Land Commission Awards [LCA]) (Sahlins 1992). Nineteen Land Grant parcels are identified in Kawaihāpai Ahupua'a on Emerson's 1896 map; one parcel straddles Kawaihāpai and Kikahi (Fig. 4; Table 1). Land use reported for these parcels included goat pens, a school house, irrigation ditches, streams, springs, fishponds, salt beds, and gardens, all suggesting an active community at the time of the land division in 1848 (McGerty and Spear 2001 citing Native Register Vol. 2, 4, and 5 revoked *kuleana* claims).

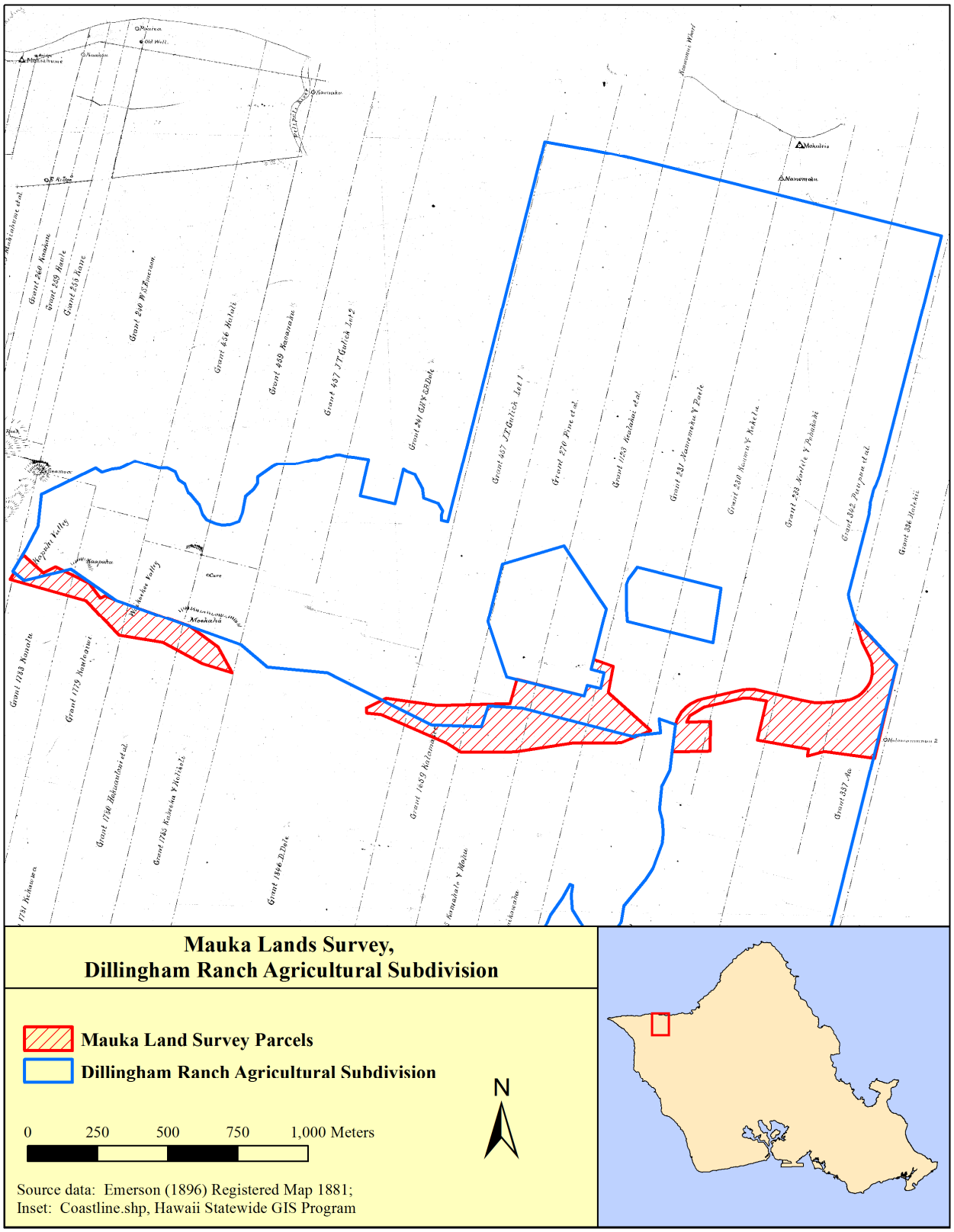

Figure 4. Emerson's (1896; Registered Map 1881) map of Mokulēʻia land grants with an overlay of the survey parcels, Dillingham Ranch Agricultural Subdivision, and *ahupuaʻa* boundaries.

Table 1. Documented Land Grants in Kawaihāpai (from Emerson 1896, Registered Map 1881). Bold text indicates land grants within the western survey parcel.

Grant No.	Year Purchased	Acreage	Awardee
240	1850	166	Emerson
258	1850	24.3	Kane
259	1850	24.5	Haule
260	1850	24.3	Kaakau
279	1850	66	Mahiahume et al.
343	1850	68	Kalauohaena et al.
456	1850	90	Halali
457	1850	197	Gulick
459	1850	90	Koanaku
1777	1855	100	Kamoku and Lahela
1779	**1855**	**50**	**Kauloaiwi**
1780	**1855**	**68**	**Hokuaulani et al.**
1781	1855	48	Kekauwa
1783	**1855**	**50**	**Kanalu**
1784	1855	100	Papa
1785	**1855**	**90**	**Kahoeka and Kolikoli**
1786	1855	50	Maaweiki
1846	1855	248	Dole
3767	1895	220	Silva

KIKAHI *AHUPUA'A* LAND OWNERSHIP

As with the residents of Kawaihāpai, many people in Kikahi, Auku'u, and Mokulē'ia Ahupua'a purchased land during the Mahele at the suggestion of Reverend Emerson. Seven Land Grants are depicted within Kikahi Ahupua'a on Emerson's 1896 map, with portions of all of them within the Dillingham Ranch Agricultural Subdivision; two of these grants straddle Kikahi and Auku'u (see Fig. 4; Table 2). The central survey parcel overlaps with three of these grants.

Table 2. Documented Land Grants in Kikahi (from Emerson 1896, Registered Map 1881). Bold text indicates land grants within the central survey parcel.

Grant No.	Year Purchased	Acreage	Awardee
241	1850	100	Dole, G.H and S.B. Dole
270	1850	180	Pao, Pine, and Mahiai
457	1850	197	Gulick, J.
1655	**1855**	**83**	**Mahu and Kamahalo**
1659	**1855**	**4.02**	**Kalamaku/Kalamakee**
1787	1855	45	Kapuepue
1846	**1855**	**248**	**Dole, D.**

AUKUʻU *AHUPUAʻA* LAND OWNERSHIP

Seven Land Grants depicted on Emerson's 1896 map fall within Aukuʻu, all of which appear to have portions that are now part of the Dillingham Ranch Agricultural Subdivision (some of the parcel boundaries are unclear, though) (see Fig. 4; Table. 3). Two of the parcels straddle Kikahi and Aukuʻu. The central survey parcel includes portions of all of the land grants.

Table 3. Documented Land Grants in Aukuʻu (from Emerson 1896, Registered Map 1881). Bold text indicates land grants within the central survey parcel.

Grant No.	Year Purchased	Acreage	Awardee
230	**1850**	**120**	**Kaumu and Kekela**
231	**1850**	**114**	**Namoku/Namomoku and Paele**
241	**1850**	**100**	**Dole, G.H and S.B. Dole**
270	**1850**	**180**	**Pao, Pine, and Mahiai**
1123	**1853**	**112**	**Makahi, Kealakai, Poli and Keoahu**
1655	**1855**	**83**	**Mahu and Kamahalo**
1659	**1855**	**4.02**	**Kalamaku/Kalamakee**
1660	**1855**	**80**	**Kaiaikawaha**
1668	**1855**	**211**	**Chamberlain, W.**

MOKULĒʻIA 2 *AHUPUAʻA* LAND OWNERSHIP

Emerson's 1896 map includes seven Land Grant parcels within Mokulēʻia 2, although land ownership across the eastern half of the *ahupuaʻa* is not included (see Fig. 4; Table 4). All but one of these grants is at least partially within the boundary of the Dillingham Ranch Agricultural Subdivision. The eastern survey parcel falls within four grants. Cattle walls depicted on the U.S. Army Corps of Engineers 1922 map document ranching activities across the four land grants within the current project area by the early 20th century.

Table 4. Documented Land Grants in Mokulēʻia 2 (from Emerson 1896, Registered Map 1881). Bold text indicates land grants within the eastern survey parcel.

Grant No.	Year Purchased	Acreage	Awardee
233	**1850**	**130**	**Pohakahi and Naelele**
273	1850	50	Gravier, E.
336	**1850**	**50**	**Haleki**
337	**1850**	**49**	**Aa**
342	**1850**	**141**	**Puupuu,Ao, Kalaikao and Malehine**
1328	1854	136	Collins, C.
1668	1855	211	Chamberlain, W.

PREVIOUS ARCHAEOLOGY

The geographical coverage of archaeological research within the western *ahupua'a* of Waialua is variable, with Dillingham Ranch standing out as the most intensively investigated area. Two general patterns have been documented by these investigations. One, pre-Contact and post-Contact burials are fairly common along the coastline with interments in calcareous Jaucas sand deposits. Minimally, the remains of 32 individuals have been recovered from the shoreline from Kawaihāpai to Mokulē'ia 2 Ahupua'a. Two, surface architecture documenting traditional habitation, agriculture, and ceremonial activities is limited to the foothills and lower slopes of the Wai'anae Range. It can be assumed that surface structures once extended across the lower coastal flat, but that they were destroyed by historical agricultural activities. Post-Contact structures, primarily cattle and boundary walls have a similar distribution.

The chronology of pre-Contact occupation is poorly developed with a handful of radiocarbon determinations obtained from deposits excavated in the area. Most of these determinations provide calibrated ages from the 17th to 20th centuries, with a pair calibrating between the 13th to 16th centuries; a single date is anomalously old with a calibrated age between the 8th and 11th cetnuries. All of these determinations were obtained from unidentified wood charcoal and therefore may provide spuriously old calibrated ages (that is, the samples include an unquantified degree of inbuilt age). Similarly, artifact and midden collections are practically nonexistent for this area. This is in contrast to the ethnohistorical record of extensive sweet potato and taro cultivation (Handy 1940:85; Handy and Handy 1972:467), and presumably a large population.

Table 5 presents details on the previous archaeological investigations completed within approximately 2 kilometers (km) of the current survey parcels. Figure 5 displays the locations of most of these projects. Table 6 presents a listing of the 38 previously documented sites within the same area, with Figure 6 displaying their locations. Note that locations for McAllister's Sites 190-196 are approximations. A few additional projects conducted at a greater distance that resulted in no findings are not tabulated or displayed (Barrera 1985a, 1985b; Carter 1979; Kennedy 1990).

Table 5. Previous Archaeological Investigations within Approximately 2 km of the Current Survey Areas.

Report Author	Results	Location
Barrera (1985c)	Reconnaissance survey; no sites	Proposed well location, adjoining to the north of the current western survey parcel
Barrera (1986)	Reconnaissance survey; two sites recorded: a wall and an enclosure/paddock (re-located by Drolet and Schilz [1992a, 1992b] and designated Sites 50-80-03-4439 and 4785, respectively)	Dillingham Ranch property; surrounding, and possibly overlapping, the current project area
Drolet and Schilz (1992a)	Inventory survey of 840 acres of Dillingham Ranch; 15 sites documenting prehistoric and historic habitation and agriculture (Sites 50-80-03-4772 to 4786	Immediately north of the current survey parcels; slightly overlaps the northern extent of the present central survey area and the western extent of the eastern survey area
Drolet and Schilz (1992b)	Inventory survey of 55 acres (divided into 50 and 5 acre parcels); four sites recorded documenting prehistoric and historic agriculture and land boundaries (Sites 50-80-03-4439 to 4442)	The 50 acre parcel is ~150-650 m south of the current eastern survey parcel; the 5 acre parcel is ~150-450 m north of the current western survey parcel

Table 5. Previous Archaeological Investigations within Approximately 2 km of the Current Survey Areas (continued).

Report Author	Results	Location
Elmore and Kennedy (1998); see also Kapeliela (1998)	Burial recovery; minimum number of individuals (MNI) of seven (Site 50-80-03-5599); six individuals presumed to date to the pre-Contact period, seventh individual dates to the post-Contact period based on glass beads associated with the burial	Approximately 2.2 km northeast of the current eastern survey parcel; along the coastline
Gregg and Kennedy (2004)	Burial recovery; single individual, exposed during construction (Site 50-80-03-6708); probably disturbed by prior construction; presumed to be Hawaiian	Coastal Mokulēʻia Ahupuaʻa, approximately 2 km north of the present survey parcels
Hammatt (1991)	Subsurface testing; no sites	
Kapeliela (1996)	Burial recovery; recovery of two human cranial fragments that had eroded from the active dune/beach face (Site 50-80-03-5467)	Approximately 2 km northeast of the current eastern survey parcel; along the coastline
Kennedy (1987)	Literature review for approximately 2,800 acres within Mokulēʻia; two day reconnaissance in selected areas	Dillingham Ranch property
McAllister (1933)	Reconnaissance-level survey (island-wide); notes six sites (Sites 190-196 [now prefixed by 50-80-03-]): three *koʻa* (fishing shrines) (Sites 50-80-03-0190, 0193, and 0195), one *heiau* (Site 50-80-03-0191), springs (Site 50-80-03-0192); one possible *heiau* (Site 50-80-03-0194); and a "village" (Site 50-80-03-0196); two (Sites 190 and 193) were no longer present with three others partially dismantled or otherwise disturbed (Sites 191, 195, and 196)	The placement of these sites is very rough, relying on the hand-drawn Waialua map included in Sterling and Summers (1978). Sites 190, 193, and 195 are 1.7-2 km north of the survey parcels along the shoreline; Site 191 is approximately 500-600 m to the northwest of the western survey parcel; Site 192 may be immediately north of, or within, the western parcel; Site 194 may be approximately 700 m to the north of the central parcel; Site 196 may be immediately east of the eastern parcel
Mitchell (1987)	Reconnaissance survey on horseback across Dillingham Ranch; six sites were recorded (no SIHP numbers provided at the time), consisting of stone walls (Sites 1 and 2; Site 1 later designated Site 50-80-03-4439), a wall and platform (Site 3; later designated Sites 50-80-03-4785 and 4786), springs (McAllister's Site 192), a wall and "rock structures" (Site 5; later designated Sites 50-80-03-4772 to 4777); and terracing (Site 6; possibly Site 50-80-03-0416)	Sites 1 (50-80-03-4439) and Site 2 are approximately 400-600 m to the south; the remaining sites are 200 m or more to the north
Moblo (1991)	Literature review and reconnaissance survey for Dillingham Airfield; multiple masonry surface structures noted that appear to be historical, but the reconnaissance area overlaps Site 50-80-03-0416	Approximately 1.5 km to the north and northwest from the present western survey parcel

Table 5. Previous Archaeological Investigations within Approximately 2 km of the Current Survey Areas (continued).

Report Author	Results	Location
O'Hare et al. (2003)	Inventory survey; one site (Site 50-80-03-6638), a buried cultural deposit and terrace were documented; three ^{14}C dates were obtained (590±70 BP [Beta-183530], 100±60 BP [Beta-183401], 140±30 BP [Beta-183402])	Approximately 1.9 km to the north of the current western survey parcel; along the coastline
Perzinski and Hammatt (1999)	Archaeological monitoring and burial recovery; single individual exposed during construction (Site 50-80-03-5766); no burial pit or associated cultural deposit, with the exception of one possible post mold	Approximately 1.7 km to the north of the western survey parcel
Pietrusewsky (1988); see also Bath and Pietrusewsky (1987)	Burial recovery; MNI of 21 (Site 50-80-03-3747)	Approximately 2 km to the north along the coast
Rosendahl (1977)	Reconnaissance survey of 64.22 acres of Dillingham Military Reservation; recorded one site—a complex of agricultural terraces (Site 50-80-03-0416), and discusses two others that could not be re-located (Site 50-80-03-0191 [*heiau*]) or is presumed to have been destroyed (Site 50-80-03-9535 [*ko'a*])	Site 416, at its closest, is approximately 150 m north of the western survey parcel
Thrum (1908:41)	Listing of *heiau*; "Paweu" Heiau, possibly McAllister's Site 191	If it is Site 191, it is approximately 500-600 m to the northwest of the western survey parcel
Tulchin and Hammatt (2007)	Inventory survey of 78 acres; five late pre-Contact/early post-Contact sites documenting habitation and agriculture/ranching recorded (Sites 50-80-03-0416, 6884 to 6888); two ^{14}C determinations (160±40 BP [Beta-220909], 140±30 BP [Beta-221342])	Adjoins the northern boundary of the current western survey parcel and the western half of the northern boundary of the central survey parcel; includes the land between these two survey parcels

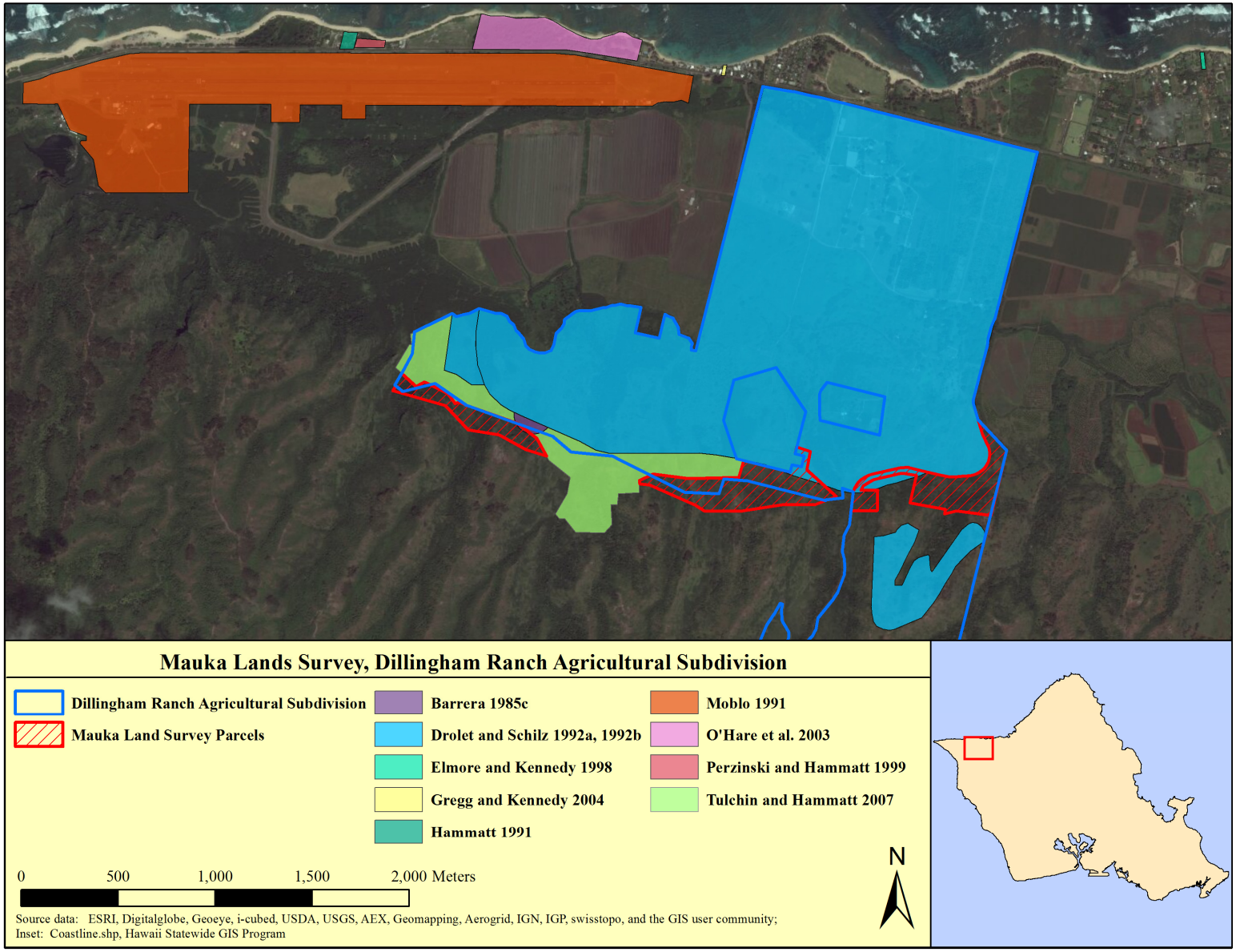

Figure 5. Locations of previous archaeological investigations within approximately 2 km of the current survey parcels.

Table 6. Archaeological Sites Previously Recorded within Dillingham Ranch and Surrounding Areas (Within Approximately 2 Kilometers).

Site No. (Prefix 50-80-03-)	Name/Description	Function	Period	Reference
190	Pu‘u o Hekili; form unknown	Religious (*ko‘a*)	Pre-Contact	McAllister (1933:128)
191	Kawailoa; two terraces, one wall	Religious (*heiau*)	Pre-Contact	McAllister (1933:128); possibly Thrum (1908:41)
192	“Hidden Waters”; unmodified springs	Springs	Traditional; Mythological	McAllister (1933:129)
193	Kuakea; form unknown	Religious (*ko‘a*)	Pre-Contact	McAllister (1933:129)
194	Wall, large rocks	Religious (possible *heiau*)	Pre-Contact	McAllister (1933:129)
195	Apparently rectangular structure, uncertain if it was an enclosure or platform	Religious (*ko‘a*)	Pre-Contact	McAllister (1933:129)
196	“Village” comprised of multiple “house sites” and terraces	Habitation	Traditional	McAllister (1933:129)
416	Terraces, walls, mounds	Agriculture	Traditional; Beta-221342, 140±30 BP	Handy (1940:85); Rosendahl 1977; Tulchin and Hammatt (2007); possibly Mitchell (1987)
3747	Human skeletal remains (minimum 21 individuals)	Burial	Pre-Contact	Bath and Pietrusewsky (1987); Pietrusewsky (1988)
4439	Wall	Boundary	Traditional	Barrera (1986); Drolet and Schiltz (1992b); Mitchell (1987)
4440	Wall	Boundary	Traditional	Drolet and Schiltz (1992b)
4441	Wall	Agriculture/ Ranching	Post-Contact	Drolet and Schiltz (1992b)
4442	Terrace	Agriculture	Unknown	Drolet and Schiltz (1992b)
4772	Enclosure (Settlement Cluster 1)	Possibly religious (possible *heiau*)	Traditional	Drolet and Schilz (1992a); Mitchell (1987)
4773	2 enclosures, 1 platform (Settlement Cluster 1)	Habitation and agriculture	Traditional	Drolet and Schilz (1992a); Mitchell (1987)
4774	Platform (Settlement Cluster 1)	Habitation	Traditional	Drolet and Schilz (1992a); Mitchell (1987)

Table 6. Archaeological Sites Previously Recorded within Dillingham Ranch and Surrounding Areas (Within Approximately 2 Kilometers) (continued).

Site No. (Prefix 50-80-03-)	Name/Description	Function	Period	Reference
4775	Enclosure (Settlement Cluster 1)	Habitation	Traditional	Drolet and Schilz (1992a); Mitchell (1987)
4776	3 enclosures, 3 terraces, 2 walls, 1 clearing, 1 alignment, 1 mound (Settlement Cluster 1)	Agriculture, habitation, religious	Traditional	Drolet and Schilz (1992a); Mitchell (1987)
4777	2 walls (Settlement Cluster 1)	Boundary	Traditional/ Historic	Drolet and Schilz (1992a); Mitchell (1987)
4778	2 enclosures (Settlement Cluster 2)	Agriculture	Traditional	Drolet and Schilz (1992a)
4779	Terraces, platforms, and enclosures (Settlement Cluster 2)	Habitation and agriculture	Traditional	Drolet and Schilz (1992a)
4780	4 terraces, 1 enclosure (Settlement Cluster 2)	Agriculture	Traditional	Drolet and Schilz (1992a)
4781	Terrace (Settlement Cluster 2)	Agriculture	Traditional	Drolet and Schilz (1992a)
4782	3 enclosures, 2 terraces, 1 mound (Settlement Cluster 3)	Agriculture	Traditional	Drolet and Schilz (1992a)
4783	1 water channel, 1 wall	Agriculture	Post-Contact	Drolet and Schilz (1992a)
4784	Ditch	Agriculture	Unknown	Drolet and Schilz (1992a)
4785	Enclosure/paddock	Agriculture/ Ranching	Post-Contact	Barrera (1985); Drolet and Schilz (1992a); Mitchell (1987)
4786	Platform	Religious	Pre-Contact	Drolet and Schilz (1992a); Mitchell (1987)
5599	Human skeletal remains	Burial	Pre- and Post-Contact	Elmore and Kennedy (1998)
5766	Human remains	Burial	Traditional	Perzinski and Hammatt (1999)
6638	Buried cultural deposit	Habitation	Pre-Contact	O'Hare et al. (2003)
6708	Human skeletal remains	Burial	Traditional	Gregg and Kennedy (2004)
6884	Walls	Agriculture/ Ranching	Post-Contact	Tulchin and Hammatt (2007)
6885	3 terraces, 1 retaining wall	Agriculture	Traditional	Tulchin and Hammatt (2007)
6886	3 terraces, 3 mounds, 1 retaining wall	Agriculture	Traditional	Tulchin and Hammatt (2007)
6887	Overhang shelter	Temporary habitation	Traditional; Beta-220909, 160±40 BP	Tulchin and Hammatt (2007)
6888	5 mounds, 1terrace	Agriculture	Traditional	Tulchin and Hammatt (2007)
"Site 2"	Wall	Military	Historic	Mitchell (1987)

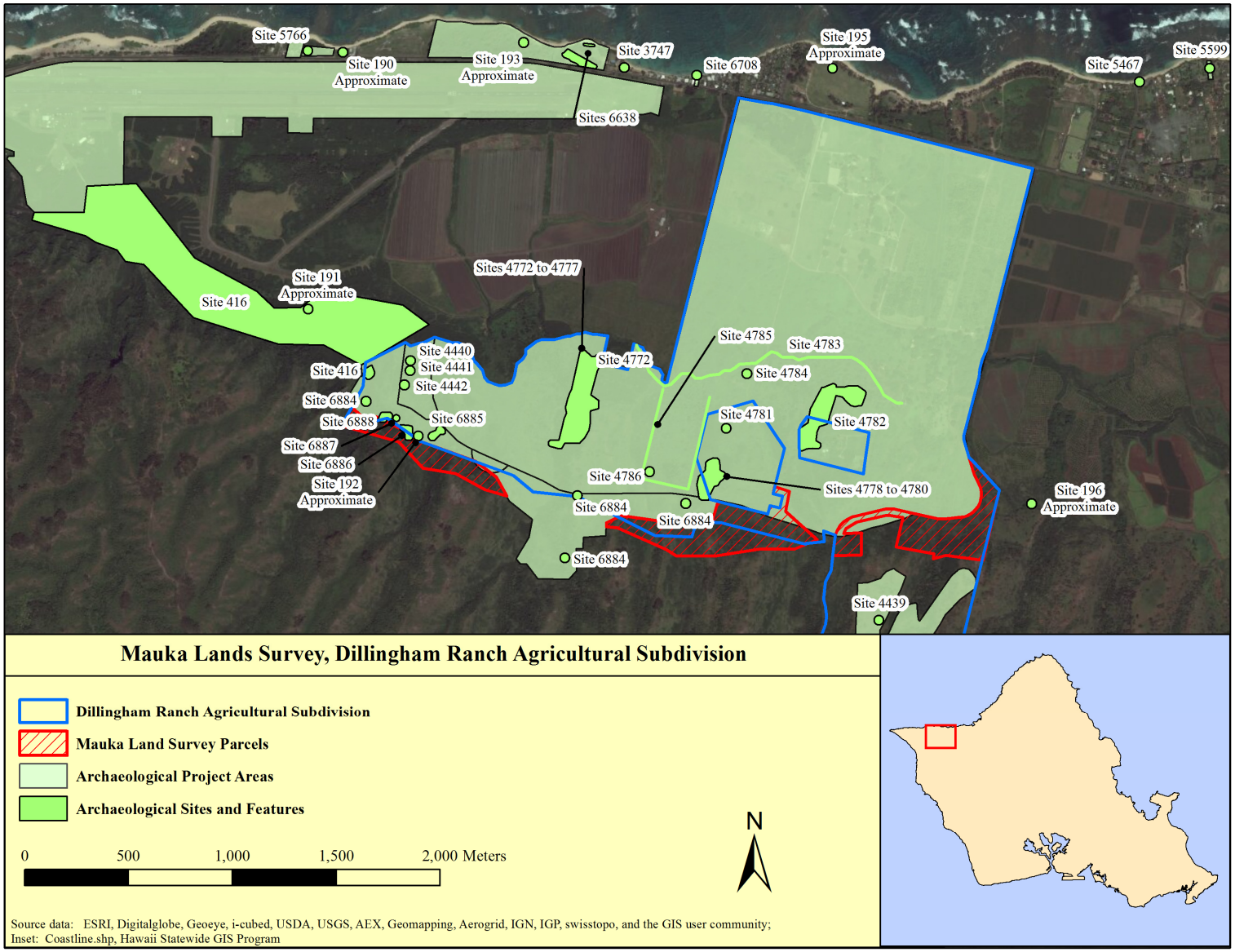

Figure 6. Previously identified archaeological sites within approximately 2 km of the current survey parcels.

No sites have been previously documented within the eastern survey parcel (see Fig. 6). McAllister's (1933:129) Site 196—"portions of house sites, isolated sections of terracing"—may be immediately to the east, however the placement of this site is an approximation following Sterling and Summers (1978:Waialua map). A possible land boundary wall (Site 4439) recorded by Mitchell (1987) and Drolet and Schilz (1992b) is about 375 m to the south (*mauka*).

No sites have been previously recorded within the central survey parcel (see Fig. 6). Tulchin and Hammatt (2007) recorded three sections of historical ranching walls (Site 6884, Feas. A, C, and D) to the north and east of the current survey parcel. Drolet and Schilz's (1992a) Settlement Clusters 2 (Sites 4778-4780) and 3 (Site 4782) are located approximately 100 m to the north. These site clusters, along with Settlement Cluster 1, are interpreted as remnants of the same, formerly continuous, traditional Hawaiian agricultural landscape. Drolet and Schilz (1992a) are equivocal on assigning a definitive pre- or post-Contact age, suggesting that at least some of the structures pre-date Contact but that the complex likely continued in use during the early post-Contact decades. The clusters include agricultural and temporary habitation enclosures, platforms, and terraces.

Although it has not been conclusive determined, McAllister's (1933:129) Site 192 may fall within the western survey parcel. The unmodified springs—named Ulunui, Koheiki, Ulehulu, and Waiakaaiea (names provide by Hookala)—are described by McAllister (1933:129) as "four hidden waters upon which Hiiaka called when she was refused water by the old inhabitants." As with all of McAllister's (1933) sites in the area, locations are approximate. Tulchin and Hammatt (2007) recorded three small traditional agricultural complexes (Sites 6885, 6886, and 6888) and one temporary overhang shelter (Site 6887) immediately to the north of the current western survey parcel. A single radiocarbon determination obtained from unidentified charcoal recovered from a hearth at Site 6887 is 160±40 BP (Beta-220909). Although the features comprising Site 6886 do not extend into the western parcel, the site boundary with a buffer does intrude approximately 15 m into the present survey area. The agricultural complexes include terraces and mounds. A historical cattle wall (Site 6884, Fea. B) was also documented slightly further to the north, and approximately 200 m to the north is a component of Site 416 (agricultural terraces, walls, and mounds) recorded by Tulchin and Hammatt (2007). A single radiocarbon determination has been obtained from unidentified charcoal recovered from excavations at Site 416, providing an uncalibrated age of 140±30 BP (Beta-221342).

SUMMARY OF PREVIOUS ARCHAEOLOGICAL INVESTIGATIONS AND EXPECTATIONS FOR THE PRESENT PROJECT AREA

Previous archaeological investigations in the foothills of the Wai'anae Range around the current project areas have documented traditional irrigated and dryland agricultural infrastructure, temporary habitation structures, and later historical cattle ranching/boundary walls. Similar structures would be anticipated for the current project. A series of natural springs of cultural and mythological importance were indicated to be in the general area by a consultant of McAllister's during the early 20th century. The locations of these springs have not been conclusively determined. Due to the apparent lack of modification (e.g., stacked stone) and detailed descriptions, confirming any particular natural spring as one of the four named in McAllister (1933:129) will be challenging.

III. RESEARCH DESIGN AND METHODS

This section presents the research questions that guided the inventory survey and the field methods that were employed.

RESEARCH QUESTIONS

Three general research questions guided fieldwork.

1) Is there surface architecture and/or evidence for subsurface deposits present?

2) What is the evidence of land use or water management upland of previously recorded agricultural/habitation sites?

3) What is the evidence for ranching or agriculture on the steeper upland slopes?

FIELDWORK METHODS

The *mauka* lands project areas vary significantly in both slope and vegetation. Small segments of the eastern and central survey areas had slopes of 6-10% with dense grasses while the majority had slopes of 40-75% with dense grasses, bushes, and trees. The westernmost section is comprised of very steep slopes and cliffs with deeply incised gullies. This section varied from dense grass to forest. Survey area boundaries were identified using natural landmarks and a Geographic Information System (GIS) shapefile of the project areas loaded into a professional grade Global Positioning System (GPS) unit.

A systematic pedestrian survey was conducted with parallel transect lines spaced 5-10 m apart, depending on the density of vegetation and the topography. Survey transect lines were oriented roughly east-west, except for a section of the eastern survey area where transects were oriented roughly north-south to take advantage of the topography. The more widely spaced transects were common in the western survey area where cliffs and very steep slopes required wider spacing to balance safety considerations with coverage (see Photos 3-4).

Feature descriptions and assessments documented feature type, construction methods, functional interpretations, and age estimates. Feature locations were recorded with Trimble Pro-XT and Pro-XH units using the North American Datum 1983, Zone 4 North (NAD 83 Zone 4N). Features were photographed with a digital camera, and plan view maps and profile drawings were completed.

Three 30 by 30 centimeter (cm) shovel test pits (STP) were excavated at two features of ambiguous function. One STP was placed flush with the upslope base of a cattle wall to identify if the wall was also used as an agricultural terrace and, if so, to obtain charcoal for radiocarbon dating. The other two STPs were placed in a rockshelter to identify any cultural deposits. Excavated sediment was screened using 1/8-inch mesh, soil descriptions were completed, and stratigraphic profiles were drawn.

IV. FIELDWORK RESULTS

The pedestrian survey of the three *mauka* parcels for the proposed Dillingham Ranch Agricultural Subdivision resulted in the identification of one archaeological site, Site 50-80-03-7653 (Fig. 7). Site 7653 is comprised of four discontinuous dry-laid ranching walls (Features 1-4), which are similar in construction and location to Site 6884, which was previously documented by Tulchin and Hammatt (2007). In addition to the ranching walls, two unmodified seeps were noted within the western survey parcel. These seeps have not been designated as new archaeological sites because of the lack of modification, however, they may be part of McAllister's (1933) Site 192.

PEDESTRIAN SURVEY: SITE 50-80-03-7653

Site 7653 consists of dry-stacked stone walls that in places incorporate large colluvial boulders and outcrops. Wall segments may parallel the slope contours (generally east-west) or run cross contour (generally north-south). Slope erosion and collapse has affected numerous portions of these walls, but the remaining segments are consistent with the extensive 19th/early 20th century ranching infrastructure in this area. These walls, and the components of Site 6884, likely once formed an integrated enclosure/exclosure system for the ranch. Table 7 provides the UTM coordinates for the ends of the wall segments.

Table 7. UTM Coordinates for Site 7653 Features.

Fea.	Easting	Northing	Location
1	586140.969	2384300.246	South terminus, western north-south wall segment
1	586147.646	2384407.08	Vertex: North terminus, western north-south wall segment/west terminus of western east-west wall segment
1	586312.667	2384410.577	East terminus of western east-west wall segment
1	586418.547	2384395.633	West terminus of eastern east-west wall segment
1	586459.882	2384388.002	Vertex: East terminus of eastern east-west wall segment/midpoint of southern segment of eastern north-south segment
1	586457.338	2384351.119	South terminus of southern segment of eastern north-south wall

Table 7. UTM Coordinates for Site 7653 Features (continued).

Fea.	Easting	Northing	Location
1	586479.913	2384478.302	North terminus of southern segment of eastern north-south wall
1	586481.503	2384486.569	South terminus of central segment of eastern north-south wall
1	586493.267	2384543.484	North terminus of central segment of eastern north-south wall
1	586498.037	2384582.911	South terminus of northern segment of eastern north-south wall
1	586463.061	2384631.241	North terminus of northern segment of eastern north-south wall
2	586352.094	2384319.959	West terminus
2	586380.71	2384318.369	East terminus
3	585118.992	2384343.308	West terminus of west segment
3	585146.368	2384345.522	East terminus of west segment
3	585152.205	2384345.119	West terminus of central segment
3	585236.546	2384333.042	East terminus of central segment
3	585281.031	2384325.393	West terminus of east segment
4	585324.912	2384315.529	East terminus of east segment
4	583360.179	2384944.022	Center

Feature 1 is a series of adjoining, or once continuous, dry-stacked stone walls located within the eastern survey parcel (see Fig. 7, Fig. 8; Photo 5-6). The longest segment is oriented east-west and extends 312 m with an 80 m wide break where a single track dirt road breaches the wall. At the western end of this segment the wall makes a nearly 90-degree turn south and continues for at least 106 m intersecting the

southern boundary of the survey parcel. The wall appears to have originally continued further to the south but it is now completely collapsed in this area. At the eastern end of the east-west segment there is another right angle intersection with a north-south oriented wall segment. This component is largely beyond the survey parcel, although a 50 m portion of it falls within the survey parcel along its northeast edge. The north-south wall segment extends across at least 295 m and is parallel to the current TMK boundary, although offset by approximately 20 m. These core filled wall segments are constructed with multiple courses of basalt cobbles and small boulders. The maximum wall height is 1.2 m and the average width is 0.7 m. There are several sections where the wall has collapsed or has been breached.

Feature 2 is a shorter dry-stacked stone wall located in the eastern survey parcel (see Fig. 7; Photo 7). This wall is 28 m long and is parallel to the east-west segment of Feature E. The core filled wall is constructed with multiple courses of basalt cobbles and small boulders. The maximum height of the wall is 0.6 m and the average width is 0.7 m.

Feature 3 is a stacked stone wall located in the central survey parcel (see Fig 9; Photo 8-9). The dry stacked wall runs east-west in three sections across ridge tops and a shallow hanging valley. The total length of the wall is 210 m, including two breaches of 6 m and 45 m. Portions of the wall have been heavily damaged by erosion and have collapsed. A segment of the wall extends outside the project area on the bluff top running south from the project area for a minimum of 30 m. The maximum wall height is 1.6 m, the maximum width is 1 m with an average width of 0.7 m.

Feature 4 is a stacked stone wall located in a steeply sided gully at the western edge of the western survey parcel (see Fig. 7, Fig. 9; Photo 10). The small L-shaped feature was built by infilling the gaps between large colluvial boulders with stacked stone courses. The northeastern portion of the wall is 7.9 m long and 0.7-0.9 m high, while the western portion of the wall, which runs parallel to the main stream bed, is 7.8 m long and 1.35-1.85 m high.

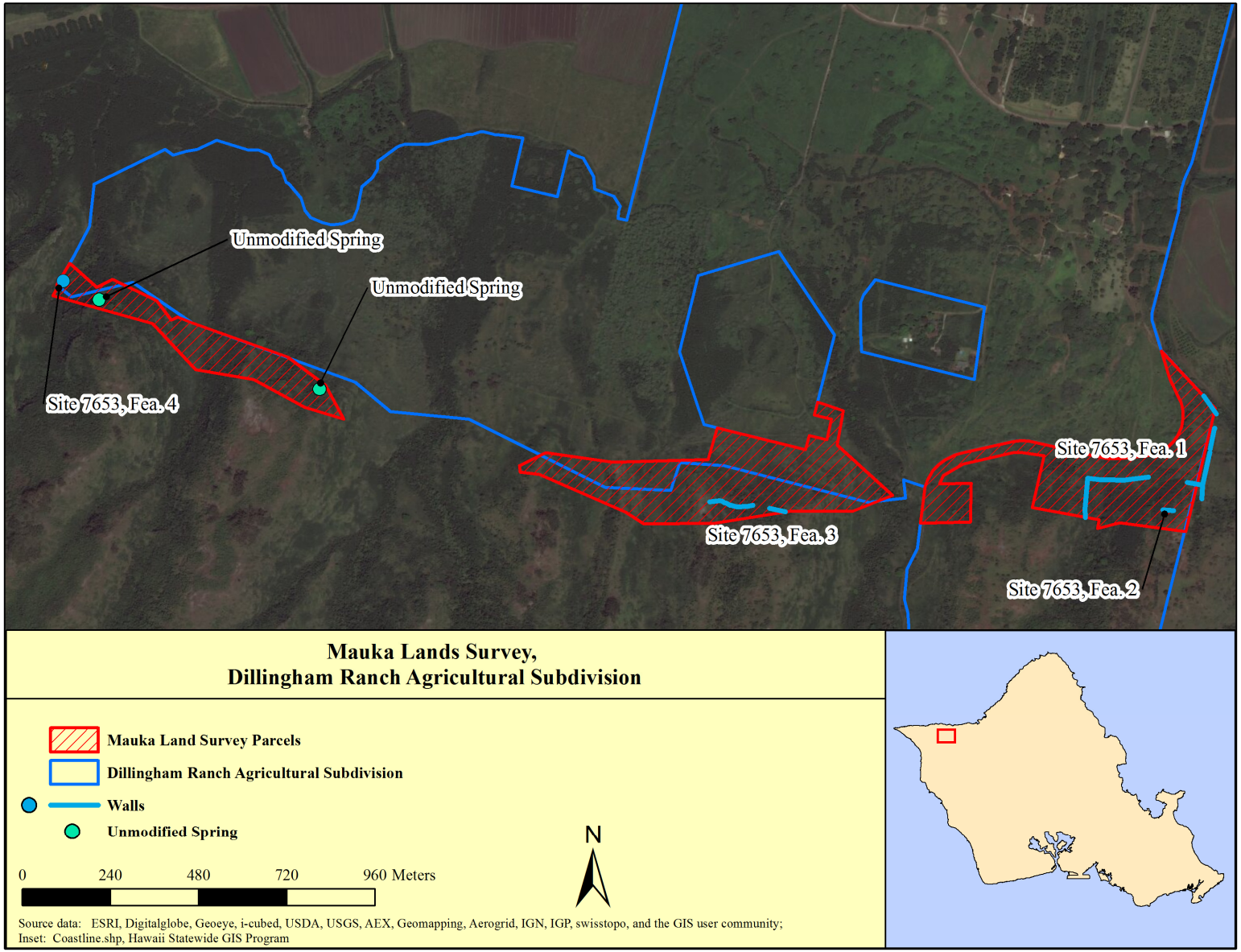

Figure 7. Archaeological features and unmodified springs identified during the current survey.

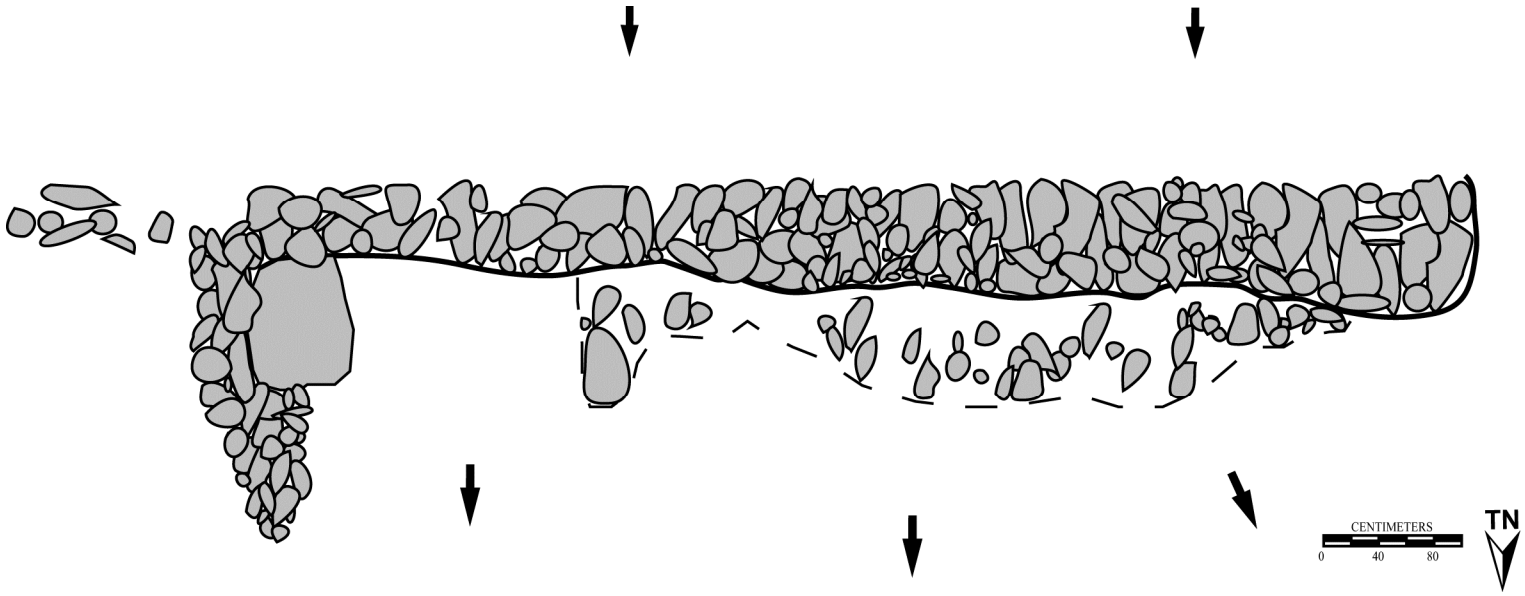

Figure 8. Plan map of portion of east-west segment of Feature 1.

Photo 5. Portion of the east-west segment of Feature 1. View southwest.

Photo 6. Portion of the east-west segment of Feature 1. View south.

Photo 7. Portion of Feature 2. View southwest.

Photo 8. Portion of Feature 3 with small rockshelter. View west.

Photo 9. Portion of Feature 3. View west.

Photo 10. Portion of Feature 4. View southwest.

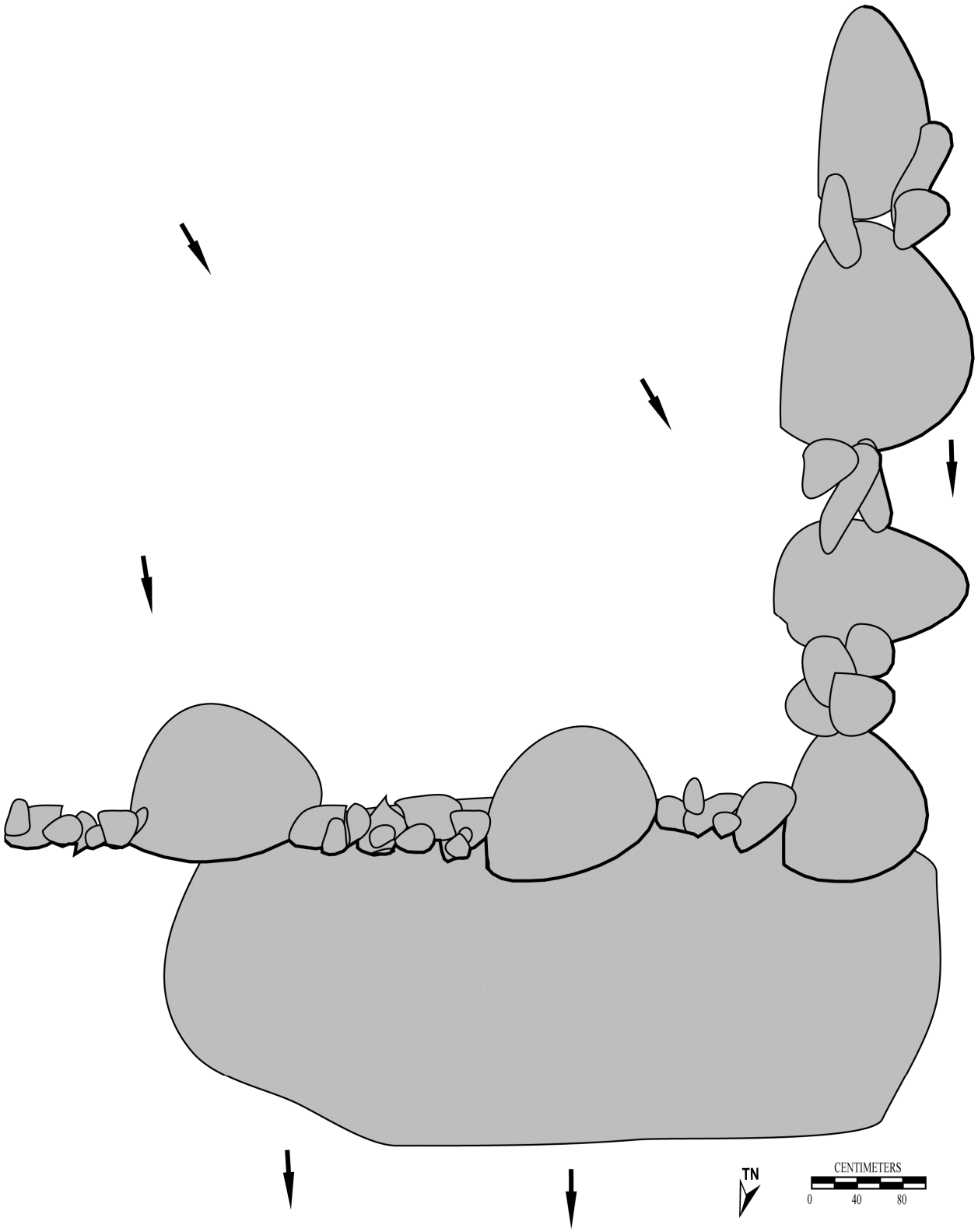

Figure 9. Feature 4 plan map.

Site 7653 is evaluated as significant under Criterion d of the Hawai‘i Register of Historic Places (have yielded, or likely to yield information important for research on prehistory or history): the site provides information about historical ranching activities and land divisions. Documentation of construction characteristics of the walls and their locations (which were recorded using GPS units) is recommended as sufficient site recording.

UNMODIFIED SPRINGS

Two natural springs/seeps were identified within the project area (see Fig. 9; Photos 11-12). These seeps are unmodified but are located in the general location of Site 192.

Photo 11. Unmodified spring on the eastern slope of Kapuhi Valley, western survey parcel. View southeast.

Photo 12. Unmodified spring, eastern portion of western survey parcel. View southwest.

SUBSURFACE TESTING

Three shovel test pits (STP) were excavated to test for a cultural deposit within a small rockshelter and to test for an agricultural deposit behind (upslope of) a rock wall. Two 30 cm by 30 cm STPs were excavated into the floor of a rockshelter that had a portion of a cattle wall (Site 7653, Feature 3) blocking the downslope opening (Fig. 10; see Photos 13-14). A third 30 cm by 30 cm STP was excavated at the upslope edge of the cattle wall (Site 7653, Feature 3) 38 m east of the rockshelter (Photo 15).

Table 8 provides the soil descriptions and depositional information for the STPs. There was little variation in the soils exposed in the excavations, with a single stratum overlying bedrock in each STP. The slopes of the area are steep and active colluvial deposition of sediments, gravels, and boulders was documented by the excavations and is visible on the surface. No surface or subsurface artifacts or cultural layers were identified in the rockshelter or ranch wall area. Additionally, the sediment and soil build up along the upslope side of the wall is the result of colluvial deposition, and there is no evidence for planting and cultivation.

Table 8. Soil Descriptions and Interpretations of Deposition for Strata Exposed in STP 1-3.

Layer	Depth (cm bs)	Sedimentary Description	Depositional History
I (STP 1, 2)	0-24	Dark brown (7.5YR 3/2) silty clay; 15% rounded granules and pebbles; very few micro to fine roots; moderate very fine to fine crumb structure; slightly hard consistency; slightly undulating lower boundary at bedrock; no cultural material	Colluvial soil, formed by erosion of the slope and rockshelter
I (STP 3)	0-30	Dark brown (7.5YR 3/2) silty clay loam; few rounded granules and pebbles; few micro roots; weak very fine crumb structure; soft consistency; slightly undulating lower boundary at bedrock; no cultural material	Colluvial soil, formed by erosion of the slope

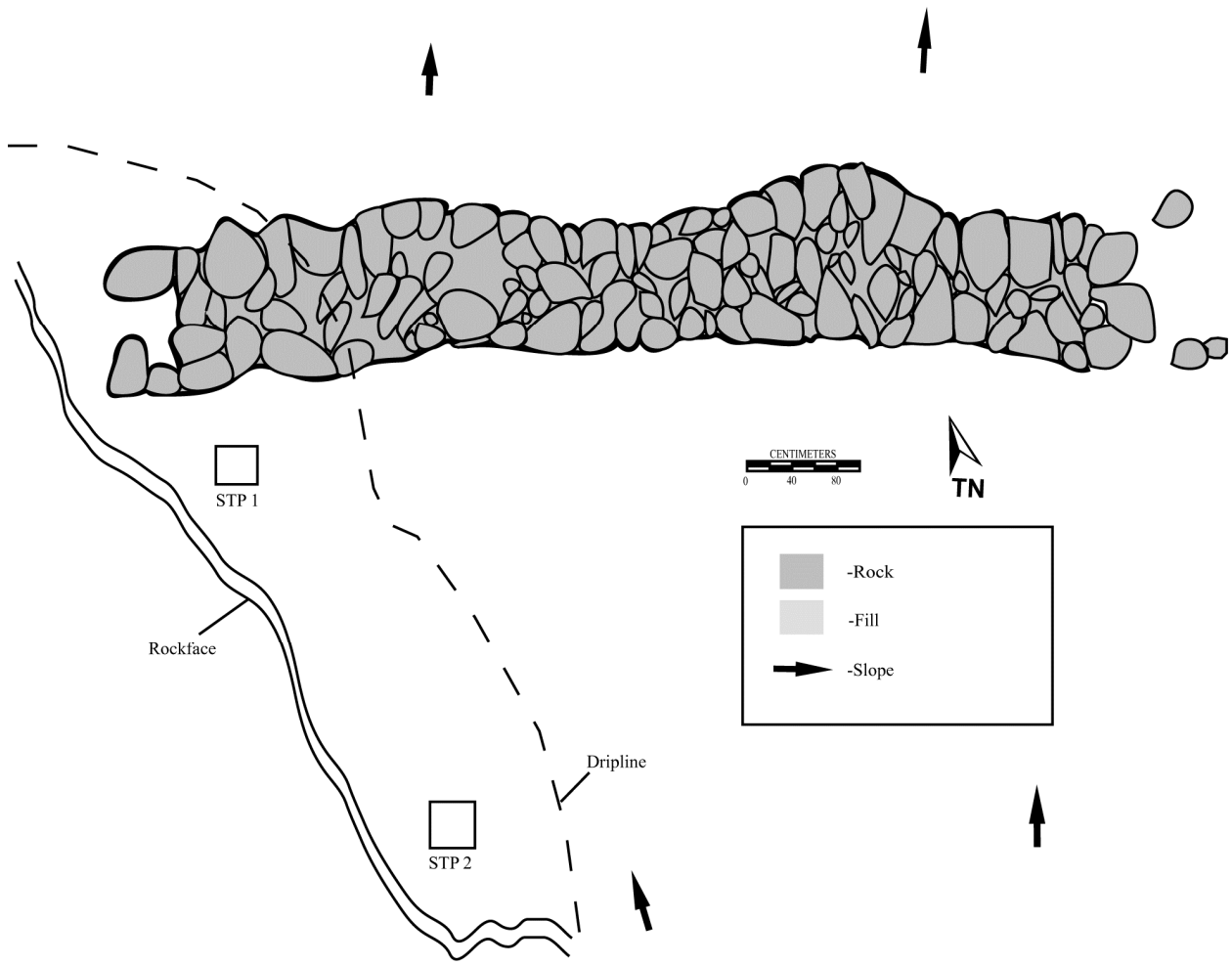

Figure 10. Plan map, portion of Site 7653, Feature 3 and associated rockshelter with STP locations.

Photo 13. STP 1 profile photograph. View west.

Photo 14. STP 2 profile photograph. View west.

Photo 15. STP 3 profile photograph. View north.

V. CONSULTATION

On May 24, 2014, Dillingham Ranch Aina and IA presented the preliminary findings of the inventory survey to members of the Mokulēʻia community. Community members in attendance included Mr. Thomas T. Shirai, Jr., a lineal descendant of the area, Mr. Mike Dailey, a resident of Mokulēʻia, and Mr. Stewart Ring, Secretary of the Mokulēʻia Community Association. The meeting was facilitated by Mr. Bob Miyasato on behalf of Dillingham Ranch Aina, LLC. Also present was Mr. Calvin Oda of North Shore Pineapple Company to present the ranch agriculture plan. The community expressed support for the proposed project and asked about several of the historic walls and the small rock shelter identified by IA. The springs located on the bluffs behind Kawaihāpai Airfield were of particular interest to Mr. Shirai. He expressed a desire to preserve and protect these seeps due to their potential link to prehistoric and historic farming in the area. The community members expressed their concern for monitoring of all subsurface disturbances to protect any burials that may be encountered.

Mr. Shirai also provided a personal perspective on the history of the area. He is a member of the Kawaihāpai Ahupuaʻa Ohana, and the lineal descendent (great-great-grand nephew) of Anton Kaʻoʻo, *hula* master from Waialua. His ancestors lived mainly in Kaʻena and Kawaihāpai Ahupuaʻa. The following is information provided by Mr. Shirai at the consultation meeting:

> Waialua/Mokulēʻia area has many legends attached to the land regarding its importance in Oʻahu legends and history. The island of Oʻahu was fished out of the ocean by Maui from Kaʻena Point. This adds to the many legends that surround Kaʻena Point, and is important because Kaʻena Point is not part of Waiʻanae, it is part of Waialua (according to land grants documented by Rev. Emerson).
>
> Waialua/Mokulēʻia is also important because it is possibly the oldest populated place on Oʻahu. Dates from archaeological investigations at Camp Mokulēʻia suggest the area was occupied from AD 700-1000 and stories corroborate that it is an older settlement than Waimea Valley.
>
> Waialua/Mokulēʻia was a breadbasket of Oʻahu with rich farmland and rich ocean resources.
>
> The rich farmlands were watered from several springs in the coastal cliffs and deeper into the mountains. Hidden Springs [Site 192] is an important place for Kawaihāpai because the springs watered farms at the base of the cliffs. A second important spring is Kaiʻana which is at Peacock Flats (also known as Kamaʻi) and feeds local streams. Waiʻu Spring (Breast Milk Spring) is at the base of the cliffs behind Dillingham Airfield. This spring produces milky water. The *ahupuaʻa* of Kawaihāpai is named from these springs. The name Kawaihāpai means "exalted or blessed waters," but "*hāpai*" actually means pregnant or carry in this case suggesting the land was pregnant with or carries blessed waters.
>
> The farmlands and rich ocean waters (including Papaloa reef flat) of the area were famous even before the field system was imposed and many Mokulēʻia plant cultivars exist because of the rich farmland and long history of the area.
>
> Several legends and stories about the strength and importance of the land are summarized below:
>
> -A *pōhaku* (stone) within the central survey area located at the edge of the stream was pushed by a bulldozer into the stream bed. The operator died and the bulldozer could not be restarted. The next day the *pōhaku* was back in place.

-The chant *Kalena Kai* was written in Mokulēʻia by King Liholiho (Kamehameha II), about his stay at Mokulēʻia and Kawaihāpai. It especially notes the productive farmlands.

-The chant *Liliʻu Ē* was written by Mr. Shirai's granduncle Anton Kaʻoʻo for Queen Kapiʻolani and modified to honor Liliʻoukalani.

-Historian Samual Kamakau born nearby, as was the first ordained Native Hawaiian minister, Samuel Kokeala.

VI. DISCUSSION

Survey of the *mauka* land parcels of the proposed Dillingham Ranch Agricultural Subdivision provides information to address the three research questions that guided the investigations.

1) Is there surface architecture and/or evidence for subsurface deposits present?

Pedestrian survey of the three parcels resulted in the identification of four historical ranch walls, which are designated Site 50-80-03-7653. The wall segments are remnants of what appears to have been a much more extensive system of ranching walls that likely originally connected at various points. The extant portions are approximately 8 to 300 m long, ranged from 0.6-1.85 m high and 0.7-1.6 m wide. The dry-stacked walls are constructed with multiple courses of basalt boulders and cobbles. Preservation ranges from poor to fair.

No subsurface cultural deposits were identified in the STPs, and there were not surface indications for buried deposits (e.g., surface artifact or midden scatters). The steep terrain ensures active colluvial deposition and erosion.

2) What is the evidence of land use or water management upland of previously recorded agricultural/habitation sites?

The historical walls identified by the survey along with historical records confirm that the area was used for ranching activities during the 19th and 20th centuries. Two unmodified springs were identified at the base of cliffs in the western survey parcel, and these may have been perennial water sources for agricultural/habitation sites down slope (and beyond the current survey parcels). However, no water channels, collection basins, or other modifications were identified at or near these springs.

3) What is the evidence for ranching or agriculture on the steeper upland slopes?

As noted above, several portions of historic ranch walls (Site 7653) are present in the survey areas, and similar walls (Site 6884) were recorded at comparable elevations by Tulchin and Hammatt (2007). These walls indicate that cattle were ranging widely through the steep slopes in the *mauka* areas of Dillingham Ranch. No evidence of agriculture (e.g., terracing, modified slopes) was identified on the steeper upland slopes. The steep grade, stony deposits, and associated active colluvial environments make it unlikely that agriculture would have been practical in these areas.

VII. CONCLUSION AND RECOMMENDATIONS

International Archaeology, LLC, completed an archaeological inventory survey of 75.3 acres of the proposed Dillingham Ranch Agricultural Subdivision. The inventory survey included a pedestrian survey of three project areas termed the "*mauka* lands" of the subdivision; site recording including text descriptions, photography, detailed feature mapping, and GPS recording; and, manual excavation of shovel test pits to test for the presence of cultural deposits and aid in feature function assessments. Four dry-stacked historical cattle walls were documented as components of Site 50-80-03-7653.

RECOMMENDATIONS

Site 50-80-03-7653 is recommended to be significant under Criterion d of the Hawai'i Register of Historic Places: the distribution and characteristics of the various historical walls provide information about ranching activities and land divisions. The site features have been recorded in detail and no further work is recommended prior to the initiation of development activities. Along with construction details, the locations of the walls have been recorded with submeter accuracy.

Although the springs noted during the survey are not culturally modified features, their potential correlation with the "Hidden Waters" recorded in oral history and by McAllister (1933) suggest that they should be protected from any adverse future effects from development.

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Appendix E

Traffic Assessment
Proposed Dillingham Ranch Agricultural Subdivision
Mokule'ia, O'ahu, Hawai'i

Traffic Assessment

Proposed Dillingham Ranch Agricultural Subdivision

Mokuleia, Oahu, Hawaii

May 1, 2014

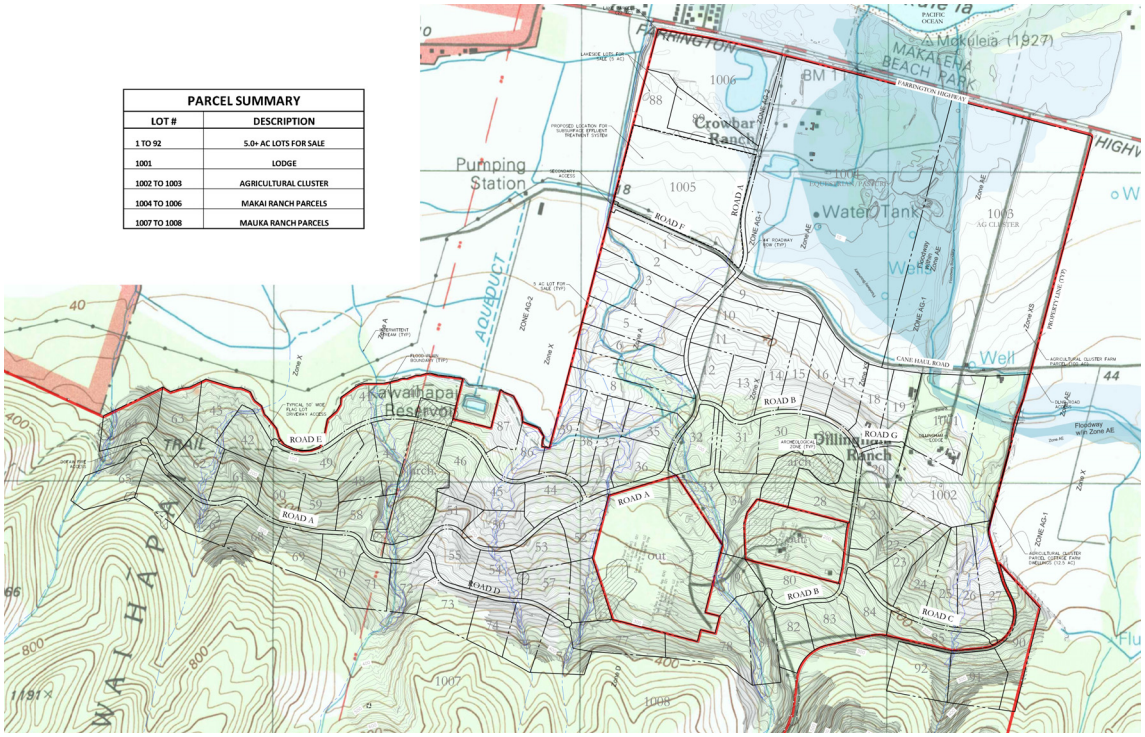
Summary

While the proposed subdivision could result in a relatively large increase in traffic volumes due to existing volumes being so low, a conservative analysis has shown that a simple connection to the highway will provide adequate capacity to minimize any delay or interruption to highway traffic. The project is not expected to have a significant impact to traffic conditions on Farrington Highway. The estimated peak hour volumes at the intersection of the project access road and the highway do not meet the guidelines for consideration of adding a separate left turn lane.

The intersection should be designed with adequate sight distance for drivers at a stop sign on the connecting street. The intersection should be clearly visible for drivers on the highway, and if necessary, warning signs on the highway should be considered to improve driver awareness of the new intersection.

Introduction

The proposed subdivision potentially could increase traffic volumes on Farrington Highway in the Mokuleia area. As illustrated herein, however, the existing highway will be able to handle the increases in traffic. Additional lanes at the proposed connection to the highway would not be warranted due to the low volumes. The property, adjacent to and east of Dillingham Airfield and south (mauka) of Farrington Highway, will be subdivided to create opportunities for the addition of up to 110 dwelling units. Figure 1 shows a conceptual plan of the proposed subdivision.



Source: Sherwood Design Engineers (Proposed Tentative Lot Mapping plan, April 15, 2014)

Figure 1 – Project Master Plan

Vehicular access will be provided by a dedicated project roadway that intersects Farrington Highway as the stem of a "T"-intersection. Traffic on the project roadway's northbound approach to the intersection will be controlled by a "STOP" sign. The project roadway, a two-lane roadway carrying traffic in both the northbound and southbound directions, will have a single lane on the northbound approach that will be shared by traffic making left turns and right turns onto the highway. Left turns into the project roadway will be made through gaps in the opposing traffic on the highway. The posted speed limit on the highway near this connection is 35 miles per hour.

Existing Traffic Conditions

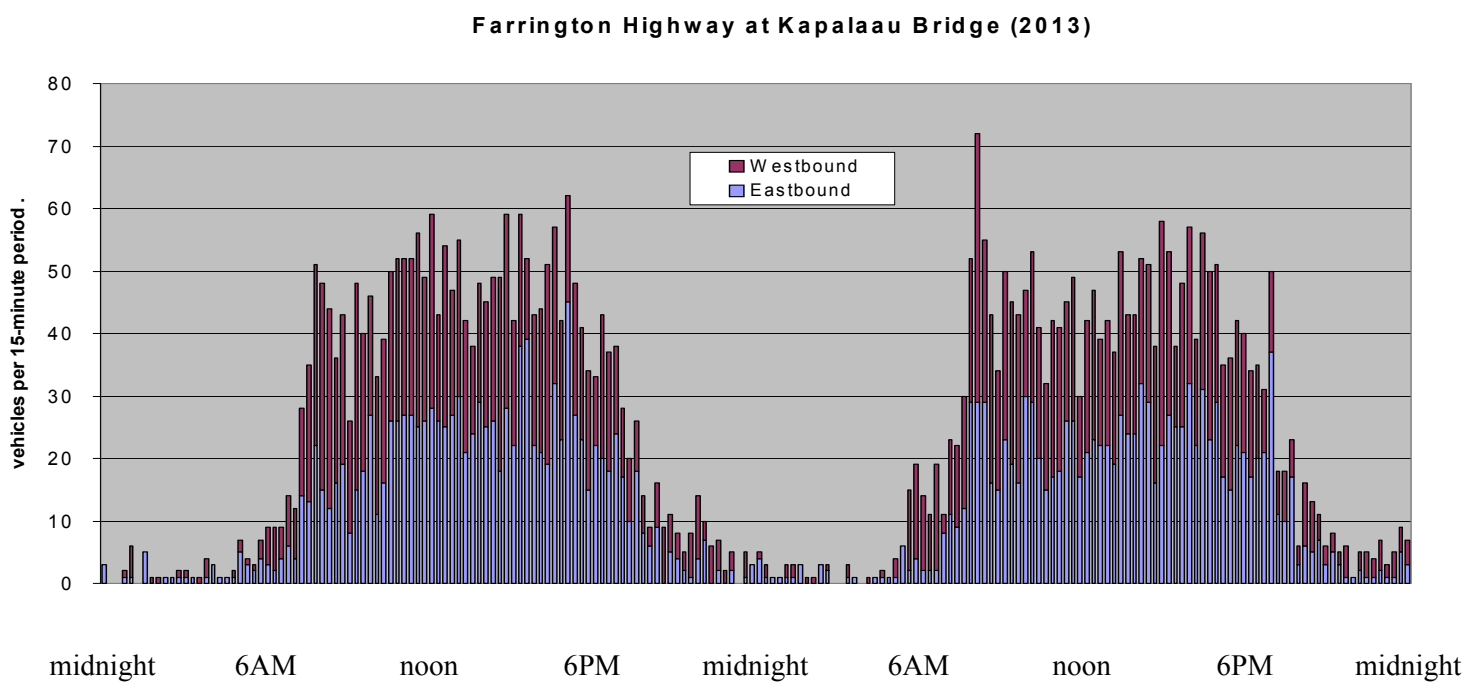
Traffic volumes on Farrington Highway are based on the latest available count data from a 48-hour traffic count taken by the State Highways Division on Farrington Highway at Kapalaau Bridge near the project site in March 2013; the daily totals and peak hour volumes from this count are shown in Table 1.

Table 1 – Existing Traffic on Farrington Highway

	24-hour total		AM Peak Hour		PM Peak Hour	
	Tuesday, March 12, 2013	Wednesday, March 13, 2013	Tuesday, March 12, 2013	Wednesday, March 13, 2013	Tuesday, March 12, 2013	Wednesday, March 13, 2013
Westbound	1,225	1,192	114	119	93	94
Eastbound	1,234	1,208	65	103	119	108
Total	2,459	2,400	179	222	212	202
Peak Hour			7:45-8:45 AM	7:45-8:45 AM	4:15-5:15 PM	3:45-4:45 PM

Source: State of Hawaii, Department of Transportation, Highways Division, Highways Planning Survey Section: Count data for Station B72093000215 (Farrington Highway at Kapalaau Bridge).

The traffic volumes are fairly constant during the day, as illustrated in Figure 2.



(counted March 12-13, 2013. Based on data from State of Hawaii Department of Transportation, Highways Division)

Figure 2 – Existing Highway Traffic

Project Impact and Peak Hour Intersection Conditions

The traffic impact of the proposed subdivision was evaluated for 110 dwelling units and one "lodge" lot. Agricultural use will typically generate only small volumes of traffic during peak hours; however, in order to determine the potential traffic impact, peak hour traffic volumes generated by the dwelling units were estimated using trip rates for suburban detached (single-family) dwellings from the Institute of Transportation Engineers. Use of these rates assumes that all residents commute regularly to work, school, shopping, and other activities. For the lodge, maintenance personnel could generate traffic during the peak hours; the typical weekday peak hour traffic generated by the lodge lot was estimated for five employees using the rates listed for hotels. Table 2 shows the estimates of peak hour traffic generation.

Table 2 – Traffic Generation

	AM Peak Hour		PM Peak Hour	
	Trip rate	% entering	Trip rate	% entering
factors per detached dwelling *	0.75	25%	1.00	63%
factors per lodge employee *	0.69	60%	0.80	54%
Project Traffic estimates	entering	exiting	entering	exiting
110 dwelling units	21	62	69	41
5 employees	2	2	3	2
Total site-generated traffic	23	64	72	43
* Source: Institute of Transportation Engineers, *Trip Generation, 9th Edition.*				

Because the existing traffic volumes are low, the potential impact to traffic volumes from the project will not be unnoticeable if typical suburban use of the lots were to occur. However, as shown below, even with the addition of project traffic and allowances for other traffic in the area to increase, the existing highway facilities would continue to serve peak hour traffic volumes adequately.

The project peak hour traffic volumes were assumed to occur during the same hour as the peak volumes on the highway. For the purpose of analyzing the proposed connection to the highway, the site-generated traffic shown in Table 2 was distributed 5% to and from the west and 95% to and from the east. The highway traffic movements are assumed to be through movements on the highway across the intersection created by the proposed access road. In addition, the existing peak hour volumes were factored to account for possible increases in traffic due to other non-project causes; while an increase of 50% is not expected (and can not be justified based on any known reason), such an increase was used to illustrate possible future conditions at the proposed connection to the highway. This increase could result in 20 years if an average annual increase in peak hour volumes of 2.05% were to occur (or over 25 years at an average annual increase of 1.63%). The traffic estimates at this location are shown in Figure 3.

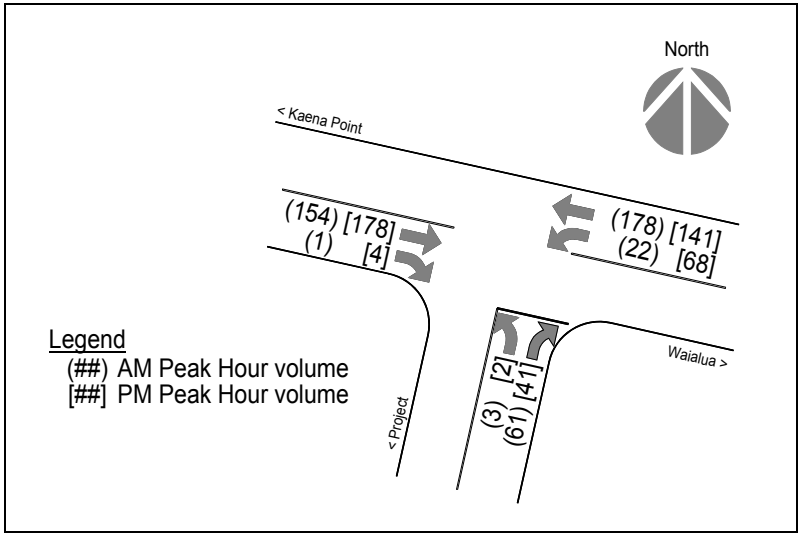


Figure 3 – Traffic Assignments

The procedure for unsignalized intersections described in the *Highway Capacity Manual*[1] *(HCM)* was used to analyze the intersection and acceptable conditions at the intersection were found, as summarized in Table 3. The analysis estimates average delays based on traffic volumes, these delays are described by "Levels of Service" for the controlled movements at the intersection; the *HCM* defines the Level of Service (LOS) for unsignalized intersections as follows (Level of Service D or better is considered acceptable):

LOS	General Description of Delay	Average Delay (seconds per vehicle)
A	Little or no delay	≤ 10
B	Short traffic delays	> 10 and ≤ 15
C	Average traffic delays	> 15 and ≤ 25
D	Long traffic delays	> 25 and ≤ 35
E	Very long traffic delays	> 35 and ≤ 50
F	Very long traffic delays	>50

[1] Transportation Research Board, National Research Council, *Highway Capacity Manual,* Washington, D.C., 2000.

Table 3 – Intersection Levels of Service (2030)

	Westbound left turns from highway		Northbound approach (shared lane at stop sign)	
Peak Hour	AM	PM	AM	PM
Volume/capacity ratio	0.02	0.06	0.09	0.06
95th percentile queue	0.05	0.18	0.28	0.19
Average Delay (seconds)	7.7	7.9	9.9	9.9
Level of Service	A	A	A	A

The level of service analyses show that left turns from the highway can be made with minimal delays and queuing on the highway is not expected. Nevertheless, the need for a separate left turn lane on the highway was also evaluated. The "green book" design manual published by the American Association of State Highway and Transportation Officials (AASHTO) provides a table showing conditions under which a separate left turn lane should be considered on two-lane highways. The AASHTO table is used to determine the advancing volume at which a separate turning lane should be considered. As shown in Table 4, the estimates of the advancing volume are less than the volumes at which a separate left turn lane should be considered.

Table 4 – Evaluation for Consideration of a Separate Left Turn Lane

	AM Peak Hour	PM Peak Hour
Proportion left turns (from Figure 3)	10%	30%
Opposing volume (eastbound, from Figure 3)	155	182
For an opposing volume of	200	200
Advancing volume above which a separate turn lane should be considered, for an operating speed of 40 miles per hour *	470	305
Advancing volume for consideration **	220	227
Consider separate left turn lane?	not necessary	not necessary

* Table 9-23 of *A Policy on Geometric Design of Highways and Streets (2011),* from American Association of State Highways and Transportation Officials, Washington, D.C.

** the larger of the advancing (westbound) volume shown in Figure 3 or the volume that would apply to attain the stated proportion of left turns

The analyses have shown that a simple connection to the highway with a stop sign controlling the side street will adequately serve future traffic volumes at the intersection. A single approach lane on the minor street that is shared by left and right turns would be adequate. A separate left turn lane on the highway is not warranted and will not be needed.

Conclusions

The proposed subdivision could result in a relatively large increase in traffic volumes (because existing volumes are so low) but a simple connection to the highway will provide adequate capacity to minimize delays. The project is not expected to have a significant impact to traffic conditions on Farrington Highway. The estimated peak hour volumes at the intersection of the project access road and the highway do not meet the guidelines for consideration of adding a separate left turn lane.

The intersection should be designed with adequate sight distance for drivers at the stop sign on the side street. The intersection should be clearly visible for drivers on the highway; if necessary, warning signs on the highway should be considered to improve driver awareness of the new intersection.

Appendix F

Agriculture Feasibility Report
Dillingham Ranch Subdivision
Mokule'ia, O'ahu, Hawai'i

DRAFT

AGRICULTURE FEASBILITY REPORT

DILLINGHAM RANCH SUBIDIVSION

MOKULEIA, OAHU, HAWAII

VOLUME 1

Prepared For:

Dillingham Ranch Aina, LLC
c/o Kennedy Wilson International
9701 Wilshire Boulevard, Suite 700
Beverly Hills, California 90212

Prepared By:

Development Strategies, LLC
1432 Kalaepohaku Street
Honolulu, Hawaii 96816

and

North Shore Pineapple Company
907 10th Avenue
Honolulu, Hawaii 96816

July 2014

Preface

This Agricultural Feasibility Report ("Report") has been prepared in compliance with the provisions of Section 1-115 of the Subdivision Rules & Regulations ("Subdivision Rules") which contains additional conditions for the subdivision of agricultural land in the City & County of Honolulu ("City"). Specifically, Section 1-115 requires that agricultural subdivisions show that the subdivision will provide feasible agricultural use . . . and that covenants and restrictions will exist to require that the subdivided properties will be put to agricultural use in conformity with applicable Federal, State and City laws and regulations.

Volume 1 provides an overview of the properties that comprise the Dillingham Ranch and the agricultural operating that are presently conducted on the property. Subsequent sections of the Report detail the Regulatory Environment and Agricultural Considerations before introducing the Subdivision Concept and a discussion of the Supporting Infrastructure. The foregoing provides a frame of reference as to the Agriculture Concept which is based on a restructuring of present agricultural operations to focus on a core activity of cultivating selected orchard crops for the local marketplace.

Volume 2 of the Report presents the Agriculture Plan for the commercial production of mango, avocado and citrus to replace imported produce with a reliable supply of high quality, locally grown produce. Volume 2 documents relevant growing site conditions for the selection of the fruit crops and selects the crops based on market potential, suitability for cultivation at the Ranch and crop specific agricultural requirements. Volume 2 also includes the Preliminary Farm Management Plan for the screening and selection of the best mango, avocado and citrus cultivars to meet to meet production and fruit quality considerations for the production of tree fruit crops at the Ranch. In addition, the Preliminary Farm Management Plan discusses the production and sales and marketing plans, crop specific agricultural practices, important pests and diseases, harvesting and storage.

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Introduction

Dillingham Ranch (the "Ranch") is situated on 2,721 acres of land in Mokuleia, Oahu, Hawaii. The Ranch has been engaged in cattle production since the early 1900s unlike the adjacent properties which cultivated sugarcane. Dillingham Ranch Aina, LLC ("DRA"), the sole owner, plans to restore the Ranch as the heart of the Mokuleia community.

As part of the transition, agricultural operations of the "Working Ranch" will be refocused on the cultivating selected orchard crops targeted for the Oahu market. Analysis of agricultural data for the State of Hawaii indicates that thousands of pounds of mango, avocado and citrus is imported from the continental United States, Central America and South America. The cultivation of selected, high quality orchard crops is designed to put underutilized portions of the Ranch into active production, with minimal transportation costs creating a price differential over out-of-state imports.

In order for orchard crops to be cultivated and harvested efficiently, 28 five acre "Orchard Lots" (total 160 acres) and a 95 acre ag field that is part of an Agricultural Cluster Development would participate in a cooperative venture with the Working Ranch. This would enable the Working Ranch to coordinate farming activities to assure the regular rotation of irrigation, controlled application of fertilizers/pesticides/herbicides and timely harvesting to maximize yields of fresh, marketable produce. Managing the orchard crops on a coordinated, commercial basis will be essential to assure the efficiencies required to minimize production costs and surplus inventories.

As part of the foregoing, a unique "Ag Cluster" concept has been discussed with the Department of Planning & Permitting ("DPP") which would maximize the cultivation on a 95 acre parcel with highly productive soils. To enable this, the Ag Cluster would employ a "Joint Development Agreement" to link two parcels and permit placement of the related farm housing units on the adjacent property closer to subdivision infrastructure and utilities. The concept has received favorable consideration by DPP as cluster developments are encouraged by the Land Use Ordinance.

In keeping with the historical aspects of the Ranch, cattle production will remain a significant activity and the present herd (66 head) will be increased over time to 220 to 250 head to gain operating economies. While the increase in the herd size is intended to bolster cattle production, this is also part of a prudent program of land stewardship to reduce excessive vegetation to minimize the potential for uncontrolled wild fires. Related benefits include the protection of critical habitats, enhanced watershed management and buffering of the forest reserve owned by

the State of Hawaii ("State"). In addition to grazing cattle in the mauka areas of the Ranch, 16 subdivided lots ("Grazing Lots") in the upper tier of a new agricultural subdivision planned for the property will participate in a cooperative venture for cattle production with the Working Ranch.

Equestrian activities have long been identified with the Ranch and will be expanded through upgrading training facilities, individual and semi-private paddocks and irrigated open pasture areas for the boarding of horses. The "managed pasture" areas in the makai portion of The Flats will provide enhanced opportunities for equestrian activities such as dressage, quarter horse competitions, a Mokuleia Derby and Pony Club events.

A total of 48 five acre lots (the "Pasture (Flex) Lots") will be available to individuals wishing to pursue other ag activities not involving participation in cooperative ventures with the Working Ranch. However, all subdivided lots in the "Agricultural Subdivision" will be subject to recorded agricultural covenants requiring the land be used for bona fide agricultural activities. While revenue from the individual activities on the Pasture Lots will accrue solely to the owners, the Ranch may benefit through related services such as lot maintenance and irrigation management.

Non-agricultural activities, such as rental of the historic Dillingham House for special functions, photo shoots and filming, are anticipated to remain part of the Ranch but revenue will likely remain level. Future agribusiness activities are planned to encompass site tours, farm-to-table crops and fresh herbs, an enhanced "roadside stand" for marketing of products grown on the Ranch and an outdoor restaurant featuring a menu incorporating produce, meat, fish and other products from the "breadbasket of Mokuleia."

The foregoing activities, particularly the cultivation of orchard crops, will generate operating revenues to enhance the long-term viability of the Ranch. However, these agricultural ventures are dependent on improvements to the existing facilities. DRA recognizes that current operations do not justify capital investment in infrastructure improvements and plans to generate capital through the subdivision and sale of agricultural lots in a new Agricultural Subdivision to fund the necessary upgrades. The new infrastructure systems will also service the existing Ranch facilities and provide the basis for restructuring the operations of the Working Ranch.

Overview

Location: The Ranch is located in Mokuleia on the North Shore of Oahu (Figure 1). The property stretches from the frontage

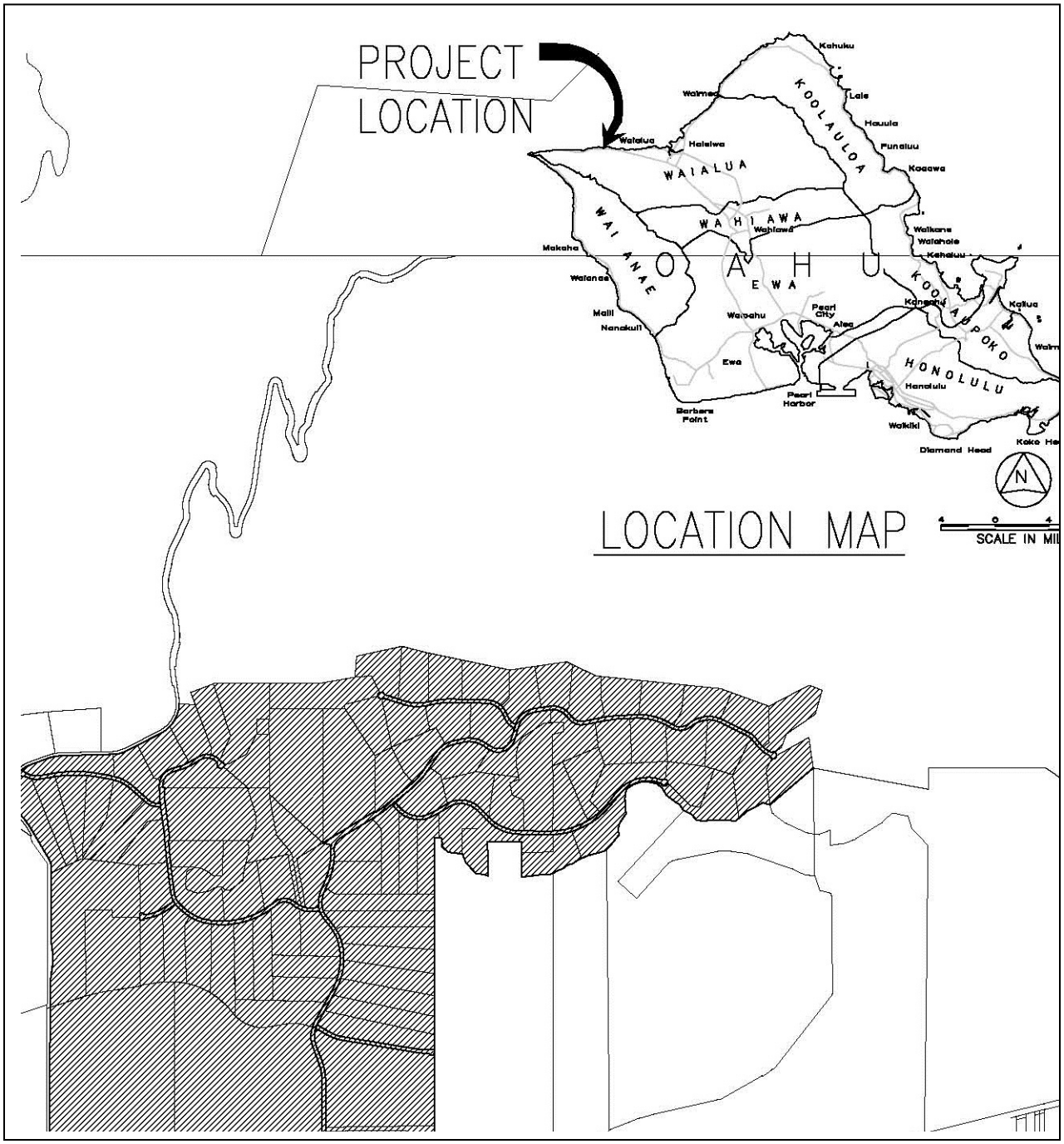


Figure 1: Location Map

along Farrington Highway up the slopes of the Waianae Mountains to the boundary with the State forest reserve.

Land Area: The perimeter of the Ranch encompasses approximately 2,778 acres, which includes two properties (TMK: 6-8-03: 21 & 34) owned by other parties. The net area of the parcels owned by DRA is 2,721 acres

Tax Map Keys: The existing parcels that comprise the Ranch are identified by the following Tax Map Keys:

TMK	Land Area
6-8-03:05	433.41
6-8-03:06	927.75
6-8-03:15	72.98
6-8-03:19	36.81
6-8-06:30	16.96
6-8-03:31	57.64
6-8-03:33	9.52
6-8-03:35	2.10
6-8-03:40	140.09
6-8-02:06	1,023.66
Total Acres:	2,721.02

Zones: Putting the existing legal parcel boundaries aside, the Ranch is naturally segregated into three distinct zones by the topography of the land (Figure 2):

The Flats - This zone encompasses the area of the Ranch starting at Farrington Highway and extending inland for a distance of approximately ¾ of a mile. The terrain is relatively level, with slopes less than 2% by Farrington Highway increasing to 5% at the transition into The Foothills at an elevation of about 60'. This low lying portion of the property encompasses approximately 320 acres.

An existing coconut tree farm, horse paddocks and equestrian facilities occupy the marginally higher areas of The Flats, with the remaining areas used for open pasture or fallowed. A historic structure, the "Dillingham House" and its related grounds presently occupy about 40 acres at the southeast corner of The Flats. The Dillingham House (aka "The Lodge") was constructed by Walter Dillingham in 1917 as a country retreat for his family and friends. The structure was completely restored in 2009.

A large pond is located in the northwest corner of the Ranch, just to the right of the main entrance into the Ranch. The pond, a former sand mining pit, was created through gradual filling by storm water runoff over the years and is now an artificial wetland.

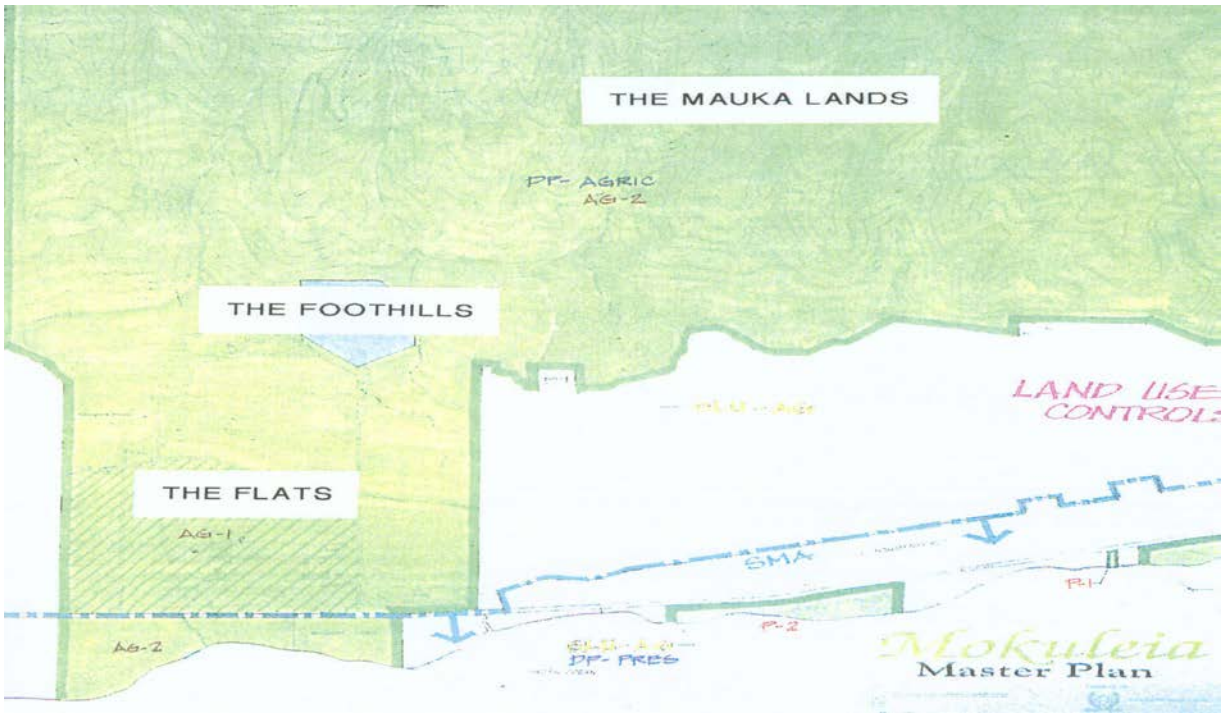


Figure 2: Zones

<u>The Foothills</u> - This is the transitional portion of the property ranging in elevation from roughly 60' to 400'. Although the landform undulates in an east–west direction, slopes steadily increase in steepness from about 5% to 25%+ with the rise in elevation into the Waianae Mountains. The Foothills encompass roughly 560 acres that is presently used to graze cattle. This area will be the location of the new Agricultural Community.

<u>The Mauka lands</u> - In the large area above The Foothills, the property continues to rise up to the boundary with the State forest reserve at about 1,100 feet. Slopes in The Mauka Lands vary considerably, but can exceed 25% to 40% along the mauka-makai ridgelines. The Mauka Lands comprise approximately 1,900 acres of the property.

The Mauka Lands were previously used to graze cattle, but this activity has been curtailed by the inability to deliver water to higher elevations of the Ranch. Plans contemplate the construction of new water lines to deliver water to troughs to be located in The Mauka Lands.

Adjacent Uses: Lands to the east of the Ranch were historically owned by Castle & Cooke, Inc. and leased to its agricultural arm, Waialua Sugar Plantation, for the cultivation of sugarcane (Figure 3). Sugar operations were terminated in the late-1980s due to cheaper production costs in other States and foreign countries. Most of the lands have been purchased by Pioneer Hi-Bred International for their seed corn operation which can grow 2 to 3 crops per year in Hawaii.

Figure 3: Adjacent Land Uses (Prior to 1990)

Lands to the west of the Ranch are still owned by Castle & Cooke, Inc. and are leased to Larry Jeffs. The property is cultivated in bananas and other crops. Further west is the Dillingham Airfield which is administered by the Airports Division of the State Department of Transportation.

Ranch Operations: The Working Ranch generated income from three primary agricultural activities in 2013:

Cattle Production – A herd of approximately 66 head, 64 heifers and 2 bulls are currently grazed in The Foothills, with 52 calves born each year. Weanouts are sold to other local ranches roughly every quarter. Annual revenue amounted to $17,200 in 2013. The current size of the herd is down significantly from 2007 when there were about 130 head which produced revenue of $30,100. The cattle market today favors shipping weaned calves to West Coast buyers, where they are resold to finishing lots. Unfortunately, at the present scale of production this is not a viable option.

Coconut Trees – The coconut tree farm has a large inventory of field stock landscape material on about 40 acres in the northeast corner of The Flats adjacent to Farrington Highway. Currently the field stock trees line both sides of the long access road to the Dillingham House.

The trees are mostly mature and starting to reach heights of 30'+. This does not command premium pricing as landscape material due to the difficulties involved in excavating and handling material of this size – all of which is done at the cost of the landscape contractor. For the past several years, the market for coconut tree sales has been impacted by the decline in resort and golf course development. Annual revenue from the sale of coconut trees in 2013 was $3,100. In 2007, field stock coconut trees generated revenue of $326,000.

Horse Boarding – In 2013, boarding was available in private, single horse paddocks for $ 250/month, semi-private paddocks for $350/month and multi-horse, mixed pasture areas for $200 per house/month. Approximately 75 horses are presently stabled at the Ranch generating revenue of $205,800. For an additional fee of $100/month arrangements can be made for a tack area and feed storage shed. In 2007, revenue from boarding 100 to 110 horses was $226,000.

Other Income: Commercial Filming/Photo Shoots - Non-agricultural income was generated by rental of the property for commercial filming and photo shoots. This may or may not include separate rental of the fully restored Dillingham House. Income in 2013 was $18,300.

Large Special Events - The Dillingham House has an approved Variance that permits limited commercial use of the historic structure for meetings, community gathering, special events and social functions. A separate Special Use Permits allows two large (300 guests) functions to be held each month at the Dillingham House and the outdoor lawn area. Such functions must have the food and beverage service catered as a restaurant is not permitted by the Variance. No rental of the Dillingham House is permitted for overnight stays. Revenue from the rental of this historic facility amounted to $64,300 in 2013. In 2008, revenue was $31,800 through May, after which reservations for further functions were placed on hold due to initiation of restoration work on the historic structure.

Regulatory Environment

State Land Use: The Ranch is located within the State Land Use Agricultural District (Figure 4). Chapter 205 of the Hawaii Revised Statues ("HRS") limits use of agricultural land to the "Permitted Uses" identified in Section 205-4.5.

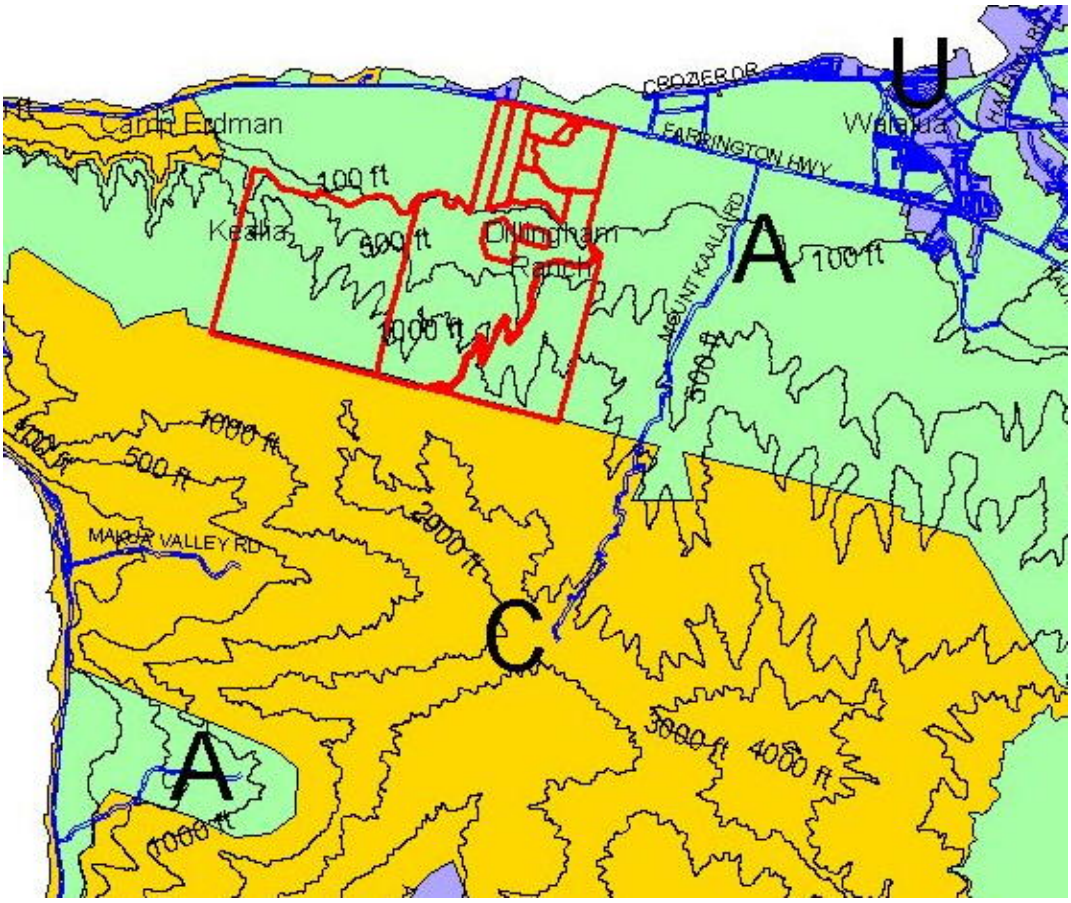


Figure 4 – State Land Use

County Zoning: The parcels comprising the Ranch are zoned AG-1 Restricted Agriculture or AG-2 General Agriculture. AG-1 zoned lands are located in about 100 acres of land the central and eastern portions of The Flats on fertile soil deposited by the Makaleha Stream (Figure 5). The remainder of the Ranch is zoned AG-2.

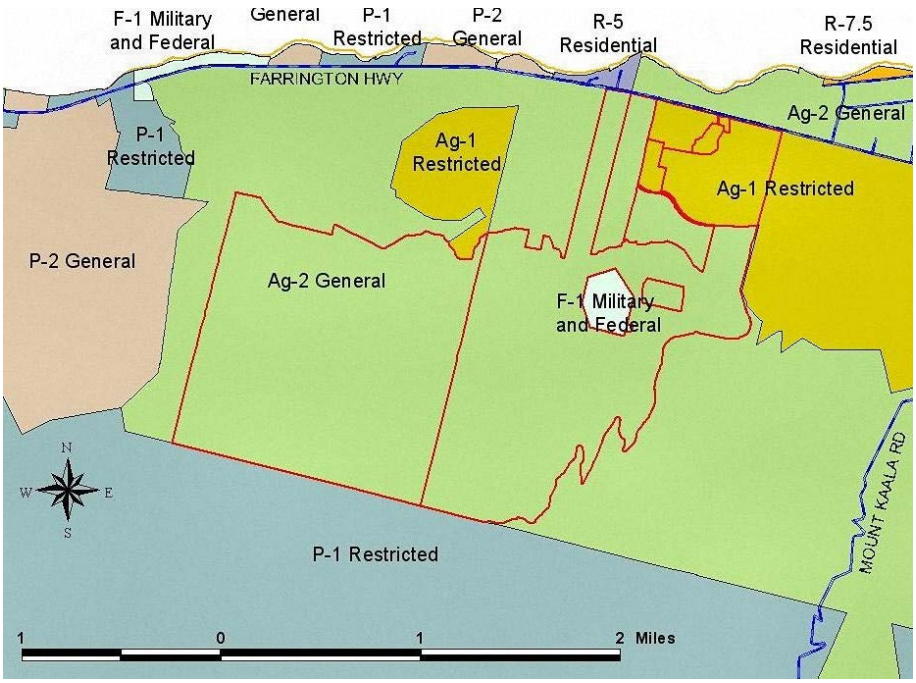


Figure 5 - Zoning

AG-1 – The intent of the Restricted Agricultural District is to preserve and protect important agriculture lands the production of food, feed, forage, fiber corps and horticultural plants. Minimum Lot Size is 5 acres.

AG-2 – The intent of the General Agricultural District is to protect and preserve agricultural activities on smaller parcels of land. Minimum Lot Size is 2 acres.

<u>Other Regulatory Considerations</u>

Sustainable Plan: The North Shore Sustainable Communities Plan establishes a “Rural Communities Boundary” within which urban uses such as commercial structures and residential subdivisions are restricted. The Ranch is located outside of the Rural Communities Boundary in an area designated for the preservation of agriculture.

Subdivision: The City’s Subdivision Rules incorporate special provisions for the subdivision of agricultural land. In addition to an agricultural feasibility report, the requirements include:

- Verification by the Board of Water Supply ("BWS") of the availability of sufficient non-potable water to support agricultural use of the subdivided lots. Note: BWS no longer provides this verification. DRA is working with the Safe Drinking Water Branch of the State Department of Health and the Commission on Water Resource Management of the State Department of Land & Natural Resources to address this requirement.
- Recordation of agricultural covenants requiring the lot purchasers to maintain the land in agricultural use is attached as Appendix A.
- Disclosure to perspective purchasers that the subdivided lots must be used for bona fide agricultural activities.

Flood Hazard: The Flood Hazard Map for the Mokuleia indicates a floodway (Zone AEF) and a floodplain (Zone AE) encumbers the central area of The Flats (Figure 6). These areas would be subject to flooding from a 100 year storm.

- Zone AEF: This designates the primary floodway where storm water flows would be swiftest and deepest. The construction of vertical structures is not permitted in Zone AEF but this restriction does not apply to agricultural crops.
- Zone AE: A floodplain that is subject to inundation that is less severe than a floodway. The construction of vertical structures would be subject to special requirements, including raising the lowest habitable floor above the Base Flood Elevation. Flood Insurance would be required.
- Zone A: This designation covers an area of The Flats to the West of Road A that is subject to inundation that has not been studied in sufficient detail to determine the depth of the flood waters or the Base Flood Elevation. Flood Insurance would be required.

The minimally sloping area of The Flats comprises the alluvial fans for the Makaleha Stream and Stream 4A, 4B and 4C. Prior to 1990, sugarcane was cultivated on lands to the east and west of the Ranch. However, the cultivation of sugarcane was not possible on The Flats as the dense crop would impede storm water runoff into the adjacent lands.

One of the reasons for selecting orchard crops is that the loose spacing to permit canopy spread allows the passage of storm water runoff. This will enable makai areas of the Ranch to be put to productive use.

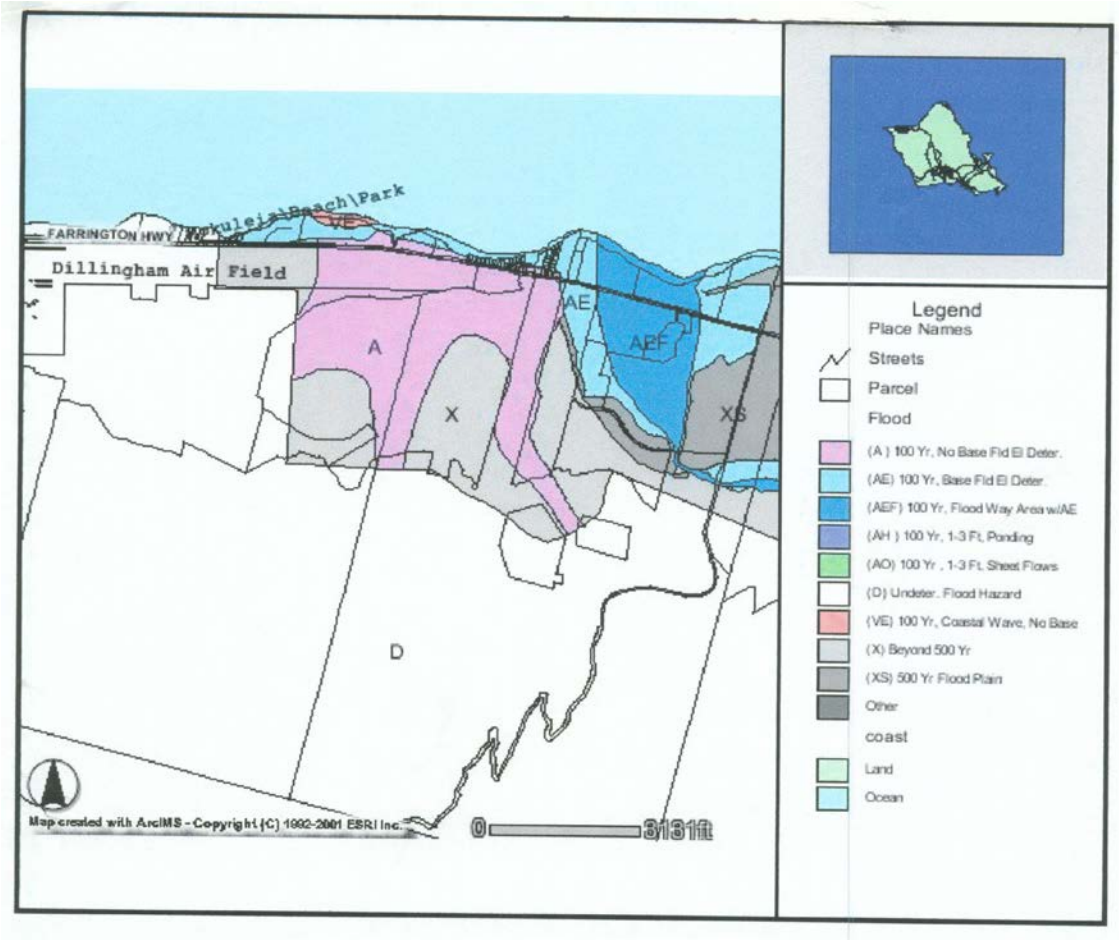


Figure 6 – Flood Hazard

The remaining areas of the Ranch are designated Zones X (minimal flood hazard) and D (unstudied areas where flood hazard undetermined). Due to the sloping topography, storm water runoff naturally flows into existing ravines and gullies. Flood insurance would not be required.

SMA: The Ranch is not located within the Special Management Area that extends from the shoreline to the middle of the right-of-way for Farrington Highway.

Agriculture Considerations

Soil Suitability: The Soils Survey of the Islands of Kauai, Oahu, Maui, Molokai and Lanai; State of Hawaii (1972 USDA Soil Conservation Service) indicates that the soils on the Ranch range in suitability for cultivation from highly productive in The Flats, transitioning to steep and rocky in The Mauka Lands (Figure 7).

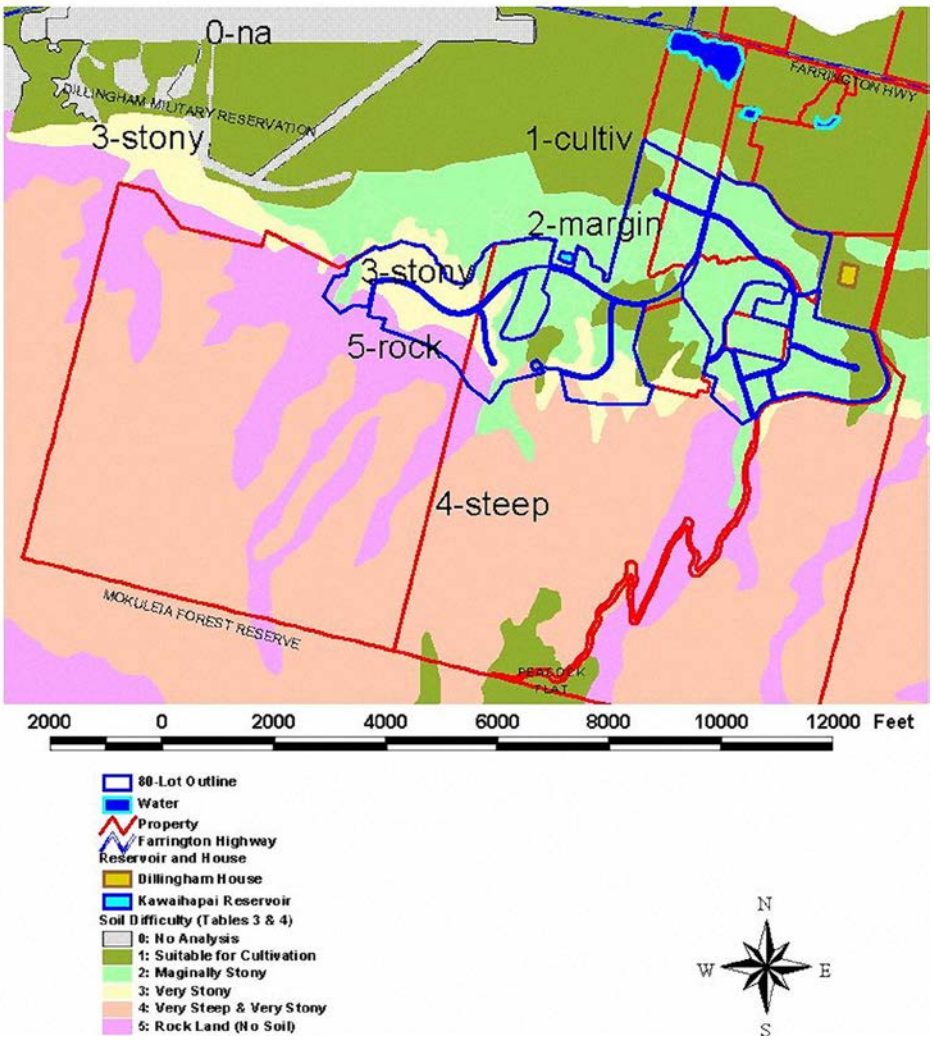


Figure 7 - Soils

Eight soil series (Ewa, Haleiwa, Kaena, Kawaihapai, Mokuleia, Pearl Harbor, Pulehu and Rockland) occur within The Flats and The Foothills.

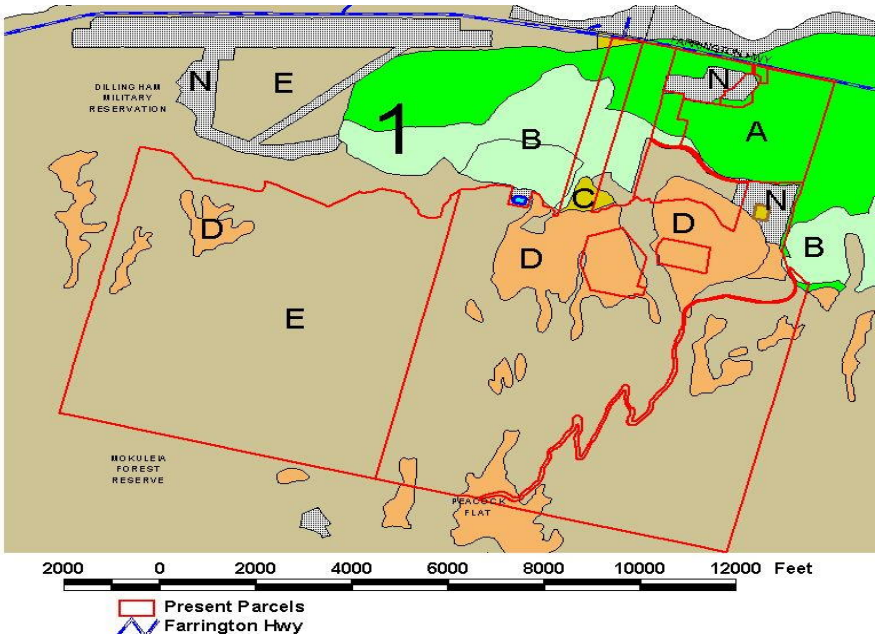


Figure 8 - LSB Rating

Soil Productivity: The Land Study Bureau of the University of Hawaii ("LSB") prepared an inventory and evaluation of the State's land resources during the late 1960s and early 1970s. A five tier productivity rating was established utilizing the letters "A" to "E" based on climate, topography, history of crop production and, in particular, soil properties such as texture, structure, depth, drainage, parent material and stoniness. "A" represents the soils with the highest productivity rating, all five productivity ratings are found on the Ranch (Figure 8), with the "A" soils in The Flats and lower portions of The Foothills, transitioning to "E" rated soils in The Mauka Lands.

ALISH: In the early 1970s, the DOA produced an independent soil classification system entitled Agricultural Lands of Importance to the State of Hawaii ("ALISH"). Under this ALISH system, soils are rated Prime, Unique or Other Important Agricultural Lands - Class 1 to 3 in terms of significance for crop production (Figure 9):

Class 1 – Prime Agricultural Lands are those best suited for the production of food, feed, forage and fiber crops. These lands have the soil quality, growing season and moisture necessary to economically produce sustained high crop

yields when treated and managed in accordance with modern farming methods.

Class 2 – Unique Agricultural Lands are lands other than Prime Lands used for the production of specific high-value crops. Unique Lands have special qualities that make them ideal for the production of a specific crop, such as coffee, taro, rice, watercress and non-irrigated pineapple.

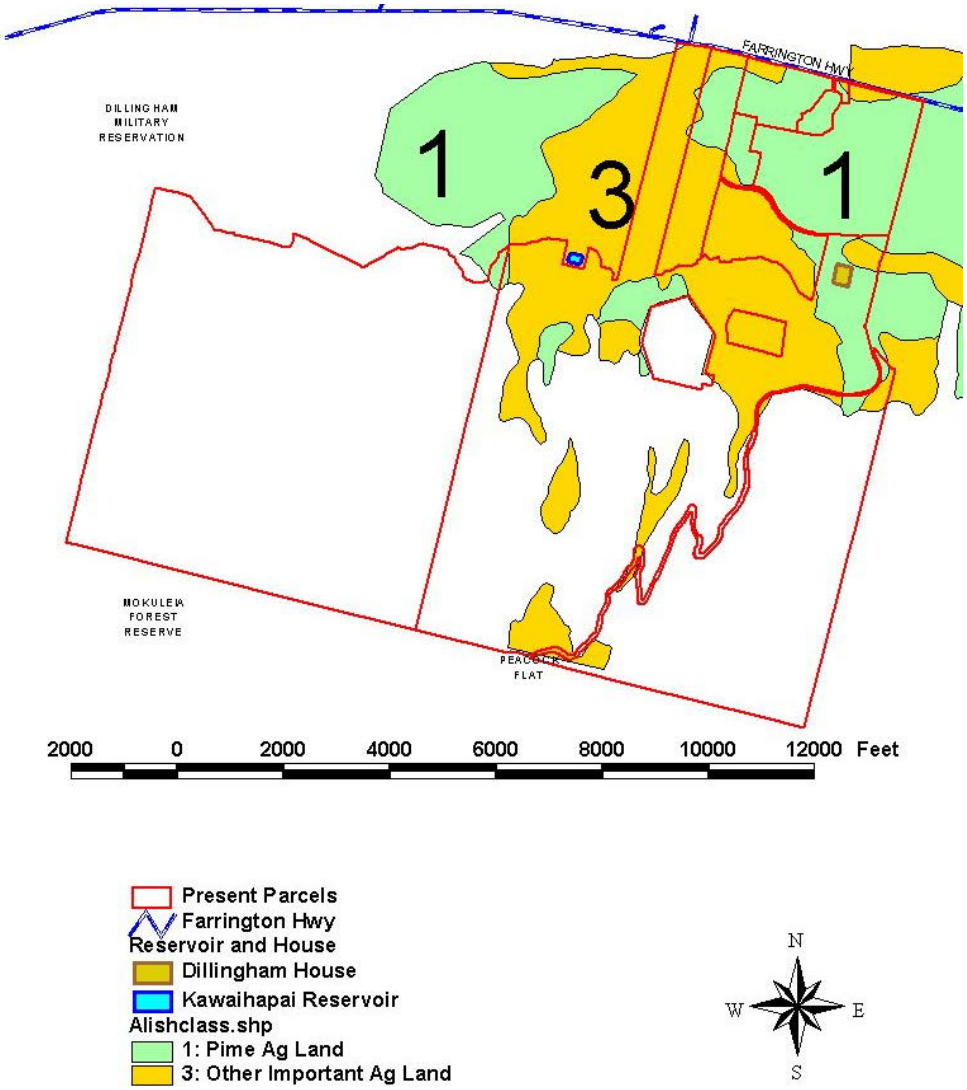


Figure 9 - ALISH

Class 3 – Other Important Agricultural Lands encompass lands of statewide or local importance for the production of food, feed, fiber and forage crops. Other Important, Lands

are prone to limitations, such as seasonal wetness, potential for erosion, limited rooting zones, slope, flooding or impacts from drought conditions. These lands are successfully farmed through the application of greater amounts of fertilizers, soil amendments, drainage improvements, flood protection, erosion control, and terracing and appropriate irrigation systems.

Less suitable soils are Unclassified.

Silty clay soils in The Flats are classified Prime and Other Important Agricultural Lands. Soils in the lower elevations of The Foothills are also classified Other Important Agricultural Lands.

Climate: The primary components shaping the climate of the Mokuleia area are:

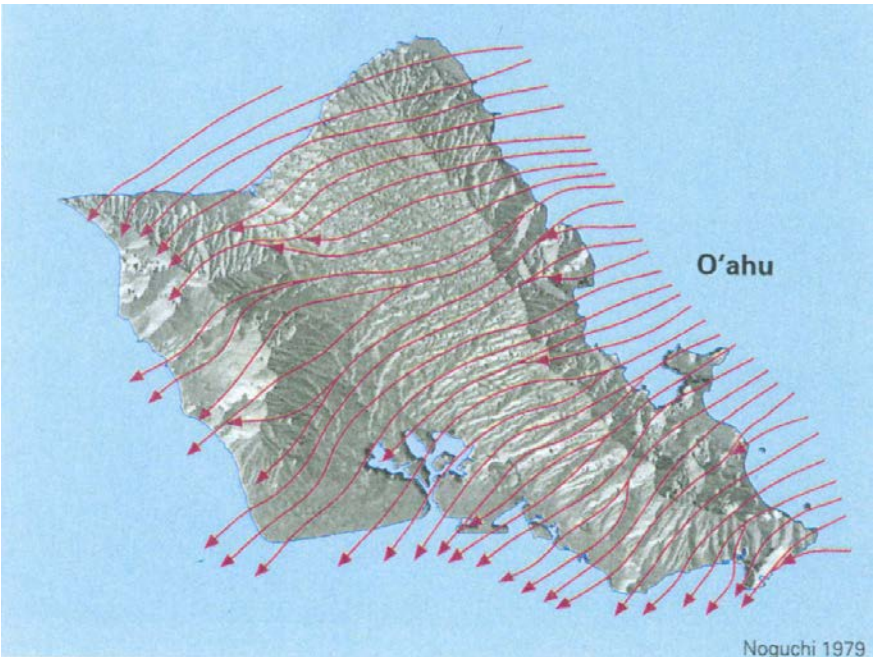


Figure 10 - Prevailing Wind

Prevailing Wind – Typical wind direction is from the east-northeast, with the breeze coming on-shore from the ocean (Figure 10). The "tradewinds" are fairly constant, with speeds of 15 to 25 miles per hour.

Precipitation – The Mean Annual Rainfall for Mokuleia is approximately 34 inches per year (DLNR Report R76. Rainfall Atlas of Hawaii, June 1986). Rainfall data from the Kawaihapai Station 841 indicates average annual rainfall is about 35 inches.

Annual precipitation in the Mokuleia area is well below the annual requirement of 70 inches for most leafy crops, including pasture grass. The precipitation pattern is also highly seasonal, with most of the rainfall occurring during the "winter season" from November to April.

Temperature – Day time temperatures range from the mid-70s to the mid-80s, with cooler temperatures prevalent at higher elevations. The annual average temperature is about 74 degrees (Fahrenheit).

Solar Radiation – Despite its north facing orientation, the Ranch receives over 200 watts/square meter of solar radiation, which is ample for plant growth.

Subdivision Concept

The 10 bulk parcels that presently comprise the Ranch (net of the two parcels that are owned by Coastalview Properties, LLC) will be consolidated and resubdivided to create 8 reconfigured bulk parcels and 92 five acre agricultural lots as depicted on the subdivision map (Figure 11).

Bulk Parcels: Parcels 1001 to 1008 will be used for various agricultural activities and support facilities as follows:

Parcel	Description	Area	Use	Ownership
1001	Dillingham House	14	Meetings/Events	HOA
1002 1003	Ag Cluster Farm Homes Orchard Field	25 95	Housing/Floral Crops Mango/Coconut Trees	CPR Housing Unit Owners (Ag Cluster)
1004	Pasture	126	Equestrian/Paddocks	DRA
1005	WWTP-Leach Field	14	Pasture (sub surface leach field)	DRA
1006	Artificial Lake	22	Scenic Amenity	HOA
1007 & 1008	Grazing	1906	Cattle Production	DRA

Agricultural Cluster Development: The innovative "Ag Cluster" concept will be employed in Parcel 1003 to maximize use of the Prime rated soils for mango production. The farm housing units will be located mauka of the Cane Haul Road on Parcel 1002. The two parcels would be linked by a Joint Development Agreement and treated as a single project:

- Ag Field: Each of the 15 farm housing units will have an undivided, fractionalized interest in the ag field equal to 6.3 acres (95acres/15 housing units = 6.3 acres/housing unit). This exceeds the 5 acre Minimum Lot Size for the AG-1 zoning.

- Farm Housing: A condominium property regime will be used to create 15 "CPR Units" on Parcel 1002. Each CPR Unit would have a maximum land area of 5,000 SF in compliance with DPP's Building Polygon that restricts the land area for a dwelling and related amenities in the Agriculture Districts (Appendix B).

The remaining land area within Parcel 1002, net of the 15 CPR Units, would allow for vehicular circulation, utilities, drainage and landscaping. The cultivation of ornamentals and flowering plants is also contemplated on Parcel 1002 in the area to the east of the Dillingham House. No additional CPR Units will be

created and both Parcels 1002 and 1003 will be subjected to recorded covenants restricting use of land to bona fide agricultural activities.

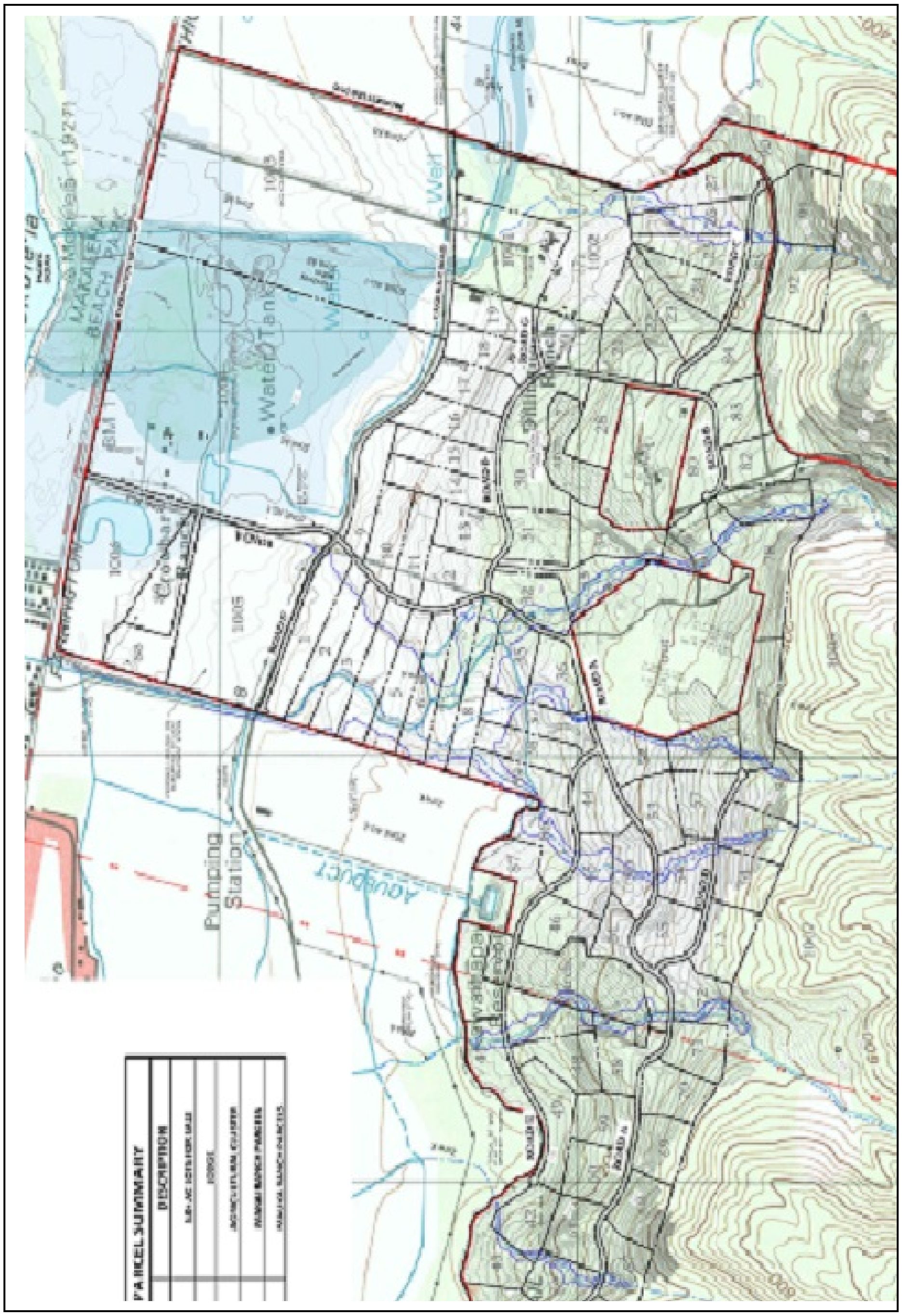


Figure 11 – Subdivision Map

Subdivided Agricultural Lots – All of the lots in the Agricultural Subdivision will be subject to recorded covenants restricting use of the land to bona fide agricultural activities. In addition, the 5,000 SF Building Polygon will be applicable to each dwelling to be constructed on a 5 acre agricultural lot.

Lot Type	Lot Numbers	Description	Area	Use
Orchard Lot	1-19, 29-32, 35-39	Cooperative Fruit Production w/Ranch	160 ac	Mango, Avocado, Citrus, Other Fruits
Pasture (Flex) Lot	20-28, 33-34, 40-64, 78-89	Pasture & Individual Farm Operations	287 ac	Alternative Ag Activities
Grazing Lot	65-77, 90-92	Cooperative Cattle Production w/Ranch	72 ac	Grazing – Rotating w/Mauka Lands

Orchard Lots – Orchard Lots will participate in a cooperative venture with the Working Ranch in the commercial production and marketing of high quality mango, avocado and citrus fruits. A detailed Agriculture Plan covering the selected orchard crops is presented in Volume 2 of this Report.

Grazing Lots – Lots located adjacent to The Mauka Lands will participate in a cooperative venture with the Working Ranch on cattle production. Regular rotation for uniform grazing will be done in The Mauka Lands and on the Grazing Lots. The natural pasture on the Grazing Lots will not be irrigated, except for a 10,000 SF area immediately around the Building Polygon.

Pasture (Flex) Lots – The remaining 48 lots are intended to provide flexibility for purchasers desiring to pursue individual agricultural activities, ranging from the pasturing of personal horses or the cultivation of various crops including ornamental plants, landscape material. Water for domestic use and irrigation will be available to each Pasture Lot, but irrigation will be coordinated on a rotating basis as to assure adequate pressure for domestic uses.

Support Infrastructure

Water: Existing Water Sources - Four wells with water allocations from the State Commission on Water Resource Management ("CWRM") are located within the Ranch:

Well No.	Location	Resignation	Allocation	Status
3410-01	Makai	Potable	500,000 GPD	Active
3410-03	Makai	Agriculture	1,500,000 GPD	Active
3310-01	Mauka	Potable-Ag	1,250,000 GPD	Capped
3310-02	Mauka	Potable-Ag	850,000 GPD	Capped

- Well 3410-01 is owned by the North Shore Water Company, LLC ("NSWC") which provides domestic water service to customers in the Mokuleia area to the west of the Ranch. All of the Mokuleia water users are located on the makai side of Farrington Highway. The Safe Drinking Water Branch ("SDWB") has oversight of the private water system identified as PWS No. 326. NSWC has easements for the well and a transmission main running down to Farrington Highway. Well 3410-01 and the water distribution system do not have the capacity to provide fire flow protection.

- Well 3410-03 is the source of agricultural water for the agricultural activities on the Ranch. Service is limited to the lower portion of The Foothills and The Flats. Well 3410-03 produces high quality water that is used limited domestic purposes at the Dillingham House and employee housing units. Well 3410-03 has been upgraded, but the existing irrigation distribution system is old and needs to be replaced to support irrigation of future orchard crops. The direct pump system has no water storage facilities.

- Wells 3310-01 and 02 are located in the mauka portion of the Ranch on TMK: 6-8-03:05, just east of the Department of Land & Natural Resources access road to the State forest reserve ("DLNR Road"). The wells were drilled by Northwestern Mutual Insurance Company in the 1980s for a contemplated golf course and housing development and have water allocations from CWRM.

Projected Water Demand - The estimated demand for the new Agricultural Community and the restructured operations of the Working Ranch are as follows:

Irrigation - Parcels & Lots:		
• Zone 1- Well 3410-03	1,638,196	
• Zone 2 – New System	999,267	
Sub-Total		2,637,463
Livestock:		
• Cattle - 250 head	18,750	
• Horses - 100	7,500	
Sub-Total		26,250
Domestic Use:		
• Farm Dwellings – Lots	69,000	
• Individual Crops/Landscape	103,050	
• Ag Cluster Dwellings	7,500	
• Dillingham House	2,000	
Sub-Total		181,550
Mokuleia Community (NSWC)		133,596
	TOTAL	2,951,149

Future Irrigation System – Well 3410-03 will be the source of irrigation water for the agricultural operations on The Flats and the Orchard Lots in the lower elevations of The Foothills. The ag water distribution system upgrades, including "typical" on lot layouts, are discussed in Volume 2.

New Water System - Subdivision of the Ranch property will require development of a completely new water system to service the subdivided agricultural lots. The New Water System will also provide fire flow and irrigation for farms located on the Pasture Lots. This will require drilling two new sources of potable water. A draft of the Water Master Plan is attached hereto as Appendix C.

The New Water System will be designed and constructed with the pump capacity, storage and distribution network sized to meet the standards of the Honolulu Board of Water Supply (“BWS”). Except for water line connections that must run through certain lots to minimize potential stagnation issues, all water mains will be located within the roadway network for the subdivision. Laterals will be extended from the mains into each Lot, with backflow (anti-syphon) valves to prevent contamination of the potable water supply.

North Shore Water Company - The NSWC has expressed an interest in possibly purchasing water in bulk from the New Water System in order to provide a more reliable source of domestic water and fire flow protection for the Mokuleia community. Well 3410-01 is old and the well shaft has been recased twice. The placement of sleeves inside of the original casing has constricted the diameter and pumping capacity of the well. The distribution network for the New Water System could extend a 12" main close to the intersection of Road A and Farrington Highway to provide the NSWC with a potential to connect at some in the future.

Roadways: Existing Roads - The existing roads within the Ranch are basically plantation field quality. The two primary internal roads are the former Cane Haul Road which runs roughly east-west, and the main access road that is aligned north-south. These primary roads have a crushed coral surface that has been compacted by years of use.

Ingress/egress is provided by the primary road from the Crowbar Ranch entry (hereinafter referred to as "Road A"). Road A intersects with the Cane Haul Road about a half mile into the property. A third ranch road with a crushed coral surface is the access to the Dillingham House through the coconut tree farm. Other ranch roads within are property are essentially unimproved jeep trails.

New Subdivision Roads - The roadway network for the new Agricultural Community will be designed and constructed to City standards, a specific requirement of the Subdivision Rules. However, a waiver will be requested to utilize the Agriculture-Country Street design standard for a 44' wide right-of-way ("ROW") with 10' grassed shoulders along both sides of an all-weather travelway. A design waiver will also be requested to substitute an alternate shielded streetlight to minimize the lateral emission of fugitive light.

The roadway network has been laid out with sensitive to the natural terrain to minimize cuts and fills that would alter the vistas of the Waianae Mountains. However, specific waivers may be requested in areas with severe topographic conditions at the time detailed construction plans are drafted.

Drainage: All streams on the Ranch discharge storm water runoff into one of the two drainage basins which cover most of The Flats:

Makaleha Stream - The Makaleha Stream enters the Ranch from the east, below the Dillingham House, and then turns makai with a defined channel that is visible in Parcel 1003, west of the access road through the coconut tree farm. During infrequent major storm events, the stream overtops its channel and sheet flows across The Flats in a broad fan before flowing under two bridges to the makai side of Farrington Highway. Prior to 2010, Makaleha Stream would back-up on the Ranch as its primary channel to the ocean was blocked by a compacted sand berm - the remnant of an earlier sand mining operation. In December of 2009, floodwaters from a major storm blew out the compacted berm providing the runoff with a direct ocean access. The unconsolidated sand berm which subsequently accumulates during fair weather easily erodes before storm water backs up. A second bridge just before Road A channels runoff from the western portion of The Flats under Farrington Highway, which flows through an unnamed stream channel adjacent to the Polo Field to the ocean.

Streams 4A, 4B and 4C – These three tributaries converge at the bottom of The Foothills on the west side of The Flats. The combined storm water runoff continues makai and spreads out in a broad, shallow sheet flow as it crosses the old Cane Haul Road. The sheet flow does not back up on the Ranch, but runs westward into the adjacent land owned by Castle & Cooke, then flows under Farrington Highway through a third bridge located to the west of the Pond and enters the ocean just before Laau Paina Place.

Drainage Improvements - Numerous intermittent streams cross the property from mauka to makai. Except for culvert crossings for the internal roads and their related drainage system, stream channels are not anticipated to be improved. Surface runoff will be collected and discharged into existing drainageways.

Wastewater: There are no regional municipal or private wastewater treatment systems in the Waialua-Mokuleia area. An earlier concept approved in 2008 for the use of Individual Wastewater Systems ("IWS") on each lot, then conveying the treated effluent to a common leach field below the Cane Haul Road was not accepted by the Wastewater Branch, State Department of Health ("WWB"). An alternate concept to place a septic tank on each lot and use a low pressure

pump to deliver the raw effluent to a private wastewater treatment facility on the Ranch for processing was subsequently presented to the WWB. Preliminary indications are that the proposed alternative, with a sub-surface disposal area, would be considered subject to the submission of specific technical data and a review of detailed construction plans.

Electrical Power: Current electrical facilities on the Ranch are minimal, with overhead power lines serving the equestrian center, maintenance shed, employee housing units and the Dillingham House.

The Subdivision Rules require a significant upgrade and expansion of the electrical system to meet the power requirements of the project. Unlike the current overhead lines, power for the Agricultural Community will be run underground in concrete encased conduits placed under the grassed shoulders of the roadways.

The power requirements for the project are significant and discussions have been initiated with the Hawaiian Electric Company ("HECO") to assure that sufficient capacity will be available. Preliminary engineering layouts for the project, the projected load requirements and timetable for approval of subdivision application through initial occupancies have been forwarded to HECO's Key Accounts Manager. While HECO's internal review is in its early stages, there has been no indication that electrical service will not be available for initial occupancies in 2019.

Discussion with other service providers for phone, CATV, internet and broadband service will be initiated in the latter half of this year.

Infrastructure Maintenance

The infrastructure systems constructed to service the Agricultural Subdivision and the Ag Cluster (collectively the "Agricultural Community") will be privately owned and maintained. Accordingly, it is anticipated that two legal entities will need to be created to manage the affairs of each:

- Homeowners Association ("HOA") for the Agricultural Community: Owners of Lots in the Agricultural Subdivision and CPR Units in the Ag Cluster would be members of the HOA, with the obligation to pay Maintenance Fees, Special Assessments and Specific Assessments to be determined

by the size of their Lot or CPR Unit relative to the aggregate area of all Lots and CPR Units or such other allocation as may be appropriate.

- CPR Unit Owners Sub-Association ("UOS") for the Ag Cluster: Due to the unique nature of the Ag Cluster, Unit Owners would have additional rights, and obligations related solely to the Ag Cluster. One of these would be to act as an independent body in regard to the affairs of the Sub-Association as long as such actions did not adversely impact the HOA. The UOS would have a separate Board of Directors composed of CPR Unit Owners that would handle matters related to the Ag Cluster's internal roadways, water distribution system, wastewater collection system, electrical systems, trash disposal and grounds maintenance similar to a townhouse development.

Entity	Membership	Governance	Infrastructure
HOA	Lot Owners and CPR Unit Owners	Agricultural Community	Agricultural Subdivision
UOS	CPR Unit Owners	Ag Cluster	Internal to Ag Cluster

A Master Association with the Ranch is not anticipated as overlapping use of infrastructure with the Agricultural Community is anticipated to be minimal. For example, Road A may incur some use by the crew for the Working Ranch, but this would be nominal as there are semi-improved and service roads that access the working areas of the property. Other services provided by the Ranch, such as the coordination activity on cooperative ventures would be handled on a contractual basis that would not require a Master Association.

After the completion of construction, it is anticipated that infrastructure systems will be transferred to public and private utility companies. An obvious example is HECO, which would take ownership of the electrical distribution system within the roadway network in order to directly service customers. Hawaiian Telcom or Oceanic/Time-Warner would be candidates for phone/CATV/internet/broadband service. Considerations as to the transfer of ownership for the water and wastewater systems are undetermined, but each will generate revenue through user fees and service charges.

With the revenue generating infrastructure systems dedicated or conveyed, the remaining improvements that the HOA would be responsible for maintaining will be the roadway network, its related drainage system and the culvert crossings over the streams that cross the property. A Declaration of Covenants, Conditions & Restrictions ("DCC&Rs) would establish the structure of the HOA, delineate the basis for maintenance of the roadway infrastructure, lot grading, rockfall mitigation, drainage modification, location of building pads, landscaping, grounds maintenance, dumping of greenwaste and numerous other salient items.

Agriculture Concept

The future operation of the Working Ranch will be focused on a new core activity of cultivation and marketing high quality orchard crops, primarily for the Oahu market. In addition, traditional Ranch activities, cattle production and the stabling of horses, would be expanded as supporting infrastructure becomes available as part of the development of the Agricultural Community.

Orchard Crops: Approximately 255 acres on The Flats and in the lower portion of The Foothills will be cultivated for orchard crops. Selected varieties of mango will be grown on 95 acres in the eastern corner of The Flats. A portion of this area is presently the coconut tree farm, which will be incrementally phased out as the field is converted to mango production. The analysis and selection process for the mango varieties is detailed in Volume 2.

A variety of premium quality avocado has been identified for cultivation in the lower elevations of The Foothills. The selection process centered on high quality avocado for the local market and varieties that would extend the harvest period is detailed on Volume 2.

While not as extensive in terms of cultivated area as mango or avocado, selected citrus trees have been identified for cultivation in The Foothills. Located in higher elevations, cooler temperatures would promote flowering for pollination. Part of the selection strategy for limes is the blight that is impacting lime production in East Coast areas, potentially leading to shortages and higher prices.

Initial planting of orchard crops will be done incrementally to permit cultivation by an on-site nursery after the initial stock of trees is purchased. This would also permit field crew size, farm equipment, supplies and a production facility to come on line sequentially through the grow-in period. As the fields mature, projected annual revenues would reach (see Volume 2):

- Mango $754,992
- Avocado $160,494
- Citrus. $57,648

Cattle Production: Presently there are 64 heifers and 2 bulls that are grazed in paddocks in The Foothills. Subject to funding, plans call for the addition of 100 new heifers over the next two to three years, in addition to 25 young cows presently in the herd. The eventual target is to have a mix of 220 to 250 heifers and bulls.

Three considerations relevant to the contemplated expansion would be:

Move to the Mauka Lands: Tentative Approval of the subdivision application in 2015 would set the stage for preliminary planning for the orderly relocation off of the area for the Agricultural Subdivision by 2019. Initial relocation of the cattle to the area of Lots 1 to 8 and 9 to 19 would likely be required in order to provide water to maintain the herd when construction starts. Subsequent relocation into The Mauka Lands or to the western portion of the Ranch adjacent to the Peacock Flats Trail needs to be coordinated with infrastructure construction so that water is available.

Fencing to create the pens will be a related consideration. The perimeter fencing along the DLNR Road is in serviceable condition. While this helps to establish the large mauka paddocks, additional fencing to create smaller pens will be essential for rotational grazing. Roughly 30,000 LF of cattle fencing will be required at a rough cost of $125,000. Grazing in The Mauka Lands will be augmented by 72 acres of Grazing Lots in the upper tier of The Foothills.

Herd Size: Plans call for the expanding the size of the herd to gain the efficiencies necessary to ship calves to the West Coast. Expansion will be done incrementally, predicated in part upon the availability of water to support the cattle operation and the pens required for rotational grazing. Initial grazing in presently unused areas will be necessary to remove dense overgrowth. Managed vegetation will permit efficient handling of a larger herd and an orderly rotational grazing schedule. From a forage management perspective, uniform rotational grazing is highly desirable.

Changing the Mix: This is a two part issue - 1) addressing the aging of the present herd and 2) modifying genetics:

Aging Stock - Approximately 60% of the herd is over 12 years old which is pushing heifers beyond their prime

breeding years. Part of addressing aging stock involves the addition of new cows to the heard and a systematic program to hold back desirable calves, which will have an initial impact on revenue. The can partially be off-set by selling off the older heifers, but this also initially reduces production capacity.

Genetics - The introduction of new stock also provide an opportunity to modify the herd herd's genetics for desirable traits in terms of both coping with the harder terrain and market desirability of the beef. This would involve cultivating Black Angus and Red Angus with a mix of Charolaise genetics. Charolaise also provides an earlier growth spurt, which could help increase annual revenues to $95,625 FOB Ranch gate prices (250 heifers x 90% = 225 calves x $425/weaned calf).

Horse Boarding: In 2013, the stabling of 75 horses generated revenue of $205,800. With improvements to the paddocks and training facilities, 100 houses could increase annual revenues to roughly $275,000 at the present boarding charges. It is too premature to project additional revenue from equestrian related activities.

Coconut Trees: The existing field stock trees are starting to reach heights in excess of 25' – 30', which exceeds the desired range for transplanting. With a limited market for palm trees, it is anticipated that the existing fields will be systematically converted to the cultivation of mango trees, starting with the area to the east of the access road to the Dillingham House. The next area to be placed in mango cultivation will likely be to the west of the Makaleha Stream channel.

The field between the Makaleha Stream channel and the access road will be retained to maintain a supply of field stock coconut trees until time for conversion to mango production. Annual revenue is not anticipated to significantly increase from the $3,100 in 2013 as there are no major resort and golf course developments on the horizon.

Other Ag Activities: The generation of income from other ag related activities on the Ranch, such as farm-to-table produce, specialty crops and agribusiness tours has future potential but are dependent upon establishing the orchard crops as a draw. Ag related enterprises ventures such as a roadside stand

and a restaurant utilizing products grown on site and in the area are likewise future endeavors.

A service activity that has more immediate potential is a working relationship with Waialua High School to provide on the job training for students as the cultivation of orchard crops is initiated. The employment of students would also be valuable during harvest seasons for mango and avocado which will stretch over eight months of the year.

Non-Ag Activities: The rental of the Ranch for film and photo shoots is anticipated to continue but is an unpredictable source of revenue. On the other hand, rental of the Dillingham House for large special functions is anticipated to remain a steady source of income at about the $60,000 generated in 2013. Approval to modify the lawn area for outdoor events has been received approval from the City so that construction activity on the Ag Cluster will not shut down these events. Unfortunately, a significant increase is unlikely as the conditions of the Special Use Permit limits large, catered events to two per month.

Summary

Volume 1 presents an overview of the Dillingham Ranch, its setting in the Mokuleia community and the current agricultural operations of the Working Ranch. The long-term ability of cattle production, horse stab boarding and coconut tree sales to support the Ranch is poor and a transition from present operations to agricultural activities that have more market potential and sustained revenue potential is essential for the long-term viability of the Ranch.

The challenge related to restructuring operation is securing the capital necessary to replace and upgrade deteriorated infrastructure support the expanded operations. Current revenues are too low to entice investment capital, so DRA proposes to develop an Agricultural Community in The Foothills of the Ranch. The proceeds from the sale of lots and units in the project would be used, in part, to pay off the financing used to construct the subdivision infrastructure. The same infrastructure, particularly water, would be sized to provide the basis for transforming the operations of the Working Ranch.

Based on the foregoing it was recognized that the restructuring of the agricultural activities for the Ranch would be predicated upon a real estate aspect. As such, an investigation of the Regulatory Environment was conducted with respect to both the agriculture and real estate components. Examination of relevant statutes, ordinance, codes and regulatory documents confirmed that the property has the appropriate State land use designation, City zoning and that the project would be in compliance with the provisions of Chapter205, HRS, and the Land Use Ordinance. This Report has been prepared in compliance with Section 1-115 of the Subdivision Rules relative to demonstrating viable agricultural use. The proposed is outside of the Rural Growth Boundary of the North Shore Sustainable Communities Plan in an area designated for the preservation of agriculture. Special interest was taken to the fact that large portions of The Flats are subject to occasional flooding from severe winter storms, but no habitable structures are planned within the floodway and cultivation of agricultural crops is permitted in Zone AEF, Zone AE and Zone A. The Ranch is located on the mauka of Farrington Highway and is not within the Special Management Area.

Review of Agricultural Considerations indicates that the best soils for cultivation are located in the makai areas the property. The Soil Suitability designation, Land Study Bureau (“LSB”) productivity rating and the Agricultural Lands of Importance to the State of Hawaii (“ALISH”) classification all confirm that highly productive soils on The Flats which transitions into less productive soils in The Foothills and The Mauka Lands. DRA has located the Agricultural Subdivision up in The Foothills to preserve the prime soils for agricultural activities.

Assessment of the existing infrastructure on the Ranch indicates that all of these systems are inadequate for the proposed development. New water, wastewater, roadway and electrical systems will need to be constructed to support the new Agricultural Community (drainage improvements are minimal). Preliminary engineering for the respective systems indicate that the required improvements can secure the required permitted and be constructed pursuant to existing codes and regulations. Of equal importance is the fact that an adequate supply of water can be provided to support the restructuring of Ranch operations.

Volume 2 presents a plan for the cultivation of selected orchard crops and the efficient production of high quality fruit on a commercial basis. This will become the core activity for the agricultural operation which is critical to the long-term viability of the Ranch.

APPENDIX A

Declaration of Restrictive Covenants
(Agricultural Land)

REVISED DRAFT

DRAFT

LAND COURT SYSTEM | REGULAR SYSTEM

AFTER RECORDATION, RETURN BY MAIL ( ) PICK-UP (X)

WHITE & TOM
820 Mililani Street
Suite 711
Honolulu, Hawaii 96813

This document consists of
___ pages.

TELEPHONE: 547-5151

DECLARATION OF RESTRICTIVE COVENANTS
(AGRICULTURAL USE)

DECLARANT: DILLINGHAM RANCH AINA LLC
9601 Wilshire Boulevard, Suite 220
c/o Kennedy Wilson International
Beverly Hills, California 90210

PROPERTY DESCRIPTION: DOCUMENT NO.:
Tax Map Key No.: (1) 6-8-002-006, 6-8-003-006, -015, -019, -030, -031, -033, -035, and -040

DECLARATION OF RESTRICTIVE COVENANTS
(AGRICULTURAL USES)

This Declaration, made this _____ day of _____, 2008, by DILLINGHAM RANCH AINA LLC, a Delaware limited liability company, whose mailing address is c/o Kennedy Wilson International, 9601 Wilshire Boulevard, Suite 220, Beverly Hills, California 90210, hereinafter collectively referred to as "Declarant,"

WITNESSETH:

WHEREAS, Declarant is the owner of those certain parcels of property situate at Mokuleia, Waialua, City and County of Honolulu, State of Hawaii, which are more particularly identified as Tax Map Key Nos.: (1) 6-8-002-006, 6-8-003-006, -015, -019, -030, -031, -033, -035, and -040, and more particularly described in Exhibit "A" attached hereto and made a part hereof by this reference (the "Property"); and

WHEREAS, Declarant plans to create a working ranch and an agricultural subdivision by means of subdividing the Property into eighty-four (84) lots in a subdivision application Declarant has submitted or will submit to the Department of Planning and Permitting of the City and County of Honolulu (the "Subdivided Lots"); and

WHEREAS, Declarant will establish a master association consisting of owners of all working ranch and agricultural subdivision lots, which association shall have governance over all areas common to both lot categories and all matters relating to the mutual benefit of both lot categories, and an agricultural lot owners association, having governance over all matters related solely to the agricultural subdivision.

WHEREAS, Chapter 205 of the Hawaii Revised Statutes, as amended, requires that subdivisions within the agricultural district having soil classified by the Land Study Bureau's Detailed Land Classification as Overall Productivity Rating Class "A" or "B" shall be restricted to uses primarily in pursuit of an agricultural activity, and further, that any deed, lease, agreement of sale, mortgage or other instrument of conveyance covering any land within the agricultural subdivision shall expressly contain the restriction on uses and the conditions as prescribed in said Chapter and shall be encumbrances running with the land; and

WHEREAS, Declarant, as owner, desires to establish restrictive covenants relating to the use of the Property and the Subdivided Lots in accord with Chapter 205, Hawaii Revised

Statutes;

NOW, THEREFORE, Declarant hereby declares and agrees that the agricultural subdivision to be created on the Property described on Exhibit "A" is held and shall be held, conveyed, mortgaged, encumbered, leased, rented, used, occupied and improved subject to the following declarations, which declarations shall constitute covenants running with the land and shall be binding on and for the benefit of Declarant, its successors and assigns, and all subsequent owners, lessees or occupants of any or any part of the Property and/or the Subdivided Lots and their respective heirs, executors, administrators, successors, and assigns:

1. USE. The agricultural subdivision shall be subject to the restrictions of permissible uses as prescribed in Chapter 205-4.5, Hawaii Revised Statutes, and any deed, lease agreement of sale, mortgage, or other instrument or conveyance covering any land or portion thereof within the agricultural subdivision shall expressly contain the restriction of uses and the conditions as prescribed in the statute, which restriction and condition shall be encumbrances running with the land.

All of the Subdivided Lots shall be subject to the provisions of Section 205-4.5(a) and (b) of the Hawaii Revised Statutes, as amended ("HRS"), where the soil of the land is classified Overall (Master) Productivity Rating Class "A" or "B"under the Detailed Land Classification of the Land Study Bureau of the State of Hawaii, which provisions include the following:

1. The condition that the land shall be used primarily in and for the pursuit of an agricultural activity;
2. The restriction of the use thereof to those uses specified in Section 205-4.5(a);
3. The restriction and condition above mentioned shall be encumbrances running with the land until such time that the land is reclassified to a land use district other than agricultural district; and
4. Any deed, lease, agreement of sale, mortgage or other instrument of conveyance of the land shall expressly contain the restriction on uses and the conditions above mentioned.

2. NO RESTRICTIONS ON AGRICULTURAL USE. All of the Subdivided Lots shall additionally be subject to the provisions of HRS Section 205-4.6, which prohibits restrictions on agricultural uses and activities by any private agreement contained in a deed, agreement of sale, or other conveyance document, such as easements, covenants, and servitudes; provided that restrictions taken to protect environmental or cultural resources, agricultural leases (leases where the land is primarily used for purposes set forth in HRS Section 205-4.5(a)), utility easements, and access easements shall not be subject to such prohibition.

3. WORKING RELATIONSHIP. Declarant shall cause the governing document of the master association to recommend a formal working relationship among owners of ranch lots and agricultural lot owners.

4. DURATION. The covenants, conditions and restrictions herein contained shall run with the land and shall be binding on all parties and all persons claiming under or through them.

5. VIOLATIONS. An owner of the Property or a Subdivided Lot, or any part thereof or interest therein, violating any provisions hereof, shall be subject to the violation and penalty clause of applicable State and City laws and regulations. Failure by Declarant, any successor owner or owners of the Property or the Subdivided Lots, or their representatives, heirs, successors or assigns, or said City and County of Honolulu to enforce any of the covenants, restrictions, reservations, easements or charges herein contained shall, in no event, be deemed a waiver of the right to do so thereafter, unless otherwise herein provided.

6. AMENDMENTS. It is specifically agreed by each owner that this Declaration shall continue in full force and effect and shall not be repealed, amended or altered in any way, except with the written consent of the Director of the Department of Planning and Permitting of the City and County of Honolulu or his and/or its successor.

IN WITNESS WHEREOF, Declarant has caused this instrument to be executed the day and year first herein above written.

[signature on next page]

DILLINGHAM RANCH AINA LLC
a Delaware limited liability company

By: 68-540 Farrington, LLC,
a Delaware limited liability company,
its sole member

By: KW Dillingham Aina LLC,
a Delaware limited liability company,
its managing member

By: K-W Properties,
a California corporation,
its managing member

By:_____
Name: MARY RICKS
Title: Vice President

"Declarant"

ACKNOWLEDGMENT

State of California
County of _____

On_____ before me,_____,
(here insert name and title of the officer)
personally appeared MARY RICKS personally known to me (or proved to me on the basis of satisfactory evidence) to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf on which the person(s) acted, executed the instrument.

WITNESS my hand and official seal

Signature_____

(Seal)

APPENDIX B

Farm Dwelling Polygon
(DPP 94/INT-3)

Bob S

INTERPRETATION WRITE-UP FORM

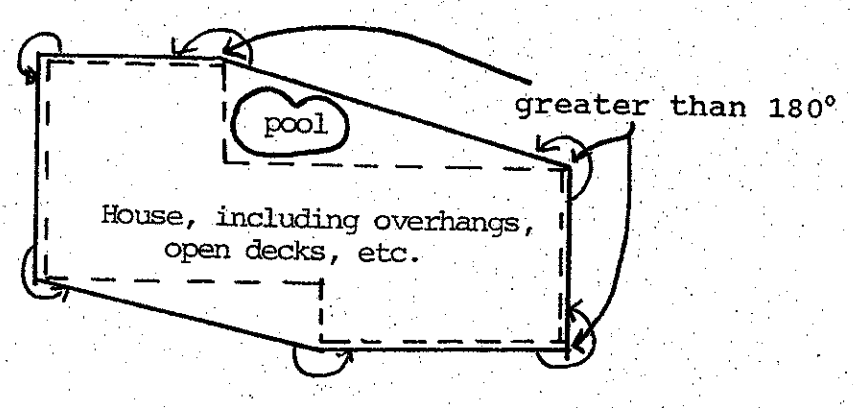
Date: May 6, 1994

Interp. No.: 94/INT-3

LUO Section(s): 5.20-4(b)
Square Footage Limitation for Farm Dwellings

Problem Statement: Each farm dwelling, and any accessory uses associated with it must be contained within a 5,000 square foot area. How is this area limitation measured?

Interpretation: The area is confined to **any polygon** drawn by the applicant on the site plan, which has an area that does not exceed 5,000 square feet in area, and for which the exterior angles are 180 degrees or greater:



The applicant will have to submit calculations supporting the area of the polygon when filing for the building permit.

In addition to building areas, elements which must be completely within the polygon: eaves and overhangs; carports and garages; gazebos and trellised areas; uncovered stairways and decks; storage sheds; swimming pools; and other similar structures and improvements.

For nonconforming dwellings*, which cannot stay within a polygon meeting the above conditions, a polygon will still be drawn and only expansions within this polygon will be permitted.

Justification: The purpose of the 5,000 square-foot limitation is to allow for a reasonable size dwelling, but not to the extent of promoting the use of agriculturally-zoned land for suburban development (country estates) which have no relationship to agricultural pursuits.

Obviously, an extremely irregular-shaped, gerrymandered polygon will call into question whether it meets the intent of this standard. It will also add to the administrative burden of calculating the area of the land involved. However, the LUO is silent on the dimensional and configuration requirements for this size limitation.

It is reasonable to balance the need to keep the land area standard flexible, with the need to reduce abuses of the intent and to avoid making the requirement unnecessarily complex to administer. The above polygon method is deemed to reflect this balance.

Director's Signature

intmisc.kks

* These are dwellings which were built prior to the establishment of the 5,000 square-foot limitation; i.e. October, 1986.

APPENDIX C

Preliminary Water System Report

Preliminary Water System Report

For Dillingham Ranch Agricultural Subdivision
Mokuleia, Oahu, Hawaii
June 2014

Prepared by:

SHERWOOD
DESIGN ENGINEERS
58 Maiden Lane, Third Floor
San Francisco, CA 94108
www.sherwoodengineers.com

Prepared for:

Dillingham Ranch Aina, LLC

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I. Introduction

A. Purpose and Scope of Report

This document presents the water master plan for the agricultural subdivision at Dillingham Ranch, Mokuleia, Hawaii. The report provides an analysis of the domestic, fire, and irrigation system demands and the proposed storage and distribution infrastructure for the Dillingham Ranch Aina Project (DRA) and the Mokuleia Community.

I. Existing Condition

Existing Site Features

Dillingham Ranch, herein referred to as the "Ranch", is a large land holding comprising approximately 2,700 AC bound by Farrington Highway, lands owned by Pioneer Ili-Bred International, the Mokuleia Forest Reserve, and Castle & Cooke. Farrington Highway is the property's northern boundary and the Mokuleai Community is located approximately 800 feet northwest of the Ranch entrance. Topography of the property is defined by low coastal plains in the north and steep mountainous terrain to the south. The flat coastal plains are located between Farrington Highway and the old agricultural Cane Haul Road with gentle slopes averaging 0% to 5%. The coastal plain is underlain by alluvial and marine sediments consisting of horizontal layers of clay, silt, sand, and coralline limestone[1]. Land use in this area is governed by agricultural fields, primarily coconut trees and pgls. This area also has paddocks, open pasture and an equestrian center with corrals.

In contrast to the flat coastal plain, the landform *mauka* (towards the mountains) of the Cane Haul Road transitions into steeper sloping terrain. Slopes in this area start at 10% to 20% slopes to steepen from 20-50% mauka of the subdivision but the terrain is very irregular. Rockfall zones are present in the upper limits of the property. There is very little existing development within the Ranch, the primary exceptions being the Dillingham Lodge and a handful of private residences. Historically, the Ranch has used the lands above the Cane Haul Road for cattle production. Refer to Appendix A, "Existing Site Conditions" for existing topography and structure locations.

Existing Water System

Existing domestic water utilities and appurtenances are managed by the North Shore Water Company. There are a total of 10 existing wells within the Dillingham Ranch property. Six wells are located in the lowlands encompassed by proposed parcels 1003, 1004, and 1005 while the remaining four are situated *mauka* of the Cane Haul Road. Dillingham Ranch is underlain by an aquifer that is situated in permeable basalts underneath a 200 to 600 foot layer of caprock sediment, therefore, all wells must penetrate below this zone to reach potable water[1].

[1]Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[2]R.M. Towill Corporation, "Prelminary Water System Report" (Feb, 2008)

Two of the 10 existing wells are currently used for potable and non-potable sources, while the rest are sealed or not permitted for use[1]. Well #3410-01 provides water to the Mokuleia Community. Previous studies conducted by Water Resource Associates (2003) and R.M. Towill (2008) have confirmed that this source has insufficient pressure and pumping capacity to provide the minimum required fire flow. Well #3410-03 functions as the site's irrigation supply source and has a permit from the State Commission of Water Resource Management (CWRM) for pumping 1.5 MGD. The agricultural well is a privately owned and maintained by the Ranch.

The following list provides a brief description of each well by geographic location:

Makai Wells (North of Cane Haul Road):

Well #3410-01 (Permitted for 0.5 MGD)
This well was constructed over 100 years ago (dating prior to 1911) and has 4 pumps; two 3 HP, one 7.5 HP, and one 15 HP[2]. Corrosion and age have played a substantial factor in the condition of this structure. Consequently #3410-01 had to be re-cased from its original 10 inch casing down to 6 inches. Well 3410-01 is owned by the North Shore Water Company, LLC, which is subject to oversight by the Public Utilities Commission. It currently serves the Mokuleia Community through an agreement with the Ranch.

It is contemplated that this well may be abandoned and when the North Shore Water Company is provided with a connection to the new water system (as outlined in Section III of this report).

Well #3410-02 (Sealed)

Well #3410-03 (Permitted for 1.5 MGD Agricultural Use Only)
This well was constructed over 80 years ago (dating prior to 1934). #3410-03 has a historical casing diameter of 10 inches, although this may now be smaller. It should be noted that #3410-03 is an agricultural use only well with a permit for 1.5 MGD.

Well #3410-04 (Sealed)

Well #3410-05 (Sealed)

Well #3410-06 (Sealed)

Mauka Wells (South of Cane Haul Road)

Well #3410-10 (Not Permitted for Use)

Well #3310-01 (Permitted for 1.25 MGD):
Situated at 470 feet, this is the highest elevated existing well on site. #3310-01 was drilled in 1980 and pump tested the same year for 25 hours at a rate of 885 GPM.

[1]Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[2]R.M. Towill Corporation, "Prelminary Water System Report" (Feb, 2008)

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The well is fitted with a 12 inch casing and has a water use permit of 1.25 MGD for irrigation and domestic use[1].

Well #3310-02 (Permitted for 0.85 MGD):
#3310-02 is situated at 367 feet and represents the second highest well on site. This well was drilled in 1980 and pump tested for 45 hours at 1400 GPM. #3310-02 has a 14 inch case and is permitted for 0.85 MGD for irrigation and domestic use[1].

Well #3310-03 (Not Permitted for Use):

Refer to Appendix A, "Existing Site Conditions" for existing well locations.

III. Proposed Concept

A. Proposed Water System

The proposed program for the Dillingham Ranch subdivision includes the construction of 92 (4-5 bedroom) dwellings on lots with a minimum size of 5-acres. Most of these dwellings will be situated *mauka* of the Cane Haul Road with the exception of lots 88 and 89 adjacent to Farrington Highway. Property 1001 will be encompass the Dillingham Lodge while Property 1002 will include a future agricultural cluster development of 15 farm dwellings each with 2 to 3 bedrooms, linked to fields located below the Cane Haul Road. The existing equestrian polo grounds and coconut farms (Lots 1003 and 1004) located *makai* of the Cane Haul Road will remain relatively unchanged with the exception of Lot 1005 - which will be designated for a subsurface effluent disposal system.

Irrigation demands for the low lying lands will be provided by the existing Ranch-owned Well #3410-03, which has been permitted for 1.5 MGD pumpage and is the current supply source for the main area. The water needed to irrigate the 5-acre residential parcels in the upper reaches of the project will be provided by the development's proposed domestic water system.

Access to the proposed subdivision will be provided by a series of new roadways labeled alphabetically from A to G (see Appendix B "Proposed Water System"). Road A will follow the property's existing main access road from the intersection of Farrington Highway to the old Cane Haul Road, then continue south into the site with secondary roads branching outwards to access the rest of the development. Most of the proposed water network will be placed within these roadway corridors although some dedicated utility easements through individual parcels will be required for access to tanks and to link distribution pipelines.

The water system was designed to maintain a static pressure range of 55 to 110 psi at roads where laterals will be provided to the agricultural lots. Because elevations vary widely across the project site, the water distribution system necessitated the creation of three pressure service zones. Two new water tanks (referred to as Tank 1 at Elevation 220 and Tank 2 at Elevation 500 in this report) will provide a combination of fire suppression and operational storage while maintaining minimum distribution pressures. Tank 1 serves Pressure Zone 1 while Tank 2 serves

[1]Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[2]R.M. Towill Corporation, "Preliminary Water System Report" (Feb, 2008)

Pressure Zones 2 and 3. An exception to this occurs when Pressure Zone 1 experiences a significant drop in pressure during fire events. In this instance, water from the upper pressure zones will feed Pressure Zone 1 via a pressure reducing valve with additional flow from the dedicated fire storage in Tank 2. Refer to Table 2 of this report for pressure zone summaries.

A proposed primary well and backup well will act as the supply source for these tanks. It has been recommended that these wells be installed 750 – 1,000 feet apart by Tom Nance, the project's geo-hydrologist. Determining the well's specific operating parameters and location will help dictate pump sizing and pumping rates during detailed design development. Well water will be disinfected using chlorine prior to storage in Tank 1. Booster pumps adjacent to Tank 1 will transfer water from Tank 1 into the upper distribution network, Pressure Zone 3, on an as needed basis to maintain minimum water levels in Tank 2. Although the water system design meets BWS requirements in terms of minimum water pressure, it is anticipated that certain lots located at an elevation higher than the roadway may install private booster pumps to deliver high pressure water to upper floor water fixtures. Similarly, lots lower in elevation than the roadway may require pressure reducing at the meter to minimize impacts of high pressure water on the internal plumbing.

Refer to the Section V Conclusions and Appendix B "Proposed Water System" for more information.

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IV. Methodology

A. Design Parameters

The proposed water layout abides by the Board of Water Supply's Water System Standards (WSS) 2002. In particular, Division 100 of the manual provides requirements for fire and domestic flow demands, peak factors, and pipe sizing amongst other guidelines. These parameters were instrumental in determining many of the water system factors such as the elevation and storage capacity of the water tank and the placement of pressure reducing valves (PRVs).

i. Fireflow Parameters

Fireflow parameters are outlined in Table 100-19 of the Water System Standards. The proposed homes for the agricultural subdivision are designated under the "agriculture" type land use. Therefore these structures must meet a fire flow demand of 1,000 gallons per minute (gpm) for 60 minutes as stipulated in the manual. Multifamily units, such as occurs within the Mokuleia Community (Camp Mokuleia), and the Dillingham Lodge are categorized under "commercial structures" and require 2,000 gpm for 2 hours.

[1]Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[2]R.M. Towill Corporation, "Prelminary Water System Report" (Feb, 2008)

ii. Irrigation Design Parameters

The domestic water system will be the supply of irrigation water for agricultural, pasturing, and personal crop and/or landscape amenities on many of the proposed lots. Except for water for cattle and horses, lots designated for grazing will not be irrigated. Based on projected irrigation uses, it is estimated that the total irrigation demand that the subdivision (includes orchard, pasture and personal irrigation) will need to provide is a total of 2.77 million gallons of water per day. However, the water storage for all agricultural uses is not required and is expected to pump directly from the wells. The total water storage for irrigation is 185,000 gallons per day (gpd). The design assumes consistent irrigation use throughout the day and 2 hours of irrigation storage in each tank.

Refer to Appendix C "Water Demand Calculations" and Table 1 in the next page of this report for more information including design parameters not described above.

iii. Domestic Water Parameters

Interior domestic water demand is assumed at 500 gpd per single family dwelling. The 15 single family dwellings for the Agricultural Cluster located on Lot 1002 would also have a demand of 500 gpd per dwelling. The existing Dillingham Lodge is a commercial facility with an average demand of 2,000 gpd. Finally, Well 3410-01 which services the Mokuleia Community had an average pumpage of 98,279 gpd in 2012 based upon records submitted to CWRM.

Refer to Appendix C "Water Demand Calculations" and Table 1 in the next page of this report for more information including design parameters not described above.

DRAFT

[1]Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[2]R.M. Towill Corporation, "Prelminary Water System Report" (Feb, 2008)

Table 1: Water System Design Parameters

Type	Rate / Value	Comment / Source
Fireflow (Dwelling Lots)	1000 gpm @ 60 min (60,000 gal)	Storage within Tank 1. Per WSS Table 100-19
Fireflow (Commecial)	2000 gpm @ 2hr (240,000 gal)	Storage within Tank 1 and Tank 2. Per WSS Table 100-19
Fireflow (Residual Pressure)	20 psi	During fireflow with max daily domestic demand. Per WSS Table 100-19
Domestic Water Demand	500 gal/single-family dwelling	Per WSS Table 100-18
Design Static Pressure Range	55 psi – 110 psi.	Per Industry standard
Max Daily Peaking Factor	1.5	Applied to avg domestic demands only. Per WSS Table 100-20
Peak Hour Factor	3.0	Applied to avg domestic demands only. Per WSS Table 100-20
Irrigation Storage at Tank	2 hrs storage @ each tank	Based on 1.1 mgd of irrigation demand per AgTech Inc.
Pipe Velocity	6 fps max (without fire flow) 12 fps max (with fire flow)	6 fps per WSS page 111-5. 12 fps based industry standard.

Refer to Appendix E in this report for supporting documents

B. Distribution System and Water Tank

The proposed system includes three water distribution systems. The first is primarily pumped directly from Well 3410-01, which serves the lots located makai. Most of the agricultural uses will be managed in this area. The uses here include orchards, 2 pasture lots and cattle grazing. The two distribution sources are by two tanks, Lower Tank – Tank 1 and Upper Tank – Tank 2. These two tanks are interconnected to support the full subdivision's domestic, fire, irrigation flows, but also the Mokuleia Community's domestic and fire flow.

The proposed water tank distribution system proposed for Dillingham Ranch consists of three pressure zones. Pressure Zone 1 covers all water services within the elevation range of 10 feet to 90 feet and is served by Tank 1 under normal operating conditions and by a combination of Tank 1 and 2 during fire flow events. Fire storage from Tank 2 will be used to supplement Tank 1 during emergencies. Therefore, Tank 1 stores 180,000 gallons of fire storage (240,000 – 60,000 gallons).

Pressure Zones 2 and 3 provide service to all dwellings between elevation 90 and 370 feet and is served by Tank 2 (located at elevation 500'). The elevation of each tank is based on providing a minimum static pressure of 55 psi at the road adjacent to highest elevated residence serviced. In addition, tanks were designed to ensure at least 20 psi of residual

[1]Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[2]R.M. Towill Corporation, "Preliminary Water System Report" (Feb, 2008)

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pressure to support fire flow. A typical 20' utility easement, as shown in Appendix B "Proposed Water System", will be provided to maintain access to each tank.

The tanks were sized assuming that each must maintain a permanent reservoir for fire storage plus 2 hours of daily irrigation demands and the operational storage needed to accommodate peak daily domestic demands. No provision was made for emergency storage, as each of the project's two wells will have the capacity to meet maximum day demands and can therefore "back-up" the other. Refer to Tables 2 and 3 below for the pressure zone and tank sizing information respectively.

Table 2: Pressure Zone Summary

Pressure Zone	Elevation Range	Lots Included	Comments
1	10ft - 90ft	1-20, 29-32, 1001,1002, 88, 89, Mokuleia Community	Lots in Pressure Zone 1 to be supplied by Tank 1 under normal operating conditions. Tank 2 will feed Pressure Zone 1 in the event of a pressure drop.
2	90ft - 246ft	21-28, 33-50, 51-53, 84-92	Lots in Pressure Zone 2 to be supplied by Tank 2.
3	246ft – 370ft	51, 54-83	Lots in Pressure Zone 3 to be supplied by Tank 2

Refer to Appendix B "Proposed Water System".

Table 3: Water Storage Summary

Tank	Tank Elevation	Pressure Zone Served	Storage Requirements (gal)	Total Storage Volume (gal)	Dimensions (ft)
1	220 feet	1	32,060 - Irrigation 38,500 – Max day domestic 180,000 – Fire 200,400 – Mokuleia demands	451,000 gal	Height - 30 Diameter - 52
2	500 feet	1 (fire flow) 2, 3	153,082 – Irrigation 63,000 – Max day domestic 60,000 - Fire	277,000 gal	Height - 25 Diameter - 40

Refer to Appendix C "Tank Sizing Summary" for detailed calculations.

C. Modeling

Table 1 "Water Systems Design Parameters" was the basis of a computer simulation of the water system using the WaterCAD program by Haested Methods. WaterCAD is used to analyze pipe pressure and velocity. This information was compared against standards

[1]Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[2]R.M. Towill Corporation, "Preliminary Water System Report" (Feb, 2008)

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set forth by local agencies to determine design feasibility. For conceptual design one computer model was produced for each tank's service area. The Lower Model reflects services by Tank 1 while the Upper Model reflects services by Tank 2 (refer to Tables 2 and 3 for sizing).

Simulations were run by placing nodes along the water mains to account for peak hourly domestic water and irrigation (where applicable) demands centered at groupings of lots. The combination of these demands constitute total normal flow conditions. The lower zone analysis only included peak hour domestic demands because irrigation in this region is supplied by the existing, privately owned, Well #3410-03.

Next, the model paired normal flow conditions with fire flow demands located at the dead ends of each run. In both scenarios, the analysis was compared against the design parameters outlined in Table 1 of this report. Specifically, the program checked that static pressures did not extend beyond 55 to 110 psi during normal flows or drop below 20 psi of residual pressure for a fire flow event. The simulation also confirmed that max velocities were not exceeded. Refer to Appendix D "WaterCAD Report" for additional information regarding the WaterCAD calculations.

V. Conclusions

A. Distribution System

The water distribution system will consist of an upper and lower service area encompassing three pressure zones. The lower service area will be supplied by Tank 1 and provides water to Pressure Zone 1 in addition to the Mokuleia Community *makai* of Farrington Highway. The upper service zone will be supplied by Tank 2 and provides water to Pressure Zones 2 and 3 (between elevations 350 to 90 at Road A and 350 to 120 at Road B) while also providing fire water storage for Pressure Zone 1.

The size of the water main varies between 10 and 12 inches in the Lower Model distribution network and between 8 and 10 inches in the Upper Model distribution network. These sizes yield at least 20 psi during a fire event and 55 psi under normal water flows. Pressure reducing valves will be required at the two locations where Pressure Zone 2 connects to Pressure Zone 3, and two additional locations where the interconnect occurs between Pressure Zone 1 and Pressure Zone 2. Refer to Appendix B "Proposed Water System" for an exhibit detailing these descriptions.

B. Water Tank

The WaterCAD Model has substantiated that the proposed tank elevations (220 feet above sea level for Tank 1 and 500 feet above sea level for Tank 2) will maintain the desired range of static and residual pressures throughout the distribution network. As noted in Section IV, the tanks were sized under the assumption that each must maintain a permanent reservoir of the required fire storage in addition to the daily domestic maximum water demand and 2 hours of daily irrigation storage. These criteria resulted in a required 451,000 gallon volume for Tank 1 and 277,000 gallon volume for Tank 2 (amounting to a total site volume storage of 727,000 gallons). Preliminary tank dimensions were selected in an effort to minimize the visibility and site impact.

[1]Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[2]R.M. Towill Corporation, "Prelminary Water System Report" (Feb, 2008)

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APPENDIX A

EXISTING SITE CONDITIONS

SHERWOOD
DESIGN ENGINEERS
[illegible] Lane, [illegible]
San Francisco, CA 94556
www.sherwoodengineers.com

APPENDIX A - EXISTING SITE CONDITIONS

DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, HAWAII

May 30, 2014

SCALE 0 150' 300' 600'

APPENDIX B

PROPOSED WATER SYSTEM

LEGEND

WATER LINE – UPPER (DW, FW, IRR)

WATER LINE – LOWER (DW, FW)

DISTRIBUTION LINE FROM SUPPLY SOURCE TO TANK

PROPOSED WATER TANK

APPROXIMATE LOCATION OF EXISTING WATER WELL

PROPOSED WELL

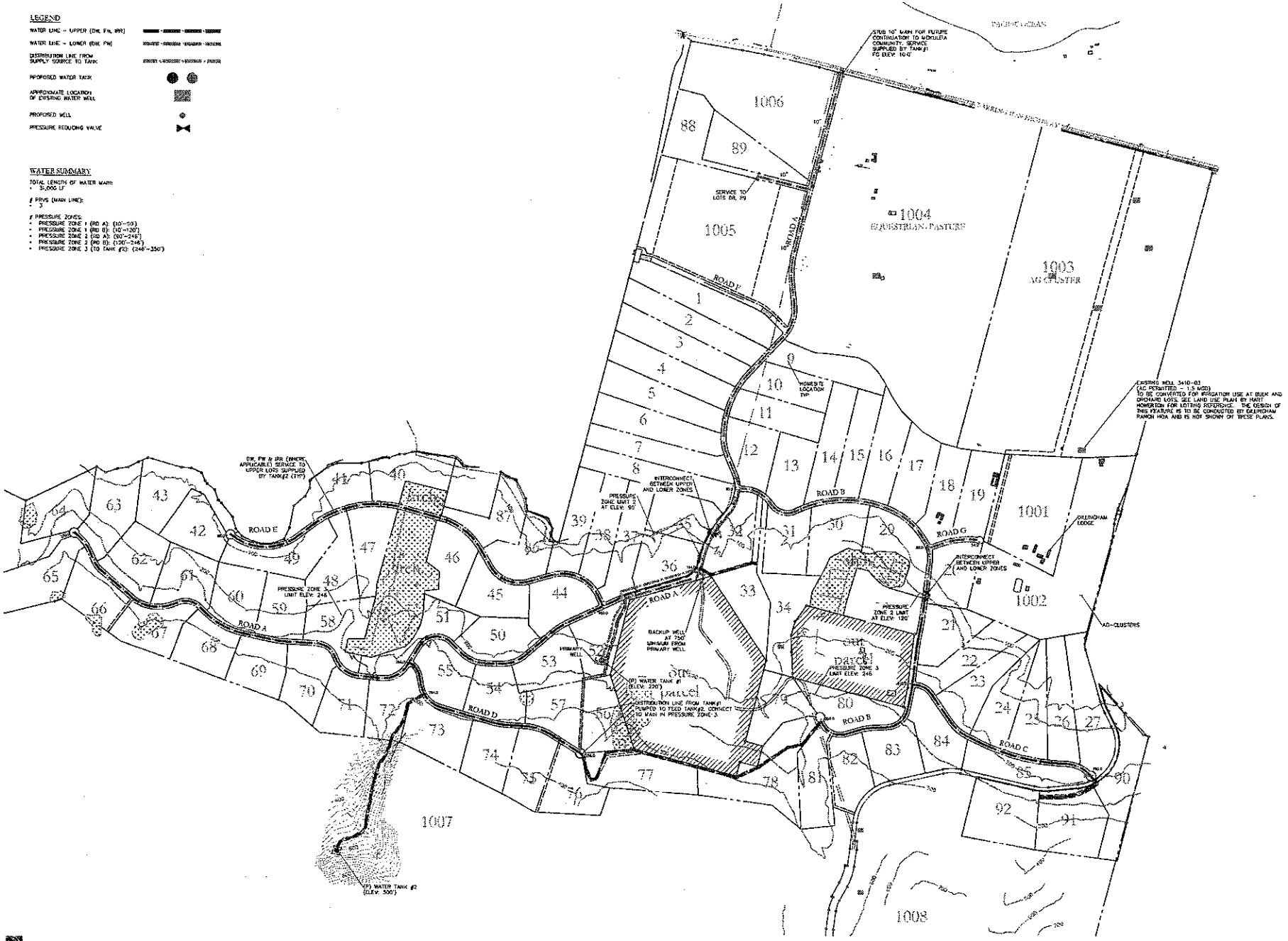
PRESSURE REDUCING VALVE

WATER SUMMARY

TOTAL LENGTH OF WATER MAIN:
- 31,000 LF

PRVS (MAIN LINE):
- 3

PRESSURE ZONES:
- PRESSURE ZONE 1 (RD A): (10'–50')
- PRESSURE ZONE 1 (RD B): (10'–120')
- PRESSURE ZONE 2 (RD A): (50'–246')
- PRESSURE ZONE 2 (RD B): (120'–246')
- PRESSURE ZONE 3 (TO TANK #2): (246'–350')



SHERWOOD DESIGN ENGINEERS
88 Kapiolani Lane, Third Floor
San Francisco, CA 94108
www.sherwoodengineers.com

APPENDIX B - PROPOSED WATER SYSTEM

DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, HAWAII

May 30, 2014

0 150' 300' 600'

APPENDIX C

TANK SIZING SUMMARY
WATER DEMAND SUMMARY

WATER DEMAND/STORAGE

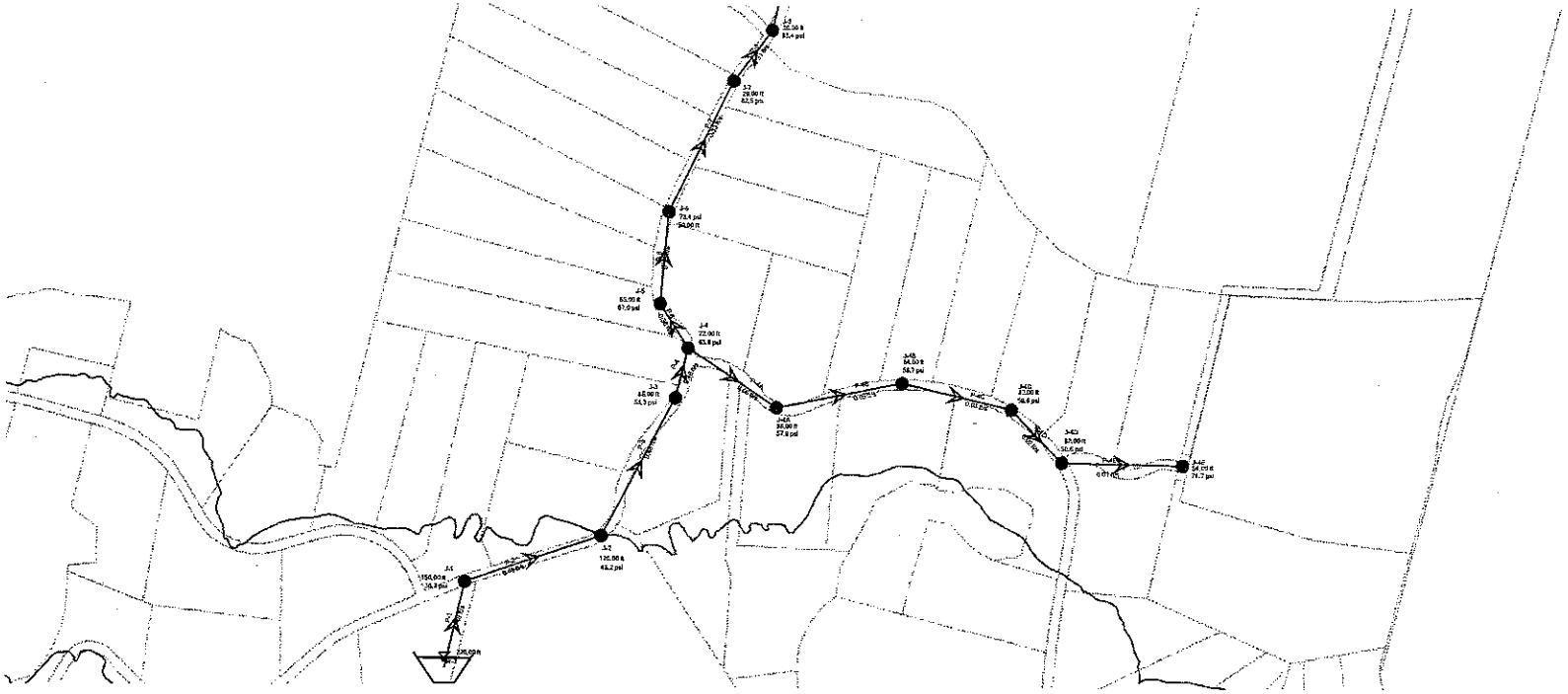
References	DW Demand	Domestic	500	GPD/Unit	Per Recommendation by Local Agency
	FW Demand	Typical Unit	1,000	GPM	See Reference HI tab (111-4) - 1000 gpm/hr for 0.5 hour
	FW Demand	Large Unit	2,000	GPM	See Reference HI tab (111-4) - 2000 gpm/hr for 2 hours
	IRR Demand (Livestock)	Animal	75	GPD/Head	Per Calvin Oda
	IRR Demand (Personal Pastur	Residential Unit	1,145	GPD/Unit	Per Calvin Oda
	Peaking Factor	Peak Hour	3	-	State of HI design guidelines - see Reference HI tab (111-5)
	Peaking Factor	Max Daily	1.5	-	State of HI design guidelines - see Reference HI tab (111-5)

	Category	Use	No Units	Rate	Units	Demand (gpd)	Storage Adjustments	
Existing Agricultural Wells	Irrigation	28 Orchard Lots	1	1,638,196	gpd	1,638,196	1,638,196	-
		Pasture (Lots 88, 89)	2	20,818	gpd	41,636	41,636	-
		Grazing (cattle)	350	75	gpd	26,250	26,250	-
						Subtotal	**1,706,082**	
Lower Tank	Irrigation	Personal Irrigation	28	1,145	gpd	32,060	32,060	-
	Domestic	Single Family Dwelling Units	28	500	gpd	14,000	21,000	Max Day flow
		Ag Cluster Dwelling Units	15	500	gpd	7,500	7,500	-
		Lodge	1	2,000	gpd	2,000	2,000	-
		Accessory Dwellings	16	500	gpd	8,000	8,000	
	Fire Flow	Mokuleia Fire Flow	2	2,000	gpm	240,000	210,000	Tank 1 and 2 will provide total Molkuleia fire flow.
		Mokuleia Max Day Domestic	1	133,600	gpd	133,600	200,400	Max Day flow
						Subtotal	**480,960**	
Upper Tank	Irrigation	Pasture	46	20,818	gpd	957,628	79,802	2 hours of pasture storage, Remainder is pumped directly from well.
	Domestic	Single Family Dwelling Units	64	500	gpd	32,000	48,000	Max Day flow
		Personal Irrigation	64	1,145	gpd	73,280	73,280	-
		Accessory Dwellings	30	500	gpd	15,000	15,000	-
	Fire Flow	Subdivision Fire Flow	0.5	1,000	gpm	30,000	30,000	-
						Subtotal	**246,082**	
						Total Storage Vol	**2,433,124**	
						Total Water Demand	**3,310,950**	

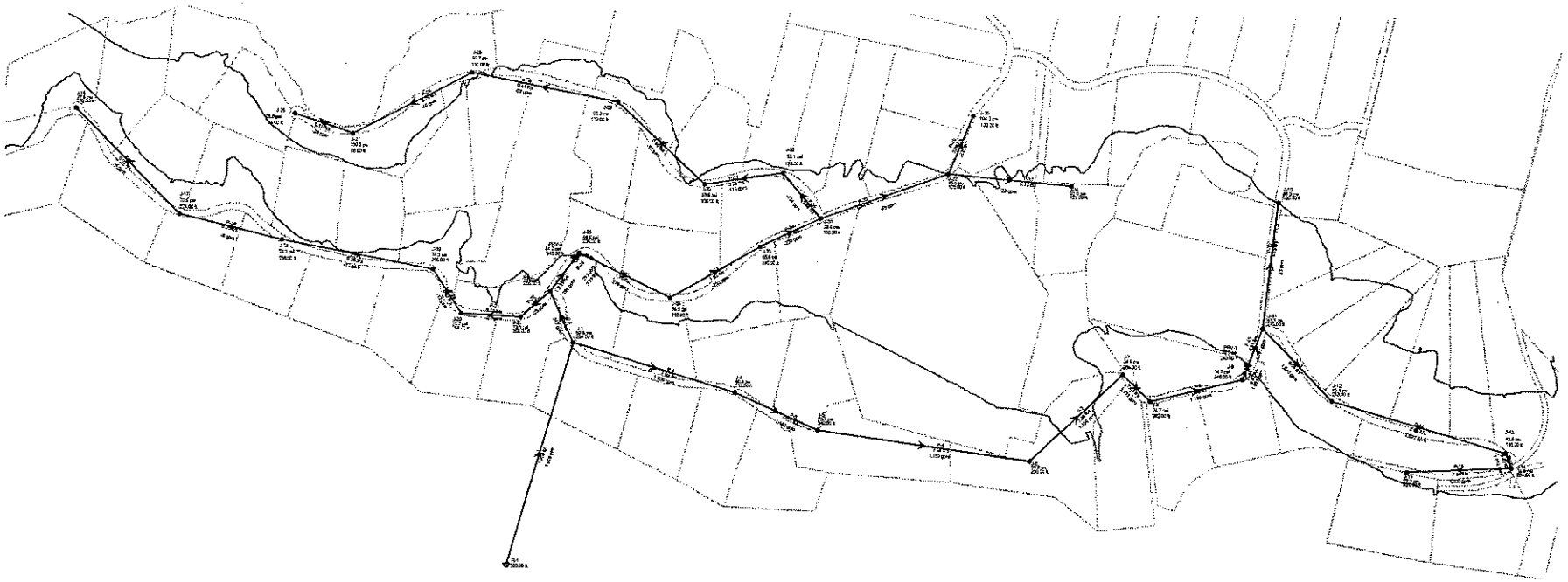
APPENDIX D

WATERCAD REPORTS

WATERCAD - LOWER MODEL



WATERCAD - UPPER MODEL



WATERCAD LOWER MODEL

GENERAL NOTES & ASSUMPTIONS

1. Lower Model refers to the pipe network servicing lots makai of Cane Haul Road (represented by Pressure Zone 1 in the Water Exhibit)
2. Static Flow Conditions assume no demands in the water main
3. Water Flow Conditions assume a pressure range of 55-110 psi
4. Fireflow Conditions require a minimum pressure of 20 psi
5. The maximum velocity in the pipe without fireflow is 6 ft/s
6. There is no irrigation component in the lower model.
7. Refer to State of Hawaii's Water System Standards page 111-5 for more information on these criteria
8. All pipes assumed to be ductile iron with Hazen-Williams Coef of 130

STATIC FLOW CALCULATIONS

JUNCTION TABLE

LABEL	ELEVATION (FT)	DEMAND (GPM)[3]	PRESSURE (PSI)
R-1 (Reservoir)	220	0.0	0
J-1[1]	150	0.0	30.3
J-2[1]	120	0.0	43.3
J-3	85	0.0	58.4
J-4	72	0.0	64
J-5	65	0.0	67.1
J-6	50	0.0	73.6
J-7	29	0.0	82.6
J-8	20	0.0	86.5
J-10 (Mokulela)[2]	8	0.0	91.7
J-09	10	0.0	90.9
J-4A	86	0.0	58
J-4B	84	0.0	58.8
J-4C	82	0.0	59.7
J-4D	82	0.0	59.7
J-4E (Lodge)	54	0.0	71.8

WATER DEMAND FLOW CALCULATIONS

JUNCTION TABLE

LABEL	ELEVATION (FT)	DEMAND (GPM)[3]	PRESSURE (PSI)
R-1 (Reservoir)	220	0.0	0
J-1[1]	150	0.0	30.3
J-2[1]	120	0.0	43.2
J-3	85	0.0	58.3
J-4	72	2.1	63.9
J-5	65	4.2	66.9
J-6	50	6.3	73.4
J-7	29	8.3	82.5
J-8	20	4.2	86.4
J-10 (Mokulela)[2]	8	4.2	91.5
J-09	10	69.4	90.7
J-4A	86	4.2	57.9
J-4B	84	6.3	58.7
J-4C	82	4.2	59.6
J-4D	82	4.2	59.6
J-4E (Lodge)	54	13.1	71.7

[1]Demand is entered as zero at these Junctions since they do not serve any houses
[2]Mokulela Community is assumed to have a demand of 100,000 GPD
[3]Refer to the Model Lower Reference Tab for more information

PIPE TABLE

LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	398	R-2	J-1	10	131	0.53
P-2	647	J-1	J-2	10	131	0.53
P-3	699	J-2	J-3	10	131	0.53
P-4	230	J-3	J-4	10	131	0.53
P-5	233	J-4	J-5	10	97	0.39
P-6	412	J-5	J-6	10	92	0.38
P-7	652	J-6	J-7	10	86	0.35
P-8	286	J-7	J-8	10	78	0.32
P-9	1210	J-8	J-09	10	74	0.3
P-10	1721	J-09	J-10	10	69	0.28
P-4A	476	J-4	J-4A	10	32	0.13
P-4B	573	J-4A	J-4B	10	28	0.11
P-4C	508	J-4B	J-4C	10	22	0.09
P-4D	328	J-4C	J-4D	10	17	0.07
P-4E	542	J-4D	J-4E	10	13	0.05

[1]Demand is entered as zero at these Junctions since they do not serve any houses
[2]Mokulela Community is assumed to have a demand of 100,000 GPD
[3]Demand values are doubled where nodes are placed between two lots

FIRE FLOW CALCULATIONS

JUNCTION TABLE - FIRE AT JUNCTION J-4E			
LABEL	ELEVATION (FT)	DEMAND (GPM)	PRESSURE (PSI)
R-1 (Reservoir)	220	0.0	0
J-1[1]	150	0.0	26
J-2[1]	120	0.0	32.1
J-3	85	0.0	39.8
J-4	72	2.1	42.9
J-5	65	4.2	45.9
J-6	50	6.3	52.4
J-7	29	8.3	61.5
J-8	20	4.2	65.4
J-10 (Mokuleia)[2]	8	4.2	70.5
J-09	10	69.4	69.7
J-4A	86	4.2	32.2
J-4B	84	6.3	27.5
J-4C	82	4.2	23.4
J-4D	82	4.2	20.2
J-4E (Lodge - Assigned Fireflow)	54	2000.0	27.2

[1]Demand is entered as zero at these Junctions since they do not serve any houses
[2]Mokuleia Community is assumed to have a demand of 100,000 GPD

PIPE TABLE - FIRE AT JUNCTION J-4E						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	398	R-2	J-1	10	2,118	8.65
P-2	647	J-1	J-2	10	2,118	8.65
P-3	699	J-2	J-3	10	2,118	8.65
P-4	230	J-3	J-4	10	2,118	8.65
P-5	233	J-4	J-5	10	97	0.39
P-6	412	J-5	J-6	10	92	0.38
P-7	652	J-6	J-7	10	86	0.35
P-8	286	J-7	J-8	10	78	0.32
P-9	1210	J-8	J-09	10	74	0.3
P-10	1721	J-09	J-10	10	69	0.28
P-4A	476	J-4	J-4A	10	2,019	8.25
P-4B	573	J-4A	J-4B	10	2,015	8.23
P-4C	508	J-4B	J-4C	10	2,008	8.2
P-4D	328	J-4C	J-4D	10	2,004	8.19
P-4E	542	J-4D	J-4E	10	2,000	8.17

[1]Demand is entered as zero at these Junctions since they do not serve any houses
[2]Mokuleia Community is assumed to have a demand of 100,000 GPD

JUNCTION TABLE - FIRE AT JUNCTION J-10			
LABEL	ELEVATION (FT)	DEMAND (GPM)	PRESSURE (PSI)
R-1 (Reservoir)	220	0.0	0
J-1[1]	150	0.0	26.2
J-2[1]	120	0.0	32.6
J-3	85	0.0	40.7
J-4	72	2.1	44
J-5	65	4.2	44.7
J-6	50	6.3	47.1
J-7	29	8.3	49.8
J-8	20	4.2	51
J-10 (Mokuleia - Assigned Fireflow)[2]	8	2000.0	27.9
J-09	10	69.4	43.6
J-4A	86	4.2	37.9
J-4B	84	6.3	38.8
J-4C	82	4.2	39.6
J-4D	82	4.2	39.6
J-4E (Lodge)	54	13.1	51.7

[1]Demand is entered as zero at these Junctions since they do not serve any houses
[2]Mokuleia Community is assumed to have a demand of 100,000 GPD

PIPE TABLE - FIRE AT JUNCTION J-10						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	398	R-2	J-1	10	2,118	8.42
P-2	647	J-1	J-2	10	2,118	8.42
P-3	699	J-2	J-3	10	2,118	8.42
P-4	230	J-3	J-4	10	2,118	8.42
P-5	233	J-4	J-5	10	97	8.28
P-6	412	J-5	J-6	10	93	8.26
P-7	652	J-6	J-7	10	87	8.24
P-8	286	J-7	J-8	10	78	8.2
P-9	1210	J-8	J-09	10	74	8.19
P-10	1721	J-09	J-10	10	70	8.17
P-4A	476	J-4	J-4A	10	2,019	0.13
P-4B	573	J-4A	J-4B	10	2,015	0.11
P-4C	508	J-4B	J-4C	10	2,008	0.09
P-4D	328	J-4C	J-4D	10	2,004	0.07
P-4E	542	J-4D	J-4E	10	2,000	0.05

[1]Demand is entered as zero at these Junctions since they do not serve any houses
[2]Mokuleia Community is assumed to have a demand of 100,000 GPD

WATERCAD LOWER MODEL REFERENCE

JUNCTION DEMAND ASSUMPTIONS

ITEM	RATE	UNIT	COMMENTS
DW Demand Rate	200	GPD/Bedroom	Per Recommendation by Local Agency
# Bedroom (Residence)	5	Bedroom	Assumed at all Parcels except for Lot 1002 and Dillingham Lodge
# Bedroom (Lodge)	8	Bedroom	Parcel 1001
# Bedroom (Ag Cluster)	40	Bedroom	Parcel 1002
Peak Hour Factor	3	-	State of HI Guidelines (Refer to Dillingham Ranch Water Balance)
DW Demand (Mokuleia)	69.4	GPM	Based on 100,000 GPD
DW Demand (Residence)	2.1	GPM	Calculated from known variables
DW Demand (Ranch)	3.3	GPM	
FW Demand	1,000	GPM	See Reference HI tab (111-4) - 1000 gpm/hr for 1 hour
FW Demand	2,000	GPM	See Reference HI tab (111-4) - 2000 gpm/hr for 2 hours

JUNCTION TABLE - LOWER (WATER FLOW ONLY)			
LABEL	DEMAND (GPM)[2]	#LOTS SERVED	CONTRIBUTING LOT #
J-1[1]	0.0	0	-
J-2[1]	0.0	0	-
J-3[1]	0.0	0	-
J-4	2.1	1	8
J-5	4.2	2	7,12
J-6	6.3	3	5,6,11
J-7	8.3	4	2,3,4,10
J-8	4.2	2	1,9
J-09	4.2	2	88,89
J-10	69.4	1	Mokuleia
J-4A	4.2	2	13, 31
J-4B	6.3	3	14, 15, 30
J-4C	4.2	2	16, 17
J-4D	4.2	2	18, 29
J-4E (Lodge)	13.1	4	19, 20, Lodge, Ag-Cluster
TOTAL	130.4	28	-

[1]Refer to the image below for a graphical representation of the junction demand

[2]Irrigation is not required for the lower zone. Demands in this Table reflect only basic domestic water demands. Refer to Model Lower tab for Fireflow scenarios

DILLINGHAM RANCH WATERCAD UPPER MODEL

GENERAL NOTES & ASSUMPTIONS

1. Lower Model refers to the pipe network servicing lots makai of Cane Haul Road (represented by Pressure Zone 1 in the Water Exhibit)
2. Static Flow Conditions assume no demands
3. Nominal Flow Conditions assume a pressure range of 55-110 psi
4. Fireflow Conditions require a minimum pressure of 20 psi
5. The maximum velocity in the pipe without fireflow is 6 ft/s
6. Total Irrigation Demand in the upper zone is assumed to be 825,000 gal
7. Refer to State of Hawaii's Water System Standards page 111-5 for more information on these criteria
8. All pipes assumed to be ductile iron with Hazen-Williams Coef of 130

PRESSURE REDUCING VALVE

PRV CALCULATIONS			
LABEL	ELEVATION	POST PRESSURE (PSI)	COMMENT
PRV-1	246	55.0	BETWEEN NODE J-9 & NODE J-11
PRV-2	246	41.0	BETWEEN NODE J-2 & NODE J-25

STATIC FLOW CALCULATIONS

JUNCTION TABLE - UPPER			
LABEL	ELEVATION (FT)	DEMAND (GPM)	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	0.0	89
J-2	266	0.0	101
J-4	318	0.0	79
J-5 (Highest Lot)	342	0.0	68
J-6	290	0.0	91
J-7	264	0.0	102
J-8	282	0.0	94
J-9	246	0.0	110
J-10 (Interconnect to Lower)	120	0.0	110
J-11	210	0.0	71
J-12	213	0.0	69
J-13	186	0.0	81
J-14	204	0.0	73
J-15	228	0.0	63
J-16	270	0.0	100
J-17	274	0.0	98
J-18	266	0.0	101
J-19	266	0.0	101
J-20	264	0.0	102
J-21	268	0.0	100
J-22	120	0.0	96
J-23	190	0.0	65
J-24	212	0.0	56
J-25	236	0.0	45
J-26	94	0.0	107
J-27	88	0.0	109
J-28	110	0.0	100
J-29	132	0.0	90
J-30	136	0.0	89
J-31	128	0.0	92
J-33	160	0.0	78
J-34	126	0.0	93
J-36 (Interconnect to Lower)	100	0.0	104

WATER DEMAND FLOW CALCULATIONS

JUNCTION TABLE - UPPER			
LABEL	ELEVATION (FT)	DEMAND (GPM)[1]	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	21.5	83
J-2	266	0.0	95
J-4	318	43.1	72
J-5 (Highest Lot)	342	32.3	62
J-6	290	0.0	84
J-7	264	21.5	95
J-8	282	32.3	87
J-9	246	10.8	102
J-10 (Interconnect to Lower)	120	21.5	110
J-11	210	10.8	71
J-12	213	32.3	69
J-13	186	32.3	81
J-14	204	10.8	73
J-15	228	32.3	63
J-16	270	53.8	92
J-17	274	21.5	91
J-18	266	43.1	94
J-19	266	21.5	94
J-20	264	10.8	95
J-21	268	21.5	94
J-22	120	10.8	94
J-23	190	21.5	64
J-24	212	10.8	55
J-25	236	0.0	45
J-26	94	21.5	105
J-27	88	21.5	108
J-28	110	21.5	99
J-29	132	21.5	89
J-30	136	21.5	87
J-31	128	21.5	91
J-33	160	21.5	77
J-34	126	21.5	92
J-36 (Interconnect to Lower)	100	21.5	103

PIPE TABLE - UPPER						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	1462	R-1	J-1	8	711	4.5
P-2	354	J-1	J-2	8	409	2.6
P-4	1069	J-1	J-4	10	280	1.1
P-5	574	J-4	J-5	10	237	1.0
P-6	1362	J-5	J-6	8	205	1.3
P-7	795	J-6	J-7	8	205	1.3
P-8	241	J-7	J-8	8	183	1.2
P-9	585	J-8	J-9	8	151	1.0
P-12	800	J-11	J-10	8	22	0.1
P-13	634	J-11	J-12	12	108	0.3
P-14	1139	J-12	J-13	12	75	0.2
P-15	101	J-13	J-14	8	43	0.3
P-16	658	J-14	J-15	10	32	0.1
P-17	927	J-16	J-17	10	-54	0.2
P-18	670	J-17	J-18	8	-75	0.5
P-19	970	J-18	J-19	8	-118	0.8
P-20	330	J-19	J-20	8	-140	0.9
P-21	379	J-20	J-21	8	-151	1.0
P-22	247	J-21	J-2	8	-172	1.1
P-24	655	J-23	J-24	8	-226	1.4
P-25	642	J-24	J-25	8	-237	1.5
P-27	385	J-26	J-27	8	-22	0.1
P-28	847	J-27	J-28	8	-44	0.3
P-29	937	J-28	J-29	8	-65	0.4
P-30	753	J-29	J-30	8	-87	0.6
P-31	503	J-30	J-31	8	-108	0.7
P-33	862	J-22	J-33	8	-54	0.3
P-34	422	J-33	J-23	8	-205	1.3
P-35	374	J-31	J-33	8	-130	0.8
P-37	773	J-34	J-22	8	-22	0.1
P-44	86	J-9	PRV-1	8	140	0.9
P-45	259	PRV-1	J-11	8	140	0.9
P-47	249	J-2	PRV-2	6	237	2.7
P-48	52	PRV-2	J-25	6	237	2.7
P-49	387	J-22	J-36	6	22	0.2

FIRE FLOW CALCULATIONS - FIRE FLOW AT J-15

JUNCTION TABLE - J-15			
LABEL	ELEVATION (FT)	DEMAND (GPM)	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	21.5	59
J-2	266	0.0	71
J-4	318	43.1	44
J-5 (Highest Lot)	342	32.3	32
J-6	290	0.0	40
J-7	264	21.5	43
J-8	282	32.3	32
J-9	246	10.8	42
J-10 (Interconnect to Lower)	120	21.5	94
J-11	210	10.8	55
J-12	213	32.3	52
J-13	186	32.3	63
J-14	204	10.8	54
J-15 (Assigned Fireflow)	228	1000.0	42
J-16	270	53.8	68
J-17	274	21.5	67
J-18	266	43.1	70
J-19	266	21.5	70
J-20	264	10.8	71
J-21	268	21.5	70
J-22	120	10.8	94
J-23	190	21.5	64
J-24	212	10.8	55
J-25	236	0.0	45
J-26	94	21.5	105
J-27	88	21.5	108
J-28	110	21.5	99
J-29	132	21.5	89
J-30	136	21.5	87
J-31	128	21.5	91
J-33	160	21.5	77
J-34	126	21.5	92
J-36 (Interconnect to Lower)	100	21.5	103

PIPE TABLE - J-15						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	1462	R-1	J-1	8	1,678	10.7
P-2	354	J-1	J-2	8	409	2.6
P-4	1069	J-1	J-4	10	1,248	5.1
P-5	574	J-4	J-5	10	1,205	4.9
P-6	1362	J-5	J-6	8	1,172	7.5
P-7	795	J-6	J-7	8	1,172	7.5
P-8	241	J-7	J-8	8	1,151	7.4
P-9	585	J-8	J-9	8	1,118	7.1
P-12	800	J-11	J-10	8	22	0.1
P-13	634	J-11	J-12	12	1,075	3.1
P-14	1139	J-12	J-13	12	1,043	3.0
P-15	101	J-13	J-14	8	1,011	6.5
P-16	658	J-14	J-15	10	1,000	4.1
P-17	927	J-16	J-17	10	-54	0.2
P-18	670	J-17	J-18	8	-75	0.5
P-19	970	J-18	J-19	8	-118	0.8
P-20	330	J-19	J-20	8	-140	0.9
P-21	379	J-20	J-21	8	-151	1.0
P-22	247	J-21	J-2	8	-172	1.1
P-24	655	J-23	J-24	8	-226	1.4
P-25	642	J-24	J-25	8	-237	1.5
P-27	385	J-26	J-27	8	-22	0.1
P-28	847	J-27	J-28	8	-44	0.3
P-29	937	J-28	J-29	8	-65	0.4
P-30	753	J-29	J-30	8	-87	0.6
P-31	503	J-30	J-31	8	-108	0.7
P-33	862	J-22	J-33	8	-54	0.3
P-34	422	J-33	J-23	8	-205	1.3
P-35	374	J-31	J-33	8	-130	0.8
P-37	773	J-34	J-22	8	-22	0.1
P-44	86	J-9	PRV-1	8	1,108	7.1
P-45	259	PRV-1	J-11	8	1,108	7.1
P-47	249	J-2	PRV-2	6	237	2.7
P-48	52	PRV-2	J-25	6	237	2.7
P-49	397	J-22	J-36	6	22	0.2

FIRE FLOW CALCULATIONS - FIRE FLOW AT J-26

JUNCTION TABLE - J-26

LABEL	ELEVATION (FT)	DEMAND (GPM)	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	21.5	59
J-2	266	0.0	66
J-4	318	43.1	48
J-5 (Highest Lot)	342	32.3	38
J-6	290	0.0	58
J-7	264	21.5	70
J-8	282	32.3	63
J-9	246	10.8	78
J-10 (Interconnect to Lower)	120	21.5	110
J-11	210	10.8	71
J-12	213	32.3	69
J-13	186	32.3	81
J-14	204	10.8	73
J-15	228	32.3	63
J-16	270	53.8	63
J-17	274	21.5	62
J-18	266	43.1	65
J-19	266	21.5	65
J-20	264	10.8	66
J-21	268	21.5	65
J-22	120	10.8	71
J-23	190	21.5	45
J-24	212	10.8	43
J-25	236	0.0	40
J-26 (Assigned Fireflow)	**94**	**1000.0**	**49**
J-27	88	21.5	55
J-28	110	21.5	52
J-29	132	21.5	51
J-30	136	21.5	56
J-31	128	21.5	64
J-33	160	21.5	53
J-34	126	21.5	68
J-36 (Interconnect to Lower)	100	21.5	79

PIPE TABLE - J-26

LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	1462	R-1	J-1	8	1,689	10.8
P-2	354	J-1	J-2	8	1,387	8.9
P-4	1069	J-1	J-4	10	280	1.1
P-5	574	J-4	J-5	10	237	1.0
P-6	1362	J-5	J-6	8	205	1.3
P-7	795	J-6	J-7	8	205	1.3
P-8	241	J-7	J-8	8	183	1.2
P-9	585	J-8	J-9	8	151	1.0
P-12	800	J-11	J-10	8	22	0.1
P-13	634	J-11	J-12	12	108	0.3
P-14	1139	J-12	J-13	12	75	0.2
P-15	101	J-13	J-14	8	43	0.3
P-16	658	J-14	J-15	10	32	0.1
P-17	927	J-16	J-17	10	-54	0.2
P-18	670	J-17	J-18	8	-75	0.5
P-19	970	J-18	J-19	8	-118	0.8
P-20	330	J-19	J-20	8	-140	0.9
P-21	379	J-20	J-21	8	-151	1.0
P-22	247	J-21	J-2	8	-172	1.1
P-24	655	J-23	J-24	8	-1,204	7.7
P-25	642	J-24	J-25	8	-1,215	7.8
P-27	385	J-26	J-27	8	-1,000	6.4
P-28	847	J-27	J-28	8	-1,021	6.5
P-29	937	J-28	J-29	8	-1,043	6.7
P-30	753	J-29	J-30	8	-1,065	6.8
P-31	503	J-30	J-31	8	-1,086	6.9
P-33	862	J-22	J-33	8	-54	0.3
P-34	422	J-33	J-23	8	-1,183	7.6
P-35	374	J-31	J-33	8	-1,108	7.1
P-37	773	J-34	J-22	8	-22	0.1
P-44	86	J-9	PRV-1	8	140	0.9
P-45	259	PRV-1	J-11	8	140	0.9
P-47	249	J-2	PRV-2	6	1,215	13.8
P-48	52	PRV-2	J-25	6	1,215	13.8
P-49	397	J-22	J-36	6	22	0.2

FIRE FLOW CALCULATIONS - FIRE FLOW AT J-16

JUNCTION TABLE - J-16

LABEL	ELEVATION (FT)	DEMAND (GPM)	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	21.5	60
J-2	266	0.0	67
J-4	318	43.1	49
J-5 (Highest Lot)	342	32.3	39
J-6	290	0.0	61
J-7	264	21.5	71
J-8	282	32.3	64
J-9	246	10.8	79
J-10 (Interconnect to Lower)	120	21.5	110
J-11	210	10.8	71
J-12	213	32.3	69
J-13	186	32.3	81
J-14	204	10.8	73
J-15	228	32.3	63
J-16 (Assigned Fireflow)	**270**	**1000.0**	**40**
J-17	274	21.5	40
J-18	266	43.1	49
J-19	266	21.5	58
J-20	264	10.8	62
J-21	268	21.5	64
J-22	120	10.8	94
J-23	190	21.5	64
J-24	212	10.8	55
J-25	236	0.0	45
J-26	94	21.5	105
J-27	88	21.5	108
J-28	110	21.5	99
J-29	132	21.5	89
J-30	136	21.5	87
J-31	128	21.5	91
J-33	160	21.5	77
J-34	126	21.5	92
J-36 (Interconnect to Lower)	100	21.5	103

PIPE TABLE - J-16

LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	1462	R-1	J-1	8	1,656	10.6
P-2	354	J-1	J-2	8	1,355	8.7
P-4	1069	J-1	J-4	10	280	1.1
P-5	574	J-4	J-5	10	237	1.0
P-6	1362	J-5	J-6	8	205	1.3
P-7	795	J-6	J-7	8	205	1.3
P-8	241	J-7	J-8	8	183	1.2
P-9	585	J-8	J-9	8	151	1.0
P-12	800	J-11	J-10	8	22	0.1
P-13	634	J-11	J-12	12	108	0.3
P-14	1139	J-12	J-13	12	75	0.2
P-15	101	J-13	J-14	8	43	0.3
P-16	658	J-14	J-15	10	32	0.1
P-17	927	J-16	J-17	10	-1,000	4.1
P-18	670	J-17	J-18	8	-1,021	6.5
P-19	970	J-18	J-19	8	-1,065	6.8
P-20	330	J-19	J-20	8	-1,086	6.9
P-21	379	J-20	J-21	8	-1,097	7.0
P-22	247	J-21	J-2	8	-1,118	7.1
P-24	655	J-23	J-24	8	-226	1.4
P-25	642	J-24	J-25	8	-237	1.5
P-27	985	J-26	J-27	8	-22	0.1
P-28	847	J-27	J-28	8	-43	0.3
P-29	937	J-28	J-29	8	-65	0.4
P-30	753	J-29	J-30	8	-86	0.6
P-31	503	J-30	J-31	8	-108	0.7
P-33	862	J-22	J-33	8	-54	0.3
P-34	422	J-33	J-23	8	-204	1.3
P-35	374	J-31	J-33	8	-129	0.8
P-37	773	J-34	J-22	8	-22	0.1
P-44	86	J-9	PRV-1	8	140	0.9
P-45	259	PRV-1	J-11	8	140	0.9
P-47	249	J-2	PRV-2	6	237	2.7
P-48	52	PRV-2	J-25	6	237	2.7
P-49	397	J-22	J-36	6	22	0.2

WATERCAD UPPER MODEL REFERENCE

JUNCTION DEMAND ASSUMPTIONS

1. Assumed all lots have irrigation demand
2. Irrigation demands assumed to be carried continuously over 24 hours

ITEM	RATE	UNIT	COMMENTS
DW Demand Rate	200	GPD/Bedroom	Per Recommendation by Local Agency
# Bedroom (Residence)	5	Bedroom	Assumed at all Parcels except for Lot 1002 and Dillingham Lodge
# Bedroom (Lodge)	8	Bedroom	
Peak Hour Factor	3	-	State of HI Guidelines (Refer to Dillingham Ranch Water Balance)
# Lots Served	66	-	
DW Demand (Residence)	2.1	GPM	Calculated from known variables. Doubled for nodes situated between two lots
IRR Demand	8.7	GPM	Based on 825,000 gpd from local consultant
FW Demand	1,000	GPM	See Reference HI tab (111-4) - 1000 gpm/hr for 1 hour
Total Water Flow Demand	10.8	GPM	Assumed as sum of IRR and DW Demand

JUNCTION TABLE - LOWER (WATER FLOW ONLY)			
LABEL	DEMAND (GPM)[1]	#LOTS SERVED	CONTRIBUTING LOT #
J-1	21.5	2	55, 73
J-2	**0.0**	**0**	**Dummy Node**
J-4	43.1	4	54, 57, 74, 75
J-5 (Highest Lot)	32.3	3	56, 76, 77
J-6	**0.0**	**0**	**Dummy Node**
J-7	21.5	2	78, 79
J-8	32.3	3	80, 81, 82
J-9	10.8	1	83
J-10 (Interconnect to Lower)	21.5	2	21, 28
J-11	10.8	1	22
J-12	32.3	3	23, 24, 84
J-13	32.3	3	25, 26, 27
J-14	10.8	1	90
J-15	32.3	3	85, 92, 91
J-16	53.8	5	62, 63, 64, 65, 66
J-17	21.5	2	61, 67
J-18	43.1	4	59, 60, 68, 69
J-19	21.5	2	58, 70
J-20	10.8	1	71
J-21	21.5	2	51, 72
J-22	10.8	1	36
J-23	21.5	2	44, 53
J-24	10.8	1	50
J-25	**0.0**	**0**	**Dummy Node**
J-26	21.5	2	42, 43
J-27	21.5	2	48, 49
J-28	21.5	2	40, 41
J-29	21.5	2	46, 87
J-30	21.5	2	45, 86
J-31	21.5	2	38, 39
J-33	21.5	2	37, 52
J-34	21.5	2	33, 34
J-36 (Interconnect to Lower)	21.5	2	32, 35
TOTAL	710.4	66	-

[1]Refer to the image below for a graphical representation of the junction demand

[2]Irrigation is not required for the lower zone. Demands in this Table reflect only basic domestic water demands. Refer to Model Lower tab for Fireflow scenarios

APPENDIX E

SUPPORTING DOCUMENTS

Table 100-19 - FIRE FLOW REQUIREMENTS				
LAND USE	FLOW (GPM)/DURATION (HRS)/FIRE HYDRANT SPACING (FT.)			
	HAWAII	KAUAI	MAUI	OAHU
Agriculture	500/0.5/600 (1)	250/1/500	500/2/500	1000/0.5/700
Rural			1000/2/500	
Single Family	(2)	(4)	1000/2/350	1000/1/350
Duplex	1500/1/300	(4)	1250/2/350	1000/1/350
PUD Townhouse and Low Rise Apartments	1500/1/300	(4)	(5)	1500/1/250
Schools, Neighborhood Businesses, Small Shopping Centers, Hotels (except Maui), and High Rise Apartments	2000/2/300	2000/2/350	2000/2/250	2000/2/250
Light Industry, Downtown Business, Large Shopping Center, and Hospitals	2,000/2/300	3000/3/350	2000/2/250	4000/3/250
Heavy Industry, Hotels	2,000/2/300	3000/3/350	2,500/2/ 250	(3)

(1) - Applies to one acre lot size or less
(2) - 10,000 sq. ft. or larger lot size = 500/2/600; Less than 10,000 sq. ft. lot size = 1000/1/600
(3) - Subject to special review and control by Manager
(4) - R-2 = 500/1/500 R-4 = 750/2/500 R-6 = 1000/2/500 R-10 = 1250/2/350
R-20 = 1500/2/350 RR-10 = 1500/2/350 RR-20 = 2000/2/350
(5) - A-1 = 1500/2/250 A-2 = 2000/2/250

Note:

1. On dead end streets, the last F.H. shall be located at one half the spacing distance for F.H.s from the last house/unit (frontage property line or to the driveway/access for the property).
2. Spacing of fire hydrant shall be measured along the roadway.

Table 100-20 - DEMAND FACTORS		
Island	Maximum Daily Demand	Peak Hour
Hawaii	1.5 x Average Day	5.0 x Average Day
Kauai, Maui, Oahu	1.5 x Average Day	3.0 x Average Day

111.06 PIPELINE SIZING.

Pipelines shall be sized to meet the following requirements:

1. Maximum daily flow plus fire flow with a residual pressure of 20 psi at critical fire hydrant.

2. Peak hour flow with a minimum residual pressure of 40 psi.

3. In determining the carrying capacity of the mains, the "C"* values to be applied are shown in Table 100-21.

Table 100-21 - "C"* FACTORS	
Pipe Diameter (In.)	"C"
4", 6"	100
8", 12"	110
16", 20"	120
24" and Larger	130

* Not for metallic non-cement lined pipe.

4. Maximum velocity in distribution main (without fire flow) is 6 feet per second.

5. *For Maui Only: In addition, the maximum velocity in mains shall apply as follows:*

   a. *Distribution mains - 10 feet per second with fire flow at max day domestic flow.*

   b. *Transmission mains without water services or fire flow - 20 feet per second.*

   c. *Fire lines - 13 feet per second.*

Agriculture Feasibility Report
Volume 2

Dillingham Ranch

Prepared for

Dillingham Ranch Aina LLC
c/o Kennedy Wilson International
9601 Wilshire Boulevard, Suite 220
Beverly Hills, California 90210

Volume 1 Prepared by

Development Strategies, LLC
1432 Kalaepohaku Street
Honolulu, Hawaii 96816

Prepared by:

Calvin Oda
dba North Shore Pineapple Company
907 10th Avenue
Honolulu, Hawaii 96816

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Executive Summary

The Dillingham Ranch Aina LLC is proposing to develop 92 five plus acre lots in an agricultural subdivision and 15 cottages in an agricultural cluster on approximately 814.5 acres out of 2,780 total acres of land located in Mokuleia, Oahu, Hawaii. The 92 lots for sale includes 48 pasture lots, 28 orchard lots, and 16 grazing lots. The development concept also allocated about 95 acres of land in bulk lot 1003 as the agricultural area for the Ag Cluster.

The Agricultural Plan for the Ranch is proposing to use the orchard lots and Ag Cluster parcel for commercial production of avocado, mango, and citrus to replace imported produce with locally grown produce. The plan also includes growing of farm to table crops, coconut and nursery crops for landscape purposes, managed pasture, pasture lots, and grazing lots to preserve the Working Ranch and to support the Ranch and Mokuleia communities.

The growing site has several advantages and disadvantages. The advantages include good production volumes with excellent fruit quality, focused and integrated plan, coordinated agricultural services and marketing cooperative, close proximity to primary market, wealth of available information, and low input, sustainable agriculture. The disadvantages include alternate-year bearing habit of mango, plant and fruit diseases, changing consumer preferences, low volume and lower fruit quality of citrus, capital costs and long time required for orchard establishment, labor cost and availability, use of residual fruit, and ag theft.

The results of the Agricultural Feasibility Report indicated that it is technically and economically feasible to grow avocado, mango, and citrus at the Ranch, if best management practices are used. The development of the best management practices is in progress. Some of the best management practices to mitigate risks associated with the commercial production that were discussed in detail in the Report are listed below.

- Development of a focused and integrated plan based on growing the best tree fruit crops with good local market potential that are well adapted to the growing conditions at the Ranch,

- Selection of the best agricultural areas based on soils, slopes and terrain, and availability of low cost irrigation water for the commercial production;

- Selection of the top avocado and mango cultivars to produce high yields of premium quality fruit over longer than traditional harvest periods to spread volumes;

- Production of significant volumes of avocado and mango that has superior quality to imported Hass avocado and Tommy Atkins mango and/.or locally grown Haden mango to allow for delivery of consistent weekly volumes;

- Identification of agricultural practices to improve on flowering and fruit set and to minimize the negative yield impacts from the alternate-year bearing habit of avocado and mango,

- Development of Pest and Disease Risk Management Plan to minimize tree mortality and attain high yields and saleable product recovery per acre; and

- Implementation of effective and uniform crop management practices by Ranch Agricultural Services and orderly sales and marketing of the commercial production by the Resident's Farmers' Cooperative.

The challenges of development of the largest commercial avocado and mango farms in Hawaii has been identified and will be addressed effectively in the design phase of the planning process. Failure is not an option.

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1. Introduction and Purpose

The Dillingham Ranch Aina LLC is proposing to develop an agricultural subdivision consisting of 92 five plus acre lots for sale. In addition, an Agricultural Cluster consisting of 15 farm dwellings is planned in a location mauka of the historic Dillingham House. Each farm dwelling in the Ag Cluster will have an ownership interest in about 95 acres in one of the bulk lots located in the lower portions of the Ranch. The sale of the farm lots and Ag Cluster will generate much needed capital funds to upgrade equipment and infrastructure required to support the Working Ranch and the new agricultural activities.

The detailed discussion of the development concept, background information, existing uses, land use classification, and historical context are presented in Volume 1 of this Agricultural Feasibility Report.

This Agricultural Feasibility Report, Volume 2 evaluates the technical feasibility of the commercial production of orchard crops to replace imported produce with premium quality, locally grown tree fruits. The format of this Report follows the guidelines established by the Department of Land Utilization of the City and County of Honolulu for approval of an agricultural subdivision.

The objectives of this Report are to:

1) Present relevant background, site specific, and crop specific information required to evaluate the technical feasibility of the commercial production of tree fruits and tropical specialty tree fruits at the Ranch;

2) Screen and select the best tree fruit and tropical specialty tree fruit crops based on market potential, soil properties and climatic conditions, and crop specific requirements for cultivation at the Ranch;

3) Develop the Agriculture Plan based on using a focused and integrated approach for the commercial production of consistent supplies of premium quality avocado, mango, and citrus to replace imported produce with locally grown production;

4) Develop the Preliminary Farm Management Plan to document the agricultural practices for the crop specific cultivars grown at the Ranch. Prepare the Preliminary Production and Marketing Plans to estimate gross revenue from the commercial production.. Conduct preliminary cultivar specific risk and benefits analysis and pest and disease risk management to identify issues of potential concern and agricultural practices that may mitigate potential risks;

5) Conduct an Opportunities and Constraints Analysis to identify advantages and potential constraints of commercial production of tree fruits at the Ranch; and 5) Identify the next steps in the economic analysis to ensure development of a sustainable business model for the orchard crops.

Volume 2 of the Report includes:

- This Section, **Introduction and Purpose**;

- Section 2, **Agricultural Areas** identifies the proposed agricultural areas and acres and presents the site conditions and location specific conditions required to select orchard crops that are well suited to the growing conditions at the Ranch;

- Section 3, **Agriculture Plan** presents the screening and selection of the best tree fruit and tropical specialty tree fruit crops based on market potential, climatic conditions; and crop specific agricultural requirements. Section 3 also presents key elements of the Plan that are required to attain the efficiencies, productivity, and profitability required for a sustainable Plan and Ranch Community.

- Section 4, **Preliminary Farm Management Plan** presents the screening and selection of avocado, mango, and citrus cultivars that meet production and fruit quality considerations for commercial production of tree fruit crops at the Ranch Section 4 also presents the preliminary production plans, agricultural practices, pest and disease risk management, and other relevant crop management activities.

- Section 5, **Crop Budgets** presents the potential capital and production costs for the commercial tree fruit production.

- Section 6, **Discussion and Conclusion** presents the Opportunity and Constraints Analysis and the conclusions of the Report.

This Report also covers some of the key elements for the irrigated managed pasture and pasture lots, farm to table crops, and nursery and coconuts for landscape purposes. Detailed Production Management Guides for all agricultural activities at the Ranch will be prepared at a later phase of the planning process.

Tables for all Sections are provided in Appendix A. Figures for all Sections are provided in Appendix B. Photographs of the selected avocado, mango, and citrus cultivars from the Plant It Hawaii website are shown in Appendix C.

2. Agricultural Areas

2.1 Purpose and Scope

The purpose of this Section is to document the site specific characteristics for the agricultural areas in the Agricultural Subdivision and Agricultural Cluster that are relevant to the selection of tree fruit and other crops with potential for commercial production at the Ranch. The scope of this Section covers all agricultural uses of the agricultural areas including pasture and grazing uses.

The agricultural areas in the subdivision and Ag Cluster parcel are shown in Figure 2-1 Revised Proposed Agricultural Irrigation Areas. (Hart Howerton, May 8, 2014). The gross acres for the agricultural areas are shown in the map key for Figure 2-1.

For crop management purposes, the agricultural areas were divided into two major management units or growing zones based on soil characteristics, slopes and terrain, susceptibility to periodic flooding, and irrigation system design parameters.. The two growing zones shown in Figure 2-2 includes:

- Growing Zone One consisting of 28 orchard lots, the Ag Cluster parcel (bulk lots 1002 and 1003), 2 pasture lots (numbers 88 and 89), the Lodge (bulk lot 1001) ,and the managed pasture (bulk lots 1004 and 1005) in the lower portions of the subdivision.

- Growing Zone Two consisting of the 46 pasture and 16 grazing lots in the upper portions of the subdivision.

Site visits were conducted on several occasions. This Report considers observations of the site conditions and information shared by the late Sam Delgado, long time Dillingham Ranch manager. Sam was a good hard working, knowledgeable, and honest man with the utmost integrity and respect for people and the aina. May he rest in peace.

2.2 Growing Zone One.

2.2.1 Soil Series and Characteristics

The soil series and their respective soil properties and qualities that includes soil infiltration rates, depth of soils, soil moisture holding capacities, soil nutrient levels, and soil pH are critical to site selection for the orchard crops.

The soil series and their respective soil properties and qualities are presented in a Natural Resources Conservation Service Custom Soil Resource Report for the Dillingham Ranch (NRCS, July 2013). The soil series for the previous subdivision plan were cataloged in Appendix J of the previous Agricultural Feasibility Report (Development Strategies LLC, November 2007). The detailed soil properties and other

characteristics are documented in the Official Soil Series Descriptions from the National Cooperative Soil Survey.

The soil properties and qualities for the soil series found in each agricultural area of Growing Zone One are shown below.

Ag Cluster. The soils in the Ag Cluster parcel identified by bulk lot number 1003 consist of the Pulehu soil series. The Pulehu soil series is a very deep, well drained clay loam soil that formed on alluvial fans and flood plains along drainage ways from sea level to 300 feet. Slopes in this field ranges from 0 to 5 percent. Soil pH in the soil profile ranges from 7.0 to 7.4. The soil moisture holding capacity is about 14 percent and organic matter content is about 1.5 percent.

The Pulehu series is suitable for pasture, orchard, and truck crops.

Orchard Lots. The soils in the Orchard Lots identified by lot numbers (1-19, 29-32,35-39) and the green color coding on the Figure 2-1 consists of Ewa, Haliewa, Kaena, Kawaihapai, and Pulehu stony clay soil series. Descriptions of these soil series are as follows.

- **Ewa Soil Series**. The Ewa soil series consists of deep, well drained silty clay loam soils that formed on alluvial fans and terraces at elevations from sea level to 150 feet. Slopes in this soil series ranges from 0 to 15 percent. Soil pH in the soil profile ranges from 7.0 to 7.2. Soil moisture holding capacity is about 13 percent and organic matter content is about 2.50 percent.

- **Haliewa Soil Series**. The Haliewa soil series consists of deep, well drained silty clay soils that formed on alluvial fans and flood plains at elevations from sea level to 250 feet. Slopes in this soil series ranges from 0 to 6 percent. Soil pH in the soil profile ranges from 6.4 to 6.9. Soil moisture holding capacity is about 14 percent and organic matter is about 2.0 percent.

- **Kaena Soil Series.** The Kaena soil series consists of deep, poorly drained stony clay soils that formed on fans and colluvial slopes at elevations from 50 to 150 feet. Slopes in this area range from 2 to 12 percent. The Kaena soils are located in middle lower part of the western side of the orchard lots. Soil pH in the soil profile ranges from 6.6 to 7.1. Soil moisture holding capacity is about 12 percent and organic matter content is about 2.0 percent.

- **Kawaihapai Soil Series**. The Kawaihapai soil series consists of deep, well drained clay loam soils that formed on alluvial fans and in stream valleys at elevations from sea level to 300 feet. Slopes of these soils in the orchard ranges from 0 to 2 percent. Soil pH in the soil profile ranges from 7.0 to 7.3. Soil moisture holding capacity is about 13 percent and organic matter content is about 1.5 percent.

- **Pulehu Stony Clay Loam**. The Pulehu (PuB) soil series consists of deep, well drained stony clay loam soils with slopes ranging from 3 to 6 percent. Soil moisture holding capacity is about 11 percent and organic matter content is about 1.5 percent.

The Ewa, Kawaihapai, and Pulehu soils are well drained soils with acceptable soil pH levels that are suitable for orchard crops. The Haliewa soils are well drained but have slightly low soil pH that may require lime applications.. The Kaena series is poorly drained requiring additional land preparation steps to decrease potential for water logged soils that may lead to root rot.

The soils in the orchard lots are suitable for pasture, orchard, and truck crops. The well drained Ewa, Haliewa, Pulehu, and Kawaihapai soils and gentle slopes are well suited for orchard crops. The Kaena soils are poorly drained with relatively low soil pH in the lower soil horizons. With proper management, the Kaena soils are suitable for orchard crops.

Managed Pasture. The soils in the Managed Pasture consists of Pulehu and Pearl Harbor soils series. The Pearl Harbor soil series is a deep,very poorly drained clay that formed from alluvium that deposited over and mixed with muck. The Pearl Harbor soils are located on the western side of bulk lot 1005.

The Pulehu and Pearl Harbor soils are suitable for managed pasture uses.

2.2.2 Slopes and Terrain.

For mechanized crop production, the 'rule of thumb' is to grow crops on slopes ranging from 0 to 15 percent. Avocado can be grown on slopes ranging from 0 to 30 plus percent. Most of the current local avocado production is grown on the slopes of Northern and Southern Kona, Hawaii.

The slopes and terrain of Growing Zones One and Two are shown in Figure 2-3 (Hart Howerton, Slope Analysis). The area specific slopes and terrain are discussed below.

The Ag Cluster Parcel and Managed Pasture located below the Cane Haul Road have relatively flat topography with 0 to 5 percent slopes. The elevation of the Ag Cluster parcel and managed pasture ranges from 10 to 20 feet above sea level. The gentle slopes and nearly flat terrain of this area are conducive to efficient field maintenance activities. Due to the long life of orchard crops, the uses of the Ag Cluster parcel must consider flooding potential, chloride content of soils, and potential salt injury from large surf during winter months.

The orchard lots near the Cane Haul Road have gentle slopes ranging from 0 to 10 percent and increasing to about 10 to 20 percent at the upper part or southern side of the lots. The elevation of the orchard lots ranges from 20 to 120 feet. The terrain at the western site of the upper part of the orchards lots are sloping towards the west from

about 10 to 20 percent to 0 to 5 percent. The elevation of the orchard lots ranges from 20 to 120 feet. The terrain of the eastern side of the upper part of the orchard lots are sloping towards the east from 20 to 30 percent to 10 to 20 percent. The moderate to slightly steep slopes are acceptable for cultivation of orchard crops.

2.2.3 Drainage and Streams.

The orchards will be located in areas with relatively flat to moderately sloping terrain within the drainage pathways of storm water from the Waianae Mountains. Avocado and citrus trees do not tolerate water logged soils. Drainage of excessive water out of the fields, infiltration of water into the soils, and evapotranspiration are important in maintaining the proper water balances in the orchards.

The Makaleha Stream is the major stream that flows through the upper and lower portions of the Ranch. It is listed as a perennial stream by the Atlas of Hawaiian Watersheds. The total stream length is 15.1 miles. The stream drains the Makaleha Watershed. The area of the watershed is 6.8 square miles with a maximum elevation of 3,976 feet.

The drainage pathways of storm water through the subdivision and historical flood plain are shown in Figure 2-4.

Ag Cluster. The western side of the Ag Cluster parcel is located within the flood plain for the Makaleha Stream. The agricultural plan will limit the types of orchard crops grown in the historical flood plain.

Orchard Lots. There are three drainage pathways that flow through the orchard lots. The drainage pathways drain the Waianae Mountains during periods of heavy rainfall. The drainage pathways flow through the western side of the orchard lots then discharge onto the flood plain or into the stream bed located at the western edge of the Ranch. Orchard crops will need to respect these natural drainage pathways as peak storm water flows can be significant due to the steep terrain in the upper portions of the subdivision.

Managed Pasture. The eastern side of the managed pasture sits within the historical flood plain. The agricultural uses in this area will be limited to pasture and coconuts. Coconut can tolerate about 12 days of water logging on the surface and can be planted within the flood plain.

2.2.4 Present Conditions.

The present conditions in the Ag Cluster parcel includes cultivation of coconut and palm trees for landscape purposes in lots 1003A and 1003B. There is guinea grass and other weeds growing under the coconut tree canopy Field 1003C is currently part of the managed pasture and paddocks and is planted with bermuda grass.

The present conditions in the orchard lots consists of kiawe, feather finger grass, guinea grass, bristly fox tail, lantana, koa-haole, Bermuda grass, and guava. This area is currently used as un-irrigated pasture for cattle.

The present conditions of the managed pasture is paddocks for horses that is planted with Bermuda grass. The use as paddocks will continue and may be expanded by construction of an Equestrian Center.

2.2.5 Climate.

The climatic conditions such as rainfall. temperature, and wind speeds are important factors in the selection of fruit trees that are well suited to cultivation at the Ranch. Since irrigation water is available, dry conditions especially during the winter months is highly desirable to minimize root rot development, improve on flowering and fruit set, and reduce incidence and severity of fruit diseases. The prevailing winds cannot be too strong or wind damage such as broken branches and poor fruit set may occur. Air temperatures will influence tree growth and development, flowering and fruit development times, and the length and the timing of the bearing period.

Prevailing Winds. The prevailing winds are east-northeast trade winds. Wind speeds are fairly steady averaging 10 to 25 miles per hour.

Rainfall and Temperature. The Camp Erdman station located along Farrington Highway to the west of the Ranch at an elevation of 10 feet above mean sea level is representative of weather conditions in Growing Zone One.

Average annual and monthly rainfall and average monthly air temperatures for Camp Erdman are shown in Table 2-1. Mean annual rainfall at Camp Erdman for the period from 1981 to present is 28.17 inches. The average monthly rainfall ranges from 0.83 inch (June) to 4.17 inches (December). There is a wide variation in mean annual rainfall among years in the period ranging from 10.08 inches (year 2000) to 55.70 inches (year 1982).

The average annual air temperature is 74.5 degrees F. The average monthly air temperatures ranges from 69.2 in March to 78.8 degrees F. in September.

2.3 Growing Zone Two.

2.3.1 Soil Series and Characteristics..

Pastures are usually grown in areas that are not suitable for sugarcane, pineapple, orchard, or truck crops.

Pasture Lots. The soils in the pasture and grazing Lots consists of EaC (Ewa silty clay, 6 to 12 percent slopes), EwC (Ewa stony silty cclay, 6 to 12 percent slopes), KaeC (Kaena stony clay, 6 to 12 percent slopes), KaeE (Kaena very stony clay, 10 to 35

percent slopes), and iRK (rock land). The soil properties for these soils are similar to those described in Section 2.2.1, however, the soils in the upper parts of the subdivision have more stones in the soil profile and relatively steep slopes that may hinder mechanized agriculture.

The soils in the pasture lots are suitable for pasture. The Ewa series is considered as prime farm land, if irrigated. The Kaena series is considered as not prime farm land. The rock land is unclassified.

2.3.2 Slopes andTerrain.

Growing Zone Two has moderate (10 to 20 percent) to steep (> 35 percent) slopes with slopes increasing with elevation. The elevation of the pasture lots range from 120 to 310 feet above mean sea level. The moderate to steep slopes will be difficult to irrigate with sprinklers due to variations in water pressures and potential run-off of surface water on the steeper slopes. The steepest areas in the subdivision will be used for grazing lots and will not be irrigated.

2.3.3 Drainage.and Streams.

There are six drainage pathways that flow through the western side of Growing Zone Two. The drainage pathways drain the Waianae Mountains during periods of heavy rainfall.

Three of the six drainage pathways flow into the orchard lots then to the flood plain or the stream bed at the western edge of the Ranch.. The other three drainage pathways follow their natural drainage pathways from the lower slopes of the Waianae Mountains then onto the flood plain of the Dillingham Air Field.

The drainage pathways through the pasture lots will not hinder the management of the irrigated pasture lots.

2.3.4 Present Conditions.

The current use for the proposed pasture and grazing lots is un-irrigated pasture for cattle. The area is covered in kiawe, kiu, lantana, koa-haole, and finger grass.

2.3.5 Climate

Rainfall and Temperature. There were no weather stations that are representative of Mokuleia, Oahu at elevations ranging from 200 to 400 feet. The Rainfall Atlas of Hawaii Interactive map was used to estimate mean annual and monthly rainfall for Growing Zone Two at about 300 feet above mean sea level..

Mean annual rainfall near the base of the Waianae Mountains is 34.52 inches. The average monthly rainfall ranges from 0.84 inches (June) to 4.92 inches (January).

The wide variation in annual rainfall at the Camp Erdman station indicates the potential for long periods of drought. It may be appropriate to develop emergency sources of feed for the cattle by growing forage crops in the Flats during periods of extended drought

3. Agriculture Plan

3.1 Purpose and Scope.

The purpose of this Section is to present the Agriculture Plan for the commercial production of tree fruit crops at the Dillingham Ranch. for the. The Agriculture Plan uses a focused and integrated approach to utilize the land and water resources of the subdivision to develop a low input, sustainable tree fruit farm. The scope of the Agriculture Plan focuses on the commercial production of orchard crops to replace imported fruits with local production. The orchard crops will serve as the foundation of the plan and allow for greater efficiencies in all aspects of the agricultural activities at the Ranch.

The Dillingham Ranch is in the final phase of planning in the development of an agricultural subdivision and Ag Cluster consisting of 92 five plus acre lots and 6 bulk lot parcels on 814.5 acres of land located in Mokuleia, Oahu, Hawaii.

The Agriculture Plan proposes to cultivate orchard and farm-to-table crops on the better soils and gentler slopes of Ag Cluster parcel and the orchard lots. The mauka areas of the subdivision with steeper slopes and stony soils will be used for irrigated pasture or grazing lots. The new agricultural activities will convert current un-irrigated coconut farm and pasture lands to more productive agricultural uses.

In order to achieve the overall goals, the Dillingham Ranch will preserve the current Working Ranch and the historical Dillingham House. The Ranch will make major infrastructure improvements to facilitate more intensive agricultural uses of the lands. The major investments in agriculture and the Ranch community will only be possible by infusion of new capital from the sale of lots in the agricultural subdivision.

The Dillingham Ranch provides a unique opportunity to transform an underutilized area into a productive agricultural area that will be a great asset to the Ranch and Mokuleia Community. The successful transformation to more productive agriculture uses will need to be based on the planning and execution of an innovative, cooperative, low input, and sustainable Agriculture Plan.

3.2 Growing Zones

The total or gross acres and net acres for the agricultural areas in Growing Zones One and Two are provided in Table 3-1. As described in Section 2, the available agricultural lands were divided into two growing zones based on soil types and characteristics, slopes and terrain, potential for flooding, and irrigation system design parameters. The agricultural subdivision includes 92 five + acre lots for sale. The proposed Ag Cluster includes15 cottages for farm dwellings and about 94.75 gross acres of land for orchards, farm-to-table crops, a fresh fruit packing/warehouse area, and nursery.

The assumptions used to estimate arable acres available in each growing zone are described below.

3.2.1 Growing Zone One.

The Ag Cluster parcel and managed pasture in bulk lots 1003 and 1004 are shown in Figure 3-1. The 28 orchard lots identified by lot numbers 1 to 19, 29 to 32, and 35 to 39 are shown in Figure 3-2.

Ag Cluster Bulk Lot. The Ag Cluster bulk lot located in the Flats identified by bulk lot number 1003 is approximately 94.75 gross acres. For farm management purposes, bulk lot 1003 will be divided into three sub-lots. Under current conditions, Lots 1003A and 1003B contains un-irrigated coconut and palm trees. Lot 1003C is currently part of the managed pasture in the paddocks. Approximately 90 percent of this lot or about 85.3 net acres will be irrigated.

Managed Pasture. The managed pasture located in the Flats below the Cane Haul Road consists of two bulk lots identified as bulk lot 1004 and 1005. Bulk lot number 1004 is a well maintained pasture that currently provides paddocks for horses. In the future, bulk lot 1004 may also include an Equestrian Center.

Bulk lot number 1005 is currently an un-irrigated pasture. The proposed future uses include a leach field for treated effluent from the privately owned wastewater treatment plant serving the Ag sub-division. The remainder of bulk lot 1005 will be used to expand the irrigated pasture. Combined acreage o the two bulk lots is 139.51 acres. Approximately 90 percent of these lots or about 125.6 net acres will be irrigated.

Lake Surrounds. The Lake Surrounds located at the western edge of the Flats near Farrington Highway and identified by bulk lot number 1006 is approximately 21.96 acres. Approximately 20 percent of this lot or about 4.4 net acres will be irrigated.

Lodge Ornamental. The Dillingham Lodge is located at the eastern side of the property and identified by bulk lot numbers 1001 and 1002 is approximately 38.55 acres. Bulk lot 1001 contains the Dillingham Lodge, the Ranch Manager's House, fruit and landscape trees, palms, and lawns. Bulk lot 1002 consists of the proposed area for the cottages of the Ag Cluster. It currently includes fruit trees, royal palms, and lawns. Approximately 90 percent of this lot or about 34.7 net acres will be irrigated.

Orchard Lots. The Orchard Lots consisting of 28 five plus acre lots are located above the Cane Haul Road is approximately 160.03 acres. Approximately 126.0 net acres or about 79 percent of the orchard lots will be used to grow fruit trees

3.2.2 Growing Zone Two.

The pasture lots color coded as yellow and the grazing lots color coded as white are shown in Figure 3-3.

Pasture Lots. The Pasture Lots consisting of 46 five plus acre lots located in the mauka portion of the subdivision and 2 lots located north of bulk lot 1005 is approximately 265.0 acres. Approximately 184 net acres of Growing Zone Two or 4 out of 5 acres will be used for irrigated pasture for horses. About 8 acres of the pasture lots in Growing Zone One will be irrigated.

Grazing Lots. The Grazing Lots consisting of 16 five plus acre lots located in the upper most portion of the subdivision covers about 94.0 acres. The grazing lots will support the cattle grazing activities that occurs on about 1,900 acres of the mauka lands above the suddivision.

3.3 Crop Selection Screening Criteria

The purpose of the Crop Selection Screening Criteria is to identify strengths and weaknesses of orchard and fruit and vegetable crops that may be adapted to the climatic and growing conditions at the Ranch. In order to optimize the efficiencies of agricultural activities, heavy emphasis was placed on evaluating the orchard crops that may be suitable for cultivation at the Ranch that have good current or future Oahu market growth potential.

In order to minimize potential environmental impacts and potential residential exposure to pesticides, the selected crops must be conducive to low input sustainable agriculture. At this phase of the planning process, 'generally regarded as safe'(GRAS) conventional and/or organic growing practices will be considered. At later stages of the planning process, all growing practices will need to be approved by the residents who own the small farm lots prior to their use at the Ranch..

The orchard crops were selected using the standard level of professional care based on:

- Market potential for import replacement and/or to meet growing consumer demands for locally produced fruits;
- Suitability for cultivation under climatic and growing conditions at the Ranch;
- Crops that produce predictable yields of good to excellent fruit quality to support consumer preferences for fresher, more flavorful locally grown produce;
- Crops that can be managed with organic and/or 'GRAS' conventional growing methods that will be approved by the residents/owners; and
- Crops that can be grown economically that will provide consistent positive revenue sources for the residents/owners and the Ranch.

Site conditions (soils, elevation, and slopes and terrain) will influence the types of orchard crops (and farm-to-table crops) that can be grown successfully at the Ranch. At this stage of the planning process, it is important to select the best tree fruit crops and cultivars that are well suited to the site and growing conditions. Once the orchards are established, they will provide sustainable value to the residents and the Ranch for 50 plus years. Therefore, it is critical to make the right decisions on the orchard crops prior to planting.

3.4 Hawaii Agricultural Statistics

The first step before crop selection can commence is to conduct a Production and Marketing Analysis based on the Hawaii Agricultural Statistics to determine production and consumption level trends of the various commodities for the targeted market. The target market, Oahu has the highest population level of all of the main Hawaiian islands. Therefore, Oahu farmers may be able to capitalize on increased effeciencies due to the close proximity of the primary market. Oahu growers will benefit from not having to incur inter-island and/or intra-state freight and handling charges, thus lowering costs and supporting sustainability of the small farms.

In this Report, potential crops will be selected for a pre-determined growing site. Due to limitations posed by site conditions, crop requirements, and internal restrictions on pesticide uses, the orchard crops will be restricted to crops with excellent local market potential that can be managed with organic and/or 'generally regarded as safe' conventional growing methods.

Once the potential crop is identified, the crop specific production and market data is used to prepare estimates on growing and production acres to meet the targeted market demand. The Production and Market Survey should consider the volume of local production and imports, quality (size and standards), and pricing of the potential crops. In order for Hawaiian agriculture to expand, the consumers and distributors must be willing to replace imports with locally grown commodities, if availability, quality, and pricing are competitive.

3.4.1 Production and Market Data

Annual Hawaii crop production data is provided in National Agriculture Statistics Service (NASS) reports at http://www.nass.usda.gov/hi.com. NASS data does not consistently report volumes of tropical fruit imported into the State. More detailed and difficult to obtain information will be required to validate the Agriculture Plan presented in this Report.

The NASS report entitled, Statistics of Hawaii Agriculture 2009 dated January 2011 was used in the initial screening and subsequent detailed screening, evaluation, and selection of orchard crops that are well suited for cultivation at the Ranch.

It makes absolutely no sense to grow crops that cannot be sold. One of the common marketing problems plaguing small farmers in Hawaii is under utilization of the production. At times, only 50 percent of the production is reported as sold. The root cause of the poor recovery will need to be identified and corrected for the small farms at the Ranch to be successful. The adoption of the Ranch Agricultural Services concept described in Section 3-12 will allow for uniform and effective agricultural practices to be used at the Ranch.. The establishment of a growers' cooperative described in Section 3-13 will help to attain the market potential for the orchard crops.

3.4.2 Hawaii Tree Fruit Production and Imports (Years 2005-2009)

Annual average Hawaii fruit imports and production between the years 2005 and 2009 are summarized in Table 3-2. Between 2005 and 2009, the highest annual average Hawaii imports of fruit were orange (13,404,000 lbs.), lemon (3,972,000 lbs.), avocado (2,196,000 lbs.), lime (1,881,000 lbs.), tangerine (1,652,000 lbs,) and grapefruit (1,564,000 lbs.). During this same period, no imports of guava, papaya, and pineapple were reported.

Between 2005 and 2009, the highest annual average Hawaii production levels of fruit were reported in the following order: 1) pineapple-26,5000, 000 lbs; 2) papaya-17,655,000 lbs.; 3) guava-5,080,000 lbs.; 4) avocado-1,004,000 lbs.; and citrus (grapefruit, lemon, lime, and tangerine)-251,000 lbs..

Preliminary Selection of Fruit Crops. Pineapple production in Hawaii has been declining steadily since 2007. Current pineapple production relies heavily on the local market although fresh pineapple is still exported to West Coast markets. The soil pH of the soil series at the Ranch are higher than optimum soil pH levels for pineapple production. Therefore, pineapple was removed from further consideration in the Agriculture Plan at this time.

Papaya production in Hawaii has been increasing steadily since the introduction of the ring spot virus resistant papaya cultivar, Rainbow. One of the selection criteria for fruit crops at the Ranch is to use organic and/or GRAS conventional growing methods with minimal pesticide use, if feasible. Non-GMO Sunrise papaya may be a good fit for the cultivation at the Ranch, however, it is critical to conduct a detailed risk assessment to determine if Sunrise papaya can be grown economically without suffering catastrophic losses to ring spot virus and other plant and fruit diseases (anthracnose, Phytopthora root rot and stem canker, etc.). Non-GMO papaya grown on Molokai may be satisfying the niche market for organic papaya. Papaya will not be included in this plan but may be considered at a later date.

Guava production in Hawaii has been on the steady decline due to imports of cheap foreign guava puree for juice, jelly, and baking products. There is a very small fresh local market demand for guava and the price per pound for processing fruit in only 15 cents. Guava was eliminated from further consideration in this Agricultural Plan due to its low fresh market potential and low price per pound for processing fruit.

Hawaii production of avocado was relatively static between the years 2005 to 2009, however, avocado has long been recognized as the most promising tree fruit crop for local expansion for import replacement. Hawaii avocado production satisfies approximately one third of the local market demand with about two thirds of the Hawaii market demand supplied by imports. The market and production data clearly show that Hawaii's avocado farmers can tap into the opportunity to replace about 2,196,000 lbs. of imports with local production. The opportunities and constraints of expansion of local avocado production will be fully developed in subsequent sub-sections of the Agriculture Plan.

Hawaii production of citrus crops such as grapefruit, lemon, lime, orange, and tangerine is non-existent to very low. Hawaii imports the bulk of the citrus fruits consumed in Hawaii. Hawaii citrus crops grown organically may fill a high end retail niche market and will be evaluated in the selection of fruit crops based on site conditions and crop specific requirements. The recent shortages of limes from Mexico may present an opportunity to expand local lime production.

3.4.3 Hawaii Tropical Specialty Fruit Production and Imports (Years 2005-2009).

Annual average Hawaii production of Tropical Specialty Fruit Crops for the years 2005 to 2009 are shown in Table 3-3.

Between 2005 to 2009, the highest annual average production of tropical specialty fruit crops were in the following order: 1) Mango-532,000 lbs.; 2) Rambutan-450,000 lbs.; 3) longan-219,000 lbs.; 4) lychee-181,000 lbs., and 5) atemoya-17,300 lbs.

US imports of mango for the years 2005 to 2008 averaged 295,029 metric tons per year. Hawaii imports of mango are not reported in the Hawaii Agricultural Statistics.

With the exception of mango, there were no imports of tropical specialty fruit into Hawaii. Mango, rambutan, longan, and lychee will be evaluated in the selection of tropical fruit crops based on site conditions and crop specific requirements.

3.4.4 Hawaii Vegetable Production and Imports (Years 2005-2009)

Annual average Hawaii vegetable production and imports for the years 2005 to 2009 are summarized in Tables 3-4 and 3-4A. Annual average Hawaii fresh herb production for the years 2005 and 2009 are summarized in Table 3-5.

This information is provided for informational purposes only. Due to limited land, water, and labor resources, it is not economically feasible to produce commercial quantities of fresh vegetable and herbs at the Ranch. The proposed production levels for the organic farm-to-table concept focusing on providing fresh produce for the Ranch community will be relatively small. The primary selection criteria used will be suitability to site and growing conditions and fair production levels of good quality vegetables and herbs at

reasonable costs using organic growing methods. The secondary selection criteria will be to maintain the organic farm-to-table concept without creating a reservoir or source of pests and diseases for the orchard crops.

3.5 Hawaii Tree Fruit Crop Requirements for Growing Site Selection

Orchard crops represent a long term commitment of land and water resources that can provide a long term source of revenue that requires manageable labor and equipment resources for operation and maintenance.

Crop specific crop requirements for avocado and citrus for screening against the growing site conditions are presented in Table 3-6

3.5.1 Avocado.

As discussed in the previous sub-section, avocado is the best tree fruit crop with potential for replacement of imports based on current Hawaii production levels and locally grown fruit quality. Avocado grows in a wide range of soils, but grows best in deep well drained fertile soils that are high in organic matter. Optimum soil pH for avocado is 6.2 to 7.5. In Hawaii, avocado can be grown at elevations from sea level to 2,500 feet. Growth and fruit quality is best at elevations below 1,000 feet. Avocado does not tolerate water logged soils. It is also very sensitive to chlorides in the soil. Phytopthora root rot and stem canker control is essential to minimize tree mortality and maintain high yields and fruit quality. Avocado should not be planted in areas with high winds.

In general, the soils in the Orchard lots are acceptable for cultivation of avocado. The Kaena series is a poorly drained, clay soil that will require 'special' management practices to minimize water logged soils. All soil series in the Orchard lots are low in organic matter and are expected to have low soil fertility. All soils will benefit from incorporation of manure and/or compost to increase organic matter and improve soil fertility. The relatively low elevation may result in earlier and shorter bearing seasons affecting the predictability of fruit harvests and deliveries. The drainage pathways in the Orchard lots will need to be kept clear to minimize water logged soils that may lead to Phytopthora root rot and stem canker. Root rot control programs will be essential to attain yields and improve fruit quality.

Avocado grown on approximately 126.0 net acres in the Orchard lots will be the primary orchard crop at the Ranch.

3.5.2 Citrus.

The high level of imports in relation to the very low levels of Hawaii production indicate that the potential risks of Hawaii citrus production may exceed the benefits of import replacement.

Grapefruit and lemon were eliminated from this phase of the crop selection process since they should be grown at elevations of 500 to 1,000 feet. Lime, orange, and tangerine were retained in the crop selection process since they can be grown at low elevations.

Lime, orange, and tangerine grows in a wide range of soil types but are best in deep, well drained, fertile soils. Citrus grows best at soil pH of 6 to 7. The Pulehu soils in the Ag Cluster parcel is acceptable for citrus cultivation. Sweeter citrus like orange and tangerine should be grown at elevations of sea level to 500 feet. Lime is grown best at elevations of 500 to 1000 feet. Citrus is chloride tolerant. Citrus should only be grown in areas that are not affected by Citrus Canker and Citrus Greening bacterial diseases.

Citrus will be grown commercially on 12.0 net acres in bulk lot 1003A of the Ag Cluster parcel and as Backyard Trees in the Ranch Community.

3.6 Tropical Specialty Fruit Crop Requirements for Growing Site Selection

Crop specific requirements for Tropical Specialty Fruit Crops for growing site selection are shown in Table 3-7.

3.6.1 Mango.

Mango is the second best orchard crop for cultivation at the Ranch. Mango has the highest annual average production volume of all tropical specialty fruit crops grown in Hawaii. It has a very high annual US import volumes averaging 295,029 metric tons. The Hawaii imports of mango were not reported in the Hawaii Agriculture Statistics. Mango cannot be exported from Hawaii without quarantine treatment due to its susceptibility to infestation by fruit flies.

Mango can be grown in a wide range of soils but it is best to grow mango in deep, well drained, fertile soils. It grows best at soil pH of 6.5 to 7.5. Mango must be grown in areas with relatively low rainfall due to its susceptibility of the flowers and fruit to anthracnose and powdery mildew. Excessive rains during flowering causes flower and fruit drop. Tolerance to anthracnose is critical to successful commercial production. Commercial mango cultivars should also be resistant to powdery mildew. Commercial production should be in low rainfall areas (below 40 inches per year) with irrigation. Mango grows best at elevations from sea level to 1,500 feet.

The Mango bearing season is from May to October with peak harvest season of June to August. Avocado harvests are expected to peak during the fall, winter, and spring months. Therefore, mango harvests during the summer may allow for more efficient use of labor, equipment, and facilities at the Ranch.

Mango will be grown on 43.3 net acres in fields 1003A and 1003B of the Ag Cluster parcel.

3.6.2 Longan and Lychee.

Longan and lychee are notorious for their alternate-year bearing habit or bearing fruit heavily every other year. Longan and lychee requires cool, dry winters for good flowering and fruit set. Longan and lychee should be grown at elevations from 1,000 to 2,000 feet on leeward sides of the islands. Both tree species are chloride sensitive. Due to the relatively low elevations at the Ranch, longan and lychee may not flower and bear fruits consistently. Therefore, longan and lychee have been removed from further consideration in the Agriculture Plan.

3.6.3 Rambutan.

Rambutan is less dependent on cool temperatures for flowering during the winter. It requires almost twice the amount of irrigation water to grow rambutan than the water required for mango. It requires water stress for good flowering and fruit set. Rambutan fruits have poor shelf life if they are removed from the panicles. Rambutan is normally grown in high rainfall areas (72 to 118 inches per year), therefore, it may not be possible to economically grow rambutan at the Ranch. Depending on the final cost of the irrigation water, rambutan may be considered for inclusion in the agriculture plan at a later date.

3.7 Other Agricultural Activities

Coconut. The Ranch has a long history of growing coconut and palm trees for landscaping purposes. Coconut and palms are currently grown in bulk lots 1003A and 1003B. The remaining coconut trees in bulk lot 1003A will be removed and re-planted in bulk lot 1003C. Bulk lot 1003C is located within the flood plain limiting the potential uses for fruit tree crops. Coconuts can withstand short periods of water logged soils and can be grown in the flood plain..

Coconut will be grown on about 27 acres in bulk lot 1003C of the Ag Cluster parcel.

Nursery. A small nursery will be established as a staging area for the grafted seedling avocado, mango, and citrus trees. The nursery will also grow backyard citrus trees, palms, Samoan coconut, pulmeria, hibiscus, pikake, Ti leaf, and other landscape plants for the Ranch community..

Pasture Lots. The pasture lots will be seeded with Bermuda grass and Spanish Clover and maintained as irrigated horse pasture for the residents/owners. The moderate to steep slopes and stony soils of the upper portion of the subdivision are acceptable for pasture uses.

Approximately 192.0 net acres of pasture will be grown on 48 Pasture Lots (or 4 acres per pasture lot).

Organic Farm-to-Table Fruit and Vegetable Crops. Organic fruit and vegetable crops will be grown on a small scale to provide the Ranch community with healthy, fresh produce to promote a sustainable, holistic lifestyle. Similar to the orchard crops, the organic fruit and vegetable crops need to be adapted to low elevations and relatively high temperatures. The preliminary list of organic farm-to-table crops include:

Low Elevation Crops

Green beans	Manoa lettuce	Pumpkins	Sunrise papaya
Bittermelon	Chinese peas	Italian squash	Green onions
Cucumber	Green Pepper	Oriental squash	Dry land taro
Eggplant	Sweet potato	Chili pepper	Radish

Fresh Herbs

Sweet basil
Asian basil
Parsley
Chinese parsley
Other herbs

Organic crop production will require crop rotation to reduce pest and disease pressures. It is important to develop an Integrated Pest Management Program to ensure that the small scale organic fruit and vegetable production does not become a reservoir for pests and diseases for the commercial orchards.

The Pulehu soils in bulk lot 1003A are acceptable for growing most of the crops listed above. Organic crops require more time for land preparation to control weeds during the fallow period. Cover crops such as Sunn Hemp may be planted prior to planting of organic crops to increase nitrogen and organic matter in the soils.

The farm-to-table crops and the small nursery will be grown on about 3.0 acres on the southern end of bulk lot 1003A.

3.8 Preliminary Gross Revenue Analysis

The estimated gross revenue per acre per year at the mature tree stage of orchard development is shown in Table 3-7. The estimated gross revenue per acre per year for coconut and nursery plants is shown in Table 3-8. The proposed acreage for the orchard and farm to table crops, average estimated yields (lbs./acre) of saleable product recovery per acre, and current prices for the Hawaii Agriculture Statistics or wholesale produce price index were used to estimate gross revenues at the mature stage of orchard development.

The total estimated annual gross revenue from avocado, mango, orange, lime, tangerine and farm to table crops is $1,003,563.

The estimated total value of landscape coconut is $1,447,200. Annual sales are variable, therefore gross revenue per year from the coconuts will be estimated at a later date. The value of the nursery plants will be determined at a later date.

The actual gross revenue may increase if higher yields or better prices for the fruit production are achieved in the future. The actual gross revenue could also decrease if less acres are planted, average yields of saleable product per acre are not attained, all the volume produced cannot be sold, or if prices for locally grown produce decline.

3.9 Pan Evaporation Projections

3.9.1 Growing Zone One

Table 3-10 presents the Pan Evaporation Projections for irrigation water requirements per acre (inch/day) for average daily, peak daily, and peak daily with 70 percent rainfall for Growing Zone One. The average annual pan evaporation data used for Station 847 is 73.35 inches. The average annual rainfall data used for the Camp Erdman station is 28.17 inches.

The average daily water requirement is 0.12 inch per day. The average peak daily water requirement is 0.23 inch per day. The average daily and peak daily water requirement with 70 percent rainfall are 0.14 and 0.24 inch per day, respectively.

3.9.2 Growing Zone Two

Table 3-11 presents the Pan Evaporation Projections for irrigation water requirements per acre (inch/day) for average daily, peak daily, and peak daily with 70 percent rainfall for Growing Zone Two. The average annual pan evaporation data used for Station 861 is 64.43 inches. The average annual rainfall data used for Growing Zone Two (Hawaii Rain Atlas Interactive Map) is 34.52 inches.

The average daily water requirement is 0.10 inch per day. The peak daily water requirement is 0.19 inch per day.

3.10 Crop Water Demand

The Crop Water Demand were estimated for Growing Zones One and Two using net acres for the list of selected crops or proposed uses, middle stage of growth crop factors, form of irrigation and irrigation efficiencies. It is important to note that the estimated crop water demand is intended to estimate irrigation water needs for the orchards at steady state or mature trees. It will take three to five years to plant all of the orchard acres then another five years to reach the young tree stage of orchard development and finally another five years to reach the mature tree stage of orchard development.

The orchards will be irrigated using micro-sprinklers. Micro-sprinklers have excellent irrigation efficiency of 85 percent and are easier to maintain than drip irrigation. The managed pasture and pasture lots will be irrigated using solid set sprinkler irrigation system with 70 percent irrigation efficiency.

3.10.1 Growing Zone One

Table 3-12 estimates the average daily water requirement, peak daily water requirement, and peak daily water requirement with 70 percent rainfall for the preliminary crop list for Growing Zone One using the Pan Evaporation Projections in Table 3-9. .

The estimated average daily irrigation water requirement for Growing Zone One is 1,638,196 gallons of water per day. The peak daily irrigation water requirement is 3,141,714 gallons of water per day. The peak daily irrigation water requirement with 70 percent rainfall is 3,278,308 gallons of water per day.

3.10.2 Growing Zone Two.

Table 3-13 estimates the average daily water requirement, peak daily water requirement, and peak daily water requirement with 70 percent rainfall for the pasture using the Pan Evaporation Projections for Growing Zone Two shown in Table 3-10

The estimated average daily irrigation water requirement for Growing Zone Two is 999,267 gallons of water per day. The estimated peak daily irrigation water requirement is 1.925,596 gallons per day. The estimated peak daily irrigation water requirement with 70 percent rain is 1.925,596 gallons per day.

3.11 Irrigation Plan

The economic development and delivery of sufficient irrigation water for the Working Ranch and the agricultural activities in the subdivision and Ag Cluster parcel is an essential component of the Agriculture Plan.

3.11.1 Groundwater Supply Wells.

Domestic and irrigation water for the Ranch is currently provided by two groundwater supply wells located in the Flats. Potable water for Ranch and the Mokuleia Community is currently provided by Well No. 1 (State Well No. 3410-01). The depth of the borehole for Well No. 1 extends to 417 feet below sea level. The groundwater level is 18.2 feet above mean sea level when the well was first developed. The pumping rate is about 400 gallons per minute at 50 psi. The groundwater allocation for Well No. 1 is 500,000 gallons per day.

Irrigation water for the Ranch is currently provided by Well No. 2 (State Well No. 3401003). The surface elevation at the drilling platform is about 20 feet above mean

sea level. The depth of the borehole is finished to about 498 feet with the bottom of the well at about 438 feet below sea level... In the future, Well No 2 will provide irrigation water for Growing Zone One through dedicated irrigation water supply lines. The groundwater allocation for Well No. 2 is 1,500,000 gallons per day. The pumping rate for the water allocation is about 1,042 gallons per minute.

The estimated average daily irrigation water requirement for Growing Zone One is 1,638,196 gallons per day. The total pumping capacity of the two wells is 1,726,000 gallons per day. Well No. 1 should be converted to irrigation uses after the new domestic water system is developed.

When the orchards are mature, it may be necessary to prioritize irrigation according to its greatest benefits. The orchards and farm-to-table crops should be assigned the highest irrigation priority in the Irrigation Management Plan. The orchards lots and Ag Cluster parcel have an estimated daily irrigation water requirement of 567,736 gallons per day. With effective irrigation management, Well No. 2 will provide adequate irrigation water in the short term for the more intensive agricultural activities and managed pastures in Growing Zone One.

Irrigation water for the Mauka lands were previously provided by Well No. 3 (State Well No. 3310-01) and Well No. 4 (State Well No. 3310-02). These wells will be replaced with two new groundwater supply wells located closer to electrical and domestic water systems for the subdivision.. The groundwater allocation for Well No(s) 3 and 4 is 2,050,000 gallons per day It is intended to transfer the water allocations for Well No (s) 3 and 4 to the new groundwater supply wells in the future. The new wells will provide domestic water for the subdivision and the Mokuleia Community and irrigation water for Growing Zone Two.

The estimated average daily irrigation water requirement for Growing Zone Two is 999,267 gallons per day. The combined domestic and irrigation water requirement for the Growing Zone Two water system is 1,342,953 gallons per day.

The new groundwater supply wells, domestic water storage system, domestic water supply lines, and fire protection lines for the subdivision will be presented in the Water Master Plan.

3.11.2 Irrigation Sets

The agricultural areas of Growing Zone One will be irrigated with water from Well No. 2 using new irrigation supply lines, sub-mains, and laterals. The current pump in Well No. 2 may deliver about 800 gpm into the main irrigation supply lines. The friction losses due distances from the well, changes in elevation, pipe diameter and changes in angles and fittings, and the impacts on water flow and pressure of the irrigation system needs to be taken into account in the final design of the irrigation systems.

Well No. 2 is located at about 20 feet above mean sea level at the intersection of the Lodge access road and the Cane Haul Road.. The Agriculture Plan identifies three primary irrigation targets in Growing Zone One. In this Section, the irrigation targets were preliminarily divided into irrigation sets as described below.. The preliminary irrigation system design of irrigation sets were based on trying to use the full flow of the well in one or more irrigation sets. The preliminary irrigation sets include:

Ag Cluster Bulk Lot. The Ag Cluster bulk lot is nearly flat. The surface elevation at the Cane Haul Road is about 20 feet above mean sea level and slopes slightly downwards to 15 feet above mean sea level as its northern edge meets Farrington Highway. The orchard and farm to table crops will be planted in the width (East to West) direction to maximize sunlight exposure and to minimize creation of micro-environments within the orchards. Bulk lot 1003A is about 2,625 feet in length and 638 feet in width. Bulk lots 1003B and 1003C were combined into one irrigation unit for greater irrigation efficiency. The combined dimensions of these bulk lots are about 2,850 feet in length and 900 feet in width.

The four irrigation sets for the Ag Cluster parcel are shown in Figure 3-4. The Ag Cluster parcel was divided into four equal size irrigation sets and labeled as 1 to 4. Irrigation sets 1 and 2 located in bulk lot 1003A are each about 16.85 acres in size. Irrigation sets 3 and 4 located in bulk lots 1003B/1003C are each about 25.8 acres in size.

Orchard Lots. The 28 orchard lots were divided into four irrigation management sections. In general, the orchard lots are sloping downwards from East to West. The orchards will be planted in the East to West or length direction to maximize sunlight exposure and minimize the creation of micro-environments within the orchards.. The irrigation management sections and irrigation sets shown in Figure 3-5 includes:

- **Section 1** (lots 9-19) starts at about 20 feet above mean sea level at the Cane Haul Road and rises to about 80 feet above sea level near Road B. Section 1 is about 2,400 feet in length and about 750 to 1,425 feet in width. This section will be divided into two irrigation sets, Section 1A (lots 15 to 19) and Section 1B (lots 9 to 14).

- **Section 2** (lots 1 to 8) starts at about 20 feet above mean sea level at the Cane Haul Road and rises to about 50 (western end of lot 8) to 70 feet (eastern end of lot 8) above sea level. It is about 1,200 feet in length and about 1,800 feet in width. This section will be divided into two irrigation sets, Sections 2A and 2B.

- **Section 3** (lots 29-32) starts at about 90 feet above sea level and rises to about 140 feet above sea level. Section 3 is about 1,800 feet in length and about 600 feet in width. This Section will consist of one irrigation set.

- **Section 4** (lots 35 to 39) starts at about 50 feet above sea level and rises to about 120 feet above sea level. It is about 1,200 feet in length and about 900 feet in width. This Section will consist of one irrigation set.

Managed Pasture. Bulk lots 1004 and 1005 includes about 125.6 acres of pasture. The managed pasture will be irrigated with solid set sprinklers. Due to the higher flow rate of solid set sprinklers and the current limitation of the 800 gallons per minute pumping rate, the irrigation sets are estimated to range from about 8 to 16 acres in size.

Bulk lot 1004 is the main body of the managed pasture in Growing Zone One. Bulk lot 1004 is about 2,400 feet in length and 1,800 feet in width.

The irrigation sets for the managed pasture in bulk lot 1004 are shown in Figure 3-4. Bulk lot 1004 will be divided into twelve irrigation sets with dimensions of about 1,200 feet in length and 300 feet in width each. The irrigation sets in the managed pasture will be labeled from 1 to 12.

3.11.3 Irrigation System Components

Pipeline Sizes.

The following sub-sections presents the conceptual irrigation design and should not be considered as the final irrigation system design. The final irrigation system design must be based on engineering design to calculate water flow and mainline/sub-main/lateral water pressures. Water pressures will be influenced by friction losses and water pressure gains resulting from changes in elevations, pipeline sizes and lengths, and micro-sprinkler and/or sprinkler nozzle size and spacing and output per sprinkler.

The preliminary layout for the main lines and sub-mains for the irrigation system in Growing Zone One are shown in Figure 3-6.

Ag Cluster Parcel. For pipeline sizing for the Ag Cluster parcel, the average daily crop water demand for mango, citrus, coconut, and the farm to table crops is 241,431 gallons per day for 83.5 net acres. The average peak daily crop water demand for the Ag Cluster parcel is 464,582 gallons per day.

The Ag Cluster parcel will be supplied with irrigation water from Well No. 2 through a 1,500 foot 8 inch diameter schedule 120 PVC pipeline installed along the Lodge access road and crossing with risers into the four irrigation sections. The 8 inch diameter pipeline is not necessary for the Ag Cluster parcel, however, it is necessary to deliver the combined crop water demand for the managed pasture and the Ag Cluster parcel.

Orchard Lots. For pipeline sizing for the orchard lots, the average daily crop water requirement for 126 acres of avocado is 386,417 gallons per day. The average peak daily crop water requirement for avocado is 740,633 gallons per day. The orchard lots will be supplied with water from Well No. 2 through a 3,300 foot long, 8 inch diameter

schedule 120 PVC pipeline. The 8 inch diameter pipeline is required to take the full flow of the well and to reduce friction loss from pumping water to about 120 foot higher elevation than the well..

The pipeline will cross the Makaleha Stream at the bridge for the Lodge then proceed from East to West at the half acre line of Section 1 of the orchard lots. The pipeline will cross Road A into Sections 2. The sub-mains will T-off to the south to along the property lines between lots 14 and 15 and to 120 foot elevation between lots 30 and 3 to irrigate Section 4.. The sub-mains will T-off the main line along Road A to the half acre line of lot 36 for irrigation of Section 3.

Managed Pasture. For pipeline sizing for 125.6 acres of the managed pasture, the average daily crop water requirement is 818,530 gallons per day. The average peak daily crop water requirement is 1,568,849 gallons per day.

The managed pasture in bulk lot 1004 will be supplied with water from the well through a 2,700 foot long 8 inch pipeline schedule 120 PVC pipeline that T off of the Ag Cluster pipeline along the Lodge access road and crosses through bulk lot 1003B and 1003C and through bulk lot 1004 to the Ranch access road. The pipeline will eventually cross the Ranch access road to supply irrigation water for bulk lot 1005, pasture lots 88 and 89, and the Lake Surrounds.

Pasture Lots. For pipeline sizing for the 184 net acres of the pasture lots in the upper subdivision, the average daily water requirement is 999,267 gallons per day. The peak daily crop water requirement is 1,925,596 gallons per day.

The irrigation water for the pasture lots will be supplied from the domestic water system for the subdivision. The connections of the sub-mains to the domestic mainline will be at the fire hydrants.

The proposed pumping rate for each new domestic groundwater supply well is 1,000 gallons per minute. The domestic mainline will be 12 inch with water pressures ranging from 55 to 110 psi. The domestic water will be stored in two water tanks depending on the pressure zone. There are three pressure zones identified as zones 1, 2, or 3. The tanks are engineered to store adequate domestic water, fire protection water, and about 91,700 gallons of irrigation water.

Sprinkler Systems.

Micro-Sprinkler Irrigation for Orchards. Micro-sprinkler irrigation is a low pressure, low to medium volume irrigation system that is well suited for high value crops like fruit trees. If managed properly, micro-sprinklers can increase yields and decrease water use and fertilizer and labor requirements. Micro-sprinkler irrigation saves water due to its high irrigation efficiency (85 percent) and high water distribution uniformity. Micro-sprinklers are ideal for irrigating sloping and irregular shaped orchard blocks. Fertilizers will be injected into and applied with the micro-sprinklers to reduce labor costs when

compared to traditional manual side dress applications. The wider orifice spacing compared to drip irrigation reduces clogging.

Micro-sprinklers operates under low water pressures, typically 20 to 35 psi with wetting patterns of 10 to 30 feet and a variety of discharge flows ranging from 8 to 90 gallons per micro-sprinklers per hour. This flexibility allows irrigation to more closely match the water needs to soil infiltration rates, orchard size, tree maturity and spacing, and the depth of the rooting zone.

A pressure regulator is used to control the line pressures to maintain maximum operating pressures for optimal efficiency. Multiple pressure regulators may be necessary in areas with large elevation changes since water pressure will increase with elevation drops. The main lines are designed to deliver water at the upslope part of the irrigation sets since it is easier to move water efficiently down hill than up hill through the sub-mains. Small diameter PVC pipe (1/2 to 1 inch) is generally used for in-row laterals. The laterals are laid on the ground with risers or suspended above ground on wire and T-posts in the tree row with drop nozzles. The suspended laterals will allow for mowing to occur around the laterals. The preliminary engineering design for the orchard crops are shown below.

- **Avocado.** For Section 1A in the avocado groves, the outlets from the mainline to the sub-mains will be installed to divide the irrigation set into two halves to allow for better water distribution within the laterals. For Sections !B, 2A, and 2B, the outlets to the mainline will allow the sub-mains to provide water in the laterals from the East to West direction. For Section 3 and 4, the outlets from the mainline to the sub-mains will deliver water to the highest point in the Sections at the half acre mark to allow water distribution in the laterals in the East to West direction. The sub-main or width dimension ranges from 450 to 975 feet in length. The lateral or length dimension ranges from 750 to 975 feet in length.

  The laterals will be installed at 25 foot intervals along the sub-mains and micro-sprinklers will be installed at 25 foot intervals along the laterals. There are 87 trees per acre with one or more micro-sprinklers per tree. With 87 micro-sprinklers per acre and about 20 acres in the set, there are about 1,740 micro-sprinklers delivering about 28 gph per micro-sprinkler when the well is pumping at 800 gpm.

- **Mango.** For mango, the laterals will be installed at 35 foot intervals along the sub-mains and micro-sprinklers will be installed at 30 foot intervals along the laterals. There are 41 trees per acre with one or more micro-sprinklers per tree. With 41 micro-sprinklers per acre and about 17 acres in one irrigation set, there are about 697 micro-sprinklers delivering about 28 gph. The water flow to operate the mango irrigation system is estimated at 325 gpm.

- **Citrus**. For lime, the laterals will be installed at 20 foot intervals along the sub-mains and micro-sprinklers will be installed at 20 foot intervals along the laterals.

There are 109 trees per acre with one or more micro-sprinklers per tree. With 109 micro-sprinklers per acre and about 12 acres in one irrigation set, there are about 1,308 micro-sprinklers delivering about 28 gph per sprinkler. The water flow to operate the citrus irrigation system is estimated at 610 gpm.

Solid Set Sprinklers for Managed Pastures. Solid set sprinkler systems have the lowest labor requirement and the highest equipment cost per acre. Solid set sprinkler systems will allow the Ranch to irrigate managed pasture more effectively and at lower labor costs than the current portable sprinkler systems.

The type of solid set sprinkler system is determined by the laterals. The laterals may be portable or permanent. Permanent laterals were selected for the solid set sprinkler system to reduce labor costs and to allow mowing of the pasture. The permanent laterals will be 1 ½ inch diameter PVC laterals buried about three feet deep to minimize equipment and animal damage.

The standard single sprinkler nozzle sizes are 7/64, 1/8, 9/64, or 5/32 inch in diameter Spacing of sprinklers on the lateral may range from 40 to 300 feet. Spacing of the outlets to the mainline may range from 50 to 330 feet apart. The required nozzle pressure depends on sprinkler and nozzle sizes used. Nozzle pressures range from 50 psi for standard sprinklers to 120 psi for big gun type sprinklers.

The design of the solid set sprinkler irrigation systems are based on spacing of sprinklers and laterals to provide full water coverage at about 70 percent irrigation efficiency to meet the peak water use rates of the pasture. The irrigation in the managed pasture will use the overflow discharge of the well when the orchard irrigation systems are operating at lower discharge capacities due to tree maturity or soil infiltration rates.

For the preliminary design, the outlets from the mainline to the sub-mains will be spaced at 300 foot intervals to divide the managed pasture into six irrigation sets with lateral spacing of 50 feet on the sub-mains or 5 laterals per irrigation set. The sprinkler spacing will be 50 feet between sprinklers on the lateral. There are 30 sprinklers per lateral or 150 sprinklers per irrigation set. The individual sprinkler nozzle output is 1.92 gallons per minute. One irrigation set may use about 300 gpm with irrigation times of about 4 hours, therefore, it may be possible to irrigated two irrigation sets at one time if the full flow of Well No. 1 is used.

Solid Set Sprinklers for Pasture Lots. The pasture lots will be difficult to irrigate due to large variation in shape of the lots and the variable terrain and relatively steep slopes. The sub-main connections from the fire hydrants will flow down slope resulting in increases in line pressures. The elevation changes varies among lots and ranges from about 60 to 100 feet. The laterals will be installed cross slope at 50 foot spacing on the buried sub-main and sprinkler spacing at 50 feet apart on the laterals. In the cross slope direction, elevation may change by plus or minus 10 feet from the connection at the sub-main to the end of the laterals.

For the preliminary design, the outlets on the main line line to the sub-mains will be spaced at the fire hydrant spacing. If adequate water pressure can be maintained along the entire length of all the laterals, it may be possible to irrigate two to four pasture lots in one irrigation set. Examples of the preliminary design of individual irrigation sets are shown below.

- For pasture lots 54 and 55, the irrigation target dimensions include laterals at about 900 foot in length and the sub-main line length of about 350 feet. The first lateral connection on the sub-main may be at about 100 feet from the main line. There are 108 sprinklers in this irrigation with target discharge rates of 1.92 gallons per minute or about 210 gallons per hour.

- For pasture lots 52, 55, 56, and 57, the irrigation target dimensions include lateral at about 825 feet in length and sub-main line length of about 800 feet. The first lateral connection on the sub-main may be about 150 feet from the mainline. There are about 248 sprinklers in this irrigation set with target discharge rates of 1.92 gallons per minute or about 475 gallons per minute.

3.12 Dillingham Ranch Agricultural Services

The Dillingham Ranch Agricultural Services (RAS) will provide full agricultural services for all agricultural areas in the Ag subdivision and Ag Cluster parcel. The Agriculture Plan will create several new jobs, however, it will be important to control labor costs in order to meet the subdivision and Ag Cluster maintenance and crop budgets.

The RAS will maintain control over management of the domestic and irrigation water systems. In order to increase efficiencies for the agricultural services, the Ranch may manage the following tasks as follows.

- **Land clearing and initial land preparation** should be contracted to outside farm services company like Kahuku Farms. This will eliminate the need to purchase or rent large equipment and to train equipment operators.

- **Installation of Irrigation Pipelines** should be contracted to outside irrigation companies like Ag Tech. RAS will participate in the installation of the pipelines as part of the training program for the operation and maintenance of the irrigation systems. This will allow the Dillingham Ranch Agricultural Services (RAS) to concentrate on implementation of the Agriculture Plan.

- **Land preparation** before planting will be completed with DRS. It is important for the Ranch to take ownership of the agricultural practices that will have a direct influence on the success or failure of the agricultural activities. Land preparation before planting will include planting of cover crops, weed control using harrowing and herbicides, and application and incorporation of soil amendments, if appropriate and necessary.

- **Propagation** will be contracted to certified nurseries like Plant It Hawaii. The certified nursery will produce grafted seedlings of the selected or available avocado, mango, and citrus cultivars. About 30 to 40 grafted seedlings per 40 by 48 inch pallet will be shipped via Young Brothers from Plant It Hawaii in Hilo, Hawaii to Honolulu. The pallets will transported via flat bed truck with side gates to the Ranch. The grafted seedlings will be staged in the nursery at the Ranch prior to planting. A small forklift may need to be leased or purchased at the start of planting to unload the pallets.

- **Planting and orchard establishment** will be completed by RAS. Planting will include digging of the 2 cubic square foot planting holes, mixing of the soil from the hole with mature yard waste compost, planting of the grafted seedlings, application of fertilizer, and initial irrigation. A backhoe should be leased or rented to support planting activities.

- **Installation of the micro-sprinkler systems** will be completed by RAS with assistance of the irrigation contractor. The RAS must be completely competent in installing, operating, and maintaining the irrigation systems. An inventory of critical parts of the micro-sprinkler systems should be maintained on the Ranch to minimize down times for repairs.

- **Installation of the solid set sprinkler systems** will be completed by the irrigation contractor with assistance from the RAS. The RAS has inadequate resources to install both irrigation systems. An inventory of critical parts of the solid set sprinkler systems should be maintained on the Ranch to minimize down times for repairs.

- **Irrigation** of the orchard lots, Ag Cluster parcel, managed pasture, and pasture lots will be completed by the RAS. Irrigation schedules based on the specific crop water demand, tree size and age, soil infiltration rates, and evapotraspiration requirements will require variable irrigation times. The RAS needs to be responsible for implementation of all important agricultural activities that may affect yields and saleable product recovery and fruit quality. For the avocado, it will be critical to apply sufficient irrigation water while minimizing over irrigation that may produce water logged soils. Soil moisture sensors should be installed at representative locations within the irrigation sets. The irrigators may need one or two all-terrain vehicles to turn valves on and off. The management of the irrigation systems should be mechanized or remotely controlled, if feasible.

- **Fertilization** will be completed by the RAS. Fertilizer schedules based on the specific crop requirements and the tree size and age using soluble fertilizer formulations will be developed by the ag consultant. The ag consultant will observe visual indices for leaf and trunk nutrients and monitor leaf tissue nutrient levels and take corrective actions to address under and over application of fertilizers. The fertilizers will be applied through the micro-sprinkler irrigation

systems using portable injection system. A portable injection system will need to be purchased in the early stages of orchard establishment as a labor savings measure. The irrigators will be responsible for fertilization and possibly pest and disease control.

- **Pest and disease control** will be completed by the RAS. Insect and disease levels will be monitored by the ag consultant. One of the goals of the Agriculture Plan is to achieve economic pest and disease control using cultural, biological, and/or organic or 'generally regarded as safe' conventional pesticides. The Ag consultant will develop Production Guides providing general guidelines for pest and disease control. RAS may need to spray organic and/or GRAS pesticides on an infrequent basis for insect control.. Routine sprays of GRAS fungicides like copper hydrodoxide may be necessary to control anthracnose and powdery mildew in avocado and mango. The RAS will need one tractor mounted orchard sprayer and one tractor mounted boom sprayer. If the organic farm to table crops are successful, duplicate equipment may be required to meet production guidelines.

- **Wild Pig Control** by trapping should be continued by the current Ranch personnel. It is important to reduce the wild pig population levels before planting of the orchard and farm to table crops to minimize damage to seedlings and other succulent plants.

- **Honeybee pollination** may be contracted to existing bee keepers on Oahu. The RAS will be responsible in managing the beehive availability based on the acres that are flowering and coordinate the movement of the beehives in the avocado orchard. Potassium nitrate will be applied as foliar sprays by the RAS to induce better flowering and fruit set in mango for management of the alternate-year bearing habit..

- **Pruning and training** will be completed by the RAs using mechanical pruning equipment. It will be important to purchase mechanical pruning equipment with the flexibility to prune avocado, mango, and citrus trees.

- **Compost** will be produced by the RAs. The composting operation will recycle yard trimmings, wood and cuttings from the orchards, and straw and manure from the paddocks. The compost will be used as fertilizer or mulch on the Ranch.

- **Farm to Table Crops** will be grown by the RAS with participation from the Ranch community. A small greenhouse will be constructed in bulk lot 1003A to produce transplant for the organic herb and vegetable cultivation.

- **Nursery** will be managed by the RAS. A chain link fenced area may be necessary to minimize theft of the potted palms.

- **Harvesting** of the fruit from the orchards will be managed by the RAS. It will be important to attain target productivity (boxes per harvester per hour) to control labor costs. The harvesting operation will need a tractor, trailer, and field bins to accumulate and deliver the harvested fruits to the packing plant. The hand held harvesting equipment can be purchased on line.

- **Packing** of the saleable fruit will be managed by the RAS in a new fresh fruit packing plant. Similar to harvesting, it will be important to attain target productivity (boxes per packer per hour) to control labor costs. A new fresh fruit packing plant with refrigerated storage should be constructed when the orchards reach the young tree stage of development.

- **Sales and marketing** will be completed by the Dillingham Ranch Farmer's Cooperative. The RAS will deliver the palletized product to wholesale and retail accounts. The Cooperative will sell product at Farmer's markets.

3.13 Dillingham Ranch Farmer's Cooperative

Although the agriculture plan is based on the commercial production of avocado, mango, citrus, and coconut, it is important to foster a small family farm oriented approach at the Ranch. The Ranch community needs to be proud of producing the premium quality fruit and unique consumer preferred products. A family and community farm can work together towards the greater good of all to ensure efficient, productive, and profitable operations that leads to long term sustainability.

The successful execution of the agricultural plan is highly dependent on the formation of a Farmer's Cooperative. In order to replace imports and/or increase local consumption, it is critical to be able to supply consistent volumes of premium quality fruit during the harvest season. The only plausible way to achieve this goal is to develop the Agricultural Plan based on using all of the arable acres designated for orchard and other crops as an integrated and focused unit.

Small farms are often at a disadvantage because:

1) Limited capital resources and low revenue stream makes it difficult to invest in equipment;

2) Individual farmers do not or are unable to make improvements to increase efficiency and productivity;

3) Restrictions on production and inefficiencies due to limited family labor pool;

4) Higher material and supply costs due to low volume purchases; and

5) Sale of low production volumes individually does not adequately supply markets reducing leverage in pricing.

One of the best approaches to overcome disadvantages faced by small farms is to form a farmer's cooperative. Besides the marketing advantages of the cooperative described in the previous sub-section, the cooperative can provide other benefits if the residents/owners of the orchard lots and Ag Cluster are willing to work closely together.

Some of the advantages of the formation of the Cooperative include: 1) sharing of farm equipment; 2) joint purchases of materials and supplies; 3) more resources for production system improvements; 4) coordinated planning and farm management; 5) joint conduct of market surveys; 7) cooperative problem solving; and 8) Community outreach.

3.14 Good Agricultural Practices

A good model for the Good Agricultural Practices for the Ranch is the California Avocado Association's GAP program. A basic requirement of the sale of fresh produce to wholesale, retail, and export marketing channels is certification for compliance with Good Agricultural Practices. Good Agricultural Practices consists of the development and compliance with Prerequisite Programs and Standard Operating Procedures to ensure chemical, microbiological, and physical safety of the products. The GAPs must cover both agricultural, packing, and distribution activities.

Microbiological safety for the organic fruit and vegetable production due to the need to use manure as a fertilizer source may be the most important issue of potential concern. Organic certification limits the use of sanitizing agents like chlorine for post-harvest fruit washing. It will be critical to clean and sanitize the packing equipment to minimize the incidence and severity of fruit diseases and surface mold.

Another issue of potential concern that may be difficult to address is trace back and product recall. Individual orchard lots will need to be assigned an unique identification number to allow for product tracking.

After the Prerequisite Programs and Standard Operating Procedures are prepared and initial compliance is attained, it is appropriate to conduct an internal audit based on a checklist to determine if a full third party audit should be scheduled. Compliance with GAPs is time consuming and requires periodic reviews of records, development of corrective action strategies, and follow-up investigations to ensure continuing compliance.

3.15 Soil and Water Conservation Plan

Perennial crops have less stringent requirements for the Soil and Water Conservation Plan (SWC plan). However, the SWC plan will also need to consider soil erosion and to a lesser extent animal waste run-off from the pasture lots into the orchards. At later

phases of the planning process, the Ranch should contact the Soil and Water Conservation Service for assistance in preparing the SWC for the Ag Subdivision and Ag Cluster. It will be important for all owners and other interested parties to understand their responsibilities and to hold themselves accountable for conservation of resources. The agricultural activities of the Subdivision will not be sustainable if excessive soil erosion occurs.

The natural contours and drainage pathways have stood up to the test of time in flood water drainage and should not be disturbed, if feasible. Some of the drainage pathways in the Orchards in the Community should be consolidated, widen, and deepen to prevent waterlogged soils in the orchards. Storm water will flow more rapidly over the cleared area during early stages of the orchard establishment. After land clearing, grasses and other weeds will be prolific in the inter-space between the rows of trees. The areas should be mulched with green waste compost to control weeds in the early stages of orchard establishment. Eventually, it may become to expensive to maintain the organic mulches for weed control. Once the noxious weeds are controlled, the inter-space between the rows should be planted with non-seeding perennial grasses that can be mowed. The grasses will slow down storm water flow in the drainage pathways and can be considered as a soil erosion control measure.

A surface drainage system may need to be developed for the Ag Cluster parcel to channel storm water into the flood plain.

3.16 Sales and Marketing Plan

Hawaii produce sales are dominated by the produce distributors. There is very little incentive to buy local first since the quality and availability of imported produce is often superior to locally grown products. It is easier to source the weekly volumes from one big grower with proven quality than to try to accumulate the volume from multiple growers with variable quality.

The Ranch will need to gain the trust and support of the major producer distributors on Oahu. The avocado and mango will have superior quality when compared to imported products. The production volumes are significant and should provide fairly consistent weekly deliveries that allows development of a viable customer base. The distributors will be more efficient in storing and delivering product to wholesale, retail, and restaurant accounts.

It is important to recognize that by using distributors that the maximum prices will not be attained. However, it is important to receive fair and equitable pricing so the Cooperative will need to monitor prices closely. A detailed sales and marketing plan will be developed at a later phase of the planning process.

Avocado. The avocado production is estimated to produce approximately 706,000 pounds per year. The average fill weights of the 25 lb. trays is about 26 pounds. The estimated number of 25 lb. trays produced per year is 27,153 cartons. There are 70

cartons per pallet. The production period is about 10 months (September to June) or about 43 weeks. Therefore, if the production is spread over the 43 week production period evenly, the Ranch will need to deliver about 91 pallets or about 6,400 boxes per week to the Honolulu or local market. Obviously, agricultural production is rarely like a factory type production, therefore, periods of oversupply and undersupply will need to be managed.

Mango. The estimated mango production volume is 154,321 pounds per year produced from May to October. Mango will be packed in the 25 lb. trays and stacked up to 70 cartons per pallet. If the mango production is spread evenly over the 26 week production period, the Ranch will deliver about 85 pallets or about 6,000 boxes per week.

Orange and Tangerine. The estimated orange and tangerine production volumes are 55,180 pound per year produced from October to February. The orange and tangerine will be packed in 20 lb. half slotted containers. With the overpack, the fill weight of the cartons will be about 21 lbs. The orange and tangerine production spread evenly over the 22 week production period delivers about 38 pallets or 2,660 cartons of orange and tangerine per week.

Lime. The estimated lime production volume is 7,663 pounds per year produced over a 10 month period with two harvest peaks. The limes will be packed in 20 lb. half slotted containers. With the over pack, the cartons will weigh about 21 lbs. The lime production spread evenly over the 43 week production period is about 10 pallets or about 350 cartons per week.

4. Preliminary Farm Management Plan

4.1 Purpose and Scope

The purpose of the Preliminary Farm Management Plan is to present an outline of the crop specific management practices to assess the technical and economic feasibility of commercial production of orchard crops at the Ranch. The scope of the Preliminary Farm Management Plan discusses critical issues in the initial planning process such as cultivar selection, pest and disease risk management, and production plans for the commercial production. This Section also covers potential issues to address for other agricultural activities at the Ranch.

The Agriculture Plan presented in Section 3 of this Report proposed to use avocado and mango as the foundation of the commercial production of tree fruit crops at the Ranch. The successful commercial production will allow the Ranch Agricultural Services to increase the number of personnel to support the commercial production and other agricultural activities at the Ranch. Combining the commercial production and support activities such as irrigation of the pasture lots into one operating unit will increase efficiencies and productivity possibly leading to sustainability of the subdivision and Ag Cluster.

4.2 Selection of Local Consumer Preferred Avocado Cultivars

4.2.1 Avocado

The Avocado (*Persea americana*) is a perennial evergreen tree that has spreading to erect growth characteristics attaining tree heights of 40 feet or more. The leaves are elliptic or oval in shape and 3 to 10 inches long. Flowers are small, greenish, and perfect (has both male and female flowers). The avocado fruit may be round, pear shaped, or oblong and the skin of the fruit may vary in texture and color. The skin may be pliable to woody, smooth to rough, and green-yellow, reddish-purple, purple, or black in color when the fruit matures. The flesh of the fruit is greenish-yellow to bright yellow when ripe and buttery in consistency. The avocado has one large seed which makes up 10 to 25 percent of the fruit weight. The fruit of different avocado cultivars may vary in moisture and oil content from less than 5 percent oil to more than 30 percent oil. Avocado fruits may range from 0.25 lb. to more than 3.0 lbs. in weight.

Pollination is usually done by honeybees and other insects. There are two avocado flowering types, A and B. Each flower opens twice functionally female (pollen receptive) in the first opening and functionally male (pollen shedding) at the second opening. Type A opens first in the morning, closes at midday, and reopens in the afternoon of the following day. Type B opens first in the afternoon, closes in the evening, and reopens the following morning. The presence of both types of trees in the orchards is important to improve production by adequate pollination.

There are three distinct races of avocado: Mexican, Guatemalan, and West Indian. The Mexican race is the most cold tolerant, while the West Indian is most adapted to warmer growing conditions. Fruits of the Mexican race are generally small with thin, smooth skins. The Guatemalan race have skins that are thick, hard, brittle, and warty. The West Indian race has shiny skin that is thin to medium in thickness. Some of the important commercial cultivars include:

- **Hass** is black skinned, ovate cultivar with fruit weights ranging from 5 to 12 ounces. It descends primarily from the Guatemalan race. This cultivar accounts for about 75 percent of the production in California, the main producing area in the US. Hass is also important in Mexico, the world's largest avocado producer. Chile is the main foreign supplier to the US. In Mexico, Hass is harvested year round but the main harvest season is from October to May. In Hawaii, Hass has not produced high quality fruit and is rarely grown due to its poor flowering characteristic.

- **Sharwil** is a Mexican and Guatemalan cross and represents more than 57 percent of the commercial production in Hawaii. Its green skinned fruits weigh about 6 to 20 ounces and mature in winter and spring. Green Gold and Murashige are other green skinned cultivars recommended by the College of Tropical Agriculture and Human Resources for commercial planting.

4.2.2 Hawaii Avocado Cultivars

Cross pollination of avocado cultivars results in the production of new hybrids. There more than a hundred avocado cultivars that are grown in backyards for home consumption. Most of the commercial avocado cultivars are crosses between Mexican and Guatemalan races.

The principal avocado growing area in Hawaii is the lower slopes of Mauna Loa in Kona, Hawaii. The other important avocado growing area in Hawaii is Kula, Maui. The percentage of acreage for top avocado cultivars, their respective bearing season, and potential production volumes by bearing season are presented in Table 4-1.

The primary avocado cultivars in the following order of importance are Sharwil (45%), Malama (21%), Yamagata (11%), Murashige (3%), Hass (0.9%), and others (13.1%). The estimated annual production volumes by avocado cultivar is shown in Table 4-1. Due to the high percentage of Sharwil acres, the bulk of the Hawaii avocado production is available during the winter to spring bearing season.

The initial avocado screening criteria is high yields with regular bearing characteristics of excellent quality fruit with fruit weights averaging about 1 lb. or less. Since Hass is the primary cultivar grown in California and Chile, the locally grown avocado should have better taste and oil content than Hass.

The harvest or bearing periods for top avocado cultivars that meet the initial avocado screening criteria are shown in Table 4-2. The goal of commercial production is to deliver relatively consistent weekly volumes of excellent quality fruit throughout the fall to early summer bearing seasons. Therefore, one of the most important characteristics to meet this goal is the bearing season of the top avocado cultivars. In order to attain the higher production volumes, it will be necessary to plant some acreage of both A and B flower types in the avocado orchard. The A type flowering type cultivars that are available in Hawaii include Green Gold, Lamb Hass, and San Miguel.

4.2.3 Avocado Selection Criteria

Environmental factors strongly influences the production and quality of characteristics of avocado cultivars. Season of maturity varies considerably with elevation. The low elevation of Growing Zone One is expected to advance the season of maturity when compared to higher elevations and shorten the time that fruit can be held on the tree. The low elevation of Growing Zone One may also increase the oil content of the fruit making it more flavorful than fruit grown at higher elevations.

The desirable characteristics for avocado cultivars for commercial production at the Ranch includes:

- **Production Considerations.** A desirable commercial avocado cultivar is high yielding, begins to bear fruit at an early age, is easy to harvest, and has fruit that can be stored on the tree for a long period of time. Resistance to Phytopthora root rot and anthracnose is also a desirable trait for commercial cultivars.

- **Fruit Quality Considerations**. **Avocado flavor** can be categorized on a scale ranging from mild (or watery avocado flavor) to rich (strong avocado flavor). Texture of the fruit flesh should be smooth and free of fibers (stringiness). Oil content affects flavor and texture. Low oil content (less than 10 percent) may result in insipid, watery taste. Higher oil content (above 12 percent) is associated with richer flavor and a buttery texture. Fruits with very high oil content (above 25 percent) sometimes has an undesirable pasty or dry texture, especially when overripe.

  Other important fruit quality considerations include: 1) **Fruit Appearance**-The shape of the fruit, the color, tone, and texture of the skin, and flesh color contributes to the fruit appearance; 2) **Fruit size**-Hawaii consumers prefer relatively small fruits (from 10 to 18 ounces) while hotel and restaurant sales prefer larger fruit sizes (larger than 1.0 lb.); 3) **Seed size and skin qualities**-Small seed size is desirable so that a greater portion of the fruit can be consumed; 4) **Ripening and Storage**-Mature fruit that will ripen uniformly at ambient temperatures with postharvest shelf life of at least two weeks.

4.2.4 Selection of Avocado Cultivars for the Ranch

The top avocado cultivars were evaluated by the University of Hawaii in three reports presenting relevant information on the selection of commercial avocado cultivars for import replacement (CTAHR, Fruits and Nuts, March 1999; Hawaii Avocado Industry Analysis, Part 1:Supply Focus, November 2007; Hawaii Avocado Industry Analysis, Part 2: Buyer Preference Focus, July 2008). The production characteristics of the selected avocado cultivars are summarized in Table 4-3. The fruit quality characteristics of the selected avocado cultivars are summarized in Table 4-3A. Photographs of the fruit of the selected avocado cultivars are available in the Plant It Hawaii avocado plant list on the website, plantithawaii.com.

Based on the commercial avocado selection criteria and the information presented in the three reports the following avocado cultivars are recommended for cultivation at the Ranch.

- **Green Gold.** A selection from Sharwil that is a consistent heavy bearing tree with excellent fruit quality characteristics. Produces higher yields than Sharwil. Harvest period is January to April. Type A flower and will be planted in orchards to facilitate better pollination and produce higher yields.

- **Kahaluu**. A Guatemalan and West Indies races cross that has been rated as the best tasting avocado grown in Hawaii. Harvest period is August to November. Selected due to its early bearing characteristic and excellent fruit quality. Its tall, upright growing characteristic will make it harder to harvest when the trees mature. Its light, irregular bearing characteristic may reduce overall production volumes.

- **Malama.** One of the top five best tasting avocado cultivars in Hawaii. Flavor is rated as higher than Sharwil and Hass. Harvest period is September to December. Selected due to excellent fruit quality, its heavy, regular bearing characteristics on medium sized spreading form tree type, and harvest period.

- **San Miguel**. Type A flower. It has moderate, regular bearing habit on a medium sized spreading tree. Harvest period is Fall to Winter. It is included in the orchards to promote better pollination and production.

- **Sharwil**. A cross between Guatemalan and Mexican races with moderate, regular bearing characteristics on a low, spreading form tree. Harvest period is October to February. Selected in recognition of its prominence in current commercial production and the flexibility to export Sharwil to Continental United States markets without quarantine treatment.

- **Lamb Hass.** Lamb Hass has higher yields and better fruit quality than Hass. Type A flower. Harvest period is April to June. It has heavy, regular bearing characteristics on a medium sized, spreading tree. It is included in the orchards to promote better pollination and higher production.

- **Yamagata**. One of the top five best tasting avocado in Hawaii. Flavor is rated as higher than Sharwil and Hass. Harvest period is March to June. It is selected due to its excellent fruit quality, its heavy, regular bearing characteristics, and harvest period. Its tall, upright growth characteristics will make it harder to harvest when the trees mature.

- **Other Commercial Avocado Cultivars.** There are two avocado cultivars recommended by the University of Hawaii, Murashige and Semil-34, that were not selected for cultivation at the Ranch. Murashige has excellent fruit quality, however, it has poor shelf life and may too risky to grow on a larger scale. Semil-34 has good flavor and excellent shelf life but has low oil content (12%). Semil-34 has a lower flavor rating than Sharwil and was not rated as a top avocado cultivar for import replacement.

4.3 Selection of Local Consumer Preferred Mango Cultivars

Mango (*Mangifera indica*) trees are deep rooted symmetrical evergreens that can attain heights of 90 feet and widths of 80 feet. Mango trees have simple alternate lanceolate leaves that are 12 to 16 inches in length and yellow-green, purple, or copper when young. Mature leaves are leathery, glossy, and deep green in color. New leaves arise from terminal growth flushes that occur several times a year. Mature terminal branches bear pyramidal flower panicles that have several hundred white flowers that are about ¼ inch wide when open. Most of the flowers perform as male flowers by providing pollen, but some are bisexual and set fruit.

The fruit weighs about 1.4 to 3 pounds. Fruit shape may be round, ovate, or obovate depending on the cultivar. The immature fruit has green skin that turns yellow, orange, purple, red, or combinations of these colors. Mature fruit has a characteristic fragrance and a smooth, thin, tough skin. The flesh color of the mango is pale yellow to orange. The flesh is juicy, sweet, and sometimes fiberous. The fruit has one seed that is flattened and sticks to the flesh. The seed contains one or more embryos depending on the variety or type.

Most of the mango in Hawaii is grown in backyards and home gardens. Commercial production has been attempted but remains small. Mango has an alternate-year bearing habit or bears every other year which has resulted in limited commercial success. The shipment of mango grown in Hawaii to Continental US markets is prohibited due to the presence of the mango weevil and fruit flies. The commercial irradiation facility in Kunia can treat mango for these pests possibly improving on the market potential for commercial mango production.

4.3.1 Mango Cultivars

Mango cultivars in Hawaii are classified by embryo type: polyembryonic and monoembryonic. Polyembryonic varieties develop multiple embryos of which all except one is derived from maternal tissue in the developing seed. Polyembryonic seeds are

often underdeveloped and fail to germinate. Polyembyonic varieties include Hawaiian and Chinese mangos. These varieties are not coveted for fresh consumption due to their small size and tart taste. The polyembryonic mango are often used for pickling in Hawaii.

Indian mango varieties are mostly monoembryonic cultivars. Many of the monoembryonic cultivars have been introduced to Hawaii as a result of their introduction and selection in Florida, the most important mango growing area in the US. Several monoembryonic cultivars have been selected and named in Hawaii.

The most common mango cultivars in Hawaii are Haden and Pirie. There are many other mango cultivars that have superior production and fruit quality when compared to Haden and Pirie. Due to the relatively small commercial production, most of the mango at retail are Haden mango. Therefore, Haden is the mango cultivar that most Hawaii consumers will compare the newer mango cultivars against.

- **Haden** originated from a 'Mulgoba' seedling grown in Florida in 1902. It is the most widely planted mango in Hawaii. The fruits are medium to large weighing 16 to 24 ounces. The attractive skin color of the Haden fruit, crimson over a deep yellow under color has supported its popularity in Hawaii. Although Haden was superior to most locally available cultivars at the time of its introduction, it has ranked considerably below several other cultivars in taste panel tests. The harvest period for Haden is June to July. The fruit flesh is somewhat fiberous and tends to separate from and deteriorate around the seed resulting in marginal quality and poor shelf life. Haden seeds are relatively large and the trees usually develop an undesirable alternate-year bearing habit. All of the cultivars recommended for commercial production and home gardens are superior to Haden in fruit quality and bearing habit.

- **Pirie** is a widely planted older variety that also exhibits alternate-year bearing habit like Haden. Pirie fruit are fiberless, juicy, and sweet. Fruit size is small averaging 8 to 10 ounces. The harvest period for Pirie is July to August. The tree grows vigorous but should be planted in dry areas only since it is highly susceptible to infection by anthracnose.

The goal of the mango production plan at the Ranch is to increase commercial production by about 25 percent increase in current annual Hawaii production volumes. This goal will be attained by minimizing the alternate-year bearing habit, improving fruit quality, and increasing availability of local mango from the traditional June to August harvests to May to October harvests. To achieve this goal, there is a need to use a wide range of mango cultivars some of which are recommended by UH for home gardens but not for commercial production.

4.3.2 Mango Selection Criteria.

The data set for the selection of the mango cultivars is not as extensive as the data set for avocado. More information should be gathered and evaluated before making the final selection of mango cultivars.

- **Production Considerations.** The desirable characteristics of the commercial mango cultivars include: 1) high yields with weak alternate-year bearing habit; 2) medium to large fruit size (19 to 24 ounces) to meet consumer preference for larger fruits; 3) anthracnose and powdery mildew resistance to optimize flowering and fruit set during the wet winter months; 4) medium tree height to reduce harvesting costs; and 5) early and late fruit bearing period to extend the annual mango harvest season..

- **Fruit Quality Considerations.** The desirable fruit quality characteristics of commercial mango cultivars include 1) flavor and texture that is superior to Haden mango; 2) small seed size to allow a greater portion of fruit to be consumed; 3) attractive skin color and skin appearance; and 4) good shelf life to allow for organized sale and distribution.

The top Hawaii mango cultivars recommended by Dr. R. A. Hamilton includes Ah Ping, Fairchild, Gouveia, Harders, Keitt, Manzanillo, Momi K, Pope, and Rapoza. Other top Hawaii mango cultivars recommended by Plant It Hawaii includes Brook's Late, Carrie, Excel, Florigon, Glenn, Golden Glow, Julie, Nam Doc Mai, R2E2, and Mapulehu/Joe Welch.

4.3.3 Selection of Mango Cultivars for the Ranch

The complete list of the available mango cultivars recommended for commercial use or backyards and their respective bearing periods are shown in Table 4-4 . The fruit quality characteristics (fruit weight, flavor and texture, fruit shape, and skin color for mango cultivars on this list were evaluated and used to select potential varieties for commercial production at the Ranch.

The production and fruit quality considerations for the selected mango cultivars with potential for cultivation at the Ranch are presented in Table 4-5. Photographs of the fruit of the selected mango cultivars are shown in the Plant It Hawaii mango plant list. The selected mango cultivars and brief description of their characteristics are shown below.

- **Carrie** is a Florida selection that regularly bears fruit in June and July. The flesh is fiberless, sweet, and spicy with a thin seed. The skin is golden yellow with a green ting. Fruit shape is round and fruit weights range from 10 to 16 ounces. It is resistant to anthracnose and tree growth is dense and compact.

- **Excel** is a high quality Hawaii selection that bears regularly in July and August. The fruit has very little fiber with a thin seed. Fruit average about 16 ounces in weight. Fruit shape is obovate with red skin color when mature. The trees are

medium size and upright in form. Excel is susceptible to anthracnose and should be planted in dry areas only.

- **Fairchild** is a Florida selection that bears fruit in June and July. Fruit size is small averaging 8 to 12 ounces. The flesh is sweet, juicy, and rich and is low in fiber. The fruit shape is obovate and skin color is yellow with greenish tinge on the upper part of the fruit. The trees are medium sized and upright in form. Fairchild can be planted in wet areas because it is tolerant to anthracnose.

- **Florigon** is a Florida selection that bears fruit between May and July. Fruit size is small averaging 10 to 16 ounces. The fruit shape is obovate with golden yellow skin color. The flesh is juicy and fiberless with excellent flavor. The trees are large and upright. It is resistant to anthracnose and can be planted in wet areas.

- **Glenn** is Florida selection from a Haden seedling that regularly bears fruit between May and July. The flesh is spicy, rich flavored and low in fiber. Fruit shape is round with yellow skin color. Fruits average about 16 ounces in weight. The trees are small to medium sized. It is resistant to anthracnose and can be planted in wet areas.

- **Gouveia** is a Hawaii selection from a Pirie seedling that regularly bears fruit in July and August. The fruit is sweet and fibreless averaging 16 to 24 ounces. The fruit shape is obovate with yellow skin color. The trees are medium sized and grow upright. Gouveia is susceptible to anthracnose and should be planted in dry areas only.

- **Keitt** is a Florida selection from a Mulgoba seedling (the Haden parent). It is considered the best export variety in the Americas. It regularly bears fruit from August to October. The fruit has excellent quality and is sweet with low fiber and a thin seed. The fruit shape is round with green skin color with a purple or yellow blush. The fruits are large averaging two to four pounds. The trees are medium sized and grow upright. The fruit has long shelf life. It is resistant to anthracnose and can be planted in wet areas.

- **Pope** is a Hawaii selection by Dr. R.A. Hamilton for an Irwin seedling. It regularly bears high quality fruit in July and August. The fruit shape is obovate with yellow-green skin color with reddish blush. Fruits average about 10 to 18 ounces. The trees are medium sized and grow upright. It is susceptible to anthracnose and fruits the best in dry areas.

- **Rapoza** is a Hawaii selection by Dr. R.A. Hamilton from an Irwin seedling. It regularly bears large fruit averaging 16 to 24 ounces from mid-July to October. The fruit has excellent fruit quality. The flesh is sweet and fiberless. The fruit shape is obovate with reddish-orange skin color. The trees are medium sized

and grow upright. It is susceptible to anthracnose and should be planted in dry areas only.

- **Other Mango Cultivars**. Harders is recommended by Dr. R.A. Hamilton as a potential commercial mango cultivar. Harders is a Hawaii selection from unknown parentage that regularly bears fruit during the off-season in fall and winter. Harders was not listed on the Plant It Hawaii mango list for grafted seedlings for sale. It is not practical for the Ranch to propagate its own grafted seedlings at the start of the plantings, therefore, Harders was not selected as a mango cultivar for cultivation at the Ranch.

4.4 Selection of Citrus Cultivars

4.4.1 Orange.

The orange (*Citrus simensis* Osbeck) is the most widely grown citrus fruit in the World. The principal growing areas in the US are California and Florida. Most of the oranges grown in California are of two cultivars: the Washington Navel and Valencia. Florida's commercial cultivars are Hamlin (early season), Pineapple (mid-season), and Valencia (late season).

The Hawaii Agricultural Statistics did not report any local commercial production of orange between the years 2005 to 2009. Orange grown in Hawaii will not develop the bright orange skin color that consumers expect. Hawaii grown oranges and tangerines have a greenish tint to the skin and tighter adherence of the peel to the fruit, making oranges and other citrus to be more difficult to peel than oranges grown in California.

Obviously, there are no production or fruit quality advantages for Hawaii grown oranges. Orange production in Florida and California is being decimated by the Citrus greening bacterial disease. The only viable solution to Citrus greening is to use genetic transformation methods to develop disease resistant cultivars. Organically grown, non-GMO oranges may fill a niche local market making it economically viable to grow orange at the Ranch.

The photographs of the fruit of the selected citrus cultivars are shown in the Plant It Hawaii citrus list. The two orange cultivars selected for cultivation at the Ranch includes Washington Navel and Fisher Naval Orange. Brief descriptions of the two orange cultivars are shown below.

- **Washington Navel Orange** originated as a mutant in Bahia, Brazil before 1820. It was introduced to Florida in 1835 and reached California in 1873. It is the most common and prolific orange cultivar grown in Hawaii. It bears large fruit with excellent flavor but is not very juicy. The tree is medium size with a round crown of dense, green leaves. It bears fruit in December to February.

- **Fisher Navel Orange** is a selection from California that bears fruit of same high quality as the Washington Navel Orange. It bears fruit earlier than the Washington Navel allowing for extension of the orange harvests at the Ranch. The fruit is large, seedless, juicy, and delicious.

The Agriculture Plan allocated 7 acres to orange production in bulk lot 1003A. Approximately 3.5 net acres each of Washington Navel and Fisher Navel will be planted to extend the orange harvest season from October to February.

4.4.2 Lime

The Hawaii Agriculture Statistics reported that Hawaii growers produced an average of 81,000 lbs. of fruit for the years 2005 to 2009. The average price per pound for this period was $0.89 per pound. During the same period, Hawaii imported an average of 1,881,000 lbs. of lime per year.

All of the lime acreage in Florida was destroyed due to citrus canker and citrus greening bacterial diseases. There is a shortage of limes due to problems with distribution of Mexican lime production. There may be an opportunity to expand lime production at the Ranch.. Lime was selected for commercial production at the Ranch due to its prolific fruit production (about 500 fruit per tree per year) and its long harvest season.

The best lime cultivar for Hawaii is the Tahitian Lime. A brief description of the characteristics of the Tahitian Lime is shown below.

- **Tahitian Lime**, also known as the Bearss lime is a medium size vigorous tree that bears fruit for about 10 months of the year. It is a prolific dependable bearer. The fruit is juicy and seedless with the skin turning slightly yellow The flesh is green and has a true acid lime flavor.

4.4.3 Tangerine

The Hawaii Agriculture Statistics reported that Hawaii growers produced an average annual volume of 81,000 pounds of tangerine for the years 2005 to 2009. The average price per pound for this period was $0.69 per pound. During the same period, Hawaii imported 1,652,000 lbs. of tangerine per year.

Similar to lime, it may be hard for Hawaii production to compete against imported tangerine. Tangerine was selected for cultivation at the Ranch due to good fruit quality of Hawaii tangerine and its prolific production (about 400 fruits per tree per year).

The best tangerine cultivars for Hawaii are Dancy and Fremont Tangerines. Brief descriptions of both varieties are shown below.

- **Dancy tangerine** is the most popular tangerine grown in Hawaii. The bright orange fruit is harvested during the winter months (December to March). The

fruit is sweet and juicy. It exhibits alternate-year bearing habit producing heavily every other year. Dancy is easy to peel. The canopy shaped trees are nearly thornless. Fruit must be picked when ripe on the tree.

- **Fremont tangerine** is an early maturing cultivar that holds well on the tree when the fruit is fully ripe. The tree has a rounded canopy with most of the fruit borne on the ends of the branches. The fruit is ready to harvest in the Fall months. In Hawaii, trees tend to bear almost year round. The fruit is sweet, rich, and easy to peel.

4.5 Farm to Table Crops.

Varietal or cultivar selection will be critical to the successful cultivation of the farm to table crops. Ideally, the selected cultivars will have natural disease resistance and be well adapted to low elevation climates. Farm to table crops will be grown between March to October to avoid high rainfall periods that may lead to uncontrollable plant disease conditions. The final selection of farm to table crops and their respective cultivars will be completed at a later phase of the planning process.

4.6 Production Plan

4.6.1 Avocado Production Plan

The Agriculture Plan proposed to plant about 126.0 acres of avocado in 28 orchard lots in the lower portions of Ag subdivision. The proposed percentages of planted acres for the selected avocado cultivars, net acres, and estimated deliveries are presented in Table 4-7

The percentage of acres were assigned to spread production of the best tasting avocado cultivars over a longer harvest period than the traditional winter to spring avocado peak season. Avocado cultivars with Type A flowers were included in the Avocado Production Plan to facilitate better pollination and fruit set required to attain higher yields.

The target production level is to produce an average of 200 fruits per tree per year. Using 200 fruits per year, average fruit weights, and tree population density of 87 trees per acre, the estimated theoretical yields for all of the selected avocado cultivars ranged from 15,225 to 17,400 lbs. per acre per year. Actual yields in California range from 5,000 to 9,000 lbs. per acre per year.

Average annual yields of 5,600 pounds per acre was used to estimate the annual production of each avocado cultivar. This yield level is relatively conservative and appropriate for use in the production plan at this stage of planning. Production levels for the selected avocado cultivars have potential to be higher than average annual production. Attainment of higher production levels will be important to off-set rising production costs in the future.

The percentages of acres were developed to deliver higher production volumes in the Fall and Spring when Hawaii production is at its lowest level. A more detailed Production Plan will need to be prepared when site specific information on yields and bearing season are available for each cultivar. Each avocado cultivar will have a typical harvest distribution that may consist of about 25, 60, and 15 percent, respectively of the fruit being harvest at the start, middle, and end of their respective harvest periods.

The Preliminary Avocado Production Plan estimates annual avocado production of 705,520 pounds. The production is spread over a longer harvest period from September to June.

More information should be gathered on the selected avocado cultivars by visiting producing orchards prior to development of the final list of avocado cultivars to be grown at the Ranch.

4.6.2 Mango Production Plan

The Agriculture Plan proposed to grow about 43,3 acres of mango in bulk lot numbers 1003A and 1003B. Table 4-8 presents the percentage of acres for the selected mango varieties and estimated deliveries by period.

The average yield assumptions used in estimating the fruit deliveries was 3,564 pounds per acre. The target is to produce a minimum of 200 usable fruit per tree per year. Using the target of producing 200 fruit per tree per year, average fruit weights for each cultivars, and the tree population density of 48 trees per acre, the estimated theoretical yield potential for the selected mango cultivars ranges from 6,600 to 14,100 pounds per acre per year.

Hawaii mango yields reported in the Hawaii Agriculture Statistics is about 2,800 lbs. per acre. Florida mango yields may range from about 6,700 to 9,600 lbs. per acre per tree. Therefore, the use of average yields of 3,564 lbs. per acre for all of the selected mango cultivars is relatively conservative and appropriate for this stage of the planning process.. The actual yield, usable product recovery per acre by mango cultivar needs to be determined after the mango orchard is established to develop the actual Fruit Delivery Schedule to be used for sales and marketing purposes.

The Preliminary Mango Production Plan estimates that the Ranch will produce a total of 155,520 pounds of mango delivered from May to October. The summer peak harvest season for the mango will fill the harvesting gap in the avocado production allowing for more efficient use of labor and equipment.

Due to less information available, there is more uncertainty on the selection of mango cultivars for the Ranch than the selection of the avocado cultivars. The availability of grafted seedlings of all of the selected mango cultivars will also be a factor on the final selection of mango cultivars that should be grown at the Ranch.

4.6.3 Citrus Production Plan

The Agriculture Plan proposed to grow about 12.0 acres of citrus in bulk lot numbers 1003A. Table 4-9 presents the percentage of acres for the selected citrus cultivars and estimated deliveries by harvest period.

The target number of fruit produced per tree per year for orange, lime, and tangerine are 300, 500, and 400 fruits per tree, respectively. Using the target number of fruit per tree per year, average fruit weights, and tree population density of 109 to 145 trees per acre, the estimated theoretical yields of orange, lime, and tangerine are 20,438, 10,219, and 16,350 pounds per acre per year, respectively Yields of usable product per acre for orange, lime, and tangerine used in the production plan are 6,131, 3,065, and 4,905 lbs. per acre per year, respectively.

The conservative yields for orange, lime, and tangerine were used to estimate the total citrus deliveries at 62,843 pounds per year.

4.7 Agricultural Practices

4.7.1 Land Clearing and Preparation

The land clearing and initial land preparation will be contracted to local farm services companies with the appropriate equipment. The costs of land clearing and initial land preparation should be considered as a development rather than farm expense.

The land clearing and preparation will depend on the specific agricultural field at the Ranch. In general, the existing trees will be cut down (or in the case of coconut removed for re-planting), removed, and saved for charcoal or firewood. The tree stumps will be removed by pushing with D-8 tractors. The under brush will be destroyed by harrowing.

It is important to complete multiple harrowing passes to prepare a weed free orchard passes. Weed seeds should be allowed to germinate and harrowing passes completed before the weeds produce seed for effective weed control. It may be necessary to spray herbicides after land clearing and before planting of the fruit trees. Herbicide applications should be kept at a minimum once the orchards are planted.

When possible, cover crops such as Sunn Hemp will be planted prior to planting of the fruit trees and farm to table crops and incorporated into the soils to increase soil nitrogen levels and organic matter. The cover crop will also be useful for weed control and may reduce nematode population densities.

The fields should be relatively weed free prior to planting to minimize the use of herbicides after the orchard crops are planted. Once the fields are weed free, a non-seeding grass will be planted to maintain the 'weed free' condition as the orchards are

planted and established. Once the orchards are established, the trees will shade out the weeds making it easier to maintain weed control with organic mulches and leaf litter.

4.7.2 Propagation

Avocado, mango, and citrus of hybrid origin do not produce true from seed. The fruit tree crops at the Ranch will be propagated using grafted seedlings from certified nurseries like Plant It Hawaii Use of grafted seedlings will ensure that the fruit from the selected cultivars are true to type.

Grafted seedlings should begin to bear fruit in about three years. Avocado cuttings are difficult to root. Air layering in avocado is normally used for research purposes only. Mango trees are not propagated from cuttings or air layering because the resulting trees are weak rooted.

Mature avocado, mango, and citrus orchards can be top worked to change from an unsatisfactory cultivar, or one declining in popularity, to a more profitable one.

4.7.3 Tree Population Densities

The row to row and tree to tree spacing for orchard crops are important to provide enough space for the trees to reach their full yield potential and to allow proper crop management practices to be implemented effectively. If not enough space is provided, the branches of the trees will touch damaging fruit and killing the branches. If there is inadequate air flow in the canopies, diseases such as powdery mildew in mango may become problematic. Commercial growing areas in California and Florida typically use higher tree population densities to increase yields and saleable product recovery per acre to provide the gross revenue required for profitable operations.

The row and tree spacing that is used should be dependent on the growth characteristics of the avocado and mango cultivars. Medium size avocado trees can be planted 20 feet between trees with the row while large size trees should be planted at least 25 feet apart. Medium size mango trees can be planted 30 feet apart within the rows while large trees should be planted at least 35 feet apart. Citrus can be planted at high densities but require frequent pruning to maintain the health and productivity of the orchards.

The typical row and tree spacing and the tree densities for avocado, mango, and citrus are shown below. The row and tree spacing selected for the orchard crops are also identified below.

Row X Tree (Ft.)	Trees/Acre
Avocado	
25'X25'	66

25'X20'	87 (Standard at Ranch)
20'X20'	109

Mango

35'X35'	36
35'X30'	41 (Standard at Ranch)
30'X30'	48
30'X20'	72

Citrus

20'X20'	109 (Orange, Tangerine)
20'X15'	145 (Lime)

Coconut

18'X18'	134 (Standard at Ranch)

Slightly higher but conservative tree population densities were selected for the fruit tree crops at the Ranch. The higher but conservative tree population densities will increase yields while allowing for easier orchard management than very high tree population densities.

4.7.4 Stages of Orchard Development

The stages of development of the orchard crops can be divided into three distinct phases. Each orchard development phase has specific requirements for fertilization, irrigation, pest and disease control, and other crop management practices. These requirements will be documented in the crop specific Production Guides and the Final Farm Management Plan at a later phase of the planning process. The stages of orchard development include:

- **Planting and orchard establishment** (Years 0 to 5) includes the planting of grafted seedlings of the selected fruit tree cultivars followed by early growth and development of the orchard. Due to the immaturity of the orchard, this phase provides small revenue potential, therefore capital and field maintenance costs incurred during this period are depreciated in the subsequent phases of the life of orchards.

- **Young Trees** (Years 6 to 10) is the period where the orchard starts to bear moderate to heavy yields of saleable fruit. During the Young Trees stage of development, fertilizer, irrigation, pest and disease control, harvesting, packing, and sales and marketing costs will increase until they reach steady state conditions.

- **Mature Trees** (Years 10 plus) is the period when the orchard reaches its full yield potential. The gross revenue estimates presented in Section 4.6 uses yields at the Mature Trees stage of development.

4.7.5 Planting and Orchard Establishment

The grafted seedling trees will be transplanted into planting holes with dimensions of 2 feet by 2 feet by 2 feet. Each tree will have approximately 300 grams of 10-30-10 fertilizer mixed with the soil of the planting hole. Mature green waste compost will be mixed at 1 part compost to 2 parts soil ratio to increase organic matter. The increased organic matter will improve on soil moisture retention and reduce root rot potential in avocado.

Avocado, mango, citrus, and coconut will be planted at the row and tree spacing described in this Section 4.7.3. Organic mulches will placed from the trunk to the edge of the micro-sprinkler irrigation swath for weed control. The trees will be irrigated immediately after planting and on a weekly basis thereafter based on soil moisture content of the soils and canopy size and tree age..

4.7.6 Fertilization

Fertilization programs in the orchard crops must take into account the crop characteristics and its ability to recycle nutrients from leaf litter, the tree size, and the stage of growth (vegetative, flowering and fruit set, and fruit development), soil nutrient levels, and crop specific nutrient requirements to attain economic yields.

There are volumes of information on fertilization of avocado and citrus that will be used to develop appropriate fertilization programs. The information that is available in mango is adequate to develop a viable fertilization program.

Pre-plant Soil Nutrient Analysis. Pre-plant soil nutrient sampling and analysis will be conducted to determine the nitrogen, phosphorous, potassium, calcium, magnesium, and micro-nutrient levels of the soils in Growing Zone One. The soil analysis will also determine soil pH and percent organic matter. A soil sampling and analysis protocol for the Ranch will be developed at later phase of the planning process.

Hawaii soils tend to have low nitrogen and potassium levels. Soil phosphorous may also be deficient. Zinc is important to avocado and should be applied to the soils, if levels are deficient. High levels of soil calcium and increased organic matter help to control Phytopthora root rot. Iron is important to citrus and should be applied to soils, if deficient.

Once the major soil nutrients such as potassium and phosphorous become sufficient, the postplant fertilization program may be limited to nitrogen applications only. Micro-sprinkler applications of fertilizer will be more cost effective if phosphorous does not to

be applied on a routine basis. Therefore, it may be appropriate to apply enough phosphorous as pre-plant soil amendments to reduce postplant nutrient needs.

Leaf Tissue Analysis. Leaf tissue analysis should be conducted for avocado and citrus to determine if nutrients in the leaves are present in deficient, sufficient, or luxury amounts. The critical levels for major elements and micro-nutrients in avocado and citrus are well established and should be used to evaluate the results of leaf tissue analysis. Leaf tissue analysis can be used to correct nutrient deficiencies or over application of fertilizers on a timely basis before they have major impacts on tree growth and yields..

Fertilizer Application Schedules. Fertilizer Schedules will be developed for avocado, mango, citrus, coconut, and pasture at a later phase of the planning process. The required amount of fertilizer increases with the age and size of the trees. Normally, smaller amounts are applied more frequently during early stages of tree growth. When trees reach the young and mature tree stages, fertilizer is applied four times per year in relatively even increments.

For avocado, it is typical to apply 10-30-10 fertilizer during early tree growth to supply phosphorous for good root development. Fertilizers that are higher in nitrogen and potassium like 10-5-20 are applied when the trees begin to bear fruit to provide the trees with the needed nitrogen and potassium for economic yields. The tree crops are efficient users of plant nutrients. Typical annual nitrogen requirements for mature avocado trees is 200 lbs. per acre per year.

For mango, it is typical to apply 16-16-16 or 10-20-20 fertilizer during early tree growth to supply nitrogen and phosphorous for good root development. Young trees should receive about 1 to 2 lbs. of 10-20-20 fertilizer per tree per year during the first year and about 1.5 to 3.0 lbs. of 10-20-20 fertilizer per tree per year for years two to three. Bearing mango receive about 1 lb. of 16-16-16 fertilizer for each inch of trunk diameter measured about 4 to 5 feet above the ground surface. Half of the fertilizer should be applied before flowering and the rest after the crop is harvested.

For citrus, apply about one half pound of 10-10-10 fertilizer per tree to one year old trees starting in February to October at 6 weeks intervals. In the second year, apply one half lb. of 10-10-10 fertilizer per tree from February to October at seven week intervals. For 3 to 5 year old trees, apply 1 lb. of 10-10-10 fertilizer per tree from February to October at 9 week intervals. For trees that are 5 or more years old, apply 10 lbs. of 10-10-10 fertilizer per tree between February to October three times per year.

The fertilizer will be applied through the irrigation systems to reduce labor costs. Organic fertilizers contain less nutrients than conventional fertilizers and may need to be applied more frequently. Depending on the formulation of the organic fertilizers, it may be necessary to apply the fertilizers using spreaders thus increasing the labor costs for fertilizer applications.

4.7.7 Irrigation

The orchard crops will require more water as they age. Irrigation will be based on meeting the orchard crops evapotranspiration requirements on a weekly basis. Under normal rainfall patterns, irrigation of the orchard crops should occur between April and November.

The orchard crops will be irrigated with micro-sprinklers to provide excellent irrigation efficiencies while reducing irrigation system operation and maintenance costs. Proper irrigation scheduling is critical to attain vigorous growth and maximum crop yields, to prevent waterlogged soils that can lead to root rot, and to achieve good and consistent flowering and fruit set.

Avocado. Avocado is a challenge to irrigate properly because of the shallow feeder root system. Approximately 80 to 90 percent of the feeder root length is located in the upper 8 to 10 inches of the root zone soil. The feeder roots are rather inefficient in moisture absorption because there are few root hairs and soil moisture is consumed rapidly in the upper layer of the root zone.

Avocado does not tolerate high levels of salts in the soils. If chloride concentrations in the soils are high, it may be necessary to leach the salts out of the root zone by applying 25 percent more irrigation water than the amount that is required to meet the evapotranspiration requirement.

Avocado does not tolerate water logged soils. Therefore, it is important not to over irrigate the orchards since it may lead to Phytopthora root rot. Grassed drainage pathways will be used to increase evapotranspiration of the orchard floor to reduce water logged soils from heavy rainfall events.

Mango. Next to coconut, mango is the most efficient irrigation water user of the orchard crops grown at the Ranch. After harvests, it is important to reduce irrigation depending on the cultivar between August to November to induce flowering and fruit set. Mango has a very deep taproot (sometimes extending 20 feet deep into the soils) and is resistant to wind damage and drought.

4.7.7.1 Irrigation Scheduling

Irrigation scheduling is one of the most important cultural operations in avocado and citrus. It is important to know both the frequency of irrigation and how much water to apply during an irrigation event.

Frequency. Soil moisture sensors or physical tests can be used to determine the available water in the soils. The soils in the orchard lots and Ag Cluster parcel have soil moisture holding capacities ranging from 12 to 15 percent. A rule of thumb is to irrigate when 50 percent of the available soil moisture is depleted.

Amount to Water to Apply. The amount of irrigation water to apply will depend on the crop, the soil series, the age of the crop and/or stage of development, and the evapotranspiration requirement. Guidelines on the amount of water to apply based on the diameter of the canopy and historical monthly evapotranspiration will be developed at a later phase of the planning process.

4.8 Flowering and Pollination

Flowering and pollination are critical factors affecting fruit set and production of avocado and to a lesser extent mango production. A typical full grown healthy avocado tree can produce millions of flowers per year, but on average fewer than 200 flowers per tree will set fruit that will hold and develop to maturity and harvest.

Some mango cultivars have a heavy alternate-year bearing habit or producing abundant flowers every other year. The newer mango cultivars that were selected for cultivation at the Ranch have less of the alternate-year bearing habit than the traditional Haden grown in backyards throughout Hawaii. For mango, once the flowers are produced it is important to protect them from anthracnose and powdery mildew to attain consistent annual production.

4.8.1 Avocado

Factors that affect flower initiation in avocado include juvenility, phenology, temperature, day length, water stress, and starch and plant growth regulator levels in the trees. The length of the flowering season is variable according to race, cultivar, and temperature. In general, Mexican cultivars flower the earliest, West Indian cultivars flower next, and Guatemalan last. Since all of the cultivars that were selected to be grown at the Ranch are hybrids, their flowering characteristics will be very cultivar specific.

As described in Section 3, there are two flower types in avocado, Type A and B. Type A flowers open as female in morning, closes by mid-day, and opens in the following afternoon as male. Type B opens as female in the morning, closes in the evening, and reopens in the following afternoon as functionally male. There are three types of pollination in avocado, cross pollination, self pollination, and close pollination.

- **Cross pollination** occurs when pollen is transferred from male flowers of a type A cultivar to female flowers of a type B cultivar, and vice versa.

- **Close pollination** occurs when pollen from male flowers land in the stigmas of female flowers during the daily overlap period of male and female flowers of the same type cultivar.

- **Self pollination** occurs in the same flower. In avocado, self pollination occurs only In male stage flowers when the stamen releases pollen onto the stigma that is still receptive.

Honey bees are important for moving pollen from the male stage flowers to the female stage flowers completing the cross pollination and close pollination process. Some of the steps to improve pollination in avocado include:

- Bring 1 to 2 strong bee hives per acre into the orchard,
- Plant one row of a type A cultivar per four rows of type B cultivar,
- Keep the orchard open to direct sunlight to produce flowers on the lower branches; and
- Allow bumble bees to forage for pollen too.

4.8.2 Mango

Mango flowers occur on the young terminal branches between December to April. Most of the mango flowers are functionally male. Only the hemaproditic flowers produce fruit. Pollination while important is not the critical factor affecting fruit set in mango.

Once the flowers are initiated, it is important to protect the developing flowers and fruit from infections by anthracnose and powdery mildew. Some of the mango cultivars selected for the Ranch are resistant or tolerant to anthracnose. Resistance of mango cultivars to powdery mildew is less well documented. Routine fungicide sprays may be required to control anthracnose and powdery mildew to attain the targeted yields and saleable product recovery per acre.

Mango cultivars can have a strong alternate-year bearing habit. For commercial production, it is important to select cultivars that do not exhibit strong alternate bearing habit. Flowering in mango may be improved by application of potassium nitrate about two weeks prior to the anticipated flowering period. Flowering in mango can also be induced with ethephon. A Special Local Needs label for ethephon to induce flowering in mango may be pursued after the mango groves at the Ranch are established.

4.8.3 Citrus

Citrus flowers produce very little pollen and do not depend on pollinators for pollination. Pollination and fruit set of citrus is not considered as an important factor to address at this time.

4.9 Pruning

Avocado, mango, and citrus should be pruned after harvests to remove deadwood and to promote new terminal growth required for flowering and fruit set. Avocado trees may need to be shaped by pruning during the early stages of orchard development. Large, upright growing avocado and mango cultivars may reach heights of more than 30 feet tall. When avocado and mango trees reach excessive heights, they may need to be top

cut back to 16 to 18 feet to allow for easier harvesting and better spray coverage. Citrus is self forming and do not need to be shaped in early pruning.

Mechanical pruning is normally practiced to control labor costs. Due to the different growth characteristics of avocado, mango, and citrus, it will be important to be sure that mechanical pruning equipment is flexible enough to complete all pruning tasks.

4.10 Composting

Composting is the actively managed decomposition of organic residuals to make nutrients available for plant uptake. The end product, compost is organic material that can be used as a soil amendment or used as a medium to grow plants. Mature compost contains a carbon rich material called humus that is dark brown to black in color with a soil-like earthy smell.

Organic wastes such a pruning and yard wastes generated at the Ranch are good feed stocks for composting. Horse manure and straw from the paddocks is also a commonly used feed stock Prior to composting, organic wastes will be screened to remove contaminants, then chopped or shredded to smaller particle sizes to foster faster decomposition. The chopped materials are blended with other organic streams like manure or wood chips for optimal density, carbon to nitrogen ratio, and moisture levels.

The total amount of organic wastes for composting needs to be estimated to select the best composting technology for the Ranch. Two commonly used composting technologies may be suitable for use at the Ranch. Brief description of these composting technologies are shown below.

- **Windrow Composting** involves spreading organic materials into long, semi-circle shaped piles which are turned by heavy equipment to maintain even decomposition. Piles range from 4 to 8 feet in height and 14 to 16 feet in length. The relative simplicity of windrow composting makes it a prime candidate for processing high volumes of materials particularly pruning and yard trimmings on larger amounts of land. Moisture may be added or a cover placed over the piles to minimize evaporation. On-site leachate, blowing debris, and odor must be managed.

- **Aerated Static Pile Composting** maintains decomposition by pushing or pulling air through the pile. Piles are created in a trapezoidal shape and receive little or no mechanical turning. Bulking agents like wood chips are added to the pile to enhance air flow and to add porosity to the pile. If the piles are covered by plastic tarps, a negative air system pulls air through the pile and into a biofilter to reduce odors. Finished compost or yard wastes may also be applied to the top of the piles as biofilters.

4.11 Pest and Disease Control

At this stage of the planning process, it is important to develop a basic understanding of the pests and diseases that may result in tree mortality, crop yield reductions, and/or negatively affect fruit quality. The inability to effectively control pests and diseases in one tree fruit crop may lead to greater problems in another tree fruit crop if the orchard (and farm-to-table) crops share similar pests and diseases.

It is anticipated that residents/owners will object to use of highly acutely toxic pesticides on their property. Therefore, the Preliminary Farm Management Plan is identifying the organic and 'generally regarded as safe' conventional pest and disease control practices for pest and disease risk management.. A Pesticide List will be prepared and provided to the residents to inform them of the pesticide names, amounts used, and the frequency of application. The residents/owners will be informed of all agricultural practices used on their properties.

After the orchards are planted and established, a monitoring program should be implemented to evaluate insect and disease threshold levels for preventative and control programs. If pests and diseases cannot be effectively controlled with the organic and/or approved GRAS conventional pesticide list, other low toxicity alternatives may be recommended for use after approval by the residents. All pesticide applications will be posted in a Central location to inform residents of the application site, the pesticide to be applied, and the restricted entry interval. The preliminary pesticide list includes products with very low toxicity and short restricted entry intervals.

4.11.1 Avocado

Insect Pests. Insect pests of avocado grown in Hawaii include ants, armored scales (several species), red-banded thrips (*Solenothrips rubrocinctus*), Chinese rose beetle (*Adoretus sinicus*); mealybugs (*Dysimicoccus neobrevipes*, *Nipeacoccus nipae*), mites (several species), and Black twigborer (*Xylosandrus compactus*).

The insect pest and proposed control measures include:

Insects	**Control Agent**
Ants	Amdro Pro Fire Ant Bait (Pasture use only)
Thrips	Insecticidal soaps
Mites	Sulfur, crop oils
Snails	TBD
Grasshoppers	TBD
Catepillars	*Bacillus thuringensis*, predatory wasps

Diseases. Phytopthora root rot caused by the fungi, *Phytopthore cinnamomi* must be controlled to prevent tree mortality and to attain high crop yields. Phytopthora stem canker and crown rot caused by *Phytopthora citricola* may also have a major impact on

tree health and yields. Other diseases of potential concern include Amillaria root rot (*Amillaria mellea*) and anthracnose.

Anthracnose (and stem end rots) is the most important postharvest disease of Hawaii grown avocado. Due to the sub-tropical growing climate in California and Florida, anthracnose is not considered as an important disease and fungicides are rarely applied for its control. The mild but slightly wet winters at the Ranch may require routine fungicide sprays to control anthracnose in avocado.

Maintaining good plant sanitation in the avocado orchards are essential for disease control. Deadwood, diseased fruits, and other potential sources of inoculum should be removed from the orchards. Maintaining proper soil pH and soil calcium levels and prevention of waterlogged soils through proper irrigation is essential for Phytopthora root rot and Phytopthora canker control.

Phytopthora Root Rot. Phytopthora Root Rot is the most serious and important disease of avocado worldwide. The casual agent, *Phytopthora cinnamomi* has over 1,000 hosts including many species of annual flower crops, berries, deciduous fruit trees, ornamentals, and vegetables.

Cultural and chemical control practices must be used their best advantage to control Phytopthora Root Rot. The proposed chemical control measures include use of phosphorous acid, a fertilizer/fungicide as a soil drench treatment. The Restricted Entry Interval for phosphorous acid is 4 hours. The Pre-harvest interval is 0 days.

Phytopthora canker and crown rot. Phytopthora canker caused by the fungi, *Phytopthora citrocola*, is second to only root rot in severity among diseases in avocado. The casual micro-organism can infect citrus, however, it is not considered as a major disease of citrus.

Cultural and chemical control practices will be used to control Phytopthora canker. The proposed chemical control measures include use of phosphorous acid according to label instructions.

Anthracnose. Anthracnose caused the fungi, *Colletotrichum gloeosporioides* is widespread in avocado, mango, and citrus orchards. Anthracnose infects flowers, young leaves, and developing fruit and can cause flower drop and poor fruit set. The disease remains latent in the fruit and does not develop until the fruit ripens.

Avocado cultivars at the Ranch will flower from late Fall to early Summer. The relatively warm temperatures and humid conditions during the winter flowering period may increase the susceptibility of avocado to anthracnose. Anthracnose is the most serious disease affecting flowers and fruit of mango. Careful monitoring will be necessary to ensure that the orchards do not contribute to build-up of high inoculum levels in the air. Copper hydroxide fungicide sprays may be required to ensure that harvested avocado has adequate shelf life for local sale and distribution. Anthracnose

in the fruit can be reduced but not controlled by postharvest applications of thiobendazole.

4.11.2 Mango

Insect Pests. Insect pests of mango include armored and soft bodied scales, thrips, aphids, mites (avocado red mite, spider mites), and caterpillars. The proposed chemical control measures for insect pests in mango are listed below.

Insect Pest	Control Agent
Scales	Crop oils
Thrips	Insecticidal soaps
Aphids	Insecticidal soaps
Mites	Crop oils, sulfur compounds
Caterpillars	Bacillus thuringiensis

Diseases. Anthracnose is the most serious disease in mango in Hawaii. Anthracnose infects flowers and fruit causing fruit drop and/or fruit rot after harvest. Anthracnose requires relatively warm (75 degrees Farenheit) and humid conditions for infections to occur. The susceptibility to anthracnose is the reason that mango should not be planted in areas with more than 60 inches of rainfall per year. Mango trees flower between December to April. Good fruit set in mango is best in areas with cool, dry winters.

Anthracnose will be managed using cultural and chemical control methods. For commercial mango production, it is highly desirable for the cultivars to have resistance or tolerance to anthracnose. Mango cultivars that were selected for cultivation at the Ranch with resistance or tolerance to anthracnose includes Carrie (tolerant), Fairchild, Florigon, Glenn, and Keitt. Mango cultivars that are susceptible to anthracnose includes Excel, Gouveia, Pope, and Rapoza.

Other cultural practices for anthracnose control includes maintaining good field sanitation All diseased or overripe fruits should be removed from the mango orchards and destroyed. The trees should be spaced wider apart to promote good air flow through the orchards.

Routine fungicide sprays like copper hydroxide may be necessary to control anthracnose in very susceptible cultivars and during periods of heavy rainfall. The frequency and timing of the fungicide sprays are critical to adequate anthracnose control.

Postharvest treatments such as hot water dip treatment (15 minutes at about 120 to 130 degrees F.) and postharvest fungicide treatments like thiobendazole may retard or reduce the development of symptoms of anthracnose.

Powdery mildew caused by *Oidium mangiferae* can cover the entire blossom panicle with a whitish powdery growth resulting in the fruit failing to set. The full bloom stage is the most susceptible to infection. Powdery mildew is more prevalent than in drier growing areas than in high rainfall areas. It is the predominant disease in lower rainfall areas in North and South Kona, Hawaii, whereas anthracnose is the predominant fruit disease in mango in the high rainfall areas of East Hawaii.

Cultural and chemical control practices will be used to control powdery mildew and anthracnose in mango at the Ranch. Select cultivars that are resistant to powdery mildew, when practical. Mature mango trees will be pruned twice per year to keep the developing flowers within the coverage of the orchard spray equipment and to improve air circulation in the canopy. Infected panicles and fruit will be removed from the trees and destroyed. Trees will be fertilized to maintain vigorous growth.

Chemical control practices will include use of phosphorous acid registered fungicides (carbonic acid, aliphatic petroleum solvent, and/or sulfur) applied as foliar sprays during the flowering and fruit development period. The mango flowering period at the Ranch that may be highly susceptible to anthracnose and powdery mildew is December to March. Fungicide sprays may be required at 14 day intervals during this period.

Postharvest Diseases. Anthracnose and stem-end rots are the most important postharvest/storage diseases of mango. The expression of the postharvest symptoms of anthracnose and stem-end rots can be retarded or delayed with postharvest fungicides or hot water dip treatment.

4.11.3 Citrus

Insect Pests. Citrus is affected by mites (citrus rust, citrus red mites), scales (red scale, citrus snow, yellow, chaff, and cottony cushion scales), mealybugs, whiteflies, and citrus black fly. The insect pest and its potential control agents are shown below.

The insect pests and proposed control measures include:

Insect	Control Agent
Mites	Crop oils, sulfur, biological control agents
Scales	Crop oils, Sulfur, Biological control agents
Mealybugs	Insecticidal soaps, ladybugs
Whiteflies	Biological control agents
Aphids	Insecticidal soaps

Diseases. Citrus canker caused by the bacteria, *Xanthomona aconopodis* (formerly campestris) is a quarantine pest that is strictly regulated by international phytosanitary programs. The casual micro-organism for citrus canker can also cause Bacterial Canker in avocado.

Citrus greening caused by the bacterium, *Candidatus liberibacter* is the most devastating of all citrus diseases. Citrus greening disease is currently devastating citrus groves in Florida and has spread to California. The current approach to control the spread of citrus greening is destroy infected root stock and citrus groves while genetically modified citrus cultivars with resistance to citrus greening are developed.

Although the insect vectors (Asian citrus physlid) is present in Hawaii, citrus canker and citrus greening is not present in Hawaii. Citrus should not be grown if these diseases spread to Hawaii.

Postharvest Diseases. Citrus fruit can be infected by a wide host of postharvest diseases. The important postharvest diseases of citrus include:

Disease and Casual Agent	Varietal Occurrence
Brown Rot (*Phytopthora citrophthora*)	Navel orange and grapefruit
Dipoldia stem-end rot (*Diplodia natalensis*)	All varieties
Anthracnose (*Colletotrichum gloeospriodes*)	Tangerines, Navel Oranges, and Grapefruit
Green Mold (*Penicillum digitatum*)	All varieties
Sour Rot (*Geotrichum candidum*)	Tangerines and Navel Oranges
Phomopis stem-end rot (*Phomopsis citri*)	All varieties
Alternaria stem-end rot (*Alternaria citri*)	Oranges and Grapefruit
Blue mold (*Penicillium italicum*)	Oranges and Grapefruit

Postharvest diseases in citrus are managed using cultural and chemical practices. Cultural practices include reduction in field inoculum, harvesting, degreening, postharvest handling and wax treatments, packaging, plant sanitation. Chemical control practices include application of preharvest and postharvest fungicides.

Anthracnose can infect citrus, therefore, the citrus groves must be managed properly to minimize field inoculum. Anthracnose spores are transmitted by rain splash and

irrigation water. Therefore, well managed citrus should not contribute to anthracnose in avocado and mango.

Commercial growing of citrus greatly increases the complexity of postharvest disease control. Organic citrus production will have to be based on sale of the fruit before it can develop postharvest problems. A risk-benefit analysis should be conducted at a later date to determine if it is better to limit citrus to backyard trees only.

4.11.4 Farm to Table Crops.

The farm to table crops will be infested and/or infected by a wide host of insects and diseases. Insects such as aphids, whiteflies, and thrips serve as vectors for devastating viral diseases. Fruit flies are of major concern especially for cucumbers and eggplant. Maintenance of good field sanitation is important to prevent insect and diseases from spreading from the farm to table crops to the orchards.

The specific insect pests and diseases and organic control measures for farm to table crops will be developed at a later date.

4.12 Weed Control

Weeds compete with trees for water and nutrients, primarily during the orchard's early years of growth. Weed competition is also a problem in nurseries and in older orchards that have been heavily pruned. Competition is strongest from perennial weeds such as lantana and koa-haole.

The present conditions at the Ranch includes mostly pasture that is covered in natural vegetation. Natural vegetation includes kiawe, kui, lantana, koa-haole, and swollen fingergrass. The managed pasture areas are planted with Bermuda grass which also can become a weed species of the orchards.

The Ranch will use appropriate integrated weed management strategies to economically manage weeds. Practices are influenced by climatic conditions, soil properties, irrigation practices, topography, cost, and grower preferences. A good weed management program includes prevention, monitoring, and a combination of management strategies.

- **Prevention.** Good weed management begins with prevention. Choose an appropriate growing site and prepare it well before planting. Applying herbicides, cultivating, and mowing are important primarily during site preparation before planting.. After planting maintain a thick layer of organic mulch from 6 inches from the trunk to the just beyond the micro-sprinkler swath. Keep the trees healthy so they develop a dense canopy that shades the soil and produce their own natural mulch through leaf drop.

- **Monitoring.** Regular monitoring allows for the selection of appropriate controls and when to take action. Identify the weed species present in and around the orchard especially when they are in the seeding stage. Weeds along the perimeters can serve as reservoirs for seeds to be blown into or carried into the orchards by wind, birds, or equipment.

Appropriate weed management practices for the various stages of orchard development will be selected and implemented at a later phase of the planning process.

4.13 Other Pests

Fruit Flies. Avocado, mango, citrus, and the potential farm-to-table crops are susceptible to infestation by the four fruit fly species found in Hawaii. They are widespread occurring from sea level to 7,000 feet elevation.

The four fruit fly species in the Tephritidae family in Hawaii includes:

- **Melon Fly** (*Bactrocera curcubitae*) is commonly found in commercial and backyard vegetable gardens at low elevations. It has over 100 hosts with the preferred hosts of solanaceous plants (tomato, eggplant, cucumber, squash, etc.) and papaya. One life cycle requires about 37 days.

- **Mediterranean Fruit Fly** (*Ceratitis capitata*) moved away from the low lands (except lowland coffee) when the oriental fruit fly arrived in 1945 and it is now frequently found in the uplands. It has over 300 hosts but the preferred hosts include coffee, peach, plum, loquat, orange, guava, rose apple, solanaceous plants (pepper), and the sapote family. One generation takes about 18 to 31 days to complete.

- **Oriental Fruit Fly** (Bactrocera dorsalis) is found at most elevations and climates. It has over 200 wild and cultivated hosts. Preferred hosts include guava, mango, papaya, starfruit, passion fruit, citrus, fig, rose apple, tomato, and many more. One generation takes about 37 days to complete.

- **Solanaceous Fruit Fly** (Bactrocera latifrons) is found only in dry areas in Hawaii (< 100 inches of rain per year). It has about 33 reported hosts that includes mostly solanaceous plants (pepper, tomato, eggplant, etc.) and occasionally cucurbits (cucumber, squash, etc.). One generation takes about 48 days to complete.

The key steps in managing fruit flies include:

- Prevention-Do not leave overripe or rotting fruit or vegetables in the field.
- Monitor pest levels and determine if economic injury is occurring.
- Identify the fruit fly species of concern and become familiar with its life cycle and host plants.

- Determine the other host plants growing in the area and when they are fruiting.
- Harvest fruit under-ripe when possible (ie papaya and Sharwil avocado are fruit fly free when picked less than ¼ ripe).
- If fruit flies cause injury, apply appropriate treatments (ie baited traps with insecticides).
- Re-assess effectiveness of fruit fly management programs.

Cultural and chemical controls can be effective for fruit fly control. Cultural practices include field sanitation, harvest early before infestation occurs, and biological controls such as predatory wasps. Chemical controls include using poisoned baits or lures in approved traps and bait sprays associated with the resting and feeding area of adults.

Wild Pigs. Similar to other rural and urban areas on Oahu, the Ranch has a large population of wild pigs that forage at night. Once the orchards are planted, the wild pigs can cause significant damage to the seedlings and young trees. In order to manage the wild pig population, it will be critical to maintain a trapping program prior to the start of planting.

4.14 Harvesting

It will be important to develop harvesting charts showing the immature and mature stages of the avocado and mango cultivars grown at the Ranch. With experience, the grower will be able to track fruit development by cultivar using the time of flowering and the cultivar specific interval between flowering and fruit maturity. For example, it usually takes three to five months after fruit set to harvest mango. Other harvesting indices are soluble solids levels in mango and citrus and oil content in avocado.

Avocado. Avocado is harvested with hand held poles and baskets. The harvested avocado is placed in sacks or pails and later emptied into field bins. The harvesting equipment can be purchased on-line. Fruits are picked when mature but still hard. Avocado do not ripen on the tree. Determining when to harvest avocado can be difficult and may require experience. A slight change in the skin color or loss in glossiness is a sign of maturity. The oil content is a good indicator of avocado fruit maturity. Pruning shears or clippers should be used to harvest avocados. The pedicel or stem should remain attached to the fruit to reduce the incidence and severity of stem-end rots.

Mango. Mango is harvested with hand held poles with cloth bags. Fruit are picked when mature but still hard. Fruits are usually picked after they develop some red, orange, or yellow skin color and when the flesh has turned yellow. Mango should be picked before they fully ripe, at which time they will soften and fall off the trees. The fruit bruises easily and must be handled carefully to avoid bruise damage that can lead to postharvest diseases.

Citrus. Citrus is harvested by hand with pickers climbing ladders and placing pulled fruit into pails or shoulder sacks. The pails or sacks are later emptied into 1,000 lb.

plastic or wooden field bins. A change in skin color is the best sign of maturity for harvesting operations. Citrus are non-climacteric or they do not ripen after harvest. Therefore, citrus must be harvested when fully mature. The fruit must be handled carefully to minimize wounds that can lead to higher incidence of postharvest diseases.

4.15 Packing

A small fresh fruit packing plant with refrigerated storage will be constructed at the southern edge of bulk lot 1003A. The packing plant will be needed prior to major increases in production during the young trees stage of development from years 5 to 10 after planting.

The packing flow chart may consist of unloading of bulk field bins, fresh water wash, manual sortation by size and defects, food grade wax and fungicide application, fruit drying, sortation by size and quality, and packing into 25 lb. trays. Oranges and other citrus are usually volume packed into 20 or 40 lb. half slotted containers.

The appropriate postharvest treatments and plant sanitation procedures will be determined at a later stage of the planning process. The standard postharvest treatments normally includes brush application of food grade fruit wax to preserve freshness and thiobendazole as a fungicide to retard postharvest disease development. Mango and papaya are treated with hot water dip treatments to retard development of anthracnose and stem-end rot.

After packing, the packed cartons will be palletized on standard 40 by 48 inch pallets and strapped to maintain pallet integrity. The cartons will be stacked five cartons per layer and up to 14 layers high. Local sales may require stacking of half pallets or pallets stacked about 7 to 10 layers high.

The packing plant should have a room cooler with pallet racks to temporarily store palletized cartons prior to delivery to wholesale and retail customers. The cooler will help to spread volumes over a longer period of time.

Unripe avocado and mango can be stored at 50 to 55 degrees F for two to three weeks. After removal from storage, the fruits should be ripen for three to four days at 65 to 75 degrees F prior to sale at retail. Oranges and other citrus can be stored for long periods of time. The optimum storage temperatures for orange and lime is 40 to 45 degrees F. The optimum storage temperature for tangerine is 37 degrees F.

5. Crop Budgets

5.1 Purpose and Scope

The purpose of this Section is to present the general format for the crop budgets for Planting and Orchard Establishment, Young Trees, and Mature Trees stages of orchard development. The scope of this Section is to complete a preliminary analysis of the costs of production for avocado and mango to ensure there are no 'red flags' that may hinder the development of sustainable and profitable farms.

The development of accurate and representative crop budgets for the different stages of orchard development is critical for estimating the typical cost of production and gross margin for the 'typical' avocado and mango acre. The budget estimates can be used in preliminary farm management programs to establish targets for efficiency and productivity to meet cost of production.

Surrogate data from avocado growers in Hawaii for years 2005 to 2006 suggests that the average avocado yields per acre is 2,400 lbs. and average cost of production per acre is $900 (with standard deviation of $841). Hawaii avocado growers reported wasting about 49 percent of the total production. Commercial production of avocado on the larger scale proposed for the Ranch will not be feasible with low yields and poor saleable product recovery per acre. Therefore, the Production Plan for avocado uses conservative but significantly higher yields than average yields reported in the Hawaii Avocado Industry Analysis, Part 1: Supply Focus. Using the surrogate cost data and average yields of 5,600 lbs. per acre per year, the average cost of production per acre is estimated at $2,100.

The agricultural practices and their respective costs are still a work in progress. It is not practical or prudent to try to evaluate every possible scenario without having planted a single tree. It will be more efficient to develop the crop budgets after the orchards are planted and crop logging and pest and disease surveys are evaluated to establish the actual crop requirements for orchard management. Costs are always changing and are likely to be different when the orchards begin to become productive than when the crop budgets are prepared.

The capital costs and the cost of production worksheet for the different stages of orchard development will be prepared for development of Proformas. Five year Proformas for the Planting and Orchard Establishment, Young Trees, and Mature Trees stages of orchard development will be prepared using a professional accountant at a later date.

5.2 Preparation for Orchard Planting

The costs associated with preparation for planting should be deferred and depreciated over a 20 year period. The key cost components include:

- **Weed Control** by herbicide applications and harrowing until a weed seed free seed bed is obtained. The type of herbicides to use will be dependent on the types of weeds that need to be controlled. Difficult to control perennial shrubs like the Koa Haole will require more effort than grass and broadleaf weeds. It is important to allow sufficient time to germinate and control the majority of the weed seed in the soils before planting.

- **Cover Crops** like Sunn Hemp will be planted in the orchards to increase soil nitrogen and organic matter in the soils. Sunn Hemp seed costs about $10.00 per lb. The typical seeding rate of Sunn Hemp is 50 lbs. of seed per acre. A small tractor mounted Herd Spreader is adequate for spreading the seed. The Sunn Hemp should be planted in November to December to take advantage of the winter rains to start and sustain the cover crop plantings.

- **Pre-plant Soil Nutrient Analyses** will be conducted to determine the phosphorous, potassium, magnesium, calcium, micro-nutrients (iron, zinc, etc.), soil pH, and percent organic matter. One composite soil sample for each irrigation set in the orchard lots and the Ag Cluster parcel will be analyzed at the UH Ag Diagnostics Laboratory. The estimated cost per sample is $75.00. The labor costs to collect the samples will be determined at a later date.

- **Soil Amendments** such as zinc sulfate, iron sulfate, ag lime, or dolomite may be applied depending on the evaluation of the results of the pre-plant soil nutrient analyses.

- **Irrigation System Design and Installation** will be conducted by Ag Tech to optimize the preliminary irrigation system design presented in this Report. The GPS surveys of the proposed main irrigation supply lines and the sub-main will be used to calculate friction losses due to distances, changes in elevation, pipe diameters and fittings, and changes in angles of water flow. The typical costs per acre is estimated at $2,700.00 per acre. The costs may be higher due to the constantly rising costs of PVC pipe. The costs may also be higher if the installation of the irrigation systems is contracted out to Ag Tech. The total costs for the irrigation systems for the orchards is estimated at $569,700.00.

5.3 Planting and Orchard Establishment (Years 1 to 5)

The costs for Preparation of Orchard Planting and Planting and Orchard Establishment should be deferred and depreciated over a 20-year period. The key components of this stage of orchard development include:

- **Field Surveys** may be required to layout the row to row and tree to tree spacing to ensure that proper tree population densities in straight rows are installed. A small surveyor's flag should be placed at each planting hole.

- **Grafted Seedlings** will be purchased from Plant It Hawaii located in KurtisTown on the Big Island. The current estimated cost for avocado is 87 trees per acre times $38.00 per tree. The current estimated cost for avocado seedlings is $3,306 per acre. The current estimated cost for mango seedlings is 41 trees per acre times $50.00 per tree. The current estimated cost per acre for mango seedlings is $2,050 per acre. The cost estimates do not include the freight and handling costs. Approximately 30 to 40 grafted seedlings per 40 by 48 pallet will be shipped via Young Brothers from Hilo to Oahu. Due to the relatively large amount of acres to be planted, it may take about 3 years to plant the entire avocado orchard and about 5 years to plant the entire mango orchard.

- **Planting** consists of digging 2 by 2 by 2 foot holes with a backhoe, mixing of compost and other soil amendments with the soils from the planting holes, planting of 41 (mango) to 87 (avocado) grafted seedlings per acre, and application of starter fertilizer and irrigation. The task of planting itself may take two to three weeks per year. Therefore, it may be appropriate to rent the backhoe rather than purchase new equipment. If the Ranch decides to install irrigation systems, it will be beneficial to purchase a used or new backhoe.

- **Irrigation** consists of connecting the micro-sprinkler systems to the sub-mains followed by weekly irrigation depending on soil moisture levels in the soils. It typically costs about $400 per acre (layflat and spaghetti lines) to connect the laterals to the irrigation system. The amount of irrigation required at this stage of development is relatively small but will increase as the orchard matures. The water costs at this stage of development is not a significant cost component.

- **Fertilization** consists of application of complete fertilizer formulation four to six times per year. The fertilizer formulations and application rates will vary depending on the stage of crop development (flowering/.fruit development versus vegetative growth) and the size and age of the trees. The fertilizer applications will be made through the micro-sprinkler irrigation systems as a labor cost savings measure. Fertilizer application schedules will be prepared in the next phase of planning.

- **Pruning/training** consists of forming the trees to the desired tree shape and form. Successful pruning requires an understanding of how the tree grows and responds to branch removal. Commercial orchards must maintain control of both tree size and orchard productivity in order to remain productive and sustainable. Initial pruning and training will be completed using manual pruning tools. When trees mature, the orchards will be pruned once to twice per year using mechanized pruning equipment. It may be necessary to purchase different mechanical pruners for avocado and mango due to differences in tree shape and size.

- **Pest and Disease Control** will include maintenance of good field sanitation and periodic applications of phosphorous acid through the micro-sprinkler irrigation system for Phytopthora Root Rot and Phytopthora Stem Canker and Crown Rot.

  Disease control may also include frequent foliar sprays of copper hydroxide and other GRAS fungicides for control of anthracnose and/or powdery mildew. The insect pest management programs will use biological control methods like predatory wasps and ladybugs and organic or GRAS insecticides like insecticidal soaps and/or crop oils. Integrated Pest Management Programs will be developed to manage insect and disease problems to maximize yields and saleable product recovery. Pest and disease control while important is not anticipated to be a major cost component at this stage of orchard development.

- **Crop Logging and Monitoring** consists of: 1) evaluation and recording the rate of tree growth per year; 2) recording the date of flowering, fruit set, date of harvest, and crop yields; 3) analysis of leaf tissue samples to evaluate the plant nutritional status of the trees; 4) determine factors that are affecting crop yields and fruit quality; and 5) development and implementation of corrective actions to attain target tree growth rates, yields, and saleable product recovery.

- **Harvesting** will start at about three years after planting of the orchards. Harvesting costs should be low since the harvests will be relatively light at this stage of orchard development.

5.4 Young and Mature Trees

The cost of production worksheets for the Young Trees (Years 5 to 10) and Mature Trees (Years 10 plus) will be prepared after planting of the orchards and collection of actual cost and yield data. The major costs for these stages of orchard development includes:

- **Irrigation** (includes water, labor, equipment, and operation and maintenance costs)

- **Fertilization** (includes fertilizer, composting, labor, equipment, and operation and maintenance costs)

- **Pruning** (includes labor, equipment charge out rates, and operation and maintenance costs)

- **Pest Control** (includes materials, labor, equipment charge out rates, and operation and maintenance costs)

- **Root Rot Control** (Avocado only, materials, labor, equipment charge out rates, and operation and maintenance costs)

- **Harvesting** (May be the highest labor costs and must be managed properly. Includes labor, equipment charge out rates, and operation and maintenance costs)

- **Cash Overhead Costs** (includes insurance, professional services, taxes, etc.)

- **Non-Cash Overhead Costs** (includes land, equipment, fresh fruit packing plant, amortized orchard establishment costs, and other capital costs)

The packing and sales and marketing costs are usually classified as a different line item than production costs. These costs will be estimated at a later phase of the planning process.

6. Discussion and Conclusions

6.1 Purpose and Scope

The purpose of this Section is to discuss the Opportunities and Constraints of the Agriculture Plan and to present the conclusions of this Agriculture Feasibility Report.

6.2 Opportunities and Constraints

6.2.1 Opportunities

Good Production Volumes and Excellent Fruit Quality. Locally grown avocado and mango have superior fruit quality than the imports like Hass avocado and Tommy Atkins mango and/or locally grown mango like Haden. The proposed production level for avocado at the Ranch represents replacing about 32 percent of the current avocado import volumes. The proposed mango production levels at the Ranch represents about a 25 percent increase in Hawaii commercial mango production. If the alternate-year bearing habit of mango can be managed effectively, it may be possible to continue to increase mango production levels.

Focused and Integrated Plan. The Agriculture Plan recognizes the limitations posed by site conditions and resource constraints. The Plan is focused and integrated on the commercial production of the best orchard crops for the site conditions at the Ranch. This will minimize costly mistakes and increase the efficiency, productivity, and profitability of the agricultural operations. Site conditions while not ideal are acceptable for avocado, mango, citrus, coconuts, and farm to table crops. The Plan does not attempt to grow or produce crops that are not suitable for cultivation at the Ranch. It limits the acreage for cultivation of farm to table crops to supply the Ranch community as a cost control measure and to reduce growing risks inherent to organic farming.

Coordinated Agriculture Practices and Marketing Cooperative. The Dillingham Ranch Residents Cooperative Association, if accepted will allow for the orderly sale and marketing of the avocado and mango. Collectively, the small farms will produce significant volumes of fruits that provide incentives for local produce distributors to buy Hawaii Grown produce. The consolidation of agricultural activities with the Dillingham Ranch Agricultural Services will ensure that the agricultural practices are uniform and proven to allow the orchards to be properly managed in all stages of orchard development. When problems arise, the farm management structure can respond rapidly and effectively.

Close Proximity to Market. There are no large avocado farms on Oahu. The avocado farm will have the same advantage as all Oahu farms of lower freight costs and fresher product while accessing the primary market. This advantage by itself is irrelevant if availability, quality, and costs are not competitive with local and imported alternatives.

Wealth of Available Information. There are volumes of information on cultivation and postharvest handling of the orchard and farm to table crops. There are adequate tools to grow the orchard crops using organic and/or 'generally regarded as safe' conventional methods that should be acceptable to the Ranch residents/owners and the Mokuleia Community.

Sustainable Community. The successful commercial production will help to spread operation and maintenance costs at the Ranch over a larger base making the managed pasture and other agricultural uses more sustainable. The Ranch and the orchards will provide a beautiful, green vista of the Waianae Mountains preserving the unique character of Mokuleia and the North Shore for decades in the future.

6.2.2 Constraints

Alternate-Year Bearing Habit. Although the selected mango cultivars exhibit less of the alternate-year bearing habit than Haden mango, the potential' 'on' year and 'off' year mango deliveries may result in lower average yields and hinder sales and marketing efforts directed at gaining consumer acceptance of the new and different mango cultivars. The alternate-year bearing habit may be mitigated by good irrigation management and the use of potassium nitrate to induce flowering. Depending on the final acreage, it may be feasible to pursue a Special Local Needs label for ethephon to induce flowering in mango.

Plant and Fruit Diseases. The plant and fruit diseases of avocado and mango are issues of concern. Anthracnose and powdery mildew in mango can cause flower drop and reduce fruit set.. Anthracnose can cause rotting of avocado, mango, and citrus after harvest resulting in loss of customers. Phytopthora root rot and Phytopthora canker and crown rot can cause tree mortality of avocado if soils become waterlogged during flood events. Postharvest diseases of citrus can negatively affect fruit quality and reduce shelf life. The plant and fruit diseases will need to be managed with resistant cultivars, field sanitation, and routine fungicide sprays. The disease control programs may increase costs reducing gross margins.

Changing Consumer Preferences. The Hawaii consumers are not used to buying and eating some of the new avocado and mango cultivars. Multiple varieties will require more consumer education and marketing to inform consumers on what are the characteristics of a good avocado and mango. The Agriculture Plan will not be successful if consumers do not accept all of the avocado and mango cultivars. When early harvests begin, it will be important to start the grass roots marketing program using media, chef tasting, and retail tasting sessions. The residents at the Ranch should take the active role in the marketing program as a means of community outreach.

Low Volume and Lower Fruit Quality. The low volume and lower quality of citrus grown at the Ranch may not be competitive with imports. Citrus is affected by a wide range of postharvest diseases significantly complicating disease management. A risk-

benefits analysis should be conducted to determine if it is best to limit citrus to backyard trees instead of commercial production. The recent shortages of imported limes due citrus stem canker and supply chain issues in Mexico may present a production and marketing advantage for locally grown limes.

Capital Costs. The high initial capital costs and the long time required for orchard establishment must be considered in determining the economic viability of the commercial production. The cost of the equipment and fresh fruit packing plant will need to be spread over sufficient volumes over a span of years to be economical. The orchards need to strive for continuous improvement to off set rising production costs.

Labor Cost and Availability. The high cost and availability of labor for harvesting is an issue of concern. The Ranch may need to have outreach programs to hire students from Waialua High School for harvesting. This will help with community outreach.

Use of Residual Fruit. Other uses of fruit that is not acceptable for fresh sale should be developed. Producing gelatos and sorbets, guacamole, jams and jellies, and salsas may be good options if the residents want to start a small business. When using reject fruit, there is a need to be careful that the users does not try to sell the rejects as fresh fruit damaging the market for the Hawaii No. 1 quality fruit.

Ag Theft. Theft of agricultural commodities is a serious problem in Hawaii. ' Everyone' wants to steal a mango. The Ranch will need to be vigilant and maintain security at night during mango harvest season to prevent massive losses.

6.3 Concluding Remarks

The Dillingham Ranch Aina LLC is requesting approval of an Agricultural Subdivision and Ag Cluster on approximately 814.5 acres out of about 2,780 total acres of land. The development concept for the Ranch allocated approximately 519.74 acres for 92 five plus acre lots. The 92 lots for sale includes 48 pasture lots, 28 orchard lots, and 16 grazing lots. The development concept also allocated approximately 94.75 acres of land in bulk lot 1003 as the agricultural area for an Ag Cluster. The proposed Ag Cluster includes about 15 farm dwellings in bulk lot 1002. The development concept also preserves the Dillingham Lodge and existing managed pastures and paddocks located on approximately 200.02 acres of land in bulk lots 1001, 1004, 1005, and 1006..

The Agriculture Plan for the Ranch is proposing to use the orchard lots and Ag Cluster parcel for commercial production of avocado, mango, and citrus to replace imported produce with locally grown produce. The plan also includes growing farm to table crops, coconut and nursery plants for landscape purposes, managed pasture, pasture lots, and grazing lots to preserve the Working Ranch and to support the Ranch and Mokuleia Communities..

The orchard lots encompasses about 160.03 gross acres with an estimated 126.0 net acres of arable land. The Ag Cluster parcel encompasses about 94.75 gross acres with

an estimated 85.3 net acres of arable lands. These lands are the primary focus of the Agriculture Plan, however, all agricultural areas and activities were covered in the Plan.

The first step of the Plan was to conduct Production and Market Analyses for tree fruit, tropical specialty tree fruit, fruits and vegetables, and fresh herbs using the Hawaii Agriculture Statistics. Tree fruit and tropical specialty fruit with the potential to replace imports or fruit with good consumer growth potential were identified and screened against the crop specific agricultural requirements, climatic conditions, and soil properties for suitability for cultivation at the Ranch. The preliminary screening of the crops selected avocado, mango, and citrus as the best adapted fruit tree crops with excellent market potential for the site conditions at the Ranch.

Designated agricultural areas were then assigned to the selected crops based on their potential to replace imports, target production levels, and field specific conditions. The tree fruit, landscape plants, and farm to table Crop List included 126.0 net acres of avocado, 43.3 net acres of mango, 27.0 net acres of landscape coconuts and palms, 12.0 net acres of citrus (orange, lime, and tangerine), and 3.0 net acres of farm to table crops.

The agricultural areas were divided into Growing Zones One and Two primarily for irrigation management purposes. Growing Zone One includes all of the acres listed above and about 125.6 acres of managed pasture and about 41.1 net acres for the Lodge (bulk lots 1001 and 1002) and Lake Surrounds. Growing Zone Two includes 46 pasture lots with about 138.0 net acres of irrigated pasture and 16 grazing lots with no irrigation besides personal landscape allowed.

Separate Pan Evaporation Projections were calculated for Growing Zones One and Two using representative weather data and historical pan evaporation values. The Pan Evaporation Projections for Growing Zone One for average daily, average peak daily, and average peak daily water requirements with 70 percent rainfall are 0.12, 0.0.23, and 0.24 inch per day, respectively. The Pan Evaporation Projections for Growing Zone Two for average daily, average peak daily, and average peak daily water requirements with 70 percent rainfall are 0.10, 0.20, and 0.20 inch per day, respectively.

The Pan Evaporation Projections, crop specific acres, mid-growth stage crop factors, irrigation methods, and irrigation efficiencies were\used to estimate crop water demands for the Growing Zones. The average daily, average peak daily, and average peak daily irrigation water requirements for Growing Zone One are 1,638,196 gallons per day (gpd), 3,141,714 gpd, and 3,278,398 gpd, respectively. The average daily, average peak daily, and average peak daily with 70 percent rainfall for Growing Zone Two are 798,328 gpd, 1,516,822 gpd, and 1,516,822 gpd, respectively.

There are four groundwater supply wells on the Ranch with a combined allocation of about 4.1 million gallons of water per day. As described in Section 3.10, the Agriculture Plan has developed the Irrigation Plan to meet the average daily irrigation water requirements for Growing Zones One and Two. The relatively dry weather conditions at

the Ranch are beneficial for plant and fruit disease management. With adequate irrigation and good crop management, the orchards should reach their full yield and fruit quality potential.

Two of the most important components of the Agriculture Plan includes consolidation of crop management activities with the proposed Dillingham Ranch Agricultural Services (RAS) and sales and marketing with the proposed Dillingham Ranch Farmers' Cooperative (RFC). The RAS will allow for efficient implementation of the required crop management programs to attain or exceed target fruit tree crop yields and saleable product recovery per acre. The RFC will allow for production and sale of consistent weekly volumes of superior quality tree fruits to replace imported produce with wholesome and safe locally grown produce.

A Preliminary Farm Management Plan was included in this Report to: 1) Identify, screen, and select the top avocado, mango, and citrus cultivars for commercial production; 2) Develop production and marketing strategies to spread production volumes over the bearing periods for multiple top cultivars; 3) Identify and outline crop specific and location specific agricultural requirements; 4) Identify and outline crop specific pests and diseases of potential concern for risk management purposes; and 5) Estimate Fruit Deliveries by bearing season for each selected avocado, mango, and citrus cultivars.

The Production Plans fpr avocado, mango, and citrus estimated deliveries in pounds produced per year. The production levels and the preliminary fruit delivery schedules are summarized below.

- For 126.0 acres of avocado, the estimated annual production level is 705,600 pounds per year or about 32 percent of the average annual imported volume. The fruit delivery period is September to June. At an average price per lb. of $1.07, the gross revenue per year is estimated at $754,992.

- For 43,3 acres of mango, the estimated annual production level is 154,321 pounds per year or an 25 percent increase in local mango production. The fruit delivery period is May to October. At an average price per lb. of $1.04, the gross revenue per year is estimated at $160,494.

- For 27.0 acres of landscape coconuts, the estimated total value for 3,518 trees sold at a conservative price of $400 per tree is $1,447.200. Sale of landscape coconuts is varies from year to year, therefore, annual gross revenue was not estimated in this Report.

- For 12.0 acres of citrus, the estimated annual production level is 62,843 pounds per year. This production level is miniscule in comparison to average annual imports of orange, lime, and tangerine. At average prices per lb. ranging from $0.67 to $1.00, the gross revenue per year is estimated at $57,648.

- For 3.0 acres of organic farm to table crops, the estimated annual production level using eggplant as the surrogate yields is 30,429 pounds per year. The farm to table crops are being grown for the Ranch community to support a holistic, sustainable healthy lifestyle. At an average price of $0.90 per lb., the gross revenue per year is estimated at $30,429.

- Collectively, the orchard and farm to table crops are estimated to produce about 959,514 lbs. of product per year with estimated gross revenue of $1,003,563.

The crop budgets for the three stages of orchard development will be developed after crop specific and location specific Production Guides and the Final Farm Management Plan are developed. The Production Guides and the Final Farm Management Plan will develop detailed fertilizer, irrigation, pest and disease management, and other agricultural practices and Master Schedules for implementation of the agricultural practices. The Production Guides and Farm Management Plan should be prepared to take the technical considerations presented in this Report to practical implementation.

This Report presented opportunities and constraints for the Agriculture Plan that may need to be considered in later phases of the planning and implementation process. The final decisions on the orchard crops and cultivars to grow and their respective acreage may change as more information is obtained and reviewed. For example, Kahaluu avocado is rated as one of the best eating avocadoes in Hawaii but has an irregular bearing habit. Higher acreage of Malama may be appropriate to increase production volumes. Another example is that orange and tangerine may be eliminated from the Plan in favor of more acreage for lime.

The results of this Agricultural Feasibility Report demonstrated that it is technically feasible to grow avocado, mango, and citrus for commercial production at the Ranch. There are volumes of information and support services for major tree fruit crops like avocado and citrus making it feasible for Ranch to effectively implement the Plan.. The amount of information available for mango are adequate to develop the proposed production plan. Farm to table crops will be grown on a small scale to meet its primary objective to support the Ranch Community limiting inherent risks of organic vegetable production.

The orchards provide a good long term revenue stream while growing crops that do not require major investments in equipment and requires minimal labor for the most agricultural activities except harvesting. Integrating all agricultural services under the RAS will increase efficiencies and productivity and support sustainability of the Ranch Community.

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Appendix A-Tables

Agricultural Feasibility Report
Volume 2

Dillingham Ranch

Table 2-1. Weather Data-Dillingham Ranch Growing Zones One and Two

Month	Growing Zone One MeanRainfall (inches)	Growing Zone One MeanTemperature (deg F)	Growing Zone Two Mean Rainfall (inches)
January	3.94	71.5	4.74
February	3.30	71.6	3.47
March	2.85	69.2	3.33
April	1.71	73.3	1.95
May	1.69	77.1	2.17
June	0.83	74.1	0.80
July	1.56	74.2	1.17
August	1.44	78.7	0.88
September	1.34	78.8	1.45
October	2.61	77.2	2.33
November	3.53	71.5	4.46
December	4.17	73.5	3.67
Total or Avg.	28.17	74.5	30.42

Weather Data (1981 to 2012)
Growing Zone One-Camp Erdman Station (10 feet above sea level)
Growing Zone Two-Rainfall Atlas of Hawaii (approx. 300 feet above sea level)

Table 3-1. Agricultural and Irrigation Area Summary-Dillingham Ranch

Type of Ag	Total Lots	Total Acres	% Irrigated	Net Acres
Growing Zone One				
Ag Cluster Bulk Lot	1	95	90	85.3
Managed Pasture	2	140	90	125.6
Lake Surrounds	1	22	20	4.4
Lodge Ornamental	2	39	90	34.7
Orchard Lots	28	160	90	126.0
Pasture Lots	2	10	4.0	8.0
Growing Zone Two				
Pasture Lots	46	255	4.0	184.0
Grazing Lots	16	94	0	0
Total	92	815		567.3

Table 3-2. Hawaii Tree Fruit Production and Imports (Yrs. 2005-2009)

Commodity		2005-2009 Production (X 1000 lbs)	Utilized Production (X 1000 lbs)	Price (dollars)	Value of Sales (X 1000)
Avocado	Inshipments	2,196			
	Hawaii	1,004	2.98	0.69	692
Grapefruit	Inshipments	1,564			
	Hawaii	42	2.68	0.69	29
Guava	Inshipments	0			
	Hawaii	5,080	17.07	0.15	740
Lemon	Inshipments	3,972			
	Hawaii	47	2.03	0.85	40
Lime	Inshipments	1,881			
	Hawaii	81	2.23	0.89	72
Orange	Inshipments	13,404			
	Hawaii	0	NA	NA	NA
Papaya	Inshiopments	0			
	Hawaii	17,655	22.71	0.4	7,062
Pineapple	Inshipments	0			
	Hawaii	26,500	NA	0.38	10,070
Tangerine	Inshipments	1,652			
	Hawaii	81	3.98	0.67	56

Table 3-3. Hawaii Tropical Specialty Fruit Production and Imports (Years 2005 to 2009)

Commodity	2005-2009 Proudction (X 1000 lbs)	Utilized Production (X 1000 lbs)	Price/lb (dollars)	Value of Sales (X 1000 dollars)
Atemoya	17.3	2.28	1.33	23
Guava	5,080	17.5	0.15	740
Longan	219	1.67	3.18	700
Lychee	181	1.36	2.85	625
Mango	532	2.71	1.04	687
Rambutan	450	2.01	2.33	1,373

Table 3-4. Hawaii Vegetable Production and Imports (Yrs. 2005 to 2009)

Commodity		2005-2009 Production (X 1000 lbs)	Yield (X 1000 lbs)	Price/lb. (dollars)	Value of Sales (X $1000)
Beans, Snap	Inshipments	553			
	Hawaii	675	5.4	1.06	716
Bittermelon	Inshipments	114			
	Hawaii	216	9.6	0.89	196
Cucumbers	Inshipments	1,460			
	Hawaii	5,300	15.4	0.51	2,679
Eggplant	Inshipments	878			
	Hawaii	1.032	16.1	0.91	931
Lettuce *	Inshipments	8,303			
	Hawaii	1,050	10.3	0.73	758
Onions, Green	Inshipments	681			
	Hawaii	1,520	11.5	1.13	1,715
Peas, Chinese	Inshipments	253			
	Hawaii	NA	NA	NA	NA
Peppers, Green	Inshipments	4,011			
	Hawaii	2,533	11.7	0.68	1,717
Potatoes, Sweet	Inshipments	1,550			
	Hawaii	7,160	16	0.5	4,399

Table 3-4A. Hawaii Vegetable Production and Imports (Yrs. 2005 to 2009)

Commodity		2005-2009 Production (X 1000 lbs)	Yield (X 1000 lbs)	Price/lb. (dollars)	Value of Sales (X $1000)
Pumpkin	Inshipments	472			
	Hawaii	233	7.18	0.6	132
Squash, Italian	Inshipments	1,641			
	Hawaii	1,290	7.3	0.6	671
Squash, Oriental	Inshipments	468			
	Hawaii	408	10.2	0.52	211
Tomato	Inshipments	4,731			
	Hawaii	14,400	20.6	0.72	10,328

Table 3-5. Hawaii Fresh Herb Production (Yrs. 2005 to 2009)

Commodity	2005-2009 Production (X 1000 lbs)	Price/lb. (dollars)	Value of Sales (X$1000)
Basil, Sweet	2,040	1.94	3,070
Basil, Asian	1,700	1.21	2,077
Parsley	185	2.01	359
Parsley, Chinese	183	2.51	456
Other Herbs	1,246	2.21	2,281

Table 3-6. Crop Specific Crop Requirements for Site Selection
Agricultural Feasibility Report-Dillingham Ranch
5-May-14

Commodity	Soil Types	Soil pH	Rainfall (inches)	Air Temp. (deg F.)	Elevation (ft AMSL)	Special Requirements
Avocado	Grows in Wide Range of Soil Types, Best in Deep Well Drained Fertile Soils High in Organic Matter	6.2 to 7.5	50 inches, Well Distributed	Mexican Varieties are Cold Tolerant	Sealevel to 2500 ft. Best below 1000 ft.	No waterlogged soils, CL Sensitive, Phytopthora Root Rot and Canker Control is Essential, Areas without High Winds
Lime	Grows in Wide Range of Soil Types, Best in Deep Well Drained Fertile Soils, Can be Grown in Sandy Soils	6.2 to 8 Best at pH 6 to 7	80 to 150 inches	65 to 80 deg. F.	Best at 500 to 1000 ft.	CL Tolerant, Absence of Citrus Canker and Citrus Greening Bacterial Diseases Micro-nutrient Deficiencies are Common in High pH Soils
orange	Grows in Wide Range of Soil Types, Best in Deep Well Drained Fertile Soils	Best at pH 6 to 7	60 to 80 inches	75 to 90 deg. F.	Best at sealevel to 500 ft.	Absence of Citrus Canker and Citrus Greening Bacterial Diseases, Areas without high winds, No water logged soils
Tangerine	Grows in Wide Range of Soil Types, Best in Deep Well Drained Fertile Soils	Best at pH of 6 to 7	60 to 80 inches	75 to 90 deg. F.	Best at Sealevel to 500 ft.	Sensitive to Strong Winds, Absence of Citrus Canker and Citrus Greening Bacterial Diseases

Table 3-7. Tropical Specialty Tree Fruit Requirements for Site Selection
Agricultural Feasibility Study-Dillingham Ranch
5-May-14

Commodity	Soil Types	Soil pH	Rainfall (Inches)	Air Temp. (deg F.)	Elevation (ft. AMSL)	Special Requirements
Longan	Grows in Wide Range of Soil Types, Best in Deep Well Drained Fertile Soils	6.2 to 8	50 to 80 inches per year	80 to 95 deg. F in Summer, 59 deg. F. in winter	Sealevel tp 1500 ft.	Sensitive to High Winds, Excessive ive Rains During Flowering Causes Flower Drop, Cool Dry Winter Required for Good Flowering, CL Sensitive
Lychee	Grows in Wide Range of Soil Types, Best in Deep Well Drained Fertile Soils	5 to 6.5	50 to 80 inches per year	82 deg. F. in summer, Day/Night Temp. of 59/50 deg. F in winter	Sealevel to 2000 ft.	Sensitive to High Winds, Excessive Rains or High Winds During Flowering Causes Flower Drop, Cool Dry Winter Required for Good Flowering, CL Sensitive
Mango	Grows in Wide Range of Soil Types, Best in Deep Well Drained Fertile Soils	6.5 to 7.5	40 to 60 inches per year	75 to 90 deg. F.	Sealevel to 1500 ft., Best at low elevation	Excessive Rains During Flowering Causes Flower and Fruit Drop, Tolerance to Anthracnose is Critical to Successful Commercial Production
Rambutan	Grows in Wide Range of Soil Types, Best in Deep Well Drained Fertile Soils	6 to 7	72 to 118 inches per year	72 to 93 deg. F.	Sealevel to 1000 ft. Best at low elevation	No Waterlogged Soils, Water Stress Required for Good Flowering and Fruit Set

Table 3-8. Estimated Gross Revenue for Orchard and Farm to Table Crops
Agricultural Feasibility Report-Dillingham Ranch
April 28, 2014

Crop	Acres	Yield (lbs./acre)	Production (Pounds)	Price/lb. (Dollars)	Gross Revenue (Dollars)
Avocado	126.0	5,600	705,600	$1.07	$754,992
Mango	43.3	3,564	154,321	$1.04	$160,494
Orange	7.0	6,131	42,917	$1.00	$42,917
Lime	2.5	3,065	7,663	$0.85	$6,513
Tangerine	2.5	4,905	12,263	$0.67	$8,218
Farm to Table	3.0	11,270	33,810	$0.90	$30,429
Total:					$1,003,563

Table 3-9. Estimated Value of Landscape and Nursery Crops
Agricultural Feasibility Report-Dillingham Ranch
April 30, 2014

Commodity	Acres	Plants/Acre	Production	Price/Plant	Estimated Value
Coconut	27.0	134	3,618	$400	$1,447,200
Nursery	TBD				

Dillingham Ranch-Growing Zone One
Pan Evaporation Projections
Pan Evaporation Data-Station 847
Weather Data Camp Erdman

Table 3-10. Pan Evaporation Projections-Growing Zone One

Month	Evaporation Mean (inches)	Rainfall Avg. Mo. (inches)	Evaporation Less Rainfall (inches)	Daily Avg. Net Evaporation (inches)	Daily Avg. Evap. 70% Rainfall (inches)
January	4.17	3.94	0.23	0.01	0.05
February	4.59	3.3	1.29	0.05	0.09
March	5.54	2.85	2.69	0.09	0.11
April	5.88	1.71	4.17	0.14	0.1
May	7.22	1.69	5.33	0.18	0.19
June	7.76	0.83	6.93	0.23	0.24
July	8.33	1.56	6.77	0.22	0.23
August	8.27	1.44	6.83	0.22	0.23
September	7.24	1.34	5.9	0.2	0.21
October	5.91	2.61	3.3	0.11	0.13
November	4.54	3.53	1.01	0.03	0.07
December	3.9	4.17	0	0	0.03
Annual Total	73.35	28.17			
Peak Daily Water Requirement				0.23	0.24
Daily Average For The Year				0.12	0.14

Dillingham Ranch-Growing Zone Two
Pan Evaportation Projections
Pan Evaporation Data-Station Station 861
Weather Data-Rainfall Atlas of Hawaii Interactive Map

Table 3-11. Pan Evaporation Projections-Growing Zone Two

Month	Evaporation Mean (inches)	Rainfall Avg. Mo. (inches)	Evaporation Less Rainfall (inches)	Daily Avg. Net Evaporation (inches)	Daily Avg. Evap. 70 % Rainfall (inches)
January	3.78	4.92	0	0	0.01
February	4.22	4	0.22	0.01	0.05
March	5.01	3.22	1.79	0.06	0.09
April	5.23	2.38	2.85	0.1	0.12
May	6.33	1.78	4.45	0.14	0.16
June	6.39	0.84	5.55	0.19	0.19
July	6.92	1.81	5.11	0.16	0.18
August	7.05	1.95	5.1	0.16	0.18
September	6.24	2.35	3.89	0.13	0.15
October	5.29	2.92	2.37	0.08	0.1
November	4.13	3.94	0.19	0.01	0.05
December	3.84	4.36	0	0	0.03
Annual Total	64.43	34.52			
Peak Daily Water Requirement				0.19	0.19
Daily Average For The Year				0.1	0.11

Dillingham Ranch-Growing Zone Or es One
Crop Water Demand

Daily Average for the Year:	0.12
Peak Daily Water Requirement:	0.23
Peak Daily Water Requirement with 70% Rain:	0.24

March 12,2014

Table 3-12. Crop Water Demand-Growing Zone One

Crop	Area (Net Acres)	Crop Factor (Kc)	Form of Irrigation	Irrigation Efficiency	Daily Avg. Req. (gallons)	PeakDaily Req. (gallons)	Peak Req. w/70% (gallons)
Managed Pasture	125.6	1.4	Sprinkler	70%	818,530	1,568,849	1,637,060
Avocado Orchard	126	0.8	Micro-spr	85%	386,417	740,633	772,835
Lodge/Ornamentals	34.7	1.01	Sprinkler	70%	163,143	312,690	326,286
Plantation Palms	27	0.7	Micro-spr	85%	72,453	138,869	144,907
Mango	43.3	0.7	Micro-spr	85%	116,194	222,704	232,387
Navel Orange	7	0.9	Micro-spr	85%	24,151	46,290	48,302
Lake Surrounds	4.4	1.4	Sprinkler	70%	28,675	54,960	57,349
Farm to Table	3	1.01	Drip	80%	12,341	23,655	24,683
Lime	2.5	0.9	Micro-spr	85%	8,146	16,532	17,251
Tangerine	2.5	0.9	Micro-spr	85%	8,146	16,532	17,251
Sub-total					1,638,196.00	3,141,714	3,278,308.00

Dillingham Ranch-Growing Zone Two
Crop Water Demand

Daily Average for the Year:	0.1
Peak Daily Water Requirement:	0.19
Peak Daily Water Requirement with 70% Rain:	0.19

Table 3-13. Crop Water Demand-Growing Zone Two

Crop	Area (Net Acres)	Crop Factor (Kc)	Form of Irrigation	Irrigation Efficiency	Daily Avg. Req. (gpd)	Peak Req. (gpd)	Peak Req. w/70% (gpd)
Limited Pasture	196	1.4	Sprinkler	70%	999,267	1,925,596	1,925,596
Total					999,267	1,925,596	1,925,596

Table 4-1. Percentage of Acres for Top Hawaii Avocado Cultivars
Agricultural Feasibility Report-Dillingham Ranch
March 17, 2014

Cultivar Name	Percent Acreage	Harvest Period	Potential Pounds/Period
Sharwil	45%	Oct.-Feb.	452,000
Malama	21%	Sept.-Dec.	211,000
Yamagata	11%	March-June	110,000
Murashige	3%	April-June	30,000
Hass	0.9%	April-June	9,000
Others	19.1%	Unknown	192,000

Table 4-2. Top Avocado Cultivars' Harvest Periods
Agricultural Feasibility Report-Dillingham Ranch
March 17, 2014

Variety Name	J	F	M	A	M	J	Jul	A	S	O	N	D
Beardslee	--									----	----	----
Fujikawa			----	----	----	----						
Green Gold(A)	----	----	----	----								
Kahaluu									----	----	----	
Lamb Hass (A)				----	----	----						
Linda			----	----	----							
Malama									----	----	----	----
Murashige				----	----	----						
Ota	----	----									----	----
San Miguel(A)	--									----	----	----
Sharwil	----	----									----	----
Yamagata			----	----	----	----						

Table 4-3. Production Characteristics of the Selected Avocado Cultivars
Agricultural Feasibility Report-Dillingham Ranch
March 28, 2014

Cultivar	Season Of Bearing	Race	Flower Type	Bearing Habit	Tree Size and Form
Green Gold	Jan-April	MXG	A	Heavy, regular	Small-medium
Kahaluu	Aug-Nov	GXWI	B	Light, irregular	Tall, upright
Malama	Sep-Dec	G	B	Heavy, regular	Medium, spreading
San Miguel	Fall-Winter	Hybrid	A	Moderate, regular	Medium, spreading
Sharwil	Oct-Feb	MXG	B	Moderate, regular	Low, spreading
Lamb Hass	April-Jun	MXG	A	Heavy, regular	Medium, spreading
Yamagata	March-Jun	MXG	B	Heavy, regular	Tall, upright

Table 4-3A. Fruit Quality Characteristics for Selected Avocado Cultivars
Agricultural Feasibility Report-Dillingham Ranch
March 28, 2014

Cultivar	Weight (oz)	Oil Content (%)	Fruit Type	Seed Size	Mature Skin	Skin Thickness	Flesh Color	Flavor	Peeling	Shelf Life
Green Gold	8-20	>20	Pear	S	G	Med.	Y-G	Excellent	Good,	Excellent
Kahaluu	12-20	17-31	Round	S-M	G	Thin	Y	Excellent	Good	Good
Malama	12-20	>20	Pear	S-M	P	Thin	Y	Excellent	Good	NA
San Miguel	12-18	>20	Pear	M	G	Thin	Y	Excellent	Good	NA
Sharwil	10-20	20-24	Pear	S	G	Thin	Y-G	Excellent	Good	Excellent
Lamb Hass	10-18	>20	Pear	L	G	Thin	Y	Good	Good	Good
Yamagata	12-20	>20	Pear	S	G	Thin	Y	Excellent	Good	Excellent

Seed size: S-small, M-medium, and L-large
Mature Skin Color: G-green and P-purple
Flesh Color: Y-yellow and G-green

Table 4-4. Top Hawaii Mango Cultivars
Agricultural Feasibility Report-Dillingham Ranch
March 17, 2014

Variety Name	J	F	M	A	M	J	Jul	A	S	O	N	D
Ah Ping						----------						
Brook's Late								----------	----------			
Carrie						----------						
Excel							---------					
Fairchild						----------						
Florigon					----------	----------						
Glenn					----------	----------						
Golden Glow					---------							
Gouveia							---------					
Haden						----------						
Julie							---					
Keitt								----------	----------			
Mapulehu/Joe Welch							---					
Momi K						----------						
Nam Doc Mai						----------						
Pirie							----------					
R2E2							----------					
Rapoza							----------					

Table 4-5. Characteristics of Selected Mango Cultivars
Agricultural Feasibility Report-Dillingham Ranch
March 28, 2014

Cultivar	Season Of Bearing	Anthracnose	Tree Size and Form	Weight (oz)	Flavor	Mature Skin Color
Carrie	Jun-Jul	T	Small, dense	10-16	Excellent	Golden Yellow
Excel	Jul-Aug	S	medium, upright	14-16	Excellent	Red
Fairchild	Jun-Jul	R	Medium, upright	10-12	Excellent	Yellow w/ green tinge
Florigon	May-Jul	R	Large, upright	10-16	Good	Golden Yellow
Glenn	May-Jul	R	Medium, upright	14-16	Good	Yellow
Gouviea	Jul-Aug	S	Medium, upright	16-24	Excellent	Yellow w/red blush
Keit	Aug-Oct	R	Large, upright	16-32	Excellent	Greenish Yellow
Pope	Jul-Aug	S	Medium, upright	10-18	Good	Yellow w/red blush
Rapoza	Jul-Aug	S	Medium, upright	15-30	Excellent	Yellow w/red blush

Anthranose: R-resistant, S-susceptible, and T-tolerant

Table 4-4. Avocado Production Plan
Agricultural Feasibility Report-Dillingham Ranch
April 8, 2014

Cultivar Name	Harvest Period	Percent Acres	Acres	Estimated Deliveries (pounds)
Kahaluu	Sept.-Nov.	10%	12.6	70,560
San Miguel	Sept.-Jan.	5%	6.3	35,280
Malama	Sept.-Dec.	25%	31.5	176,400
Sharwil	Oct.-Feb.	15%	18.9	105,840
Green Gold	Jan.-April	10%	12.6	70,560
Yamagata	March-June	30%	37.8	211,680
Lamb Hass	April-June	5%	6.3	35,280
Total		100%	126	705,520

Table 4-8. Mango Production Plan
Agricultural Feasibility Report-Dillingham Ranch
April 10, 2014

Cultivar Name	Harvest Period	Percent Acres`	Acres	Estimated Deliveries (pounds)
Florigon	May-July	20%	8.7	31,320
Glenn	May-July	10%	4.3	15,400
Excel	July-August	10%	4.3	15,480
Carrie	June-July	10%	4.3	15,480
Gouveia	Jul-August	10%	4.3	15,480
Pope	July-August	10%	4.3	15,480
Rapoza	July-August	10%	4.3	15,480
Keitt	August-Oct.	20%	8.7	31,320
Total:		100%	43.2	155,520

Table 4-9. Citrus Production Plan
Agricultural Feasibility Report-Dillingham Ranch
March 17, 2014

Cultivar Name	Harvest Period	Acres	Estimated Deliveries (pounds)
Fisher Navel Orange	Oct,-Dec.	3.5	21,459
Washington Navel Orange	Nov.-Feb.	3.5	21,459
Tahitian Lime	All year	2.5	7,625
Fremont Tangerine	Oct,-Dec.	1.25	6,131
Dancy Tangerine	Nov.-Jan.	1.25	6,131
Total		12.0	62,805

Appendix B-Figures

Agricultural Feasibility Report
Volume 2

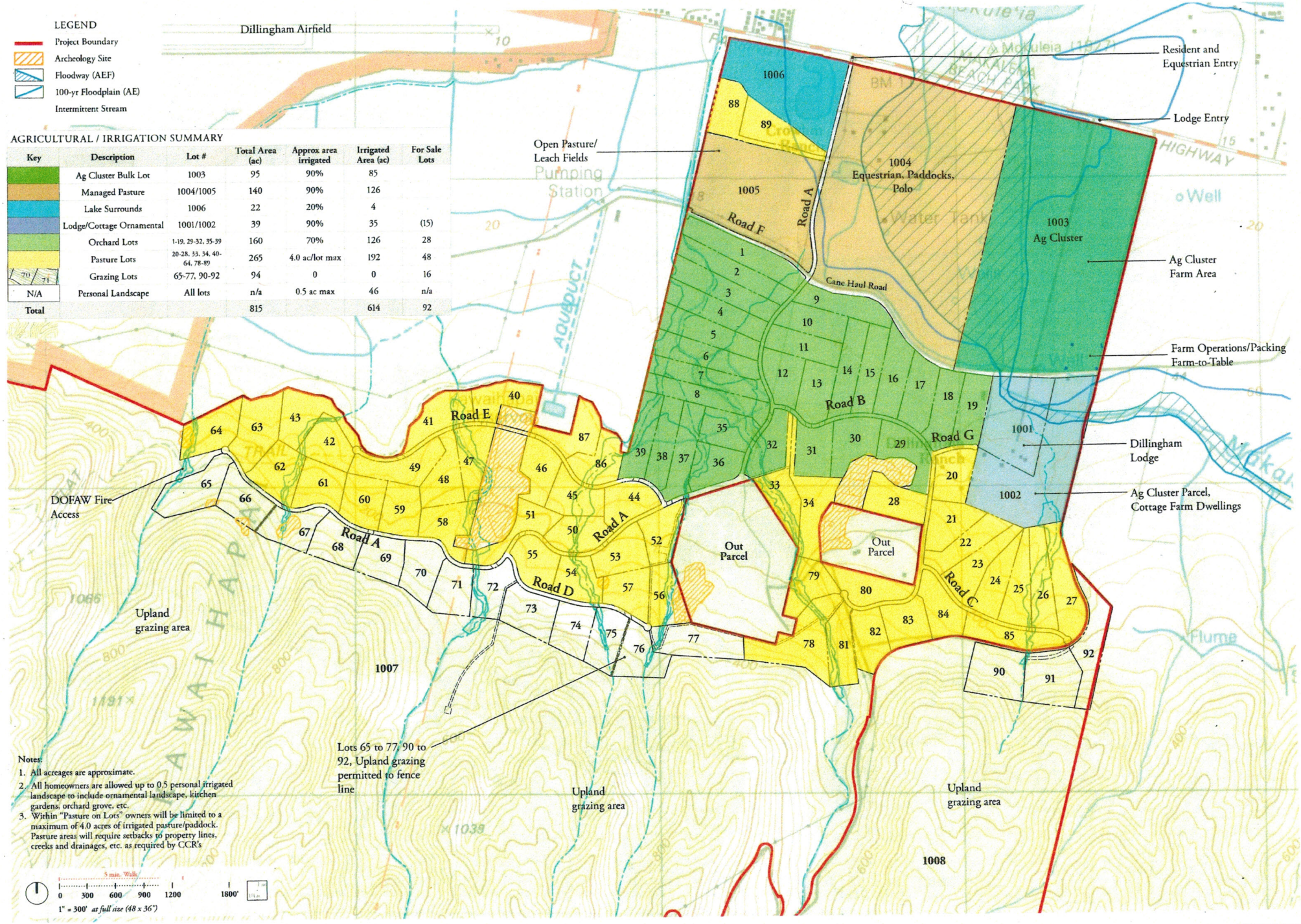
Dillingham Ranch

LEGEND

- Project Boundary
- Archeology Site
- Floodway (AEF)
- 100-yr Floodplain (AE)
- Intermittent Stream

AGRICULTURAL / IRRIGATION SUMMARY

Key	Description	Lot #	Total Area (ac)	Approx area irrigated	Irrigated Area (ac)	For Sale Lots
	Ag Cluster Bulk Lot	1003	95	90%	85	
	Managed Pasture	1004/1005	140	90%	126	
	Lake Surrounds	1006	22	20%	4	
	Lodge/Cottage Ornamental	1001/1002	39	90%	35	(15)
	Orchard Lots	1-19, 29-32, 35-39	160	70%	126	28
	Pasture Lots	20-28, 33, 34, 40-64, 78-89	265	4.0 ac/lot max	192	48
70 / 71	Grazing Lots	65-77, 90-92	94	0	0	16
N/A	Personal Landscape	All lots	n/a	0.5 ac max	46	n/a
Total			815		614	92



Notes:

1. All acreages are approximate.
2. All homeowners are allowed up to 0.5 personal irrigated landscape to include ornamental landscape, kitchen gardens, orchard grove, etc.
3. Within "Pasture on Lots" owners will be limited to a maximum of 4.0 acres of irrigated pasture/paddock. Pasture areas will require setbacks to property lines, creeks and drainages, etc. as required by CCR's

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DILLINGHAM RANCH

FIG2-1 Agriculture / Irrigation Areas

June 2014

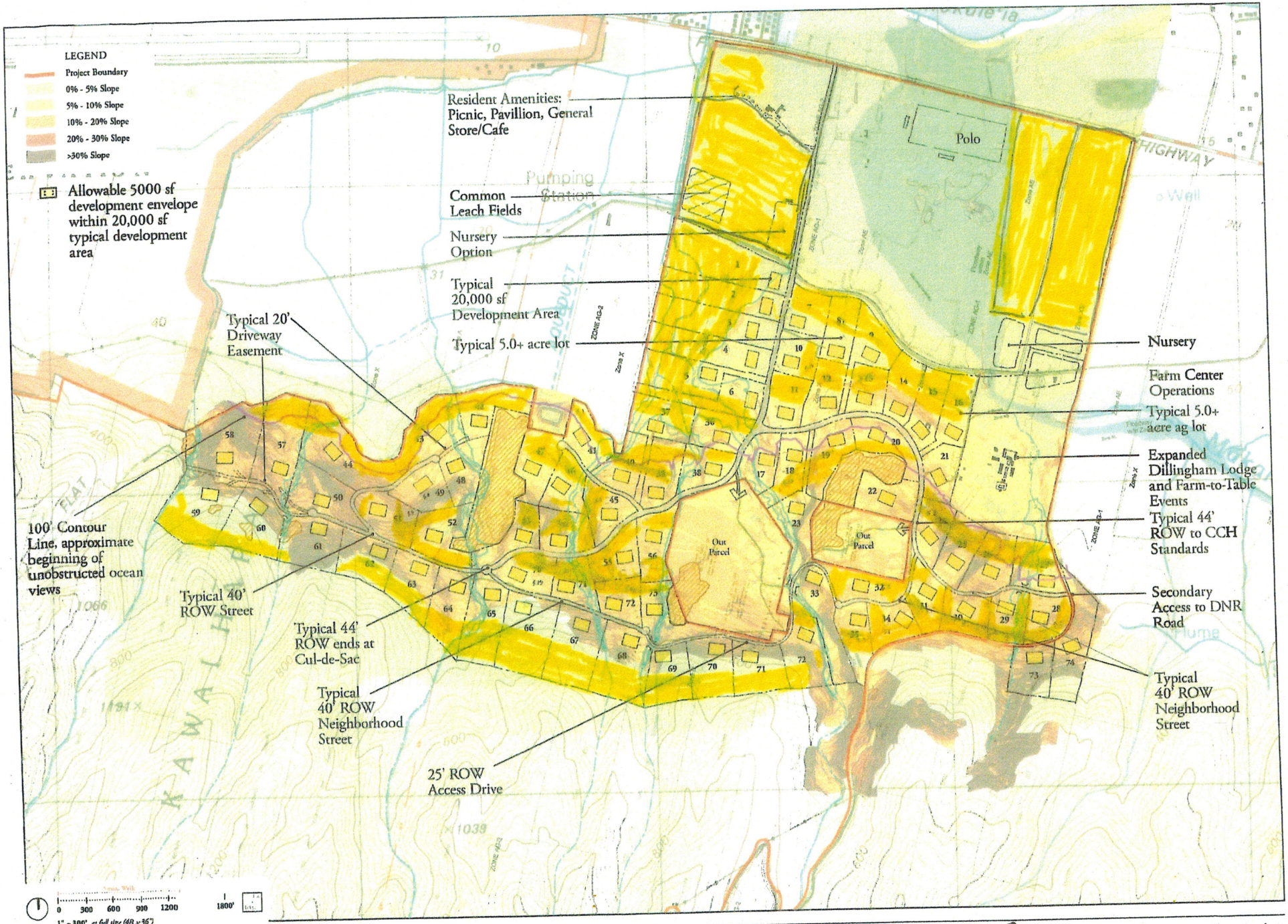


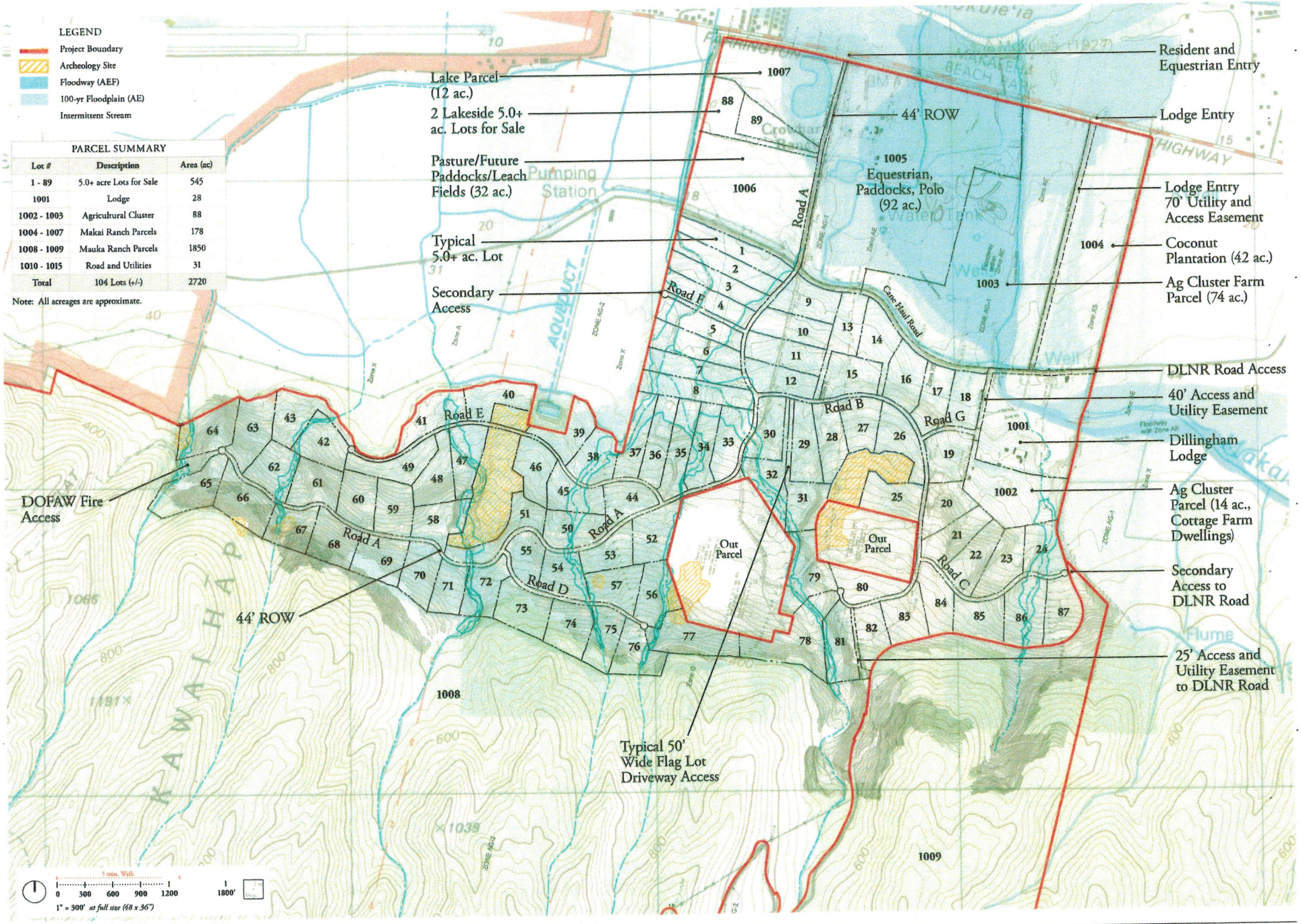
FIG 2-3 October 4 Preliminary Concept over Slope Analysis

HART HOWERTON

DILLINGHAM RANCH

Oahu, Hawaii

October 4, 2013



PARCEL SUMMARY		
Lot #	Description	Area (ac)
1 - 89	5.0+ acre Lots for Sale	545
1001	Lodge	28
1002 - 1003	Agricultural Cluster	88
1004 - 1007	Makai Ranch Parcels	178
1008 - 1009	Mauka Ranch Parcels	1850
1010 - 1015	Road and Utilities	31
Total	104 Lots (+/-)	2720

Note: All acreages are approximate.

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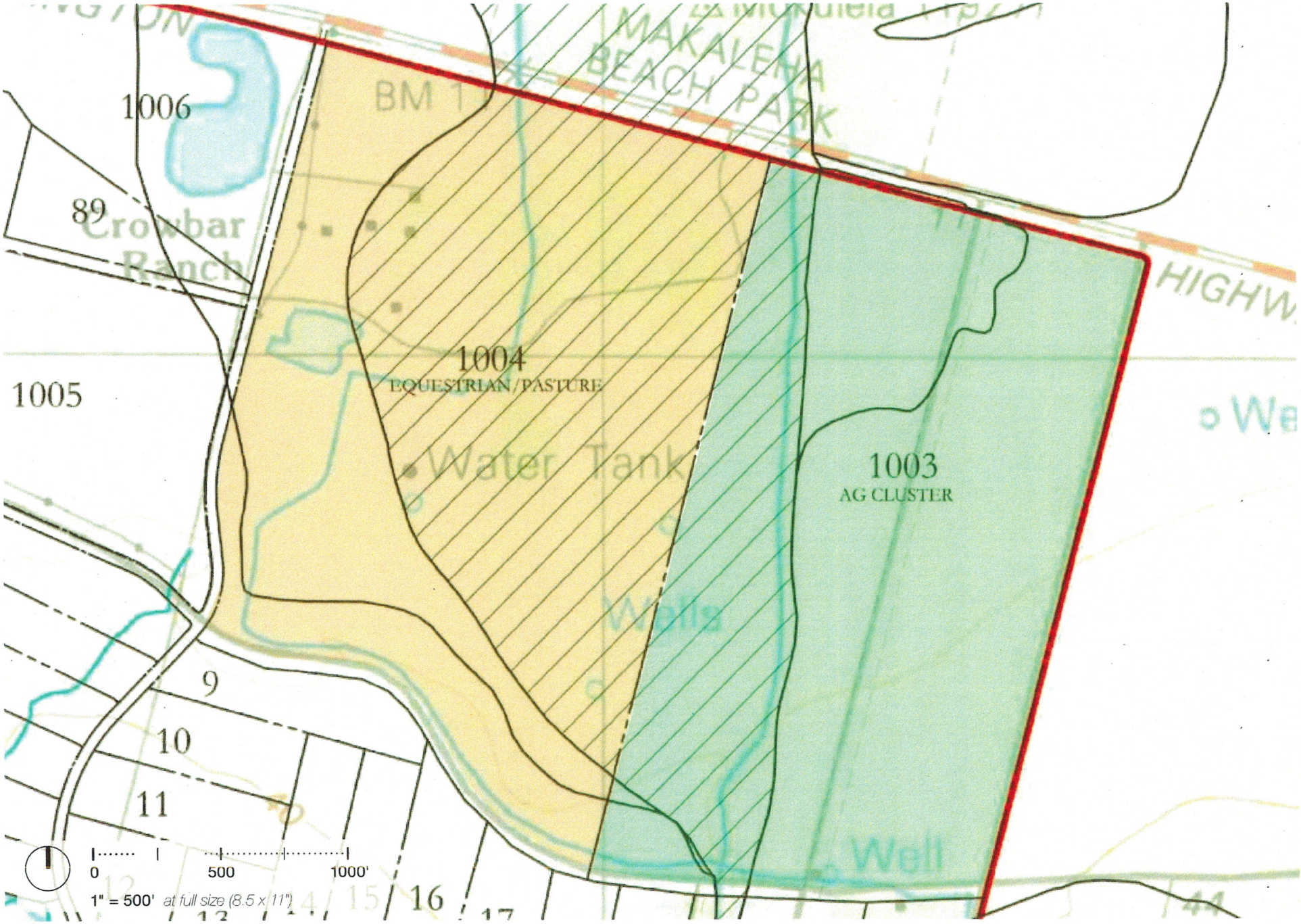
DILLINGHAM RANCH

FIG 2-4 Preliminary Lotting Plan

January 16, 2014



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DILLINGHAM ARCH

FIG 3-1 Exhibit X - Bulk Lot 1003 and 1004

May, 2014

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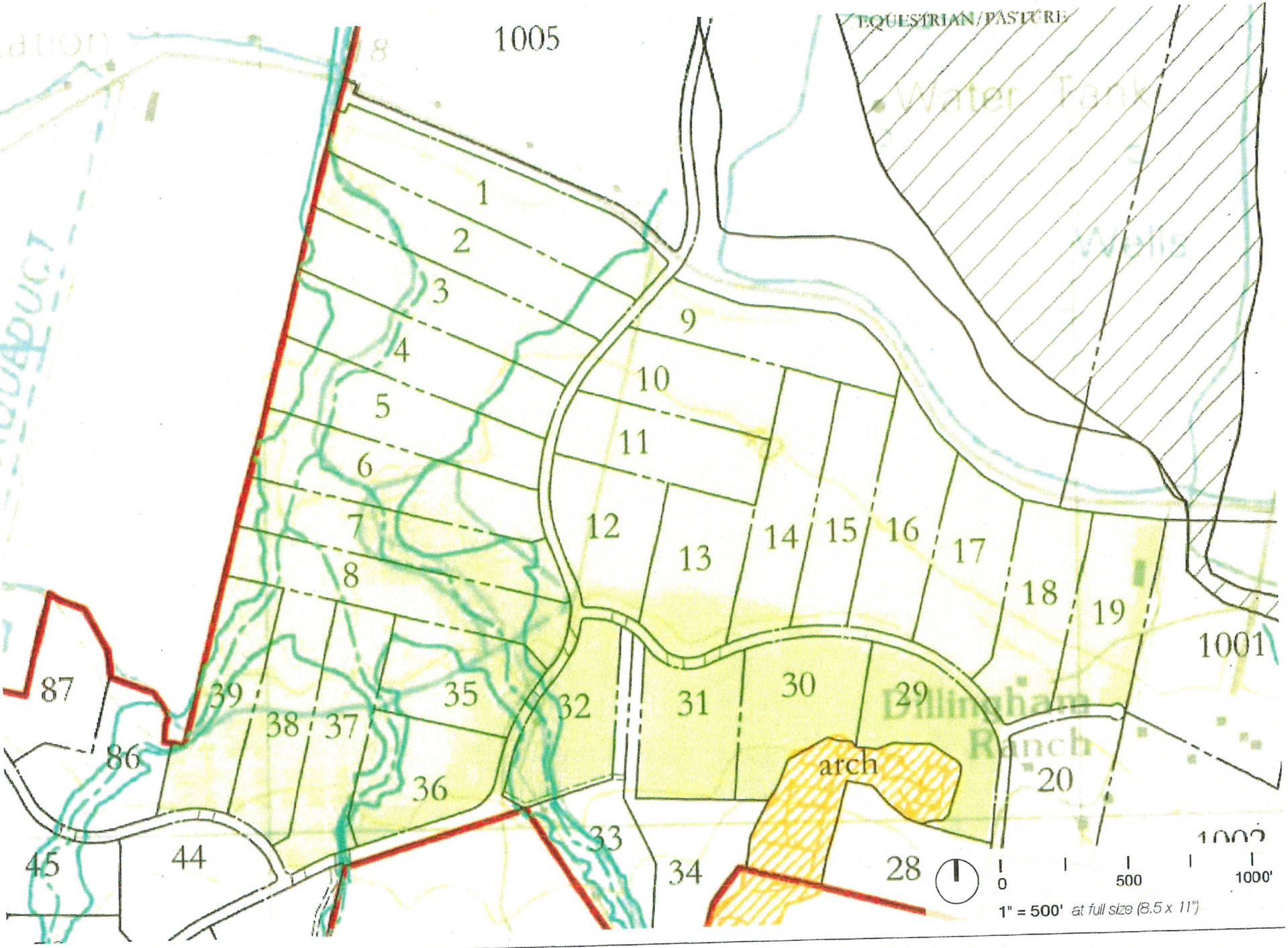

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FIG 3-2 Exhibit X - Orchard Lots

May, 2014

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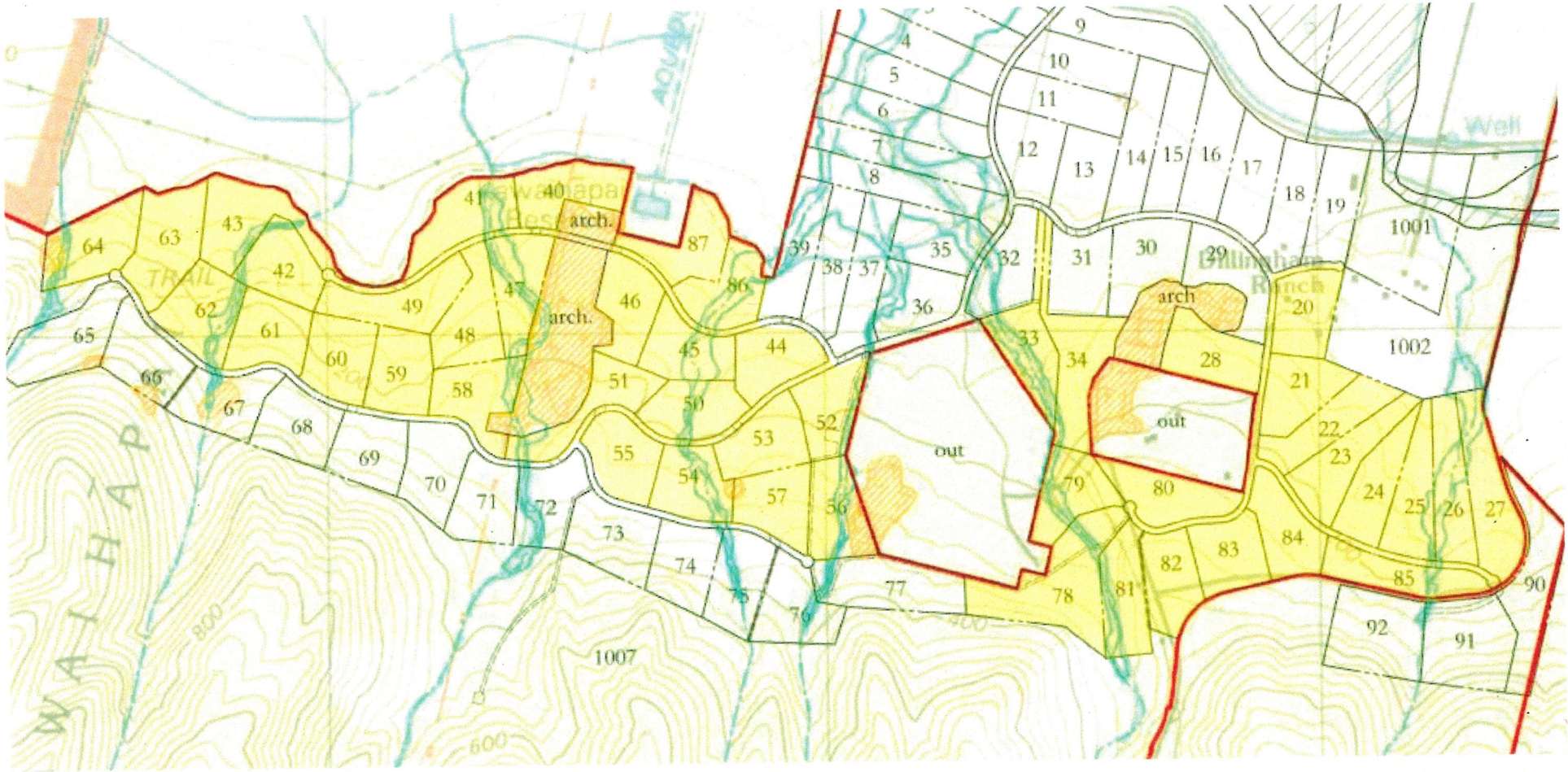

0 1000 2000'

1" = 1000' *at full size (8.5 x 11")*

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DILLINGHAM RANCH

FIG3-3 Exhibit X - Pasture Lots

May, 2014

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FIG3-4 Exhibit X - Bulk Lot 1003 and 1004

May, 2014

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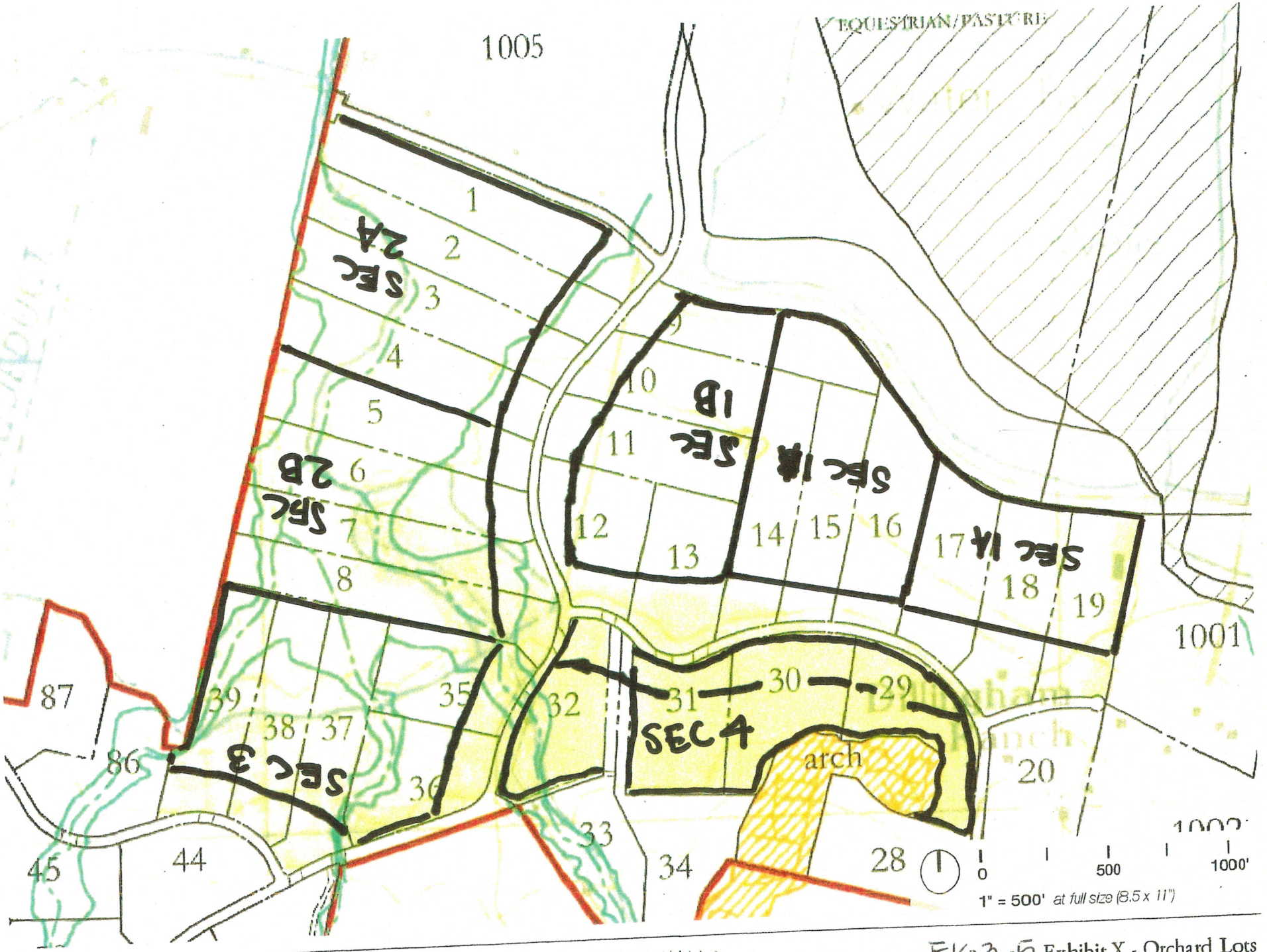

FIG 3-5 Exhibit X - Orchard Lots

May, 2014

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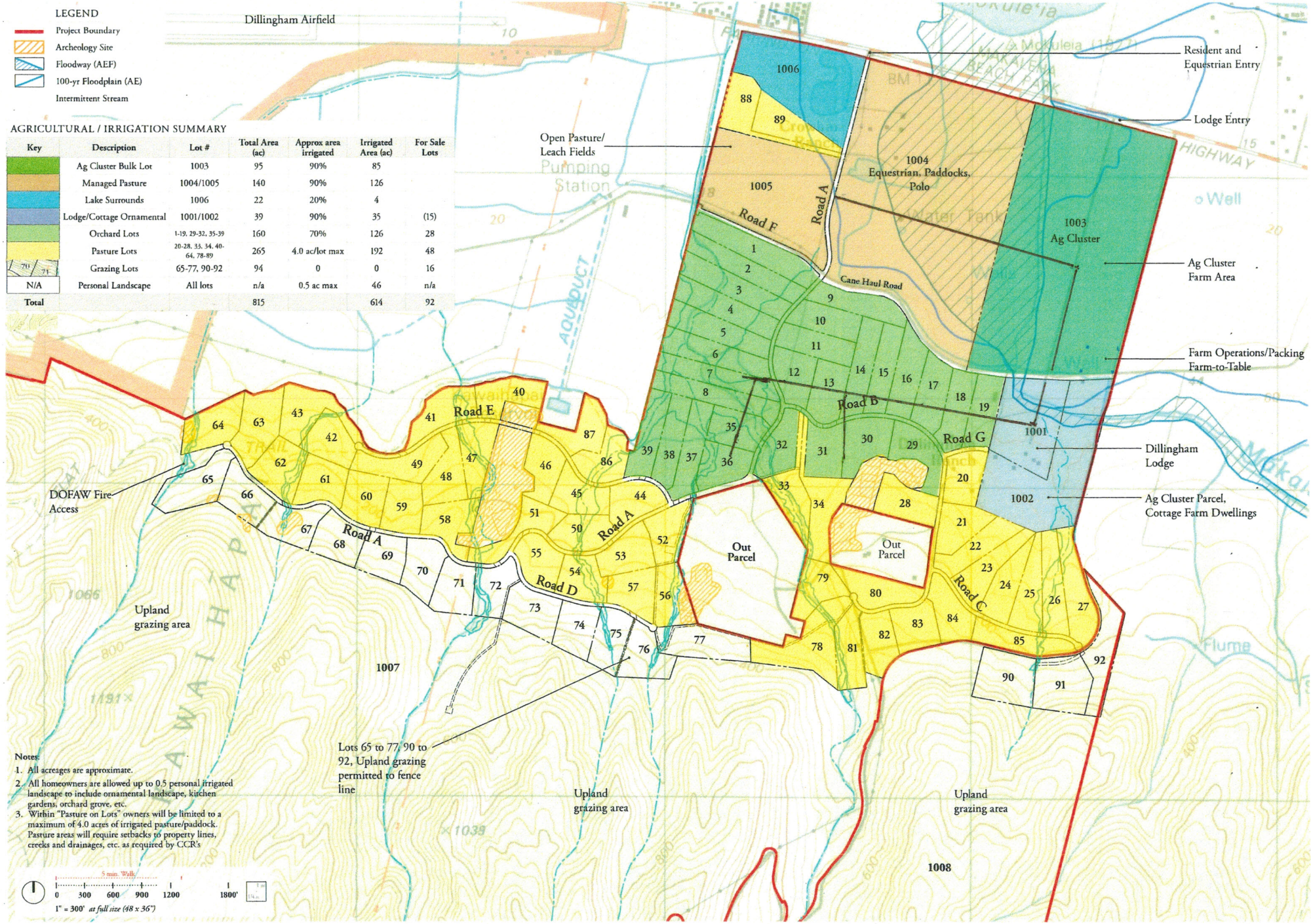
LEGEND

- Project Boundary
- Archeology Site
- Floodway (AEF)
- 100-yr Floodplain (AE)
- Intermittent Stream

AGRICULTURAL / IRRIGATION SUMMARY

Key	Description	Lot #	Total Area (ac)	Approx area irrigated	Irrigated Area (ac)	For Sale Lots
	Ag Cluster Bulk Lot	1003	95	90%	85	
	Managed Pasture	1004/1005	140	90%	126	
	Lake Surrounds	1006	22	20%	4	
	Lodge/Cottage Ornamental	1001/1002	39	90%	35	(15)
	Orchard Lots	1-19, 29-32, 35-39	160	70%	126	28
	Pasture Lots	20-28, 33, 34, 40-64, 78-89	265	4.0 ac/lot max	192	48
70 / 71	Grazing Lots	65-77, 90-92	94	0	0	16
N/A	Personal Landscape	All lots	n/a	0.5 ac max	46	n/a
Total			815		614	92



Notes:

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3. Within "Pasture on Lots" owners will be limited to a maximum of 4.0 acres of irrigated pasture/paddock. Pasture areas will require setbacks to property lines, creeks and drainages, etc. as required by CCR's

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DILLINGHAM RANCH

FIG 3-1 Agriculture / Irrigation Areas

June 2014

Appendix C-Photographs

Agricultural Feasibility Report
Volume 2

Dillingham Ranch

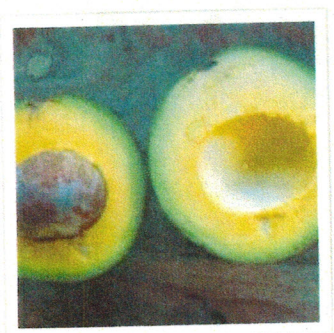
PLANT IT HAWAII

Avocado

Avocados are large trees, requiring spacing of 25′ or more. They are beautiful trees, providing cool shade and abundant fruit. There are many varieties to choose from (see list below), and with three or four varieties one can harvest fruit most of the year. Avocados grow well on most soils provided they are given excellent drainage. Good drainage is essential to their health. Without proper drainage, the trees will succumb to phytophora (avocado root-rot) and decline. Avocados can be grown with good success up to over 4000′ elevation. They prefer slightly alkaline soil (give them dolomite or crushed coral at planting) and respond well to a balanced fertilizer at regular intervals. They thrive with organic fertilizers and mulching.

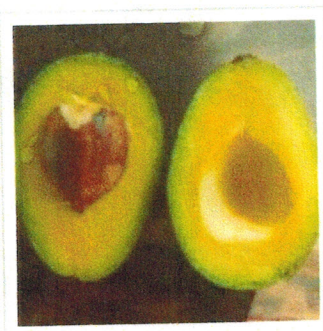
Harvest most varieties when the skin turns from a shiny gloss to a dull mat color. Each variety has a season when the fruit is ripe, although all varieties flower in the winter.

Some recommended varieties which are all delicious with excellent flavor and smooth texture are:



BEARDSLEE

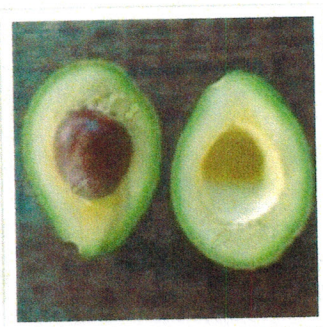
Introduced to Honolulu in 1911, Beardslee is a fall to early winter variety weighing between 24-40 oz., having an oval to pyriform shape and a purple skin. It has a rich and creamy flavor.



FUJIKAWA

A Hawaii selection that has a consistent heavy bearing spring season. The pear-shaped fruit has a medium-sized seed and green skin. The flavor is excellent.

march - June



GREEN GOLD

A cultivar developed by the UH, considered by many to be superior to the Sharwil. Has a long and heavy bearing season (January-April, or longer). Medium size, pear-shaped fruit with a small seed, high oil content, and a rough green-gold skin. Type A.

LAMB HASS

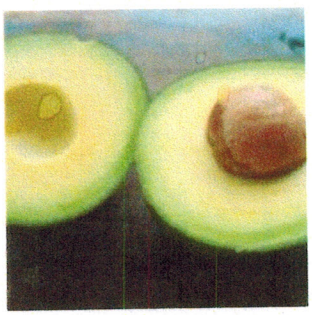
California selection bearing spring and summer fruit. It is a heavy regular bearer, with fruit averaging 10-18 oz., and the skin black when ripe. Fruit can have a larger seed grown in rainy areas. Type A

KAHALU'U

Ripe in the fall (August-October), but can be an alternate bearer (every other year). A large, oblong fruit with a small seed and green skin. Considered by many to be the best-flavored Hawaiian variety.

LINDA

Ripens in the spring. Has a large roundish fruit with a medium seed, dark purple skin when ripe, is regular and heavy bearing. Called the "dieter's avocado" due to its lower oil content and good flavor.



MALAMA

A Hawaii selection that is a regular, heavy bearer with fruit ripe early in the fall. Skin is purple when ready to eat, easy to peel, with a rich and nutty flavor. The fruit has high oil content and is deliciously creamy.

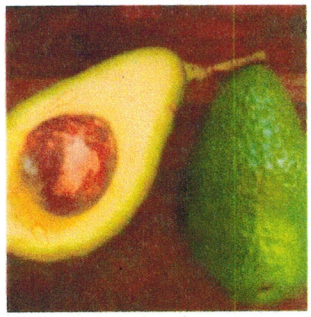
Fall bearing
Sept. - Dec.

MURASHIGE

A Hawaii selection, which is a regular, heavy bearer with fruit ripe in late spring and early summer. The fruit is large, pear shape, with a small seed and a dark green skin. It has excellent flavor but ripe fruit does not store well.

OTA

A Hawaii selection, which has a long, regular, and heavy bearing season from late in the fall and all through the winter months. The fruits are round with great flavor and a small seed. The fruit holds well on the tree.



SAN MIGUEL

Bearing each fall-winter the green skinned roundish fruit is about 8-20 oz., with creamy texture, and melts in the mouth. It is a productive spreading tree. Type A

Starts in late August

SHARWIL

Most popular with commercial growers. Has a long and heavy bearing season throughout the winter months (November-February). Medium size, pear-shaped fruit with a small seed, high oil content, and a green rough skin. 'Sharwil' is a most amazingly consistent bearer.

YAMAGATA

A Hawaii selection has a long and heavy bearing season from March-July of large, pear-shaped fruit with a small seed and green skin. The fruit is delicious and received the 2011 award for best tasting and all around best Avocado in Kona's Buyers Preference challenge.

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PLANT IT HAWAII

Mango

Mangos are widely grown as a dooryard tree in almost every area of Hawaii. The fruits are mostly eaten fresh, but are easily made into ice cream, chutney, relish, pickles, preserves, juice and a wide array of baked delights. The first plants were brought to Hawaii around 1824 from India and the Philippines. Many varieties and seedling selections are successfully grown here, with resistance to anthracnose fungus being the most important adaptation. This tolerance is crucial as the flowering season is usually humid and rainy. These wet conditions cause increased flower and fruit drop, reduced fruit set and black spots can develop later on the fruit.

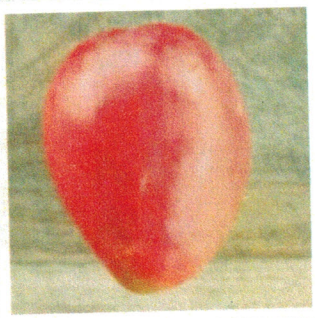
The mango grows best in areas with 40-60 inches of rain annually. It grows into a large, spreading tree that can grow to 20 feet tall or more. A grafted tree will begin to bear fruit after 3-4 years in the ground, with most varieties being harvested in the summer months. There are many popular varieties available now in Hawaii, here are some descriptions of the best tasting:

BROOK'S LATE

A Florida selection that bears from August into October. Trees are medium sized and vigorous. Fruit size ranges between 16-30 ounces. Flesh is sweet and mild, with a thin seed and green skin when ripe. It can be grown successfully on the windward areas of the islands.

CARRIE

A Florida selection that regularly fruits in June and July. The fruits are fibreless, sweet and spicy with a thin seed. The skin is golden yellow, fruits weigh between 10-16 ounces. It is resistant to anthracnose and tree growth is dense and compact.

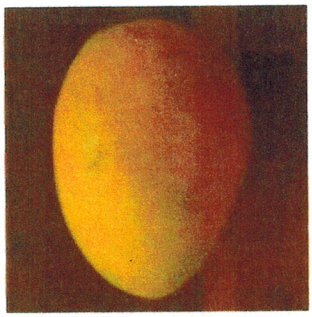


EXEL

A high-quality Hawaii selection that bears regularly in July and August. Fruits average about a pound with very little fiber and a very thin seed. Trees are upright, slow growing and medium sized and are best planted in dry areas only.

FAIRCHILD

A Florida selection that fruits in June and July. Fruit size is 6-8 ounces; the flesh is juicy, low in fiber, sweet and rich. Trees are upright; medium sized and can be planted in wet areas; it is anthracnose tolerant. Yellow skinned.

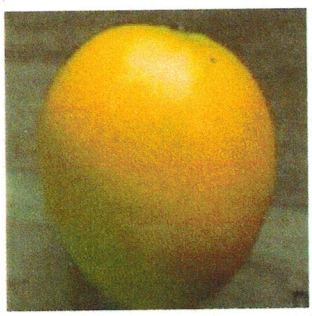


FLORIGON

A large, vigorous grower with yellow fruits of excellent flavor. The yellow melting flesh is juicy and fibreless. It bears 10-16 ounce fruits annually between May and July. It is anthracnose resistant.

GLENN

A 'Haden' seedling selection from Florida, it is a small to medium size tree that regularly bears 16 ounce, low fiber, spicy, rich flavored fruits. Season is from May-July and it is resistant to anthracnose.

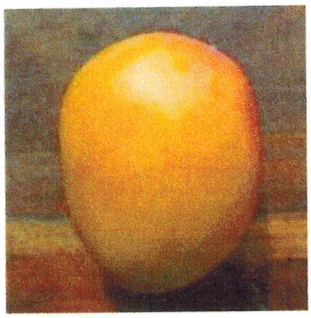


GOLDEN GLOW

A recent delicious selection from Kihei, Maui that bears regularly in May through June. The 20-24 ounce fruit has very little fiber, a thin seed and great flavor. It grows medium sized and is best suited for dry places only.

HADEN

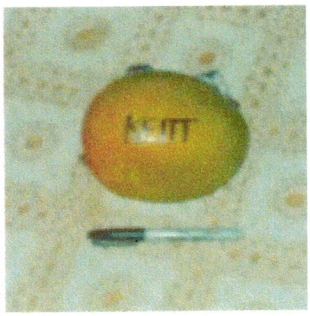
The spicy excellent flavor and good color of 'Haden' makes it a long-time favorite in Hawaii. Fruits are ready to harvest June -July, averaging between 16-24 ounces. 'Haden' tends towards a vigorous, spreading habit and alternate bearing (fruits every other year). It is best suited for dry areas only.



JULIE

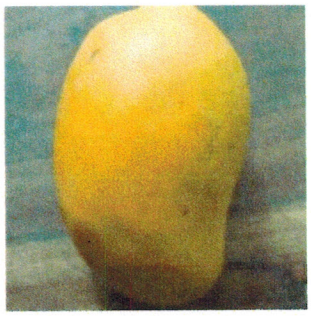
A North Africa selection that is considered to be a dwarf. It is a small, slower grower with fruit size from 6-10 ounces. The summer fruit is fibreless, smooth and delicious. It is best to plant in dry areas. Skin is yellow with a red blush.

July



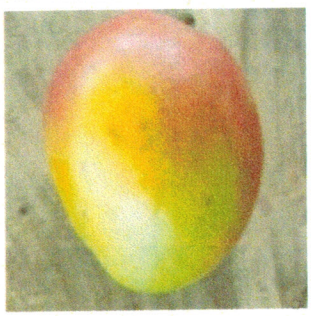
KEITT

An excellent quality, regular and abundant bearer of large fruit 2-4 pounds each. Trees grow vigorously to medium size. Harvest is from August to October. The flesh is sweet with low fiber, and a thin seed. It is anthracnose resistant and the fruit has a long shelf life. Skin is green with a purple or red blush.



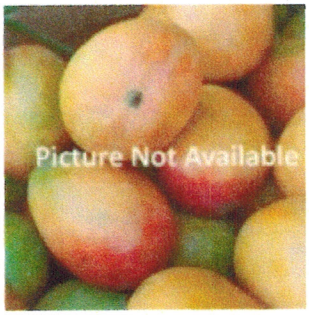
NAM DOC MAI

A Thailand variety that fruits in June and July. Fruit is slender with a somewhat thick, greenish -yellow skin. The flesh is fibreless, very sweet and juicy. It can be eaten when green and tends to flower more than once a year. In Hawaii it is an alternate bearer like 'Haden' and 'Pirie'. It is also anthracnose resistant and can be planted in wetter areas.



POPE

A medium size tree that is a regular, heavy bearer of high quality fruit. The yellow skinned, red blushed fruits are ripe in July and August and average 10-18 ounces. It fruits best in dry areas.



R2E2

A smooth skinned golden fruit with a red blush that tends to be oblong shaped with a very small seed. It bears a regular heavy crop of fruits 16 to 24 ounces that are rich, melting and spicy with no fiber. It prefers to be planted in dry areas.

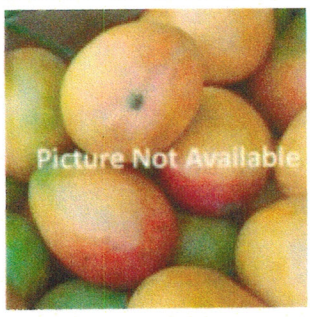
July / August

RAPOZA

A fabulous Hawaii selection is medium sized, vigorous, heavy producing tree with excellent fruit quality that range between 15-30 ounces. The ripe skin is yellow with a red or purple blush. The fruit is thin seeded, fibreless and is borne annually in July and August.

GOUVEIA

A 'Pirie' seedling selection from Oahu that regularly bears in August. Trees grow upright and medium sized. Flesh is sweet, fibreless, averaging 16-24 ounces per fruit. It is only suitable to plant in dry areas.



MAPULEHU/ JOE WELCH

A Molokai seedling selection that produces 16-20 ounce juicy and delicious fruit with no fiber, mainly in July. The tree grows vigorously and spreading. It tends to produce fruit heavily and is best in a dry area.

PIRIE

A widely planted older variety, also alternate bearing like 'Haden'. Flesh is fibreless, juicy, melting and sweet. Fruit size is 8-10 ounces, ripe in July and August. The tree grows vigorously and should be planted in dry areas only.

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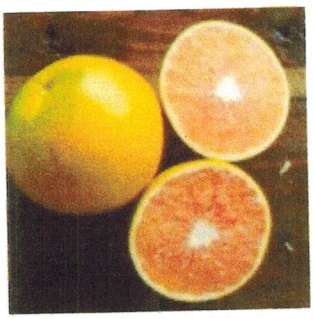
PLANT IT HAWAII

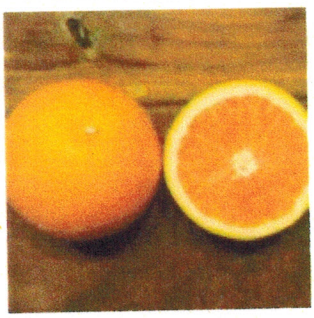
Citrus – Orange, Lemon, Lime, Tangerine, Grapefruit

Citrus is such a vast subject that volumes have been devoted to this genus. It is rich in history, dating back to 2000 BC in China and is now a billion dollar industry worldwide. Citrus can be grown from sea level to the upper slopes, each variety having its ideal growing area. In Hawaii with our tropical climate, expect Oranges and Tangerines to have a greenish tint to the skin and a tighter adherence of the peel to the fruit, making oranges and other citrus more difficult to peel than citrus grown in California. Citrus must be in a well-drained soil and requires regular fertilization with minor nutrients for maximum production. **More Info.**



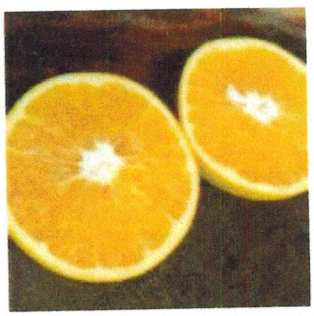
CARA CARA NAVEL ORANGE

Has a slightly pink skin, accompanied with a rich orange flesh. The interior is sweet with a relatively low acid content and few to no seeds.



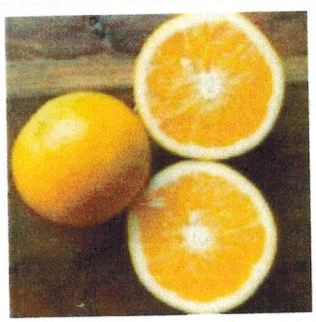
FISHER NAVEL ORANGE

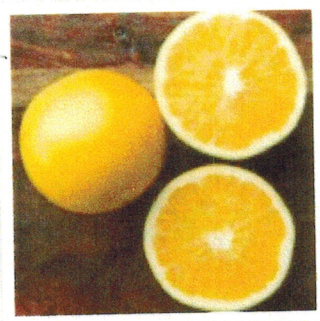
Is a selection from California that that bears the same high quality navel orange as the 'Washington Navel' but is ripe earlier in the season. The fruit is delicious and juicy and seedless.



LANE LATE NAVEL ORANGE

Is a bud sport from a 'Washington Navel' tree in Australia. The fruit has the same high quality fruit as the 'Washington' but is ripe later in the season, during our Spring months. The fruit is delicious and juicy and seedless





MORO BLOOD ORANGE

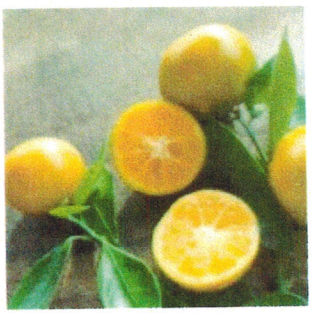
Orange is the best of the pigmented oranges for our tropical climate. Because there is very little variation between our day and night temperatures, the pigments are more subtle here in Hawaii. It is a very prolific producer of juicy sweet seedless fruit.

VALENCIA ORANGE

Is the standard "juice" orange. It is also called the 'Kona' Orange', as it began its life in Hawaii in Kona. It is the most widely grown orange in the world. 'Valencia' Oranges are very productive. The fruit is delicious, seedless and make wonderful juice and are delicious fresh eating.

WASHINGTON NAVEL ORANGE

Is the most common and prolific orange in Hawaii. The tree is medium size with a round crown of dense, dark green leaves. The fruit is large and distributed throughout the tree. The seedless fruit has a delicious, rich juicy flavor.



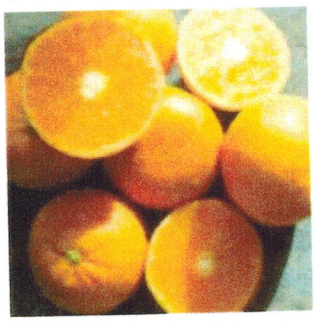
CALAMONDIN LIME

Is a small upright and bushy tree with many attractive, bright orange small fruits all through the year. The flesh is orange, tart and very juicy. It can be used just as you would use any lime and has a distinct delicious flavor. The tree is easy to prune as a bush and can be containerized for many years in a large pot on the lanai. It is enjoyed for its fragrant blossoms and fruit that cover the tree several times a year.

tinge to new growth, making the tree beautifully ornamental. The rind is striped green and cream which yellows as it ripens. The flesh is light pink at full maturity, seedless, acidic, and juicy. Trees produce an abundance of juicy, market-quality variegated lemons year round.

TAHITIAN LIME

'Tahitian Lime', also known as 'Bearss Lime' is a medium sized, vigorous tree that bears fruit about ten months of the year. The fruit is seedless, juicy and a prolific, dependable bearer. The skin of the fully ripe fruit will turn slightly yellow, but the juicy flesh inside is green, and has a true acid lime flavor. The dark green leaves and almost constant flowering make the 'Tahitian' lime an excellent orchard tree or container plant for the lanai. The consistent fragrant flowering and fruiting is a nice bonus.



CLEMENTINE TANGERINE

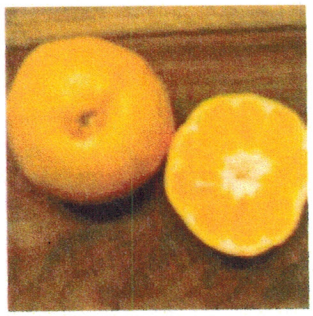
Is easy to peel, usually seedless, and ripens in the winter and spring months. The fruit is rich and very sweet and juicy. Tress prefers a coastal lowland climate for best fruit quality and production. It is a vigorous grower and comes into bearing early. The fruit achieves good color here.

DANCY TANGERINE

Is the most popular island tangerine. The bright orange fruit is ready in our winter months. The delicious fruit is juicy and sweet. The canopy shaped tree is a vigorous, upright grower tending to bear heavily every other year. 'Dancy' is easy to peel. Trees are nearly thornless and the fruit must be picked when ripe.

FREMONT TANGERINE

Is an early maturing variety that holds well on the tree when fully ripe. The tree has a rounded canopy with most of the fruit borne at the ends of the branches. The fruit is ready to pick in the fall months. In Hawaii, trees tend to bear almost year round. The fruit is rich, sweet and easy to peel. It is a beautiful orange color when ripe. It is a very productive variety.



HONEY TANGERINE

Has a sweet delicious, somewhat spicy flavor and is very juicy. There are a few seeds and the fruit will hold on the tree very well when fully ripe. It is a vigorous, upright and productive grower with the fruit being held on the outermost ends of the branches. The fruit is medium sized and can be small if there is a heavy crop. The fruit is ripe usually in mid-winter through spring.

KISHU MINI TANGERINE

Is a small, seedless early season Tangerine. The orange sweet and juicy fruit ripens October through November. It has a thin rind and produces abundantly. It is a small tree that lends itself to a patio tree, for 'on the lanai' orange sweet fruit.

SATSUMA TANGERINE

Is a seedless variety. The reddish-orange fruit is medium sized and somewhat flattened at the stem end. The sweet and juicy fruits are usually ripe in the winter months. It is a small spreading tree with an open canopy and dark green foliage that loves the higher elevations

Appendix G

Updated Phase 1 Rockfall Potential and Hillside Slope Evaluation
Dillingham Ranch Agricultural Subdivision
Mokule'ia, O'ahu, Hawai'i

GEOLABS, INC.

Geotechnical Engineering and Drilling Services

August 6, 2014
W.O. 5721-80

Dillingham Ranch Aina, LLC
Mr. Clifford Smith
9701 Wilshire Boulevard, Suite 700
Beverly Hills, CA 90210

GEOTECHNICAL ENGINEERING CONSULTATION SERVICES
UPDATED PHASE I ROCKFALL POTENTIAL AND HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
TMK: 6-8-002: 006, 6-8-003: 005, 006, 015, 019, 030, 031, 033, 035, AND 040
MOKULEIA, OAHU, HAWAII

Dear **Mr. Smith:**

In accordance with our fee proposal dated March 24, 2014, we conducted an updated evaluation of the hillsides and potential rockfall hazard conditions at the project site as a result of a revised subdivision development scheme. This report summarizes the findings based on our review of the existing site conditions and our engineering and statistical analyses of the potential rockfall processes anticipated at the project site.

The findings and recommendations presented herein are based on a revised subdivision development scheme and our performance of additional engineering analyses. Therefore, the findings and recommendations presented herein shall rescind and supersede our previous report dated February 15, 2008, and titled *Rockfall Potential and Hillside Slope Evaluation, Dillingham Ranch Mokuleia Development, TMK: 6-8-002: 006, 6-8-003: 006, 015, 019, 030, 031, 033, 035 and 040, Mokuleia, Oahu, Hawaii* in its entirety. The findings and recommendations are subject to the limitations noted at the end of this report.

PROJECT CONSIDERATIONS

The proposed project is in the Kawaihapai area of Mokuleia at the northwestern portion of the Island of Oahu, Hawaii. Based on the preliminary information provided, the project consists of developing 91 residential agricultural lots with a minimum lot size of about 5 acres. We understand the initial site development will include construction of subdivision roads and pavements, grading of home sites, installation of utilities, and the construction of rockfall protection and drainage improvements.

The project site resides along the foot of the northerly facing Waianae Mountain Range as shown on the Project Location Map, Plate 1. In accordance with the City and County of Honolulu Subdivision Rules and Regulations, Sections 2-201(c)(7) and 2-201(d), we conducted a geological and geotechnical engineering evaluation of the existing hillsides, natural hazards, and potential rockfall hazard conditions, which could affect the proposed subdivision development in the future.

Of the proposed 91 agricultural lots, 11 mauka lots appear to have some risk associated with potential rockfall encroachment from the adjacent high mountain slopes. The 11 mauka lots are along the upslope side (southern perimeter) of the subdivision development adjacent to steep undeveloped mountain ridge terrain containing weathered basaltic rock outcrops.

This report presents our Updated Phase I Rockfall Potential and Hillside Slope Evaluation and includes our preliminary recommendations for rockfall mitigation to reduce the potential hazard associated with falling rock conditions. Following the review and acceptance of the conceptual rockfall hazard mitigation scheme, a Phase II design study will be performed to refine the conceptual rockfall hazard mitigation scheme and develop a basis of design and construction documents package, which would include appropriate construction plans and technical specifications to construct the rockfall hazard mitigation scheme. Refinements to the Phase I conceptual rockfall mitigation scheme may include the adjustment of the design rockfall interception energy capacity and height and depth of proposed rockfall interception structures. In addition, some minor adjustment of the positioning and length of rockfall interception structures may be needed as a result of additional analyses performed for project design and to coordinate the design with other improvements that may be proposed within the affected lots.

In our Phase I hazard evaluation conducted for the previous subdivision development scheme, a broad system of rockfall impact barrier fencing was proposed outside and upslope from the mauka lot boundaries to reduce the potential for rockfall encroachment at the mauka lots and subdivision roadways. With this current subdivision development, designated home sites (dwelling locations) have been tentatively established to support the potential hazard analysis of the subdivision lots. Because the locations for dwelling construction will be restricted to designated areas, it permits the evaluation and development of a less expansive and more focused rockfall hazard mitigation system specifically designed to protect the designated home sites, private access driveways, and subdivision roadways that may be exposed to potential rockfall. By designating the home site locations, we are able to evaluate the probable exposure of the various home sites to potential falling rock hazards and develop site specific mitigation schemes that serve to reduce the potential hazard at the home sites and associated private access driveways, in addition to the subdivision roadways located lower on the adjacent down slopes.

In general, it is currently desired to utilize a more localized scheme of segmental rockfall impact barrier fences and rockfall catchment ditches to reduce the potential hazard at the designated home sites and associated access driveways. The current proposed

system employing segmental rockfall catchment ditches and rockfall impact barrier fencing constructed within the affected lots also serves to protect the adjacent down slope subdivision roadways that may be impacted by potential rockfall passing through the affected lots. Where our current rockfall simulation analysis indicates nil or less than 10 percent probable rockfall encroachment at the designated home site, protective mitigation measures are not required. Furthermore, the adjacent subdivision roadway would also be assessed as having nil or limited potential for rockfall encroachment as a result of its location further downslope from the home site rock encroachment analysis point. The recommended rockfall mitigation improvements would be constructed within the affected lots and would be encompassed by appropriate access and maintenance easements.

To facilitate our Updated Phase I study of potential exposure to falling rock hazards, the tentative home site and private access driveway locations were provided for our analysis of the 21 mauka lots (Lot Nos. 65 through 78, 81 through 85, and 90 and 91). The designated home site locations were evaluated with respect to potential rockfall hazard exposure. In addition, a preliminary conceptual rockfall mitigation design using rockfall impact barriers and rockfall catchment ditches was developed to protect the home sites, driveways, and portions of the subdivision roadways found to be exposed to potential rockfall hazards.

The current rockfall mitigation scheme is similar to the previous accepted mitigation scheme in that the areas identified as having potential rockfall hazard exposure are addressed by the current revised mitigation scheme. The primary difference is that the current scheme employs more focused protection designed specifically to protect the home site, driveway, and vicinity downslope of the structural site improvements. This includes some potential landscape (yard) area adjacent to and down slope of the designated home sites, including the subdivision roadway below. Remaining land area upslope of the designated building area within the lots will remain in a natural condition for ranching and grazing purpose with no provision for rockfall protection. Lot owners must be advised that activities conducted upslope from the rockfall protection improvements are exposed to potential rockfall. Thus, restrictions for development of additional dwellings are required upslope from the proposed rockfall mitigation improvements to prevent building additional dwelling structures in unprotected areas of the lot.

The primary reason for the revision of the previous accepted mitigation scheme is to utilize a more localized and site-specific focused mitigation scheme within the lot boundaries to facilitate easier access, inspection, and maintenance of the protection system. The combined use of rockfall catchment ditches and rockfall impact barriers serves the intended purpose of reducing the adverse visual impact of the above ground steel impact barrier structures reaching about 10 to 14 feet above the existing ground surface and traversing across the lower portion of the lot. Based on our analyses, appropriately dimensioned rockfall catchment ditches can be used as an alternative to rockfall impact barrier fencing for effective rockfall control in certain slope gradient and topographic terrain settings where the use of more visually intrusive above-ground interception structures is undesirable from a lot development point-of-view.

Our potential rockfall hazard analyses and preliminary conceptual design of the recommended rockfall mitigation improvements is subject to the limitations and restrictions presented in this report.

PURPOSE AND SCOPE

The purpose of our geotechnical engineering services for this updated Phase I rockfall potential and hillslope hazard evaluation is to re-evaluate the potential rockfall hazard conditions with respect to the revised subdivision layout. A Phase II design study will be needed based on acceptance of the updated Phase I study recommendations. Our updated Phase I study generally consisted of the following tasks and work efforts:

1. Research and review of the previous rockfall hazard mitigation studies performed by Geolabs, Inc. including field data and associated documentations.

2. Review of in-house soils and geological information, including available aerial photographs and topographic maps from the project site and vicinity.

3. Review of the reconfigured subdivision layout as it pertains to potential rockfall and hillslope hazard conditions at the project site.

4. Site reconnaissance by our project geologist to review our previous findings with respect to potential rockfall hazards contained within the hillslopes adjacent to the reconfigured subdivision layout.

5. Engineering analyses including the performance of preliminary rockfall simulation and slope modeling using the computer-based Colorado Rockfall Simulation Program (CRSP) to develop a statistical basis for the rockfall hazard assessment.

6. Engineering analyses to formulate preliminary geotechnical engineering recommendations for conceptual rockfall hazard mitigation using a combined system of rockfall catchment ditches and rockfall impact barrier fencing.

7. Preparation of six copies of a report summarizing our work on the project and presenting our updated findings and recommendations.

8. Additional work efforts such as meetings, correspondence, and clarifications as needed to refine the conceptual rockfall hazard mitigation scheme.

9. Design team consultation and meetings by our principal engineer.

10. Coordination of our overall work on the project by our project engineer/geologist.

11. Quality assurance of our work and client/design team consultation by our principal engineer.

12. Miscellaneous work efforts such as drafting, word processing, and clerical support.

REGIONAL GEOLOGY

The Island of Oahu was built by the extrusion of basaltic lava from the Waianae and Koolau shield volcanoes. The older Waianae Volcano is estimated to be middle to late Pliocene in age (2.7 – 3.4 million years ago), and Koolau Volcano is estimated to be late Pliocene to early Pleistocene (Ice Age) in age (2.2 – 2.5 million years ago). After a long period of volcanic inactivity, during which time erosion incised deep valleys into the Waianae and Koolau shields, volcanic activity returned with a series of lava flows followed by cinder and tuff cone formations located mainly at the southeastern portion of the Island of Oahu.

The project site is situated on the foothill pediment along the northerly facing slopes of the Waianae Range, as indicated on the Project Location Map, Plate 1. The gently to moderately sloping pediment was formed by the long-term accumulation of a relatively thick wedge of eroded and transported alluvium and colluvium (Quaternary Alluvium). The deposits are believed to have accumulated in relatively stable settings during the deposition of extensive alluvial/colluvial fans, which emanate from the primary Waianae Range drainages. The alluvial/colluvial fans are generally composed of eroded and transported clayey soils with embedded rock fragments ranging from cobbles to very large boulders. The deposits are believed to be very old as evidenced by local near-surface exposures of boulder conglomerate (semi-consolidated colluvial rock deposits) and alluvial soils that have consolidated with a residual and saprolitic soil appearance.

The steeper slopes upslope from the southern development boundary are composed of layered basaltic rock, which erupted from the Waianae Volcano. The basaltic rock exposed on the hillsides generally consists of interbedded dense (massive) lava rock layers and thinner seams of medium hard clinker, which represent sequential lava flows. Natural long-term erosion of the rock materials has produced some loose fractured surface rock outcroppings capable of producing individual boulders. As a result of the weathering and erosion processes, boulder materials may separate from the parent rock outcrop and roll or bounce from the steeper hillside terrain. The boulder movement could produce hazardous rockfall encroachment on down slope development. Based on our field reconnaissance, the primary source region for potential rockfall activity encompasses the steeper slopes composed of layered basaltic rock upslope from the southern boundary of the development.

Selected photographs of the mountain slopes bordering the southern boundary of the project site and the mauka subdivision lots are presented in Appendix A.

GENERAL SITE CONDITIONS

The project site is along the northerly facing slopes of the Waianae Range in the Mokuleia area of the Island of Oahu, Hawaii. The site generally encompasses an open range vegetated with scattered trees and heavy dry land brush and grasses. A number of existing ranch trails traverses the project site. Ground surface elevations generally range between about +30 feet Mean Sea Level (MSL) at the northern lowland portion of the proposed development to a maximum elevation of about +450 feet MSL along portions of the upslope development boundary. Proposed Lot Nos. 90 and 91 each encompass greater than about 200 acres of land and extend up to summit elevations of about +800 feet MSL. The proposed development plan including the lot, roadway, home site and driveway layout used for our analyses, and including the location of the potential rockfall source areas with respect to the affected lots, is shown on the Site Plan, Plate 2.

The project site resides where annual precipitation ranges between about 35 to 40 inches per year, with most of the precipitation falling in the winter months. Based on our observations, stream flow appears to be intermittent and generally in response to widespread storm conditions or higher elevation rainfall and runoff. Existing vegetation type indicates that the site conditions are typically dry with limited periods of stream flow, surface runoff, and wet ground conditions. Therefore, it is anticipated that the general rate of rock weathering and erosion may be slower than other wetter climatic regions on the Island of Oahu.

Based on our review of available geological and soils maps, most of the project site is underlain by rocky Quaternary Alluvium (Qa) deposits, which comprise the gentle to moderate foothill pediment slopes. The Quaternary Alluvium generally consists of mixed soils and a high volume of embedded basaltic boulders. Surface basaltic rock formation including rock outcroppings and other in-situ derived residual and saprolitic soils [referred to collectively as Tertiary Waianae Basalt (Twb)] are mainly encountered further upslope along the southern perimeter of the project site.

Based on our evaluation of the project site with respect to potential rockfall hazard conditions, the existing lower elevation alluvial and colluvial deposits, containing embedded boulders and comprising the gentle to moderately sloped pediment, appear generally stable with limited potential for dangerous rockfall hazard conditions. Based on our study, potential rockfall hazard conditions involve the development of portions of the mauka lots and roadways along the southern periphery of the subdivision development.

SITE RECONNAISSANCE

Ground site reconnaissance was performed as part of our previous Phase I and Phase II studies conducted in 2008 and earlier. The initial reconnaissance was performed to evaluate the project site conditions with respect to the location of potential rockfall source regions that could affect the development. Additional subsequent site reconnaissance was limited to the review and verification of our previous field findings, including a review of new lot locations related to the revised subdivision layout. Due to the

large undeveloped hill slope areas involved with the study of the potential rockfall conditions at the project, available aerial photographs and other aerial imagery were used to supplement our reconnaissance findings.

Our ground surface reconnaissance was performed along the southern development boundary and at selected interior hill slopes to obtain an overview of the existing site conditions with respect to potential natural hazards such as rockfall, slope instability, and debris flow. Our reconnaissance consisted of a visual evaluation of the existing hill slope conditions to investigate the potential presence of natural geologic hazards.

Because potential falling rock hazards were encountered, a primary focus of our field reconnaissance was to obtain an overview of the general location and character of existing surface boulders and rock outcroppings residing on the hillside terrain. In addition, the ground reconnaissance was performed to evaluate regions of existing boulder deposition to deduce probable boulder rolling paths and roll-out distances that could affect the proposed development. The field information was used to support our current computer simulation and statistical evaluation of potential rockfall conditions using the Colorado Rockfall Simulation Program (CRSP) engineering and statistical analytical tool.

Based on our evaluation, the potential for falling rock hazards is of significant concern for portions of the development bordering the steep mountain slopes composed of basaltic rock formation. Other natural geologic hazards such as existing slope instability due to earth movement and inundation by debris flow conditions were found to be of limited concern with respect to the proposed development scheme.

The Site Plan, Plate 2 shows the general upslope areas harboring potential rockfall source regions composed of basaltic rock outcroppings and surface boulders residing on steep mountain terrain. These potential rockfall source areas have some potential to produce falling rock hazards capable of encroaching on portions of the proposed development.

Potential Rockfall Hazard Conditions

The findings summarized herein are based on field information collected during site reconnaissance and engineering and statistical evaluations of the potential rockfall conditions using computer slope modeling and rockfall simulation trials to evaluate where potential hazardous conditions may be present and whether rockfall catchment systems may be effective in reducing the potential for hazardous rockfall conditions to encroach upon subdivision development.

General Findings

Based on our observations, some broad trends in the rockfall hazard potential and level of rockfall hazard risk with respect to the lots along the southern development boundary were identified. In general, the potential for rockfall activity to encroach upon the

development increases from east to west across the southern development boundary. This is based on the following general observations:

1. Upslope mountain ridges (rockfall source region) gradually steepen toward the west.

2. Foothill pediment slopes (probable rockfall run-out region encompassed by the lots) gradually steepen towards the west.

3. The distribution and relief of source rock outcrops increases toward the west.

4. The distribution of existing surface boulders increases toward the west.

Based on our site reconnaissance, the existing ground surfaces within the proposed lots along the upslope development boundary are composed of mixed clayey and silty soils containing an appreciable volume of basaltic cobbles and boulders. Surface boulders ranging between 3 and 12 feet in dimension were observed in generally stable ground settings within the project site interior. The larger surface boulders were generally encountered at the upper elevations of the western end of the project site. Most of the surface boulders encountered are partly embedded or have settled in stable slope settings. The boulders are believed to represent erosional remnants of older regional colluvial fan deposits that had accumulated a very long time ago. However, the distribution of non-embedded surface boulders (potentially more recent fallen rock) appears to increase toward the southwestern corner of the project site, in the vicinity of Lot Nos. 65 through 69. The greater distribution of existing surface boulders towards the southwestern corner of the development (vicinity of Lot Nos. 65 through 69) appears to correlate with the observed increased occurrence of proximal upslope rock outcroppings consisting of higher relief and fractured rock formation.

Mauka Lots Recommended for Potential Rockfall Mitigation

Based on our evaluation of potential rockfall and slope hazard conditions with respect to the proposed Dillingham Ranch Agricultural Subdivision development and designated home (dwelling) site locations, 11 mauka lots and their associated designated home sites are exposed to moderate or greater risk for potential rockfall hazard conditions. These 11 lots require the provision of an appropriate rockfall catchment structure(s) to reduce the potential for rockfall encroachment at the designated home sites and associated private access driveways on the lower elevation portion of the lots. These lots are identified as Lot Nos. 65, 66, 67, 68, 69, 74, 76, 77, 78, 90 and 91. In addition, Portions of proposed subdivision Road “A” and proposed subdivision Road “D” are exposed to some potential falling rock hazards from the adjacent upslopes. Road “A” spanning between Lot Nos. 65 through 69 and Road “D” spanning between Lot Nos. 73 and 74 require the provision of an appropriate rockfall catchment structure(s) to reduce the potential for falling rock encroachment along these sections of the subdivision roadways. The 11 affected mauka lots reside along the foothill pediment of alternating ridge and

valley topography associated with the Waianae Mountain Range. In general, the areas of potential rockfall hazard are fronting the ridgeline noses and terminal slopes of the upland mountain ridges. These affected lots and roadways are along and adjacent to the southern development boundary as shown on the Site Plan, Plate 2.

Mauka Subdivision Areas Not Requiring Rockfall Mitigation

Based on our evaluation, the designated home sites and access driveways at five other mauka oriented lots (identified as Lot Nos. 70, 71, 72, 73, and 75) are not exposed to potential rockfall hazard conditions due to their further downslope location and appreciable area of natural terrain buffer between potential rockfall source regions and the designated home site development areas. In addition portions of Roads “A” and “D” between Lot Nos. 70 and 72 and fronting Lot Nos. 75 and 76 are not exposed to potential rockfall hazard conditions due to favorable upslope terrain and limited rockfall source area. These limited risk lots and portions of roadways reside along flatter terrain comprising the lower elevation flanking mountain slopes and further removed from the upland potential rockfall source regions as shown on the Site Plan, Plate 2.

Although structural rockfall mitigation improvements are not necessary to protect the designated home sites at these lots, the lots are subject to restriction of the home site location as shown on the Conceptual Rockfall Mitigation Plans, Plates 4.1 through 4.4. Home sites should not be developed upslope from the designated location that was evaluated in this study. Additional rockfall hazard analysis will be required if the home site and driveway locations are shifted to locations other than shown on the Conceptual Rockfall Mitigation Plan.

Existing DLNR Access Road

Based on our evaluation, a portion of the existing Department of Land and Natural Resources (DLNR) access road bounding proposed Lot Nos. 82 through 85 may be exposed to some potential for rockfall encroachment from the adjacent high mountain slopes southerly of the roadway. An appropriate rockfall catchment structure(s) should be provided to protect the roadway and the far upper elevation portions of Lot Nos. 82 through 85 (adjacent to the existing DLNR roadway) from potential falling rock hazards.

Based on our evaluation, only the extreme upper elevation portions of Lot Nos. 82 through 85 adjacent to the existing DLNR roadway may experience limited potential for falling rock encroachment. Therefore, a rockfall catchment structure constructed upslope from the DLNR roadway and subdivision lots serves as an effective rockfall hazard control for the roadway and the adjacent lots. Based on our observations, most of the land area encompassing Lots 82 through 85 has minimal exposure to potential rockfall from the high mountain slopes due to flatter terrain and appreciable distance from the upland potential rockfall source regions. Based on our slope modeling and potential rockfall simulation, very limited potential for rockfall encroachment below the existing DLNR roadway corridor in the vicinity of Lot Nos. 82 through 85 is anticipated.

Other Subdivision Lots

The remaining lots in the proposed subdivision (Lot Nos. 1 through 64) do not appear to be exposed to potential falling rock hazards generally due to the long distances away from the upland potential rockfall source regions. In addition, existing surface boulders within the lots appear in generally stable settings on lower gradient terrain; thus limiting the potential for rock movement initiation. However, new development on sloping subdivision lots, including excavation, site grading, and possible excavation of new cut slopes, should be investigated and designed by a geotechnical engineer retained by the lot owner. Geotechnical engineering consultation is recommended so that potential rockfall hazard conditions are not created by future lot development, in the event buried rocky materials are encountered in deeper excavations and new cut slope exposures.

It should be emphasized that a large volume of widely scattered basaltic boulders in generally stable ground surface settings were observed throughout the project site interior generally encompassed by Lot Nos. 42 through 78 and Lot Nos. 90 and 91. The scattered boulders appear to represent remnants of older alluvial and colluvial materials derived from the early large-scale erosion and geological evolution of the Waianae Range and mountain front pediment. We believe the existing boulder deposits within the lots comprising the development have a low potential for producing hazardous rockfall conditions due to the gently sloping and generally stable depositional terrain. It is anticipated that boulders will be encountered during the grading and excavation of the individual lots. The individual lot owners should be advised to obtain the services of a competent geotechnical engineer to evaluate boulder deposits within their lots for potential instability and possible rockfall hazard mitigation.

Subdivision Roads “A” and “D”

As mentioned previously, the mauka-most portions of subdivision Roadways “A” and “D” may be exposed to potential rockfall hazards from the adjacent upland mountain slopes. Road “A” may be exposed to potential rockfall hazards between Lot Nos. 65 and 69. Road “D” may be exposed to potential rockfall hazards between Lot Nos. 73 and 74. Rockfall catchment ditches and rockfall impact barriers constructed within the lots upslope from these areas of concern should provide protection for the affected roadway segments.

In addition, new cut slopes proposed for development at subdivision Roadways “A” and “D” appear to have some potential to expose buried rocky materials such as embedded boulders that may present potential rockfall hazards for the roadway. As recommended in the project soils report, two horizontal to one vertical (2H:1V) cut slopes should be designed for the subdivision roadways to reduce the potential for instability associated with the potentially rocky cut slope exposures. Provision for contingency mitigation of potential rockfall hazards encountered in the new 2H:1V cut slopes should be incorporated into the construction documents. Possible mitigation alternatives for cut slopes encountering unstable rocky materials may include; 1) trimming of exposed portions of large boulders; 2) boulder excavation and backfill; and, 3) localized stabilization treatment of cut slope surfaces.

The Site Plan, Plate 2 shows the location of the subdivision lots and roadways with respect to the existing topography and the identified potential rockfall source regions comprising the adjacent mountain slopes.

Existing Slope and Drainage Conditions

Based on our reconnaissance, a number of existing well-established drainage ravines emanate from the large inland valleys. These substantial drainage ravines transect from south to north through the proposed development. The incised ravines provide near-surface exposures of the colluvial/alluvial fan deposits including scoured exposure of localized basalt rock formation in some upslope locations. The normally dry drainage ravines are believed to transmit appreciable runoff derived from the interior mountains during periods of high rainfall. As a result, the ravines should be considered as potential flash-flood conduits and future building sites should be set back at appropriate distances from the established channels. Hydrologic study should be performed as a basis for the designation of the infrastructure set backs from the drainage ravines.

Based on our site reconnaissance and a review of aerial photographs, overt visible signs of active, large-scale ground instability were not revealed within the project site. Because the drainage ravines incise the colluvial/alluvial fan deposits composed of unconsolidated and semi-consolidated hard cobbles and boulders, the existing ravine slopes appear to be naturally armored by the rocky and semi-consolidated deposits. However, some erosion and raveling of the natural stream banks composed of soils and rocky deposits should be anticipated; therefore, appropriate setback restrictions for future structures, roadways, and other improvements should be established by the project geotechnical engineer.

Based on our site reconnaissance, geological evidence related to the occurrence of other natural hazards such as recent debris flow and landslide activity was not encountered. Historic documentation or records of past occurrences of these natural hazards at the project site was not revealed.

DISCUSSIONS AND RECOMMENDATIONS

Site reconnaissance and literature review was performed to aid in the evaluation of the existing project site conditions with respect to natural hazards such as rockfall potential, hill slope stability, and debris flow/flash flood potential. In addition to our reconnaissance and literature review, we performed computer simulation and statistical analysis of potential rockfall activity using the Colorado Rockfall Simulation Program Version 4 (CRSP).

Based on our evaluation of the existing project site conditions with respect to potential natural hazards such as rockfall, slope instability, and debris flow, it is our opinion that the site is suitable for residential subdivision development and is feasible from a geotechnical point-of-view provided that the recommendations provided herein are implemented. Once the final grading plans for the project are available and have been

reviewed, Geolabs will render an opinion addressing the stability of slopes in the post-development condition.

Preliminary Rockfall Simulation Analysis (CRSP)

As previously discussed, site reconnaissance was performed to visually identify potential rockfall hazards such as loose surface boulders and unstable rock outcroppings residing within the project site and the adjacent slopes above. The site reconnaissance also permitted us to evaluate probable rolling trajectories in relation to the existing topography and development boundaries. Following the site reconnaissance, selected information recorded in the field was input to the CRSP to validate the field observations.

The CRSP is a computer program that is a widely accepted engineering tool used to estimate potential rockfall behavior by simulating probable rockfall activity based on input parameters that are assigned on a site-specific basis. The input parameters for this project were assigned based on the observations and measurements collected in the field. The program provides a statistical evaluation of potential rockfall behavior based on hill slope topographic profiles and other specific input information such as rock size, shape, and parameters used to quantify the typical ground surface conditions. Information obtained from the CRSP analysis includes the predicted falling rock velocity, bouncing height, kinetic energy, and roll-out distance. The output information is useful to assist in the site-specific design of various rockfall mitigation schemes such as rockfall impact barriers or other rockfall containment systems.

Topographic information pertaining to the mountain slopes outside of the project limits was obtained from the United States Geological Survey (USGS) “Kaena” topographic quadrangle map. The USGS map contours are generally at 40-foot intervals. Available topographic ground surface survey information of the project site was utilized to evaluate the slopes contained within the project site. The available ground surface topographic survey utilizes 2-foot slope contour intervals. The two sources of topographic information were blended to develop the idealized slope section profiles used in our CRSP analysis.

Twenty-two (22) idealized hill slope model profiles identified as Slope Profiles 1 through 22 were developed to support our preliminary CRSP analysis. The location of the sections was chosen to intersect each of the proposed mauka lot home sites (Lot Nos. 65 through 78, and 90, 91) and portions of proposed Roads “A” and “D”. The section profiles were developed to evaluate the potential rockfall hazard exposure and the statistical data required for the design of mitigation works at each of the designated mauka lot home sites and along the mauka subdivision roadways, including the existing DLNR access roadway. Rockfall mitigation improvements are recommended at the locations indicated where potential rockfall hazard exposure was found to be greater than about 10% of simulated falling rock indicating encroachment using the slope models and CRSP rockfall simulation trials.

Our rockfall protection criterion is defined as the probable interception and catchment of 90 percent of possible rockfall hazards assessed by the computer rockfall simulation analysis (CRSP). The 90 percent catchment criteria is a target that is commonly used in engineering practice for evaluation criteria that can be quantified by a statistical and probability analysis using model data for natural occurrences such as rockfall activity. Since the analyses are based on statistics and probability, a 100 percent criteria is impractical to achieve. In addition, it should be noted that if statistical rockfall encroachment is shown by the CRSP to be less than 10% of simulated falling rock passing a given model Analysis Point (AP), a hazardous rockfall condition is considered a remote risk and rockfall protections are typically not warranted, unless field data indicates that appreciable fallen rock deposits exist.

The approximate location of the 22 slope profiles used in our analysis is shown on the Site Plan, Plate 2. Reduced scale graphic representations of the model slope profiles are shown as Slope Profiles, Plates 3.1 through 3.11.

Our CRSP analysis was performed using spherical shaped basaltic boulders (conservative rolling velocity scenario) ranging in size from 2 to 6 feet in dimension releasing from the identified source area(s). The boulder size used for rockfall simulation was selected based on the typical dimension of boulders observed in the rockfall deposits encountered on the lower flanking slopes of the project site. For each simulation run, 1,000 source rocks were utilized to develop a statistical distribution of the results. Numerical input coefficients were selected to approximate the typical condition of the existing ground surfaces based on our field observations. Model sensitivity and calibration analysis was conducted by varying the model input parameters to correlate the model produced boulder roll-out distances versus the field observation of probable boulder roll-out distances.

CRSP Results

Based on our analysis of the mauka lots and the designated home site locations, rockfall encroachment is not anticipated (very low probability of less than 10 percent) at Lot Nos. 70, 71, 72, 75, and 82 through 85, generally due to the larger distance removed from the potential rockfall source areas and favorable natural buffer terrain such as gentle slopes and existing natural interception features such as mature drainage gullies. In addition, the portion of Road “A” easterly of Lot No. 69 and most of Road “D” (with the exception of Road “D” frontage at Lot Nos. 73 and 74) are not anticipated to experience rockfall encroachment from the adjacent mountain slopes due to very low encroachment probability as indicated by the potential rockfall simulation analysis. Engineering Analysis Points (AP) set upslope of the designated home sites and selected roadway edges indicate nil or less than 10% probability of rockfall encroachment.

Based on our analysis, potential rockfall encroachment is at least moderately probable at the designated home sites of Lot Nos. 65, 66, 67, 68, 69, 74, 76, 77, 78, 90, and 91. In addition, rockfall potential analysis for Road “A” between Lot Nos. 65 and 69 and Road “D” generally between Lot Nos. 73 and 74 and the existing DLNR roadway

between Lot Nos. 82 through 85 show some indication of probable exposure to potential rockfall hazards. These home site and roadway areas are exposed to potential rockfall hazards due to the closer proximity of the rockfall source regions, steeper mountain slopes with limited natural buffering terrain, and greater volume of rock materials comprising the upslopes. Generally, significantly greater than 10% of simulated rockfall is shown to reach the CRSP analysis points for these affected areas of the subdivision.

Finally, our analysis indicates a generally low to moderate probability of rockfall encroachment at the existing DLNR access road upslope from Lot Nos. 82 through 85. Based on our rockfall simulation, most potential rockfall is modeled to stop at or near the existing DLNR roadway corridor.

A summary of the preliminary CRSP results for the mauka lot home sites, subdivision roadways “A” and “D”, and the existing DLNR roadway which were evaluated for potential rockfall hazard conditions is provided in Appendix B.

Phase I Conceptual Rockfall Mitigation Scheme

Based on our evaluation, 11 mauka lots are believed to be exposed to potential rockfall hazards from steep mountain slopes adjacent to the subdivision boundary. The 11 lots include Lot Nos. 65 through 69, 74, 76 through 78, and 90, 91. For these 11 lots, we recommend constructing appropriate rockfall control structures such as rockfall impact barrier fencing on the hillside just above the designated home sites to reduce the potential for rockfall encroachment at the dwelling site.

To protect the private driveways accessing the home sites and the downslope subdivision roadways exposed to potential falling rock, rockfall catchment ditches are proposed as a lower visual site impact alternative to provide effective rockfall interception for the affected driveways and portions of the subdivision roadways. Catchment ditches provide a cost-effective alternative approach for rockfall control that can be utilized in suitable terrain where the longer length of rockfall impact barrier fencing and the associated ground anchorage systems may encumber view planes and access to the upper lot areas. In addition, below grade rock catchment ditches offer a reduced surface visual obstruction, which is desirable from a lot development point-of-view.

Based on our evaluation, portions of the mauka subdivision Roadways “A” and “D” are believed to be exposed to potential rockfall hazards from steep mountain slopes adjacent to the subdivision boundary. The exposure of portions of the roadways to potential rockfall hazards to due to the closer position of portions of the roadway with respect to the potential rockfall source region and limited presence of natural topographic slope buffer for potential falling rock roll-out and deposition. As mentioned previously, appropriately sized below-grade rockfall catchment ditches constructed upslope from the affected (exposed to potential rockfall hazards based on our evaluation) private driveways and subdivision roadways should provide effective interception of rolling rock, when maintained to the original design ditch dimension with removal of debris accumulations.

Based on our updated slope hazard assessment, we believe that an appropriate rockfall interception scheme for the current subdivision development layout could consist of a combined system of above-grade rockfall impact barrier fencing and below grade rockfall catchment ditches constructed within the interior of the 11 affected lots, as shown on the Conceptual Rockfall Mitigation Plans – 1 through 4, Plates 4.1 through 4.4. The segments of rockfall impact barrier constructed within the lot interiors would generally consist of medium-high to high design capacity (range of about 184 to 738 foot-ton capacity, depending on location) rockfall impact barrier fencing constructed on a graded bench about 50 to 100 feet upslope from the designated home (dwelling) site. The design height of the rockfall impact barriers may range between about 9 and 14 feet above the existing grade, depending on location. A typical schematic, section, and plan-view layout for the recommended medium-high capacity impact barriers are provided on Plates 5.1 through 5.3.

In addition, to the recommended segments of medium-high capacity barrier fencing designed to protect the designated dwelling sites at affected lots, a system of continuous-length low energy capacity rockfall impact barrier fencing is recommended spanning along the upslope side of the existing DLNR roadway as shown on the Conceptual Rockfall Mitigation Plan – 4 (Plate 4.4). The purpose of this structure is to provide rockfall interception and protection for the primarily for the existing DLNR roadway and secondarily for the upslope portions of Lot Nos. 82 through 85, thus negating the requirement for designated home sites at these lots. A typical schematic and sections for the recommended low capacity barrier system is provided on Plates 6.1 through 6.3.

As mentioned previously, rockfall catchment ditches are recommended at specified locations within specified lots to protect the private driveways and portions of the subdivision roadways in areas exposed to potential rockfall conditions. A schematic of the recommended catchment ditch structure is presented on Plate 7.

Our analysis and conceptual design is based on our lot by lot evaluation and simulation of potential rockfall activity considering the designated home site, driveway, and subdivision roadway location(s) with respect to the adjacent identified potential rockfall source area. Our evaluation included the analysis of potential rockfall energy, velocity, bounce height, and ditch effectiveness modeled/simulated at the location of each proposed rockfall interception structure. The location, length and orientation of the conceptual layout is based on a lot by lot evaluation of the existing terrain and upslope conditions derived from available topographic maps, aerial photographs, and visual observations.

Rockfall Impact Barrier Description

Rockfall impact barriers are used worldwide as an effective rockfall mitigation protection system. Rockfall impact barriers are commonly constructed on hillsides where the protection of down slope areas from varied and widespread sources of falling rock is necessary. Rockfall impact barriers are considered to be a viable rockfall protection measure where a specific and limited source of potential rockfall

cannot be readily identified and stabilized, or where the source area may encompass disturbance-sensitive land that makes other mitigation measures impractical to implement.

Rockfall impact barriers are specially designed fences consisting of steel support beams linked by wire rope (cable) or steel wire ring nets, which are designed to flex and absorb rockfall impact energy. Upon boulder impact, the net may deflect up to 20 feet in the downslope direction. The nets and beams are supported by drilled and grouted ground anchors at specified intervals. The barrier height is typically constructed 8 to 14 feet above ground level and powder coated black in coloration to blend with the outdoor environment. Rockfall barrier fences require periodic inspection and possible maintenance to remove accumulated boulder debris and replace worn components such as brake elements and netting. Portions of the barrier may require repair or replacement following a very large impact where severe deformation of the system is experienced. Ultimately, the rockfall barrier will require replacement of components affected by natural environmental degradation such as corrosion.

We roughly estimate the effective life of the steel barrier system in the semi-arid near coastal setting such as Mokuleia as being about 30 to 40 years, at which time replacement of components such as nets, ground anchors and support beams may be required to maintain the desired level of protection. Stainless steel components and special surface coatings are available to increase resistance to corrosion but at a significant extra cost; therefore, galvanized steel with additional proprietary zinc coatings on some components is preferred. The selection of a rockfall protection system manufacturer and product should take into account the material component certifications and net efficiency approvals held by the manufacturer. Installation contractors should closely follow the manufacturer's recommended installation sequence.

A schematic detail of a typical medium-high energy capacity rockfall impact barrier is presented on Plate 5.1 and a schematic detail for a typical low energy capacity barrier is presented on Plate 6.1. A summary of the CRSP results pertaining to the proposed rockfall impact barriers is presented in Appendix B on Plates B-1 through B-3.

Rockfall Catchment Ditch Description

Rockfall catchment ditches are low maintenance below-grade excavated structures commonly used to intercept falling and rolling boulders to reduce the potential for downslope rockfall encroachment. Rockfall catchment ditches are a feasible and proven rockfall control alternative that is effective in certain low gradient, vegetated soil slope settings where adequate open space is available to develop the structure. The primary attributes for the design of an effective catchment ditch are; 1) location on the slope in relation to the rock source, 2) width and depth dimensions of the

ditch, 3) geometric shape/inclination of the side slopes; and, 4) the softer yielding condition of the existing alluvial and colluvial substrate materials.

Based on our CRSP analysis, a minimum 5-foot deep by 10-foot wide ditch structure with 1H:1V side slopes was found to be effective at intercepting at least 90 percent of simulated rolling spherical shaped rock up to about 6 feet in dimension at selected areas of the project site where the existing terrain is conducive to ditch development. The recommended catchment ditches are located on the gentle colluvial soil slopes (boulder roll-out zone) that average about a 3H:1V inclination fronting the steeper slopes containing outcroppings representing the identified potential rockfall source region. The proposed catchment ditches were modeled and found to be effective at intercepting at least 90 percent of simulated falling rock at the locations selected on the alluvial/colluvial slope.

Based on our preliminary rockfall simulation results, it appears the that the modeled ditches are effective primarily because of the existing low gradient, vegetated, terrain containing appreciable surface roughness as a result of existing surface boulder deposits combined with the energy buffering effect of the existing mixed colluvial soil and cobble/boulder substratum, present the at the locations selected for ditch development.

A schematic detail of the proposed catchment ditch constructed in the anticipated typical slope setting is provided on Plate 7. The catchment ditch structure is augmented by an additional 6H:1V buffer slope constructed in the embankment fill on the downslope side of the ditch. A summary of the CRSP results pertaining to the proposed rockfall catchment ditches is presented in Appendix B on Plate B-4.

The rockfall catchment ditches must be designed for positive drainage at appropriate discharge locations. In addition, the catchment ditches must be maintained free of excessive debris accumulations that could reduce the effective depth and width of the structure. Although the growth of grass and brush vegetation in the ditch is generally allowable and should not adversely affect the rockfall interception capacity, regular scheduled cutting and removal of vegetation to expose the ditch subgrade prior to scheduled maintenance inspections is recommended. In addition, periodic clearing of possible accumulations of soil and rock debris must be performed to maintain the minimum design characteristics of the ditch.

<u>Rockfall Protection at Lot Nos. 65 through 69, 73, 74, 76 through 78, 90, 91, Associated Lot Driveways, and Portions of Subdivision Roadways “A” and “D”</u>

Based on our evaluation, a system of segmental rockfall impact barriers and catchment ditches is proposed for construction within the lots affected by potential rockfall encroachment to protect the designated home site, private access driveway, and adjacent subdivision roadway located further downslope. Rockfall impact barriers are utilized upslope of the designated home sites and catchment

ditches are utilized upslope of the access driveways and portions of subdivision Roads “A” and “D”.

The impact barrier fencing provides rockfall protection intended for the home building site only. The layout of the segmental impact barriers and catchment ditches incorporates some lateral offset and overlap between adjacent segments of protective structure to reduce the potential for rockfall encroachment via errant rockfall trajectory and to provide some space for limited access to the slope area above the interception structure.

Based on our evaluation, the following table presents a summary of the recommended conceptual rockfall protection improvements:

SUMMARY: CONCEPTUAL ROCKFALL MITIGATION IMPROVEMENTS			
Site Location	**Approximate Rockfall Impact Barrier Length**	**Approximate Energy Class of Rockfall Impact Barrier Capacity**	**Approximate Catchment Ditch Length**
Lot 65 & Road “A”	105 linear feet	738 ft-ton	None
Lot 66 & Road “A”	165 linear feet	369 ft-ton	440 linear feet
Lot 67 & Road “A”	380 linear feet	369 ft-ton	145 linear feet
Lot 68 & Road ”A”	230 linear feet	369 ft-ton	320 linear feet
Lot 69 & Road “A”	250 linear feet	184 ft-ton	250 linear feet
Lot 73 & Road “D”	None	Not applicable	240 linear feet
Lot 74 & Road “D”	290 linear feet	184 ft-ton	None
Lot 76	185 linear feet	37 ft-ton	None
Lot 77	370 linear feet	369 ft-ton	None
Lot 78	255 linear feet	369 ft-ton	None
Lot 90	345 linear feet	184 ft-ton	None
Lot 91	250 linear feet	369 ft-ton	None
DLNR Road	2,068 linear feet	37 ft-ton	None

To facilitate the installation of the impact barriers, a graded slope bench should be constructed along the slope elevation contour and encompassing at least the length of the barrier fence. The purpose of the slope bench is to facilitate construction of the post foundations and ground anchorage points in addition to providing access for future barrier inspection and maintenance, including the removal of accumulated debris. The approximate location of the proposed conceptual rockfall protection improvements for the lots and subdivision roadways is shown on the Conceptual Rockfall Mitigation Plans 1-4, Plates 4.1 through 4.4.

Rockfall Protection at DLNR Roadway

Based on our evaluation of the site conditions above the existing DLNR roadway, we propose a continuous segment of low impact energy rockfall impact barrier fencing along the upslope side of the existing roadway to reduce the potential for rockfall encroachment at the roadway. This segment of barrier fencing would be constructed on a graded slope bench which will contain the access driveway for Lot No. 91. The barrier fence alignment is upslope from and adjacent to the existing DLNR roadway, as shown on the Conceptual Rockfall Mitigation Plan-4, Plate 4.4.

Based on our evaluations and analyses, our professional opinion is that the recommended rockfall hazard mitigation scheme should significantly reduce the potential for dangerous rockfall activity to affect downslope development at the proposed Dillingham Ranch Mokuleia project site. However, it must be stated that there are no guarantees in the professional engineering and architectural design fields with respect to protection from potential rockfall hazards. The construction of rockfall impact barriers as described in the conceptual-level context of this report should provide a high level of safety against rockfall hazard based on past applications of similar mitigation methods.

Potential Drainage and Debris Flow Hazards

Based on our site reconnaissance, a number of large natural drainage ravines emanating from the upland valleys transect the proposed development. We believe the ravines are capable of transmitting appreciable runoff through the development, especially during widespread storm runoff conditions. A rapid increase in stream flow during storm conditions (flash-flood conditions) should be anticipated in the normally dry drainage channels. The stream flow hydrology should be assessed by a qualified engineering consultant to address possible safety setback requirements for development adjacent to the stream channels.

No record or documentation of previous debris flow activity at the project site is known; however, the potential for transmission of debris flow materials within the larger valley draining stream channels is considered to be a possibility due to the well-developed character of the primary drainage ravines and extensive area of the upslope off-site drainage basins. Field evidence of past debris flow activity resulting from slope instability occurring within the project limits and adjacent to the upslope development boundary were not encountered.

Restrictions Associated with Rockfall Impact Barrier Improvements

Rules and site restrictions applicable to the affected lots where rockfall impact barriers are constructed are necessary to facilitate the long-term effectiveness of the rockfall mitigation system and site safety. The following pertains to the rockfall impact barrier system:

1. The location of the designated dwelling sites and private lot access driveways shall not be relocated or shifted from the position shown on the conceptual rockfall mitigation plans. Relocation of the building sites and driveway alignments shall require a re-evaluation and possible re-design of the rockfall protection system by a qualified geotechnical engineer.

2. No dwelling structure is permitted to be constructed above (upslope from) the rockfall impact barrier system as these areas of the lot exist in a natural unprotected condition where the potential for falling rock hazards is a real risk.

3. No earthwork grading (alteration or modification of the existing slope surface elevations by excavation and/or filling) is permitted on the upslopes above the rockfall impact barrier system.

4. No building structures or planting of vegetation is permitted within the designated access and maintenance easement encompassing the rockfall impact barrier. Vegetation may be planted outside of the designated access and maintenance easement. The restriction is needed to maintain access for periodic inspection and maintenance of the barrier fence. It should be noted that under rock impact loading the barrier fence may deflect up to 20 feet in the downslope direction.

Rockfall Impact Barrier Maintenance

Although rockfall impact barriers are designed for generally minimal maintenance requirements, a program of regular visual inspection and periodic debris removal is required. Rockfall barriers require routine visual inspection to ensure optimal performance of the system. In addition, periodic maintenance work to repair or replace broken or worn barrier system components following large rock impacts may be necessary. Routine visual inspections should be performed periodically and following a rockfall impact. The visual inspection serves to identify potential rock debris accumulations that require removal and to inspect for possible changes in the system condition or effects of corrosion that may reduce the barrier performance.

Barrier maintenance such as the repair or replacement of worn/broken components (i.e. the braking elements) may be required following a large rockfall impact. The frequency of barrier maintenance typically depends on the size and frequency of rockfall events. The rockfall barriers are designed to require minimal routine maintenance.

Due to the often-difficult access condition of some barrier installations, owners or governing agencies typically establish a contract with a local rockfall specialty contractor to perform routine inspections, large volume rock debris removal, and other system maintenance, when needed. In some cases, where the barrier is clearly visible from readily accessible locations such as a roadway or the base of a low-height slope, the owner may elect to perform the routine visual inspection themselves.

Furthermore, where barriers are located at readily accessible locations, the owner may perform the removal of rock debris using construction machinery. However, a rockfall specialty contractor who maintains the proper equipment and trained personnel to conduct work on difficult access slopes should be contracted to safely perform the removal of large rockfall debris and perform barrier system repair. The rockfall mitigation specialty contractor typically utilizes portable equipment, which is transported onto the slope to perform the potentially hazardous work. Furthermore, the rockfall specialty contractor would typically employ temporary safety controls to protect downslope persons and property during the performance of the work.

It is important to note that the need for maintenance on rockfall impact barriers is minimal because the barriers are designed to withstand multiple small to medium magnitude rock impacts. Therefore, it is not necessary to clean them out if there is a limited accumulation of small rocks in the bottom of the nets. If it is not feasible to drive behind the barrier with equipment, the option is to reach over the net with a backhoe, boom truck, or small crane. The option of using a small crane is a good one particularly if the rockfall consists of just a few large rocks. Eyebolts can be attached to the rocks and the rocks can be easily lifted out from behind the barrier. If this is also not feasible, then the ring nets should be detached to provide access to the rocks from the front of the barrier.

A maintenance manual for Geobruggs GBE series rockfall impact barriers is presented in Appendix C. The manual provides general information about the manufacturers recommended maintenance of the system components and safe removal methods for possible entrained debris.

With respect to the rockfall impact barrier improvements at the Dillingham Ranch Agricultural Subdivision, we recommend the following guidelines for inspection and maintenance:

1. The lot owner should inspect the rockfall impact barrier structure at least once per year for visible signs of rock impact, debris accumulation in the net, or deterioration and corrosion of primary system components such as the wire mesh, steel posts, and ground anchor wire ropes. If a significant volume of rock material consisting of a large boulder(s), multiple boulders, or deep accumulations of rock and other debris is encountered, a rockfall specialty contractor should be contracted to properly remove the debris and restore system function. In addition, if components are visibly broken, loose and

sagging, or excessively corroded, a rockfall specialty contractor should be contracted to perform inspection and repairs.

2. If the barrier sustains a large rockfall impact which causes visible deformation to the barrier, a rockfall specialty contractor should be contracted immediately to inspect the barrier, remove entrained debris, and perform necessary repairs using manufacturer approved parts and materials to restore function.

3. At a minimum, we recommend a visual inspection of the barrier by a qualified engineer or rockfall specialty contractor two years after initial construction. The purpose is to evaluate the system for signs of necessary adjustments (such as tightening of support cables).

4. Following the 2-year post construction inspection, additional inspections should be performed at 5 year intervals by a qualified engineer or rockfall specialty contractor. The purpose of the routine follow-up inspections is to review the system for proper function and to detect adverse changes to the barrier condition that may require corrective action. Vegetation cutting and removal from the access and maintenance easement should be performed prior to the scheduled inspection site visit to facilitate access and visibility.

5. All repairs should be performed using manufacturer recommended parts and materials. The manufacturer's maintenance manual may be referred to as a guide to perform system maintenance and the replacement of components.

6. We estimate the barrier may have a useful life of approximately 30 to 40 years, (depending on the number and severity of impacts encountered and the climatic conditions affecting the corrosion rate) before major components of the system may require replacement to maintain the design effectiveness of the barrier. A contingency maintenance budget should be developed to accommodate such work.

Restrictions Associated with Rockfall Catchment Ditch Improvements

Rules and site restrictions applicable to the affected lots where rockfall catchment ditches are constructed are necessary to facilitate the long-term effectiveness of the rockfall mitigation system and site safety. The following pertains to the rockfall catchment ditch system:

1. The location of the designated dwelling sites and private lot access driveways shall not be relocated or shifted from the position shown on the conceptual rockfall mitigation plans. Relocation of the building sites and driveway alignments shall require a re-evaluation and possible re-design of the rockfall protection system by a qualified geotechnical engineer.

2. No dwelling structure is permitted to be constructed above (upslope from) the rockfall catchment system as these areas of the lot exist in a natural unprotected condition where the potential for falling rock hazards is a real risk.

3. No earthwork grading (alteration or modification of the existing slope surface elevations by excavation and/or filling) is permitted on the upslopes above the rockfall catchment ditch.

4. No building structures or planting of vegetation is permitted within the designated access and maintenance easement encompassing the rockfall catchment ditch. Vegetation may be planted outside of the designated access and maintenance easement. The restriction is needed to maintain access for periodic inspection and maintenance of the rockfall catchment ditch.

Rockfall Catchment Ditch Maintenance

With respect to the rockfall catchment ditch improvements at the Dillingham Ranch Agricultural Subdivision, we recommend the following guidelines for inspection and maintenance:

1. The natural growth of wild vegetation (such as grasses and shrubbery with stalk widths of less than about 1-inch in diameter) within the ditch and the access and maintenance easement is generally acceptable. However, the vegetation growth should be controlled on an annual basis to support routine visual inspection. Furthermore, woody stem vegetation greater than about 1-inch stalk diameter growing within the ditch and within the surrounding access and maintenance easement should be cut and removed on a periodic basis. Tree growth should also not be permitted anywhere within the ditch and the designated access and maintenance easement encompassing the ditch.

2. Planting and cultivation of non-wild vegetation within the ditch and the designated access and maintenance easement is prohibited because cutting and removal of vegetation on a periodic basis is recommended.

3. Vegetation (wild grasses and shrubbery) naturally growing within the ditch should be cut and removed to expose the ditch ground surface on an annual basis. The purpose of the annual cutting is to control the wild vegetation growth and to expose the ditch structure for routine visual detection of undesirable accumulations of debris such as eroded soil and rock deposits.

4. The lot owner or appointed person should visually inspect the catchment ditch at least annually (following vegetation cutting) for potential undesirable debris conditions, such as accumulations of eroded soil and rock, which could reduce the performance of the catchment ditch. If a significant volume of debris (generally consisting of a large boulder, multiple boulders, or debris accumulations greater than about 1-foot in thickness) is encountered, a qualified contractor should be contracted to carefully remove and dispose of the debris properly.

5. If a rockfall event is detected and produces a deposit in the catchment ditch, a qualified contractor with appropriate machinery and tools should be contracted as soon as practical to remove the debris and restore the ditch to its pre-impact condition. Debris accumulations should be removed from the ditch in a timely manner to facilitate the intended performance of the structure.

6. At a minimum, we recommend a visual inspection of the catchment ditch by a qualified engineer at about 5 year intervals. The purpose of the regular inspections is to detect possible undesirable conditions such as excessive erosion, debris accumulations, and poor drainage that could affect the performance of the ditch. Vegetation clearing should be conducted prior to the scheduled inspections.

7. Because the ditch structure is intended as a low maintenance unlined excavation, it is possible that the ditch will require future rehabilitation efforts. The rehabilitation efforts may include additional excavation and/or stabilization of undesirable erosion conditions. A contingency maintenance budget should be developed to accommodate such work.

Phase II Rockfall Mitigation Design

Our professional opinion is that the recommended conceptual rockfall mitigation plan offers a comprehensive and cost effective mitigation scheme to provide a high level of rockfall protection for development downslope of the rockfall protection improvements shown on the Conceptual Rockfall Mitigation Plans 1 thru 4, Plates 4.1 - 4.4.

Following the acceptance of the conceptual rockfall mitigation plan, design of the rockfall mitigation improvements may proceed. In support of the design phase for rockfall mitigation we anticipate needing the following:

1. Topographic ground survey encompassing the proposed rockfall impact barrier and catchment ditch improvements.

2. Civil engineering support for the design of the recommended earthwork grading to support the rockfall mitigation improvements, including design of slope grading and appropriate positive drainage transmission for the recommended catchment ditches.

As part of the design phase of the project we envision at least the following tasks and work efforts will be necessary:

1. Additional site reconnaissance to review the site specific conditions at the location of the recommended improvements.

2. Subsurface exploration at selected locations to evaluate the subsurface conditions with respect to foundation and ground anchor design.

3. Additional rockfall simulation and modeling to confirm preliminary assumptions and to refine the system design parameters where necessary.

4. Provision of geotechnical engineering design input for the design of earthwork grading for the rockfall catchment ditches.

5. Preparation of construction plans, technical specifications, and cost estimates for the design of the rockfall impact barriers.

It should be noted that depending on the existing topography and existing ground surface features at the proposed catchment ditch locations, some adjustments to the conceptual ditch geometry may be required to optimize the ditch for site drainage and for effective catchment of potential rockfall. This may include local adjustments to the ditch geometry to attain the desired catchment drainage and rockfall interception capacity. Thus, there is the potential that the preliminary designated easements may expand to encompass the required adjustments.

We understand that the proposed rockfall impact barriers and rockfall catchment ditches will be dedicated to the Dillingham Ranch Agricultural Subdivision's community or homeowners association for future maintenance responsibility. Based on the preliminary conceptual layout of the rockfall impact barriers, we anticipate that some additional access easements spanning between the proposed rockfall improvements and the public roadway may need to be established.

LIMITATIONS

The findings and recommendations submitted herein are based, in part, upon information obtained from visual site observations and computer simulation and statistical analysis of potential rockfall behavior only. Variation in the surface and subsurface conditions between our observations and analysis points may occur, and the nature and extent of these variations may not become evident until additional field exploration or construction is underway. If variations then appear evident, it will be necessary to re-evaluate the findings and recommendations provided herein.

It should be noted that slopes composed of rock materials (rock slopes) deteriorate with the passage of time due to natural weathering processes, wet-dry and hot-cold cycles, and erosion conditions. Due to the inherent deterioration of rock slopes resulting from natural processes (weathering, wet-dry and hot-cold cycles, and erosion conditions), the potential for rockfall hazard at any site changes with the passage of time. Therefore, the findings and recommendations contained herein may be used only within a reasonable time from the date of issuance of this letter report. Land use, site conditions, and/or other factors may change with the passage of time. Therefore, additional work to evaluate the applicability of the findings and preliminary recommendations contained in this letter report due to changes with the passage of time will be required. Finally, there are no guarantees in the professional engineering and architectural design fields with respect to potential rockfall hazards due in large part to the unpredictable nature of rockfall activity, which is affected by many external variables including natural and man-induced causes.

This report has been prepared for the exclusive use of Dillingham Ranch Aina, LLC and their consultants for specific application to the Potential Rockfall Hazard and Slope Evaluation Study in accordance with generally accepted geotechnical engineering principles and practices. No warranty is expressed or implied. Any party other than the client who wishes to use this report shall notify Geolabs, Inc. in writing of their intended use.

This report has been prepared solely for the purpose of evaluating and assisting the client/owner in the understanding of potential rockfall hazards located within the project study area. Therefore, this report may not contain sufficient data, or the proper information, to serve as the basis for construction cost estimates. A contractor wishing to bid on this project is urged to retain a competent geotechnical engineer to assist in the interpretation of this report and/or in the performance of additional site-specific exploration for bid estimating purposes.

The owner/client should be aware that unanticipated surface and subsurface conditions are commonly encountered. Unforeseen conditions, such as surface rock outcroppings, archeological features, terrain irregularities, perched groundwater, soft deposits, hard layers or loose fills, may occur in localized areas and may require additional exploration or corrections in the field (which may result in construction delays) to attain a properly constructed project. Therefore, a sufficient contingency fund is recommended to accommodate these possible extra costs.

CLOSURE

We appreciate the opportunity to provide our services to you on this project. If you have questions or need additional information, please contact our office.

Respectfully submitted,

GEOLABS, INC.

By _____
Steven F. Carr, R.G.
Project Geologist

By _____
Clayton S. Mimura, P.E.
President

CLAYTON S. MIMURA
LICENSED PROFESSIONAL ENGINEER
No. 4176-C
HAWAII, U.S.A.

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION.

SIGNATURE — 4-30-16 EXPIRATION DATE OF THE LICENSE

CSM:SC:mj

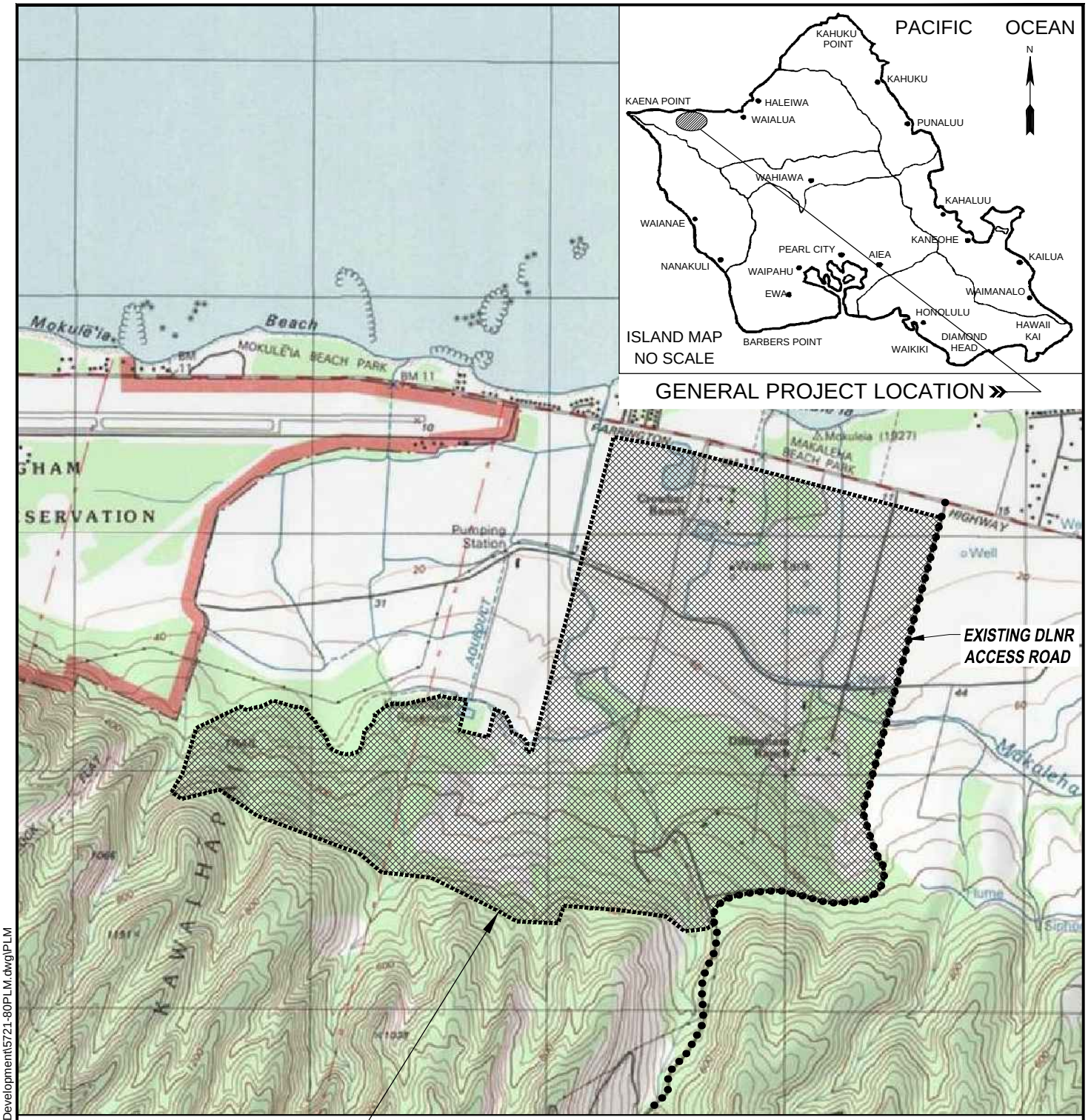
Attachments: **PLATES**
Project Location Map, Plate 1
Site Plan, Plate 2
Slope Profiles, Plates 3.1 thru 3.11
Conceptual Rockfall Mitigation Plans 1 thru 4, Plates 4.1 thru 4.4
Schematic Detail for Typical Medium-High Capacity Rockfall Impact Barrier, Plate 5.1
Typical Section Medium-High Capacity Rockfall Impact Barrier, Plate 5.2
Typical Layout for Medium-High Capacity Rockfall Impact Barrier, Plate 5.3
Schematic Detail for Typical Low Capacity Rockfall Impact Barrier, Plate 6.1
Typical Layout for Low Capacity Rockfall Impact Barrier, Plate 6.2
Typical Section Rockfall Catchment Ditch, Plate 7

APPENDIX A
Site Condition Photographs, Appendix A Plates A-1 thru A-8

APPENDIX B
Results Summary for CRSP Analyses, Appendix B Plates B-1 thru B-4

APPENDIX C
Geobrugg Maintenance Manual GBE Series Rockfall Impact Barriers (34 Sheets)

PLATES



PROJECT LOCATION MAP

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

2000 1000 0 2000 FT.

GRAPHIC SCALE

N

REFERENCE: MAP CREATED WITH TOPO!® ©2001 NATIONAL GEOGRAPHIC (WWW.NATIONALGEOGRAPHIC.COM/TOPO).

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Geotechnical Engineering

DATE	DRAWN BY	PLATE
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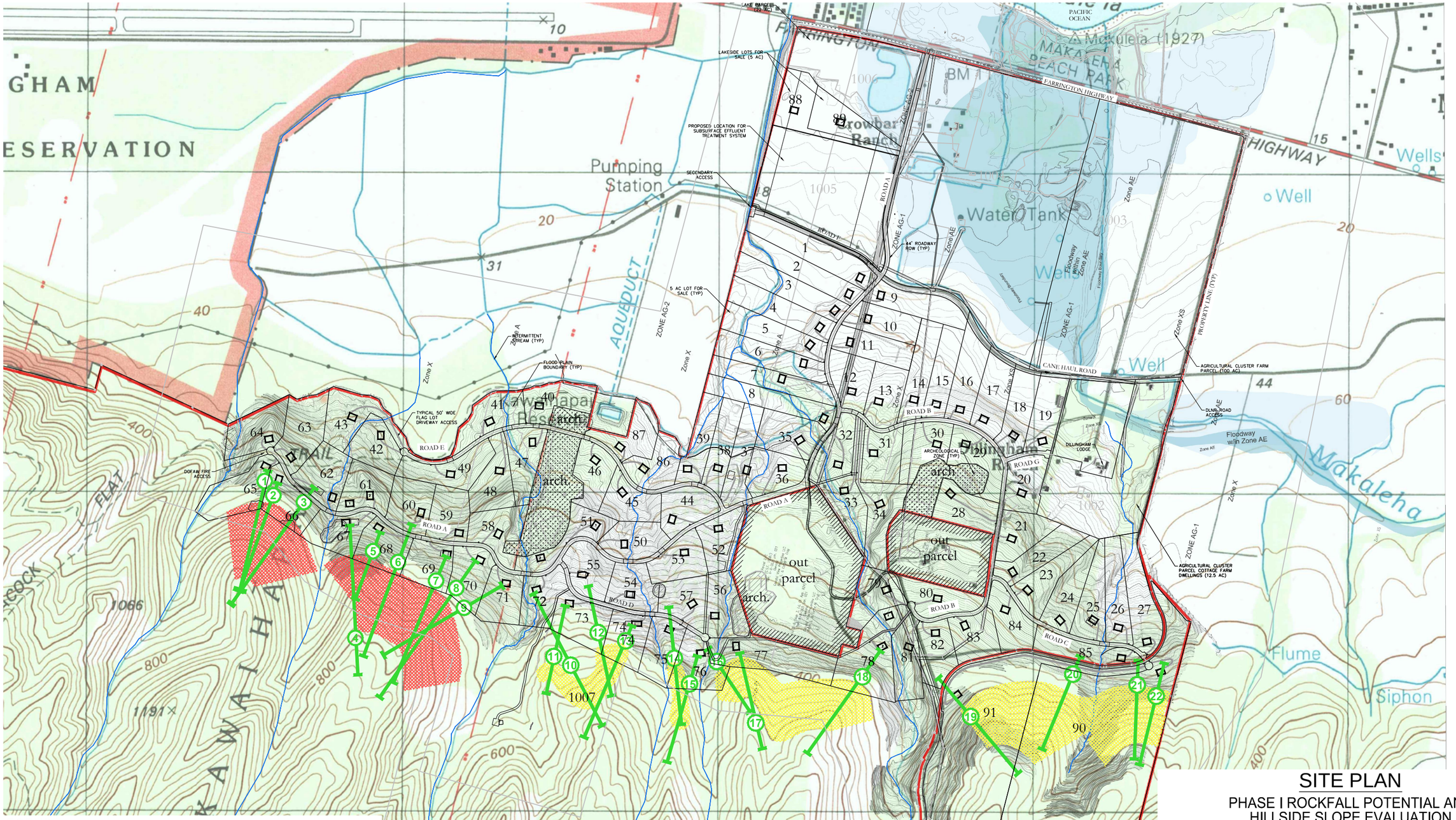

LEGEND:

APPROXIMATE LOCATION OF ROCKFALL SOURCE AREA WITH GREATER POTENTIAL TO ENCROACH ON SUBDIVISION

APPROXIMATE LOCATION OF ROCKFALL SOURCE AREA WITH LESSER POTENTIAL TO ENCROACH ON SUBDIVISION

APPROXIMATE SLOPE PROFILE LOCATION

0 500 1000 2000 3000 FT.

GRAPHIC SCALE

REFERENCE: SUBDIVISION PLOT PLAN FROM SHERWOOD DESIGN ENGINEERS DATED JUNE 9, 2014 OVERLAYED ON USGS QUADRANGLE MAP CREATED WITH TOPO!® ©2001 NATIONAL GEOGRAPHIC (WWW.NATIONALGEOGRAPHIC.COM/TOPO).

SITE PLAN

PHASE I ROCKFALL POTENTIAL AND HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

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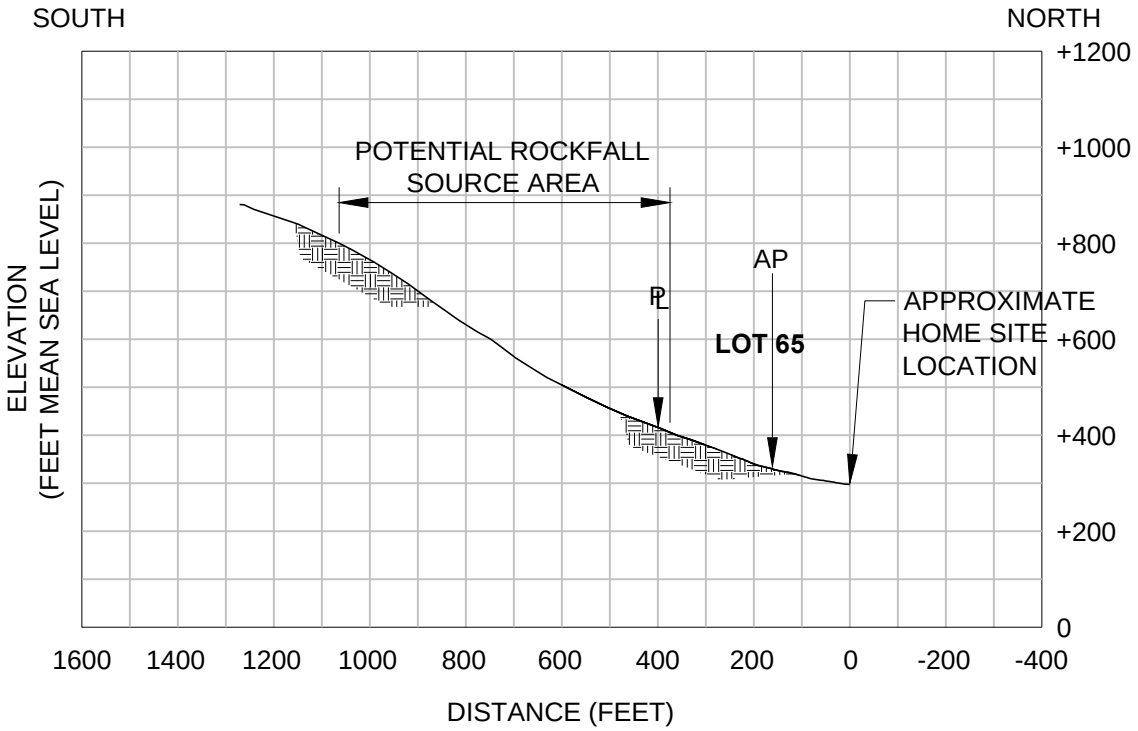
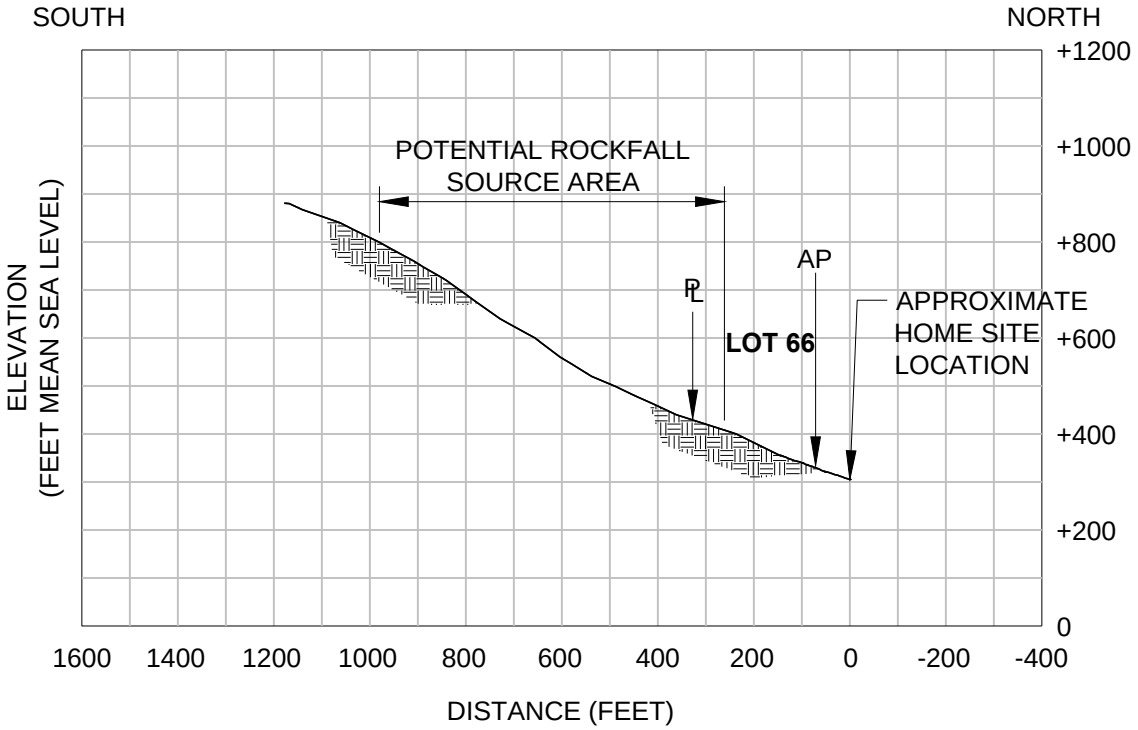


SLOPE PROFILE NO. 1 (LOT 65 HOME SITE)



SLOPE PROFILE NO. 2 (LOT 66 HOME SITE)

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

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Geotechnical Engineering

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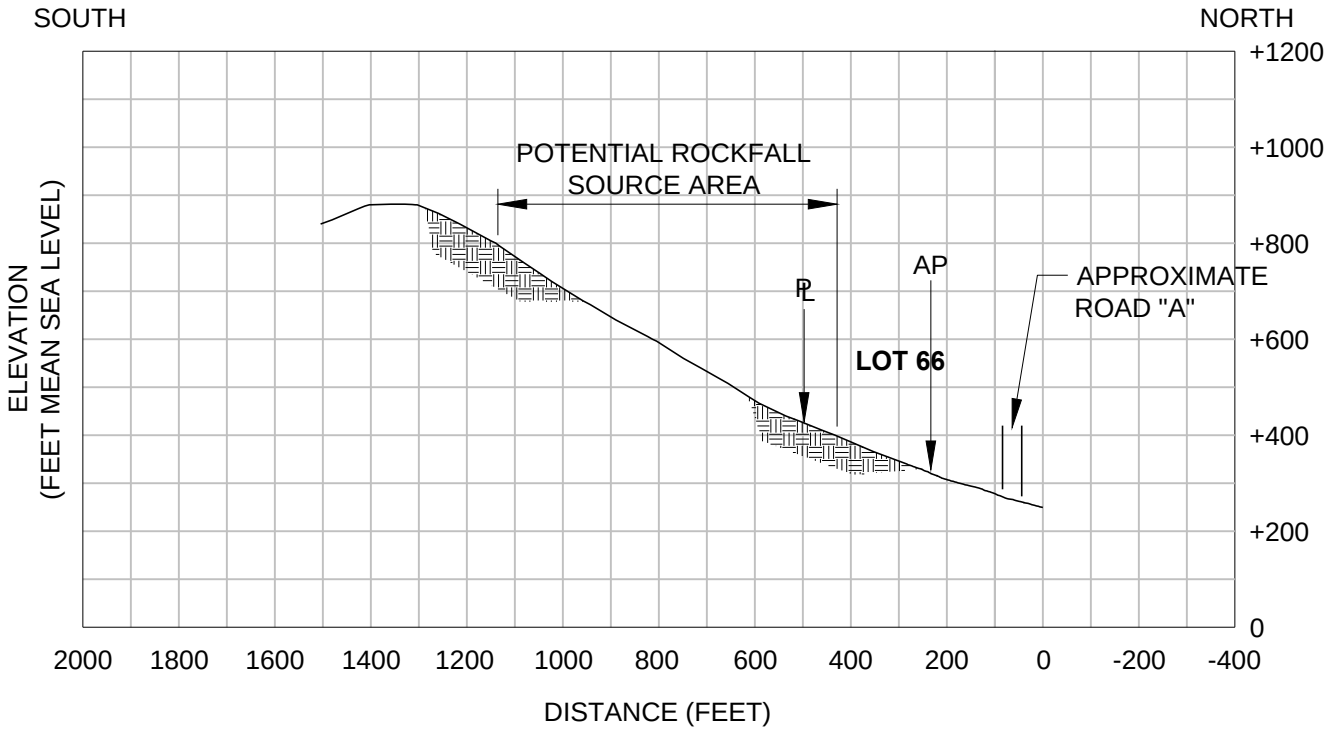

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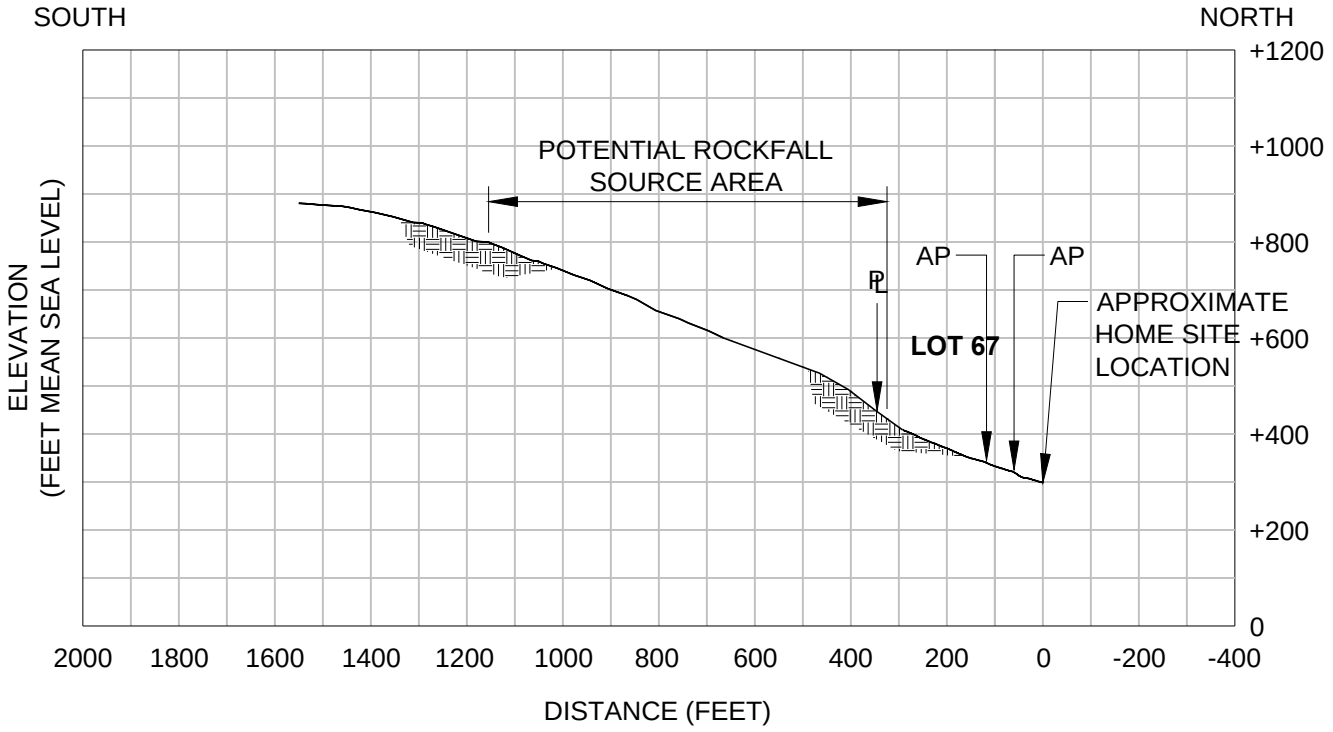

SLOPE PROFILE NO. 4 (LOT 67 HOME SITE)

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

GEOLABS, INC.
Geotechnical Engineering

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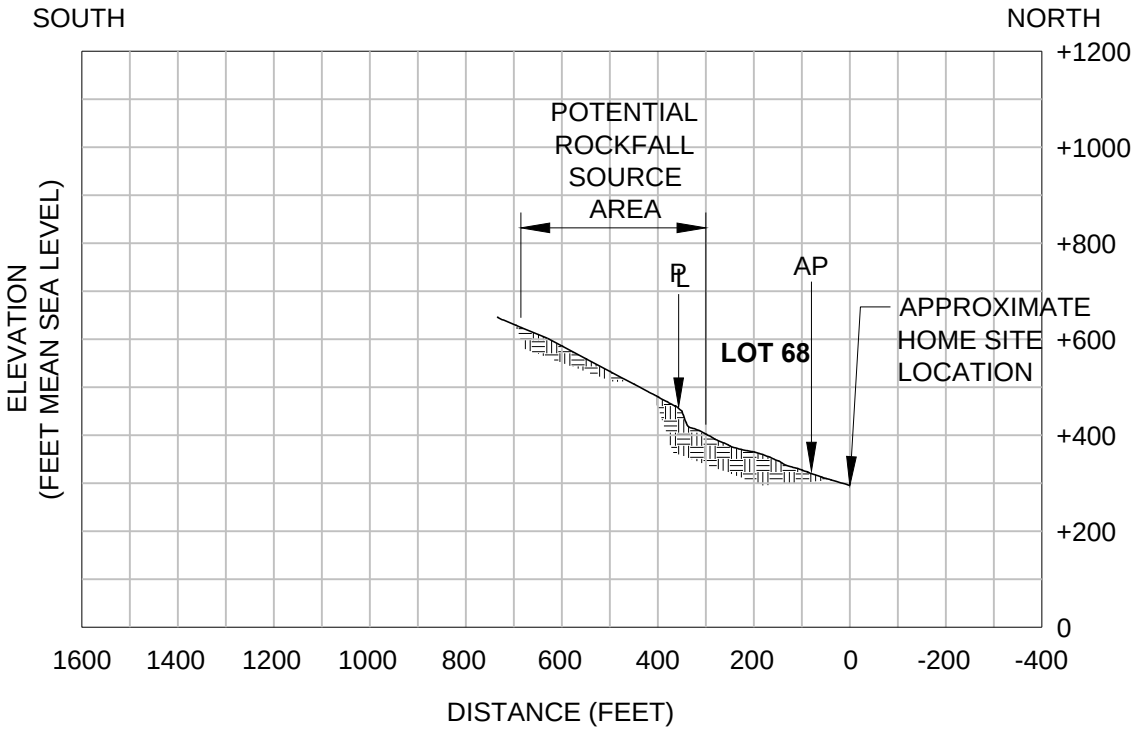
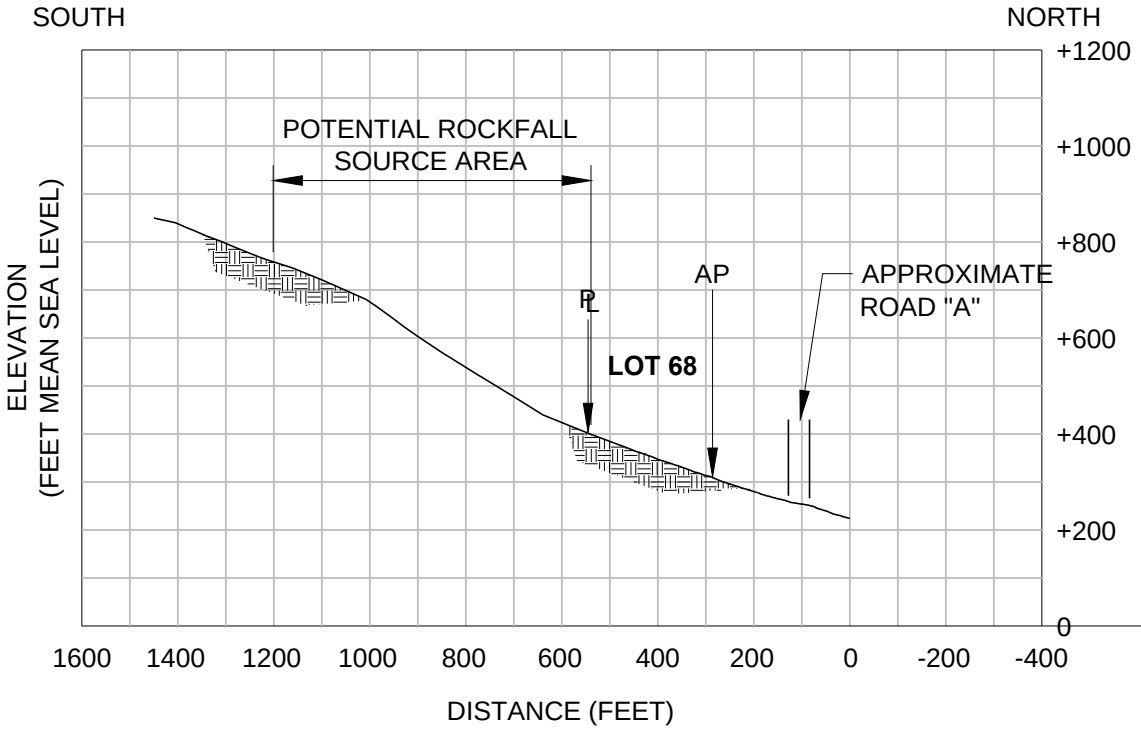


SLOPE PROFILE NO. 5 (LOT 68 HOME SITE)



SLOPE PROFILE NO. 6 (ROAD "A")

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

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Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.3
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:41:55pm Plot Date: August 06, 2014 - 11:44:22am
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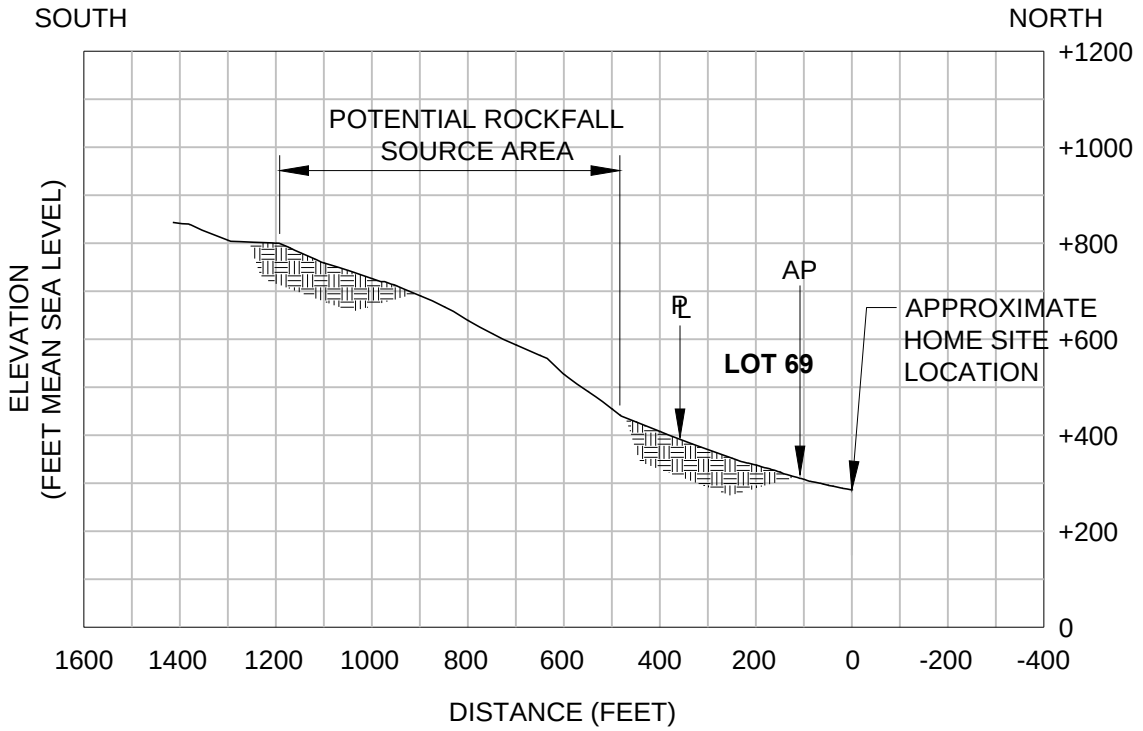
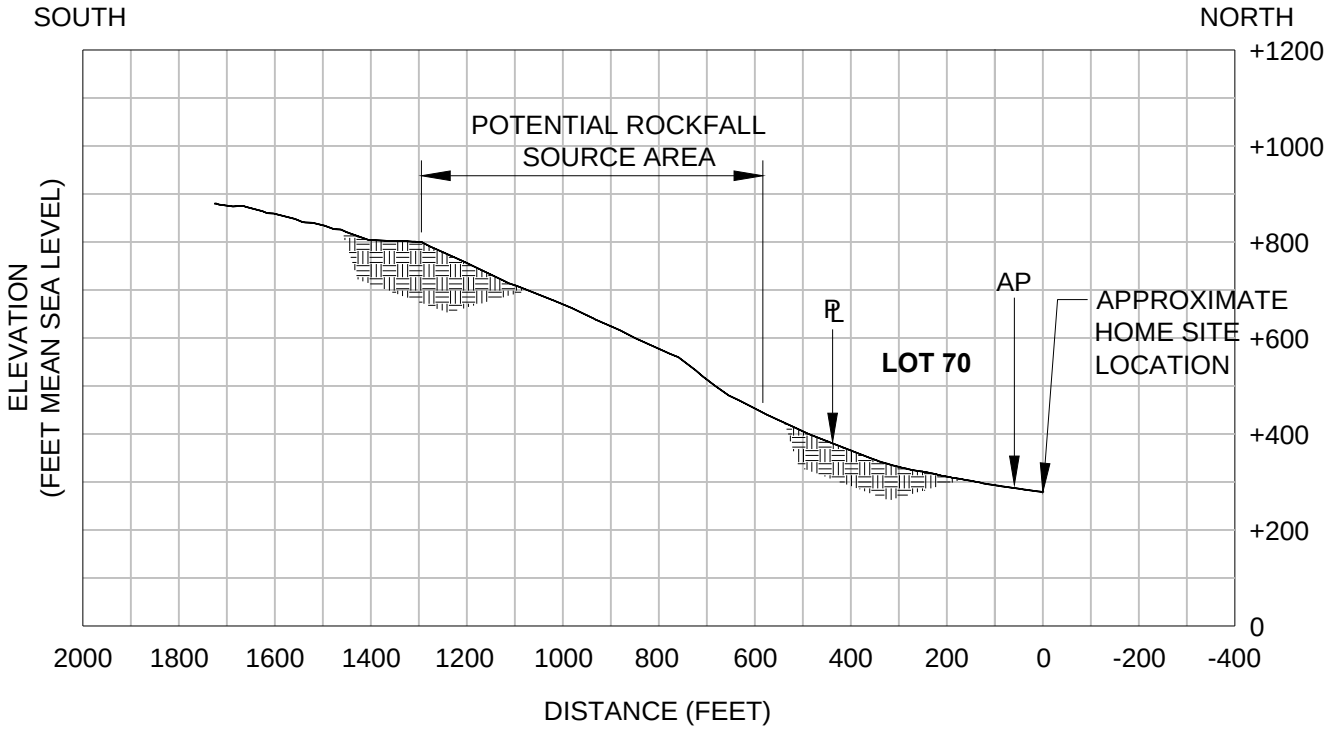


SLOPE PROFILE NO. 7 (LOT 69 HOME SITE)



SLOPE PROFILE NO. 8 (LOT 70 HOME SITE)

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

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DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.4
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:41:55pm Plot Date: August 06, 2014 - 11:44:44am
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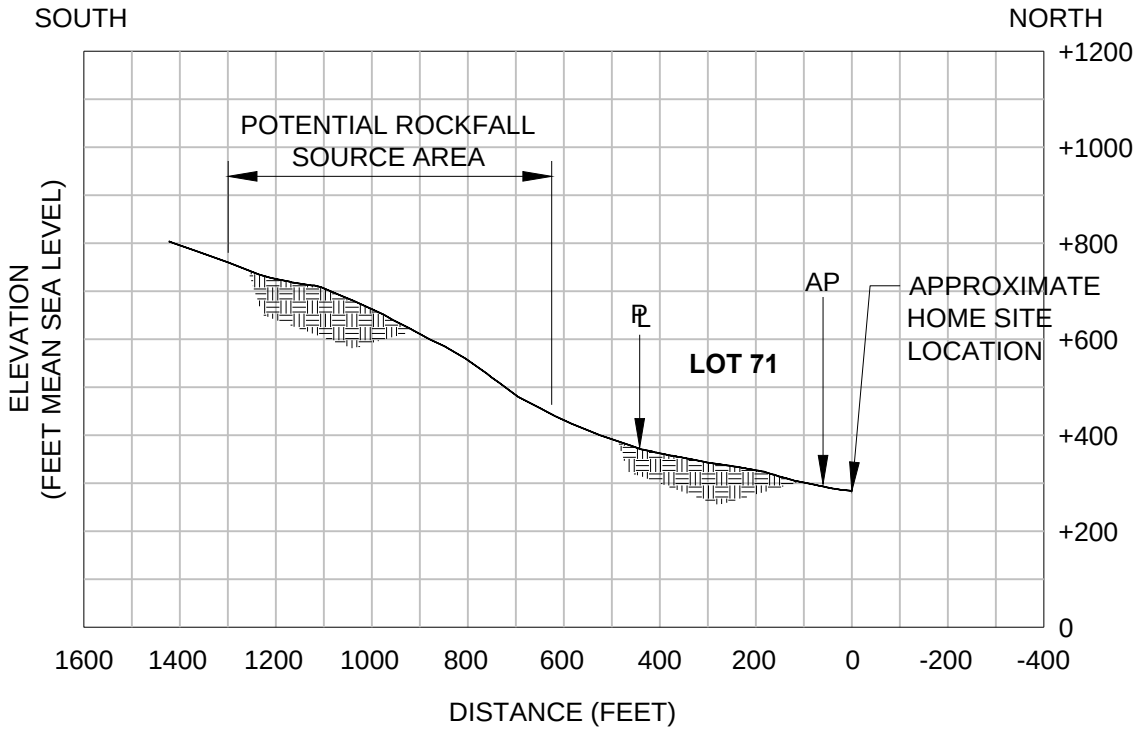
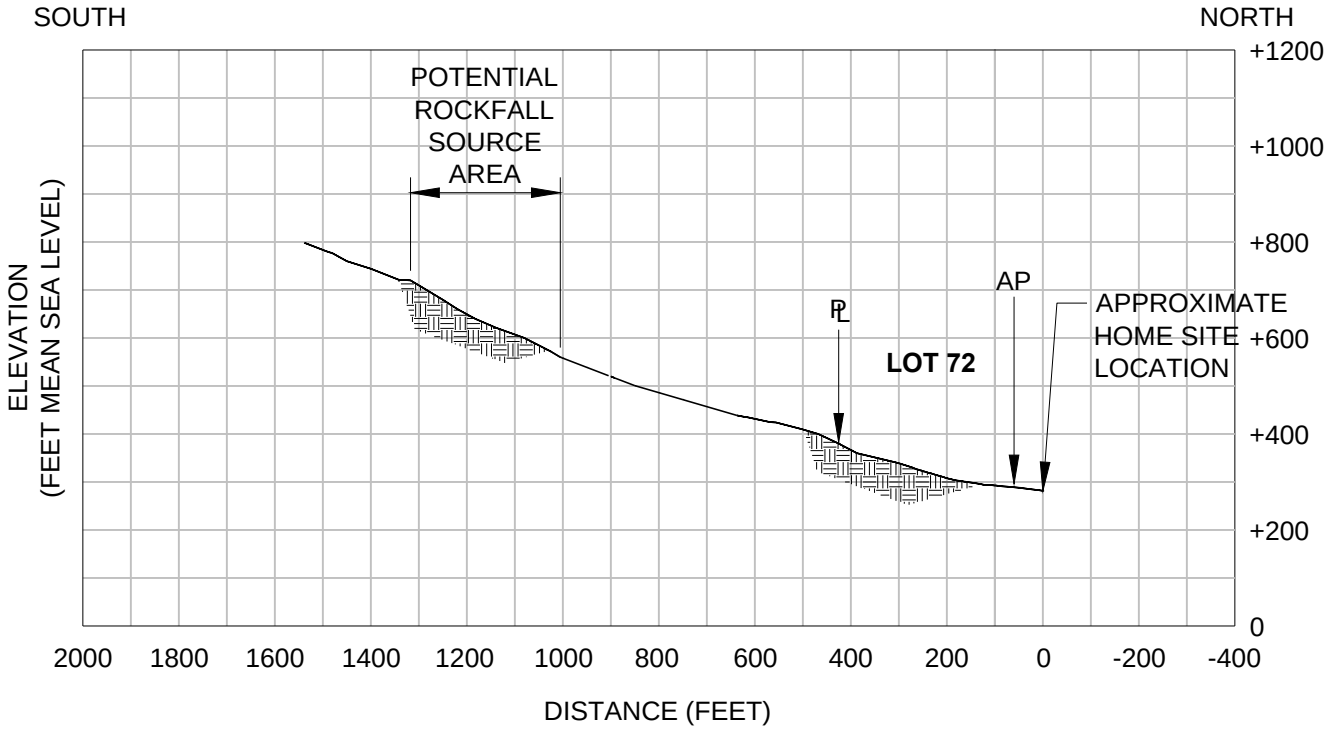


SLOPE PROFILE NO. 9 (LOT 71 HOME SITE)



SLOPE PROFILE NO. 10 (LOT 72 HOME SITE)

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

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Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.5
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:41:55pm Plot Date: August 06, 2014 - 11:44:57am
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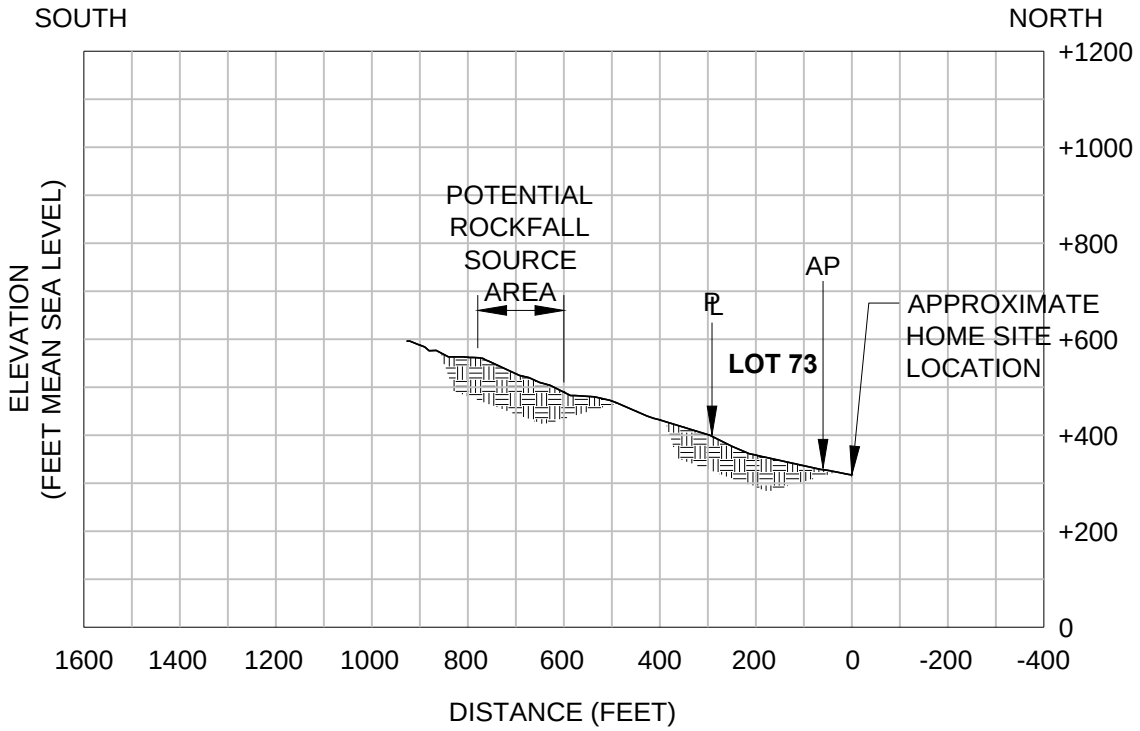
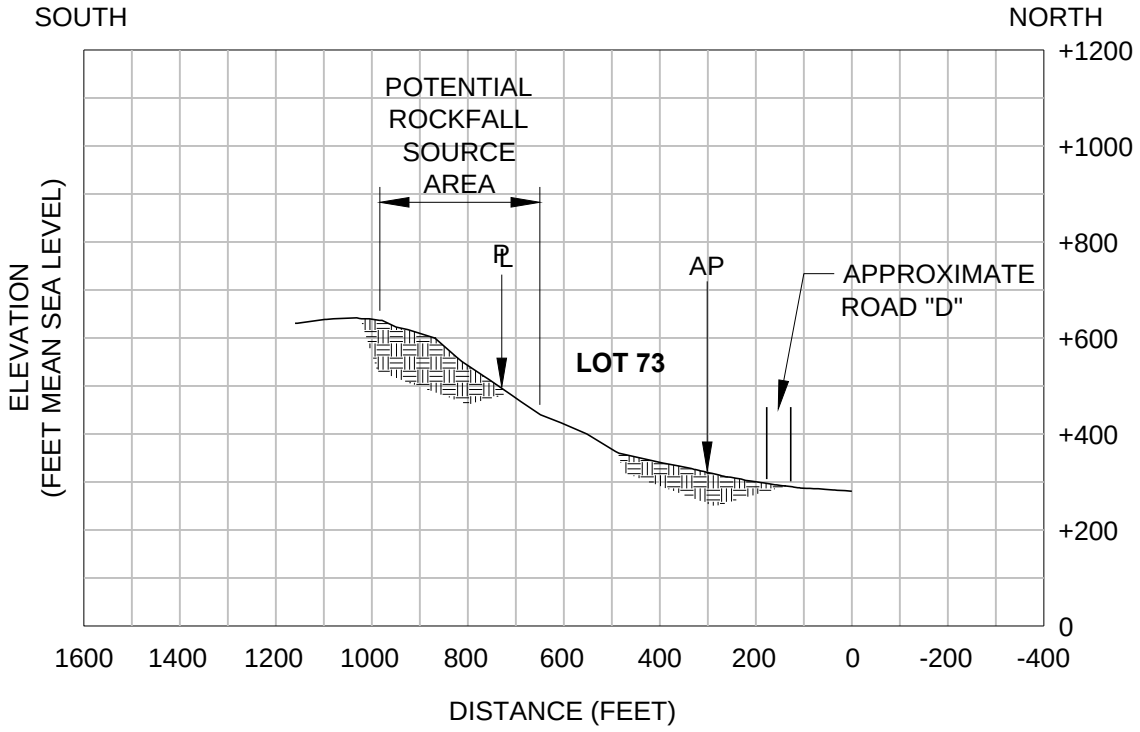


SLOPE PROFILE NO. 11 (LOT 73 HOME SITE)



SLOPE PROFILE NO. 12 (ROAD "D")

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

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DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.6
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:41:55pm Plot Date: August 06, 2014 - 11:45:10am
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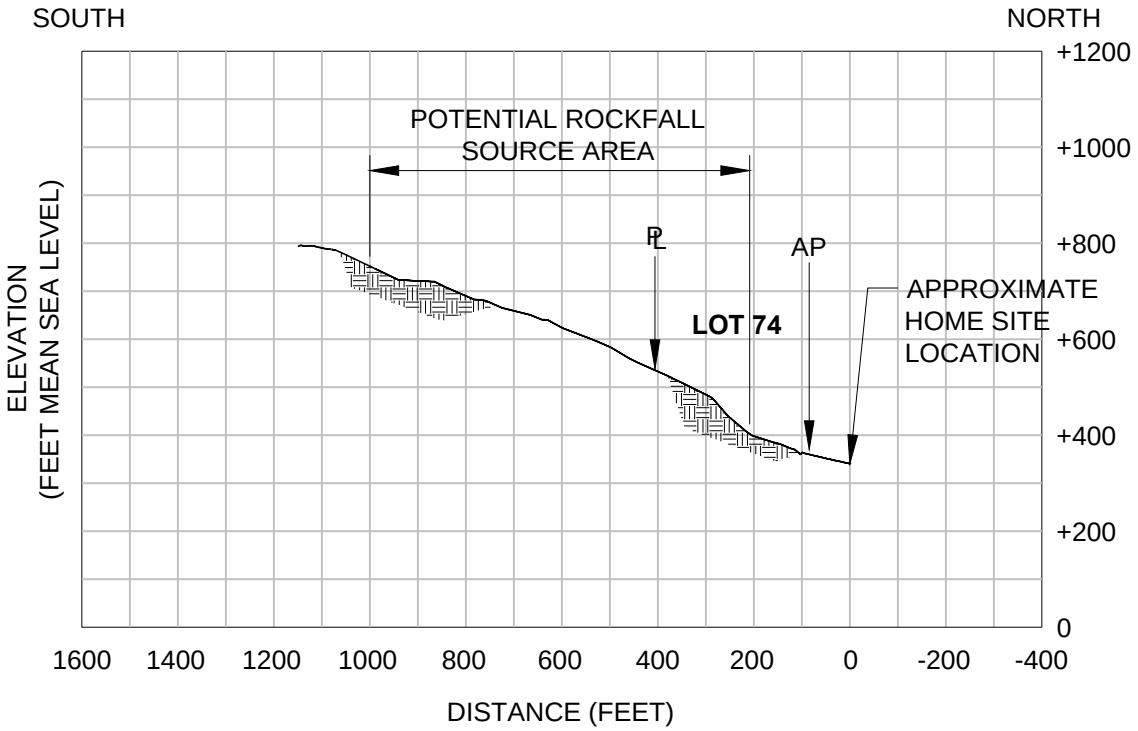
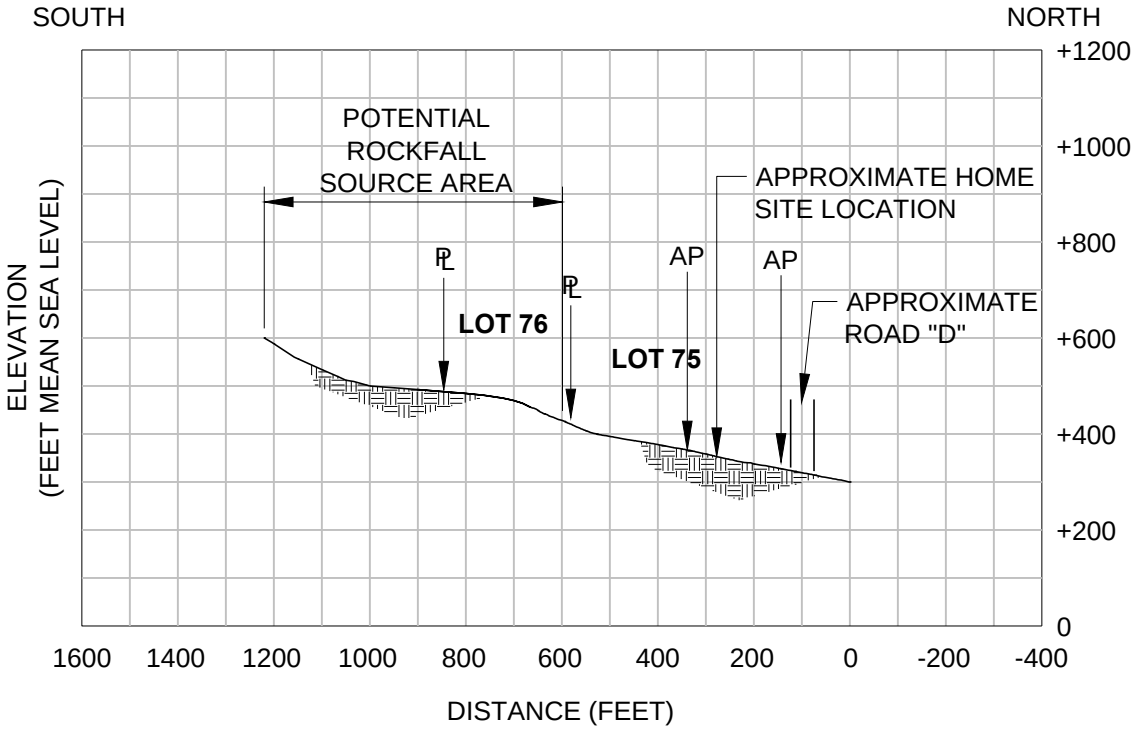


SLOPE PROFILE NO. 13 (LOT 74 HOME SITE)



SLOPE PROFILE NO. 14 (LOT 75 HOME SITE AND ROAD "D")

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

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Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.7
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:41:55pm Plot Date: August 06, 2014 - 11:45:22am
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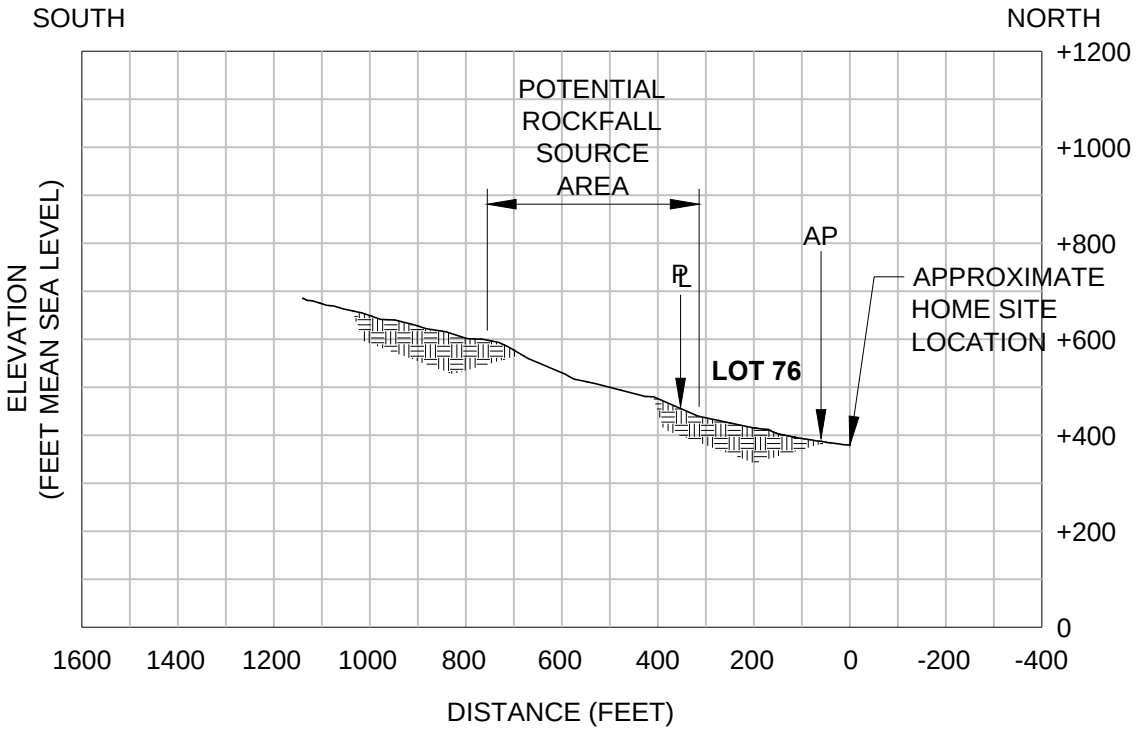
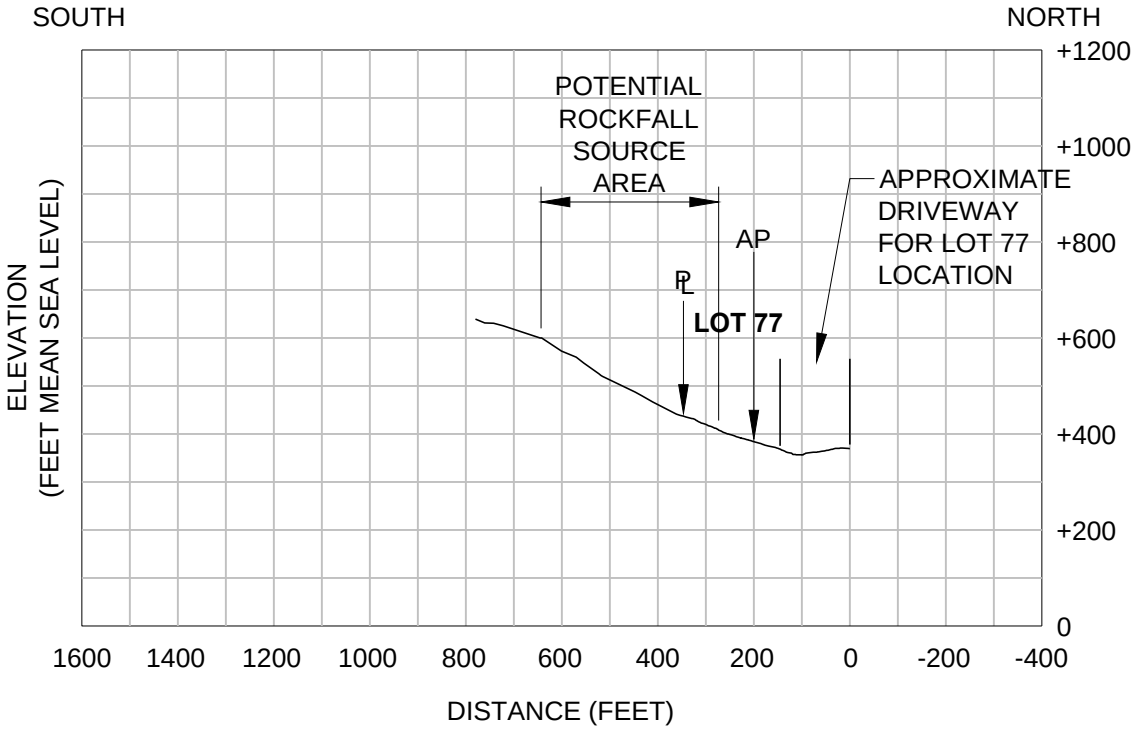


SLOPE PROFILE NO. 15 (LOT 76 HOME SITE)



SLOPE PROFILE NO. 16 (DRIVEWAY AT LOT 77)

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

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DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.8
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

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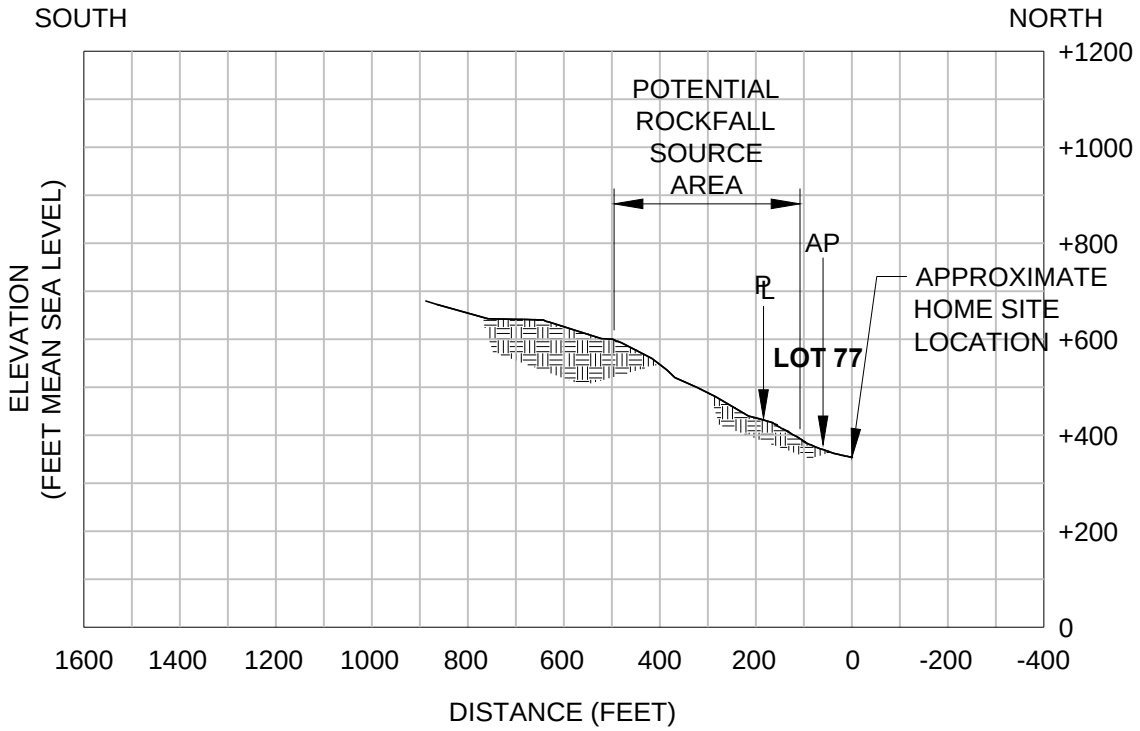
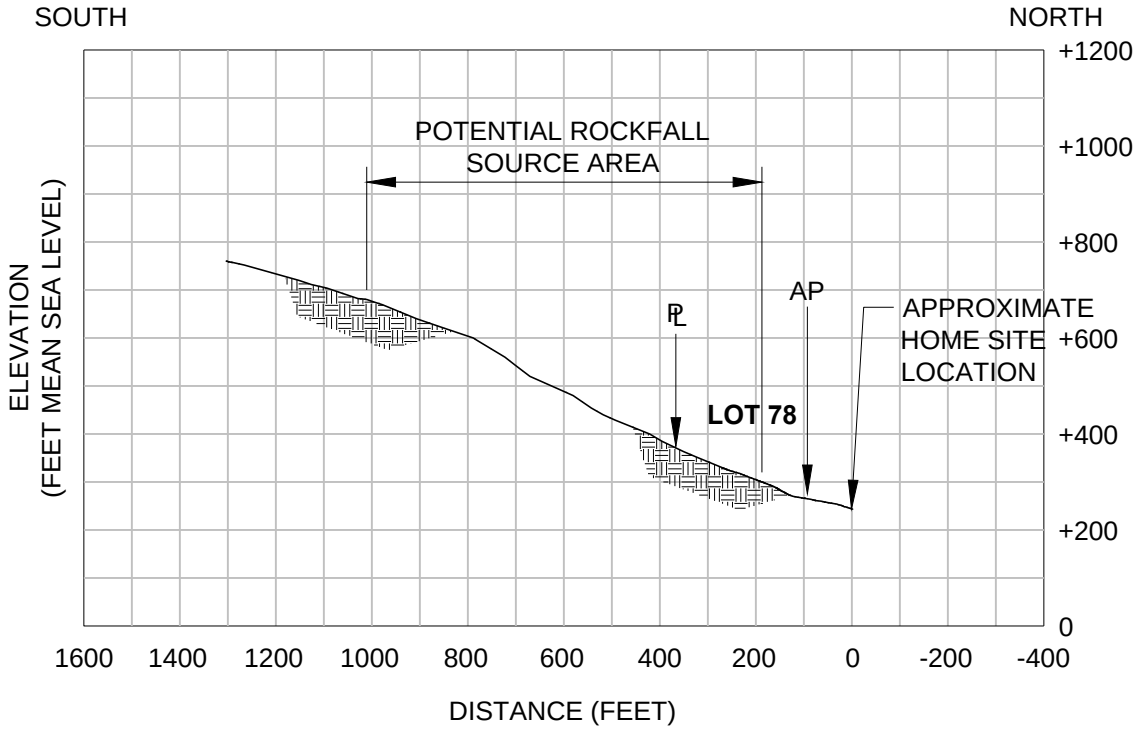


SLOPE PROFILE NO. 17 (LOT 77 HOME SITE)



SLOPE PROFILE NO. 18 (LOT 78 HOME SITE)

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.9
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:41:55pm Plot Date: August 06, 2014 - 11:45:47am
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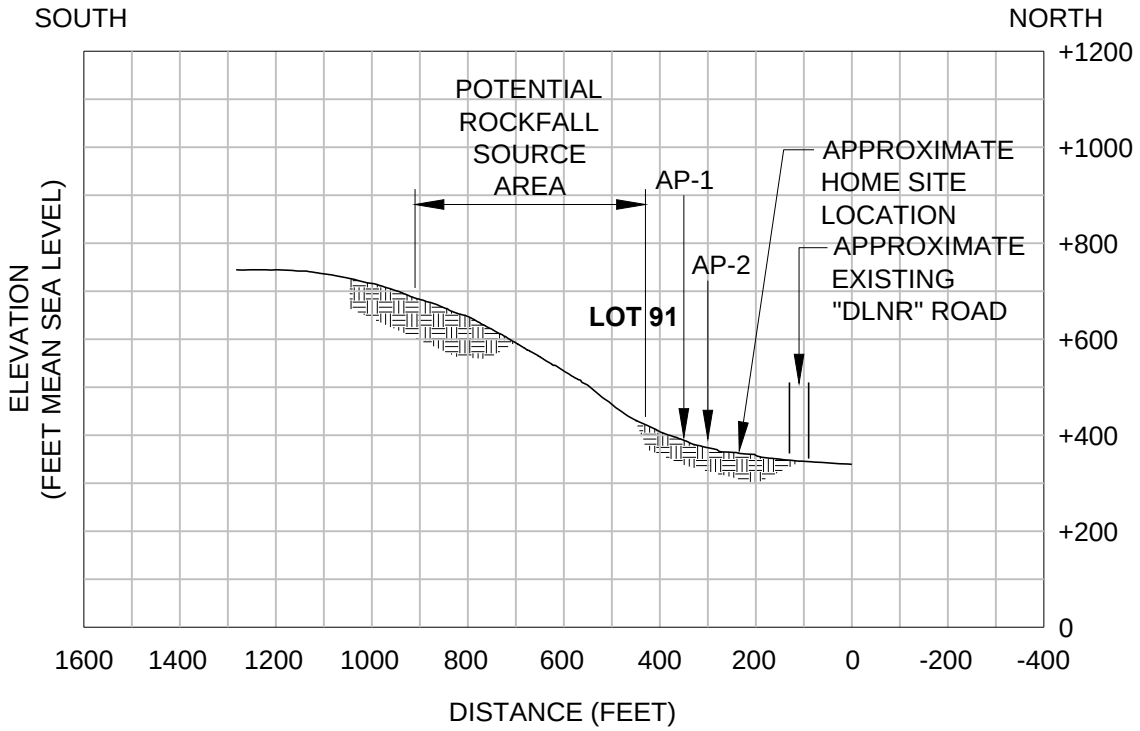
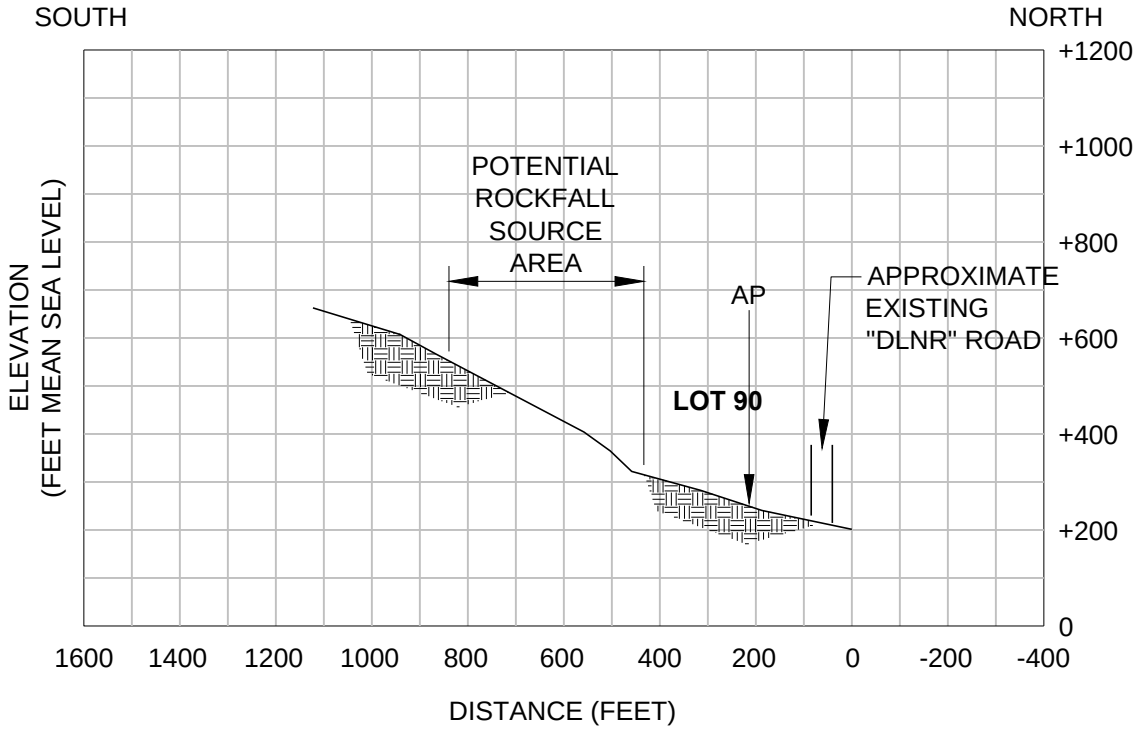


SLOPE PROFILE NO. 19 (LOT 91 HOME SITE)



SLOPE PROFILE NO. 20 (EXISTING "DLNR" ROAD)

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.10
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:41:55pm Plot Date: August 06, 2014 - 11:46:00am
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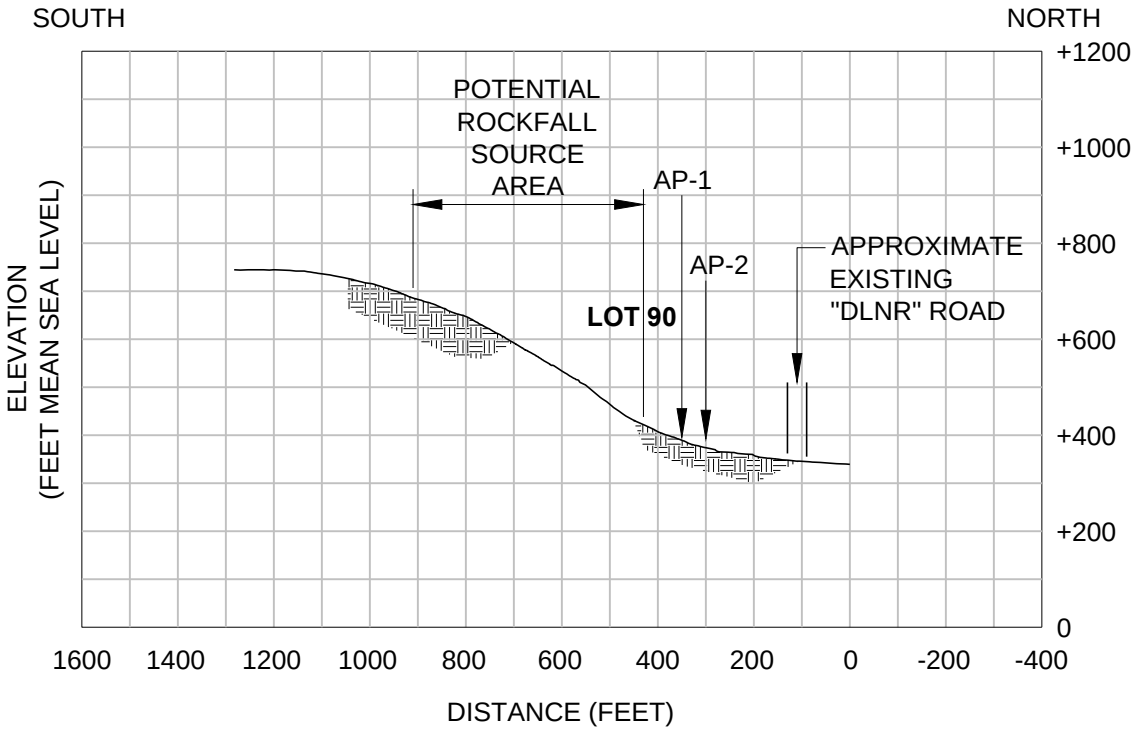
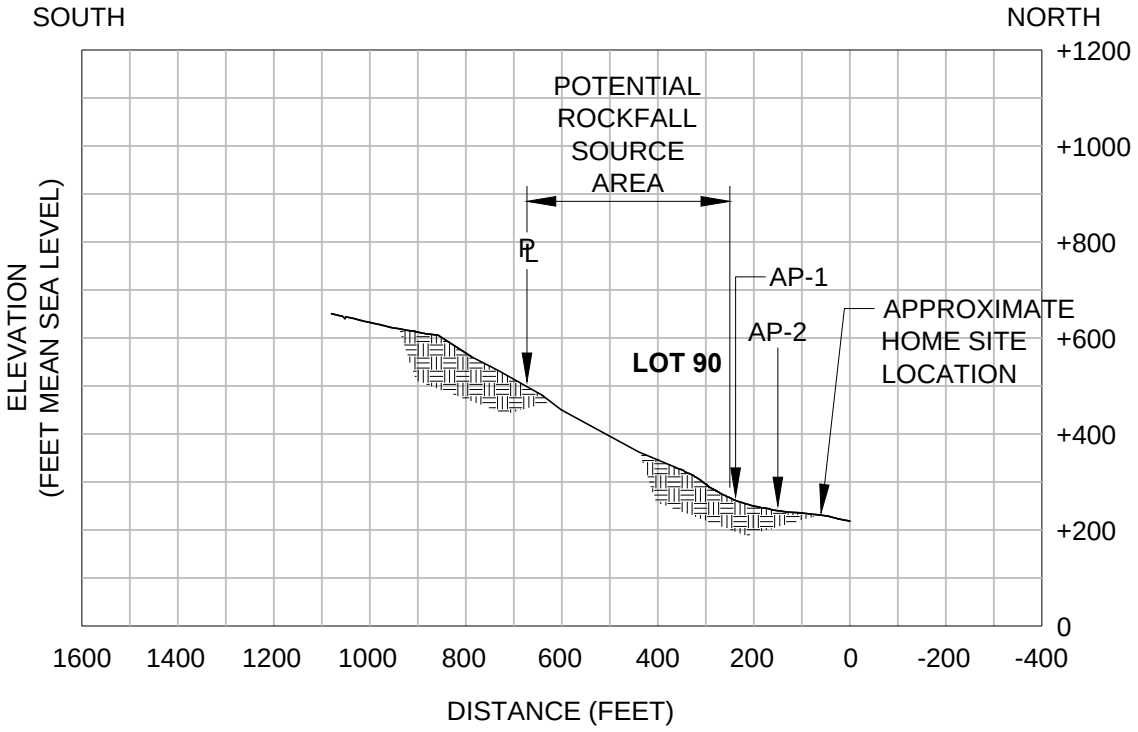


SLOPE PROFILE NO. 21 (EXISTING "DLNR" ROAD)



SLOPE PROFILE NO. 22 (LOT 90 HOME SITE)

SLOPE PROFILES

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

NOTE: "AP" DESIGNATES AN ANALYSIS POINT FOR ROCKFALL SIMULATION USING COLORADO ROCKFALL SIMULATION PROGRAM

REFERENCE: TOPOGRAPHIC INFORMATION FROM U.S.G.S. "KAENA" QUADRANGLE MAP BLENDED WITH AVAILABLE GROUND TOPOGRAPHIC SURVEY INFORMATION.

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	3.11
SCALE HORIZ. 1" = 400' VERT. 1" = 400'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:41:55pm Plot Date: August 06, 2014 - 11:46:13am
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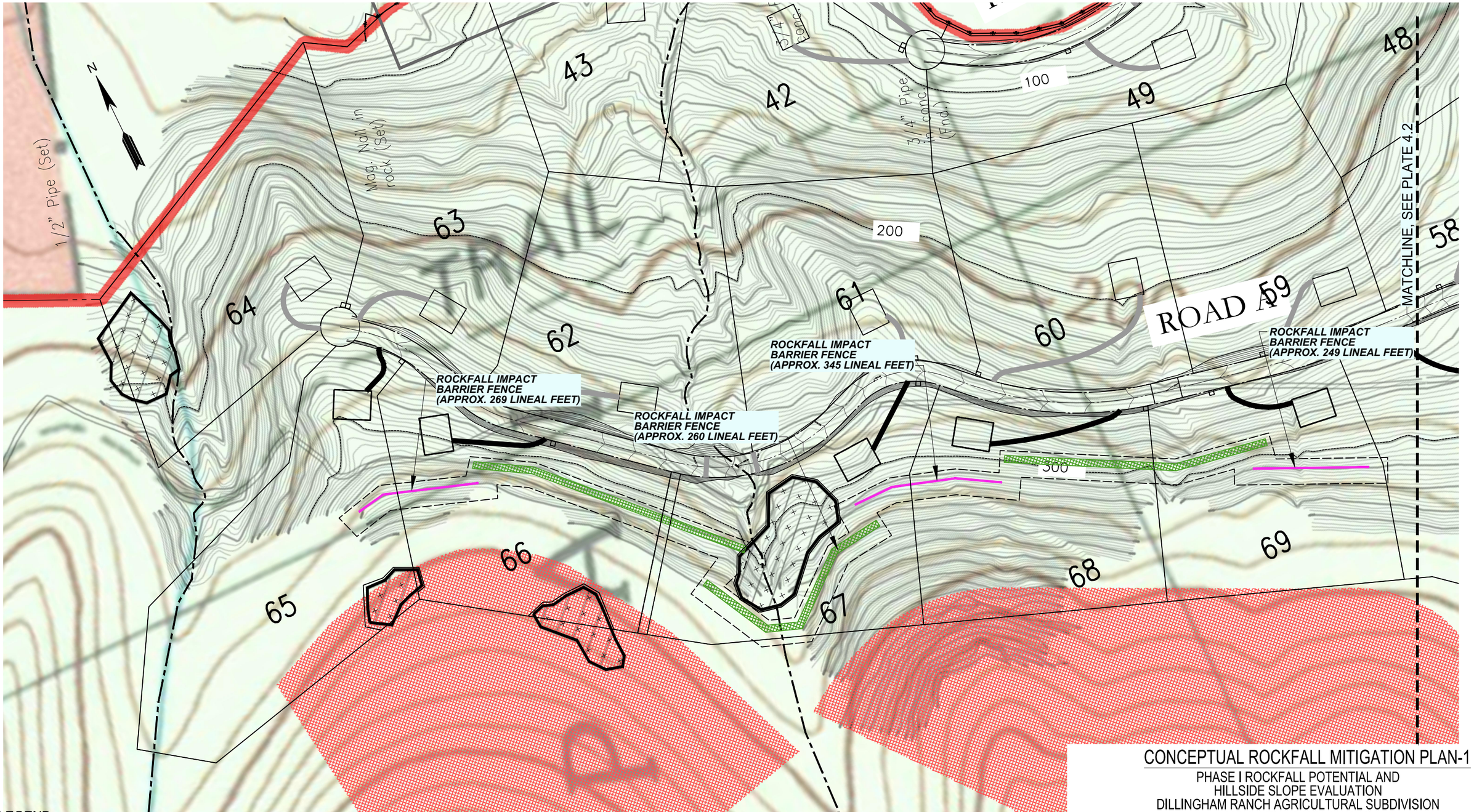


CONCEPTUAL ROCKFALL MITIGATION PLAN-1

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

LEGEND:

- APPROXIMATE LOCATION OF ROCKFALL SOURCE AREA WITH GREATER POTENTIAL TO ENCROACH ON SUBDIVISION
- PROPOSED APPROXIMATE ROCKFALL IMPACT BARRIER FENCE LOCATION
- PROPOSED APPROXIMATE DITCH LOCATION
- EXISTING ARCHAEOLOGICAL PRESERVATION FEATURE
- PROPOSED ACCESS AND MAINTENANCE EASEMENT FOR ROCKFALL INTERCEPTION STRUCTURES
- DESIGNATED HOME SITE AND ACCESS DRIVEWAY

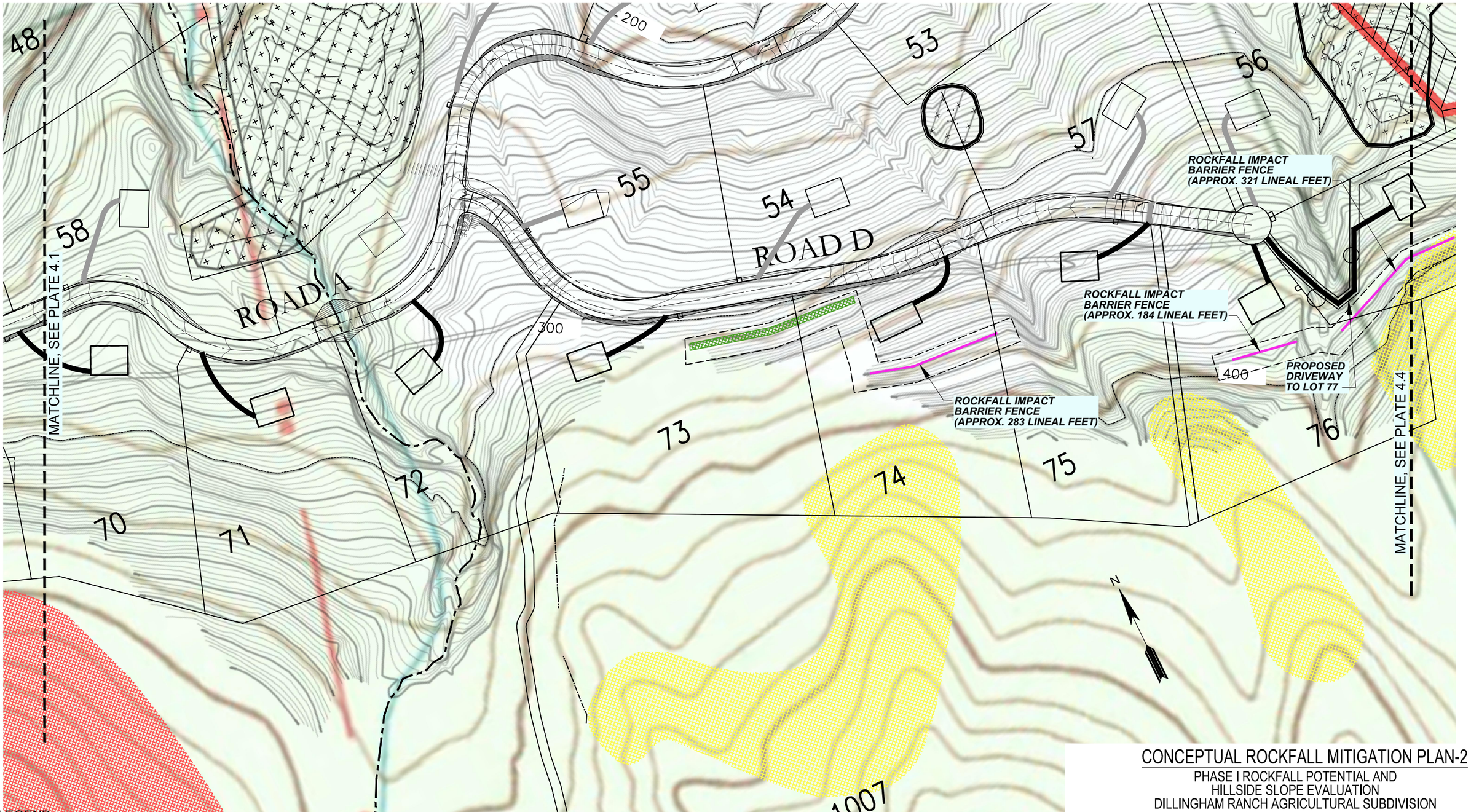
0 100 200 400 600 FT.
GRAPHIC SCALE

REFERENCE: SUBDIVISION PLOT PLAN RECEIVED FROM SHERWOOD DESIGN ENGINEERS ON JULY 23, 2014 OVERLAYED ON USGS QUADRANGLE MAP CREATED WITH TOPO!® ©2001 NATIONAL GEOGRAPHIC (WWW.NATIONALGEOGRAPHIC.COM/TOPO).

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	4.1
SCALE 1" = 200'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 05, 2014 9:44:10am Plot Date: August 06, 2014 - 11:40:57am
File: T:\Drafting-9904\Working\5721-80DillinghamRanch\MokuleiaDevelopment\5721-80ConceptualRockfallMitigationPlan.dwg\Plate-4.1
Plotter: GEO-DWG To PDF.pc3 Plotstyle: GEO-No-Dithering.ctb



CONCEPTUAL ROCKFALL MITIGATION PLAN-2

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

LEGEND:

- APPROXIMATE LOCATION OF ROCKFALL SOURCE AREA WITH GREATER POTENTIAL TO ENCROACH ON SUBDIVISION
- PROPOSED APPROXIMATE ROCKFALL IMPACT BARRIER FENCE LOCATION
- APPROXIMATE LOCATION OF ROCKFALL SOURCE AREA WITH LESSER POTENTIAL TO ENCROACH ON SUBDIVISION
- EXISTING ARCHAEOLOGICAL PRESERVATION FEATURE
- PROPOSED APPROXIMATE DITCH LOCATION
- DESIGNATED HOME SITE AND ACCESS DRIVEWAY
- PROPOSED ACCESS AND MAINTENANCE EASEMENT FOR ROCKFALL INTERCEPTION STRUCTURES

0 100 200 400 600 FT.
GRAPHIC SCALE

REFERENCE: SUBDIVISION PLOT PLAN RECEIVED FROM SHERWOOD DESIGN ENGINEERS ON JULY 23, 2014 OVERLAYED ON USGS QUADRANGLE MAP CREATED WITH TOPO!® ©2001 NATIONAL GEOGRAPHIC (WWW.NATIONALGEOGRAPHIC.COM/TOPO).

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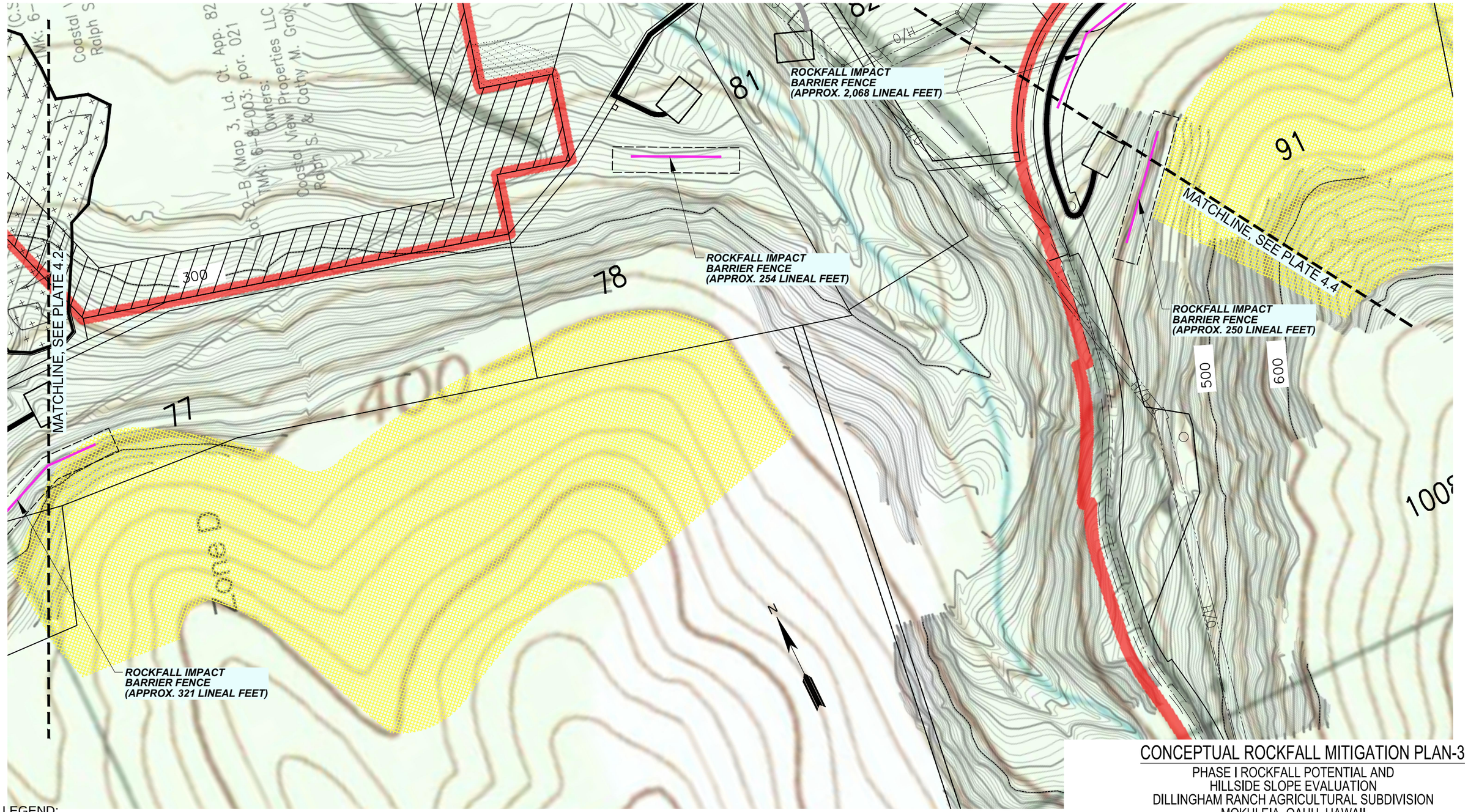
DATE	DRAWN BY	PLATE
JULY 2014	JRP	4.2
SCALE 1" = 200'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 05, 2014 9:44:10am Plot Date: August 06, 2014 - 11:41:19am
File: T:\Drafting-9904\Working\5721-80DillinghamRanch\MokuleiaDevelopment\5721-80ConceptualRockfallMitigationPlan.dwg\Plate-4.2
Plotter: GEO-DWG To PDF.pc3 Plotstyle: GEO-No-Dithering.ctb



CONCEPTUAL ROCKFALL MITIGATION PLAN-3

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

LEGEND:

- APPROXIMATE LOCATION OF ROCKFALL SOURCE AREA WITH LESSER POTENTIAL TO ENCROACH ON SUBDIVISION
- PROPOSED APPROXIMATE ROCKFALL IMPACT BARRIER FENCE LOCATION
- PROPOSED ACCESS AND MAINTENANCE EASEMENT FOR ROCKFALL INTERCEPTION STRUCTURES
- EXISTING ARCHAEOLOGICAL PRESERVATION FEATURE
- DESIGNATED HOME SITE AND ACCESS DRIVEWAY

0 100 200 400 600 FT.
GRAPHIC SCALE

REFERENCE: SUBDIVISION PLOT PLAN RECEIVED FROM SHERWOOD DESIGN ENGINEERS ON JULY 23, 2014 OVERLAYED ON USGS QUADRANGLE MAP CREATED WITH TOPO!® ©2001 NATIONAL GEOGRAPHIC (WWW.NATIONALGEOGRAPHIC.COM/TOPO).

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	4.3
SCALE 1" = 200'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 05, 2014 9:44:10am Plot Date: August 06, 2014 - 11:41:38am
File: T:\Drafting-9904\Working\5721-80DillinghamRanchMokuleiaDevelopment\5721-80ConceptualRockfallMitigationPlan.dwg\Plate-4.3
Plotter: GEO-DWG to PDF.pc3 Plotstyle: GEO-No-Dithering.ctb

ROAD C

200

85

84

83

300

90

400

91

500

600

700

300

700

ROCKFALL IMPACT BARRIER FENCE (APPROX. 2,068 LINEAL FEET)

ROCKFALL IMPACT BARRIER FENCE (APPROX. 345 LINEAL FEET)

1/2" Pipe (Set)

MATCHLINE, SEE PLATE 4.3

ROCKFALL IMPACT BARRIER FENCE (APPROX. 250 LINEAL FEET)

N

LEGEND:

- APPROXIMATE LOCATION OF ROCKFALL SOURCE AREA WITH LESSER POTENTIAL TO ENCROACH ON SUBDIVISION
- PROPOSED APPROXIMATE ROCKFALL IMPACT BARRIER FENCE LOCATION
- PROPOSED APPROXIMATE DITCH LOCATION
- DESIGNATED HOME SITE AND ACCESS DRIVEWAY
- PROPOSED ACCESS AND MAINTENANCE EASEMENT FOR ROCKFALL INTERCEPTION STRUCTURES

0 100 200 400 600 FT.

GRAPHIC SCALE

REFERENCE: SUBDIVISION PLOT PLAN RECEIVED FROM SHERWOOD DESIGN ENGINEERS ON JULY 23, 2014 OVERLAYED ON USGS QUADRANGLE MAP CREATED WITH TOPO!® ©2001 NATIONAL GEOGRAPHIC (WWW.NATIONALGEOGRAPHIC.COM/TOPO).

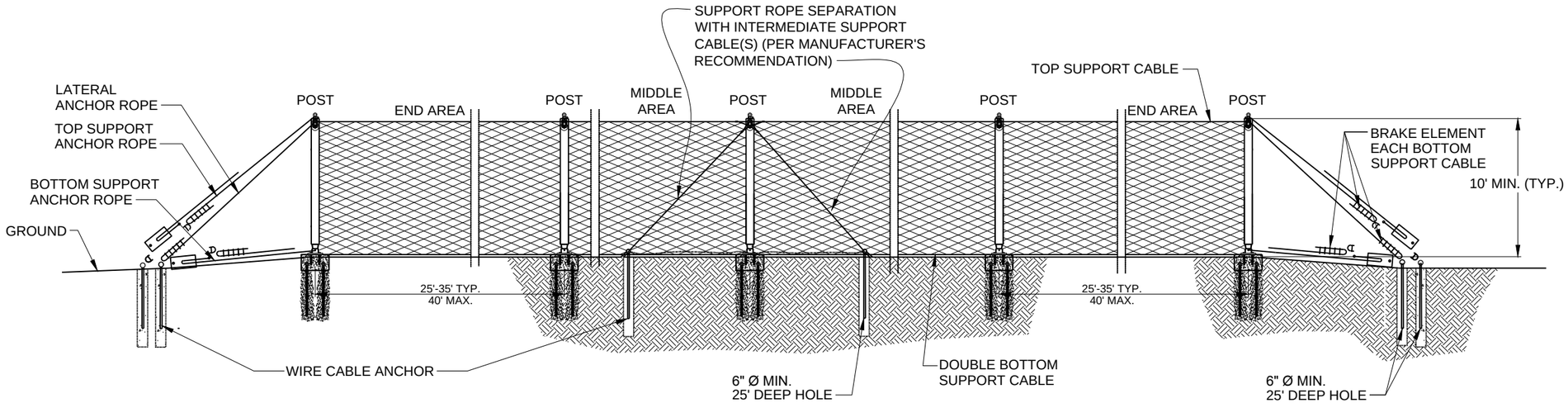
CONCEPTUAL ROCKFALL MITIGATION PLAN-4

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	4.4
SCALE 1" = 200'	W.O. 5721-80	

CAD User: JJP File Last Updated: August 05, 2014 9:44:10am Plot Date: August 06, 2014 - 11:41:56am
File: T:\Drafting-9904\Working\5721-80DillinghamRanch\MokuleiaDevelopment\5721-80ConceptualRockfallMitigationPlan.dwg\Plate-4.4
Plotter: GEO-DWG To PDF.pc3 Plotstyle: GEO-No-Dithering.ctb



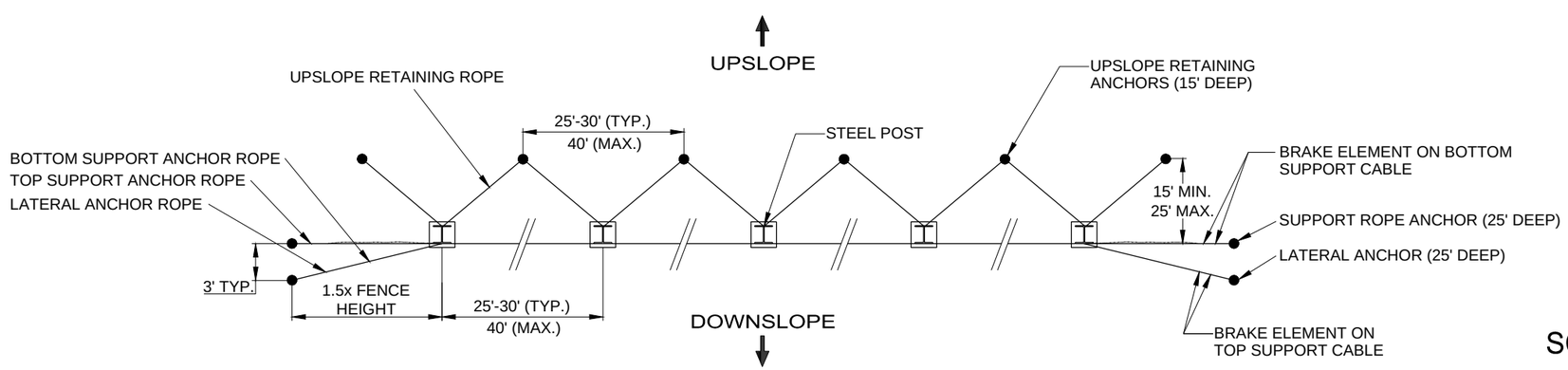
NOTES:

1. ROCKFALL IMPACT BARRIER ELEMENTS INCLUDING ALL HARDWARE FOR BARRIER SHALL BE POWDER COATED BLACK.

2. THIS DRAWING IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY. CONTRACTOR MUST REFER TO ROCKFALL IMPACT BARRIER MANUFACTURER'S DESIGN DETAILS AND APPROVED SHOP DRAWINGS FOR APPLICABLE DIMENSIONS AND MATERIAL SPECIFICATIONS.

TYPICAL MEDIUM-HIGH CAPACITY ROCKFALL IMPACT BARRIER

NOT TO SCALE



TYPICAL LAYOUT OF MEDIUM-HIGH CAPACITY ROCKFALL IMPACT BARRIER POSTS AND ANCHOR POINTS

NOT TO SCALE

SCHEMATIC DETAIL FOR TYPICAL MEDIUM-HIGH CAPACITY ROCKFALL IMPACT BARRIER

PHASE I ROCKFALL POTENTIAL AND HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	5.1
SCALE: NOT TO SCALE	W.O.: 5721-80	

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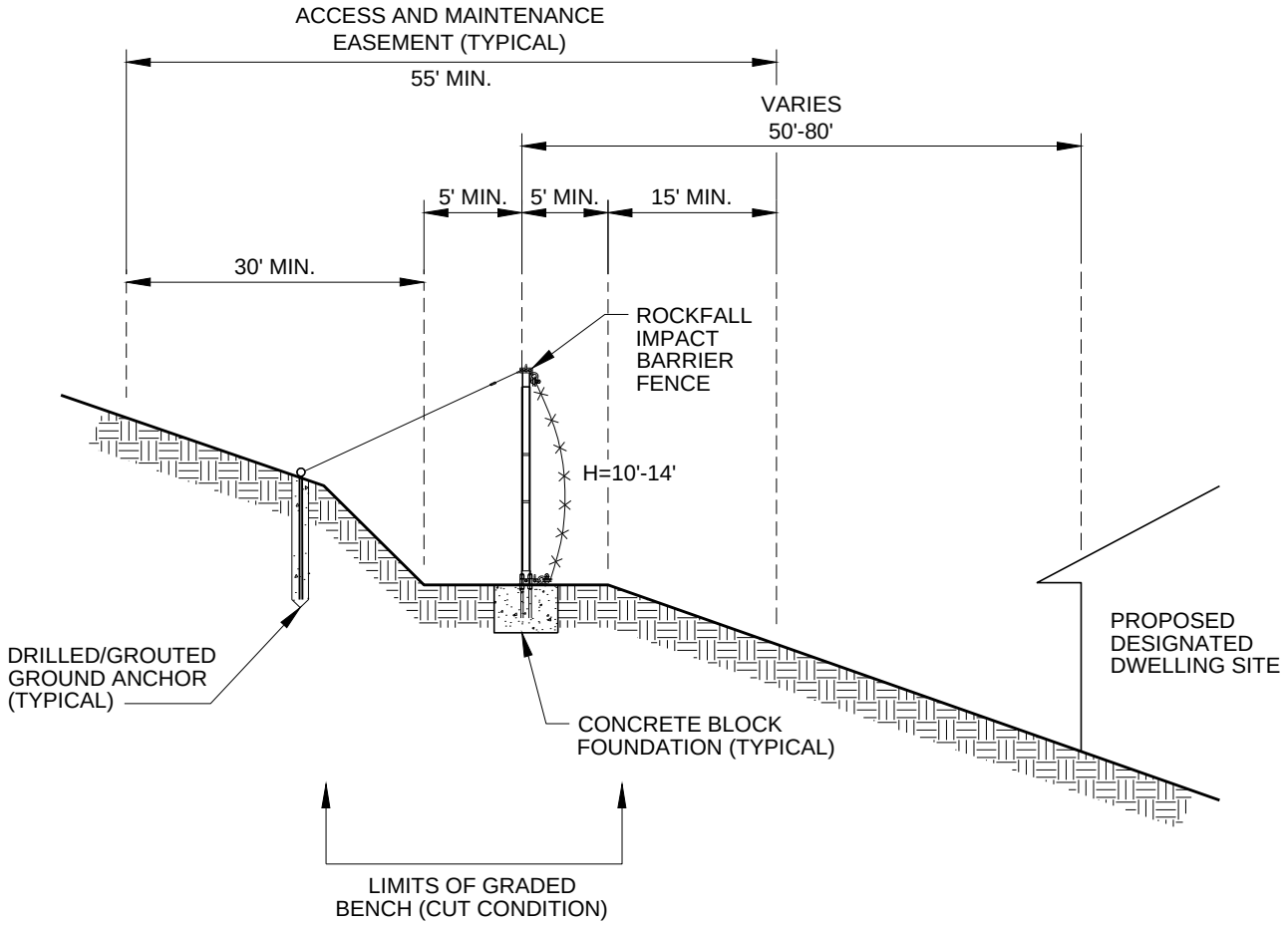

HOME SITE PROTECTION
BY ROCKFALL IMPACT BARRIER FENCE
(LOT NOS. 65-69, 74, 76-78, 90, AND 91)

TYPICAL SECTION: MEDIUM-HIGH CAPACITY ROCKFALL IMPACT BARRIER

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
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SCALE	W.O.	
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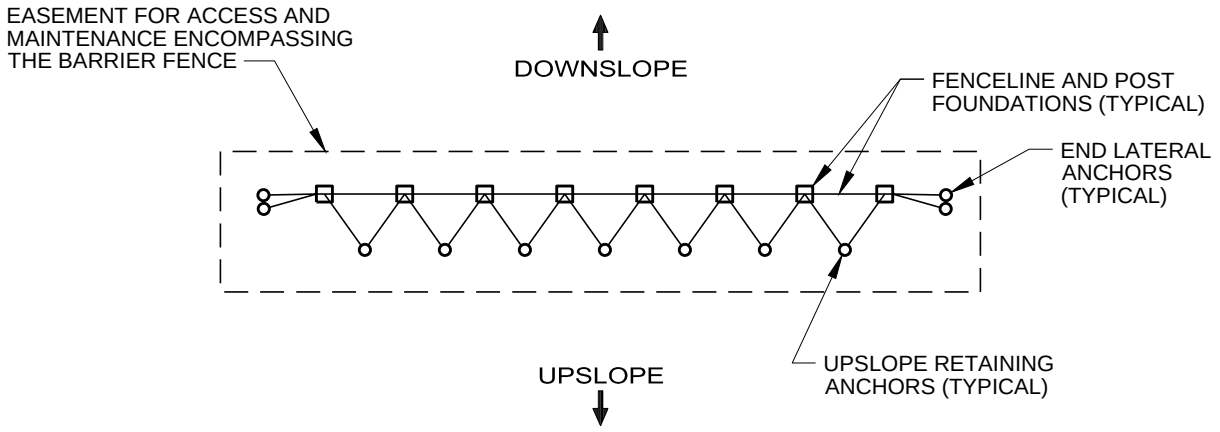
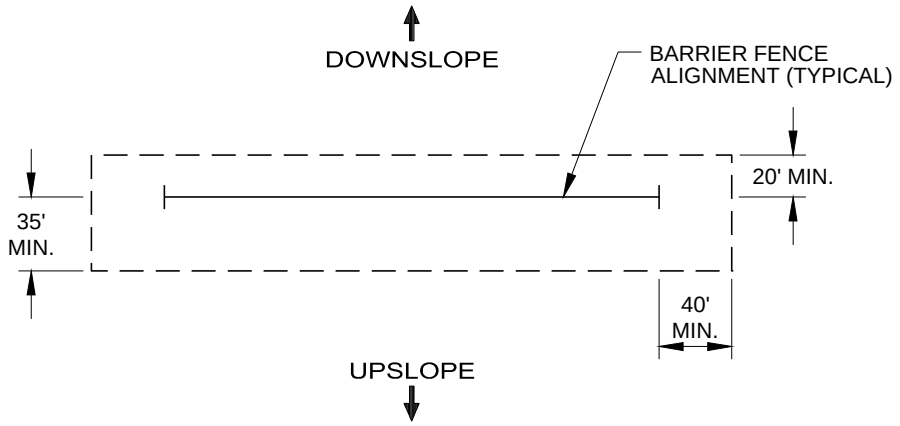


TYPICAL ROCKFALL IMPACT BARRIER AND EASEMENT LAYOUT - PLAN VIEW



MINIMUM DIMENSION OF ACCESS AND MAINTENANCE EASEMENT ENCOMPASSING ROCKFALL IMPACT BARRIER - PLAN VIEW

TYPICAL LAYOUT FOR MEDIUM-HIGH CAPACITY ROCKFALL IMPACT BARRIER

PHASE I ROCKFALL POTENTIAL AND HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

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Geotechnical Engineering

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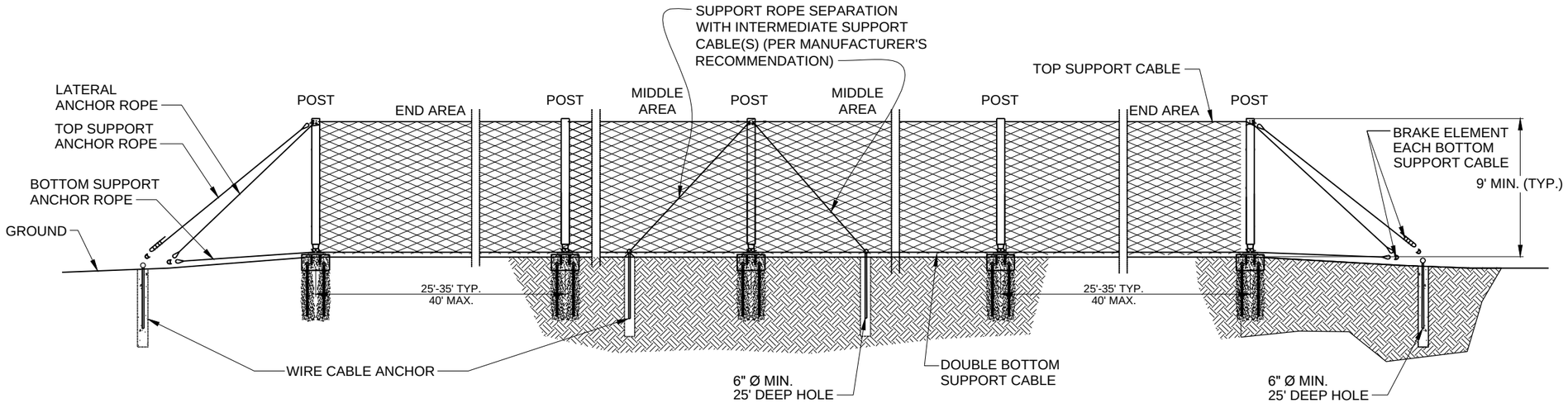


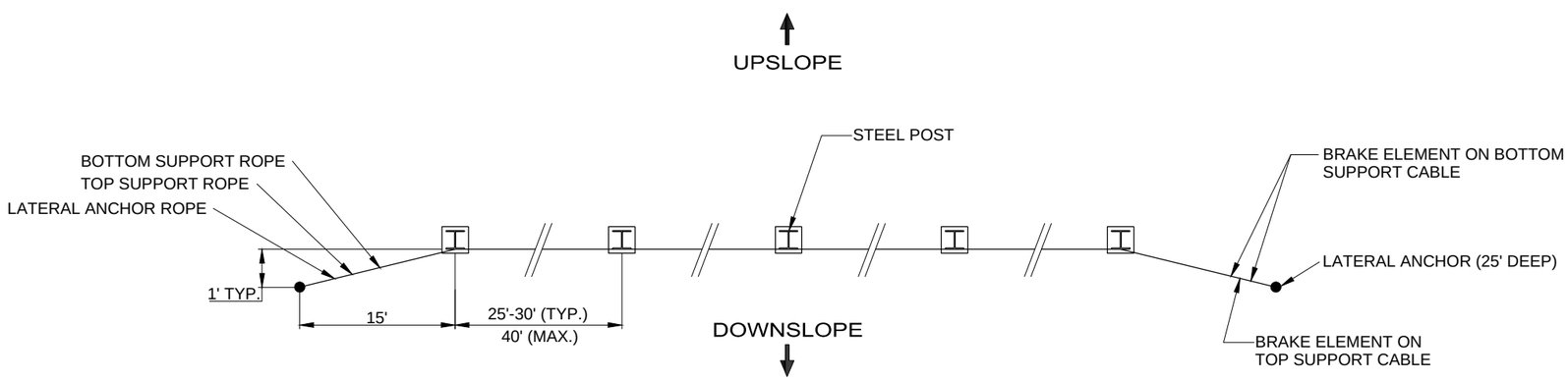
NOTES:

1. ROCKFALL IMPACT BARRIER ELEMENTS INCLUDING ALL HARDWARE FOR BARRIER SHALL BE POWDER COATED BLACK.

2. THIS DRAWING IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY. CONTRACTOR MUST REFER TO ROCKFALL IMPACT BARRIER MANUFACTURER'S DESIGN DETAILS AND APPROVED SHOP DRAWINGS FOR APPLICABLE DIMENSIONS AND MATERIAL SPECIFICATIONS.

TYPICAL LOW CAPACITY ROCKFALL IMPACT BARRIER

NOT TO SCALE



TYPICAL LAYOUT OF LOW CAPACITY ROCKFALL IMPACT BARRIER POSTS AND ANCHOR POINTS

NOT TO SCALE

SCHEMATIC DETAIL FOR TYPICAL LOW CAPACITY ROCKFALL IMPACT BARRIER

PHASE I ROCKFALL POTENTIAL AND HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

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DATE	DRAWN BY	PLATE
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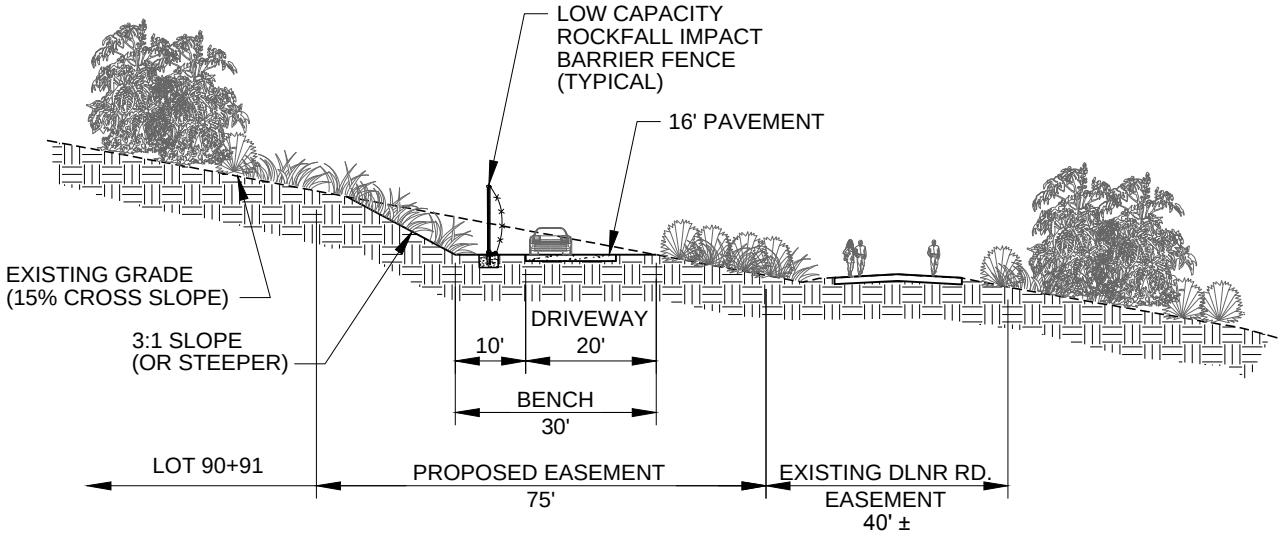

NOTE:
PROPOSED EASEMENT SERVES DRIVEWAY, ROCKFALL IMPACT BARRIER, WELL ACCESS, AND CATTLE MOVEMENT

LOW CAPACITY ROCKFALL IMPACT BARRIER
LOT NO. 91 DRIVEWAY AND EXISTING DLNR ROADWAY

TYPICAL LAYOUT FOR LOW CAPACITY ROCKFALL IMPACT BARRIER

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	6.2
SCALE	W.O.	
NOT TO SCALE	5721-80	

CAD User: JJP File Last Updated: August 04, 2014 2:43:11pm Plot Date: August 06, 2014 - 11:52:34am
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Plotter: GEO-DWG To PDF.pc3 Plotstyle: GEO-No-Dithering.ctb

CAD User: JJP File Last Updated: August 04, 2014 2:43:11pm Plot Date: August 06, 2014 - 11:52:56am
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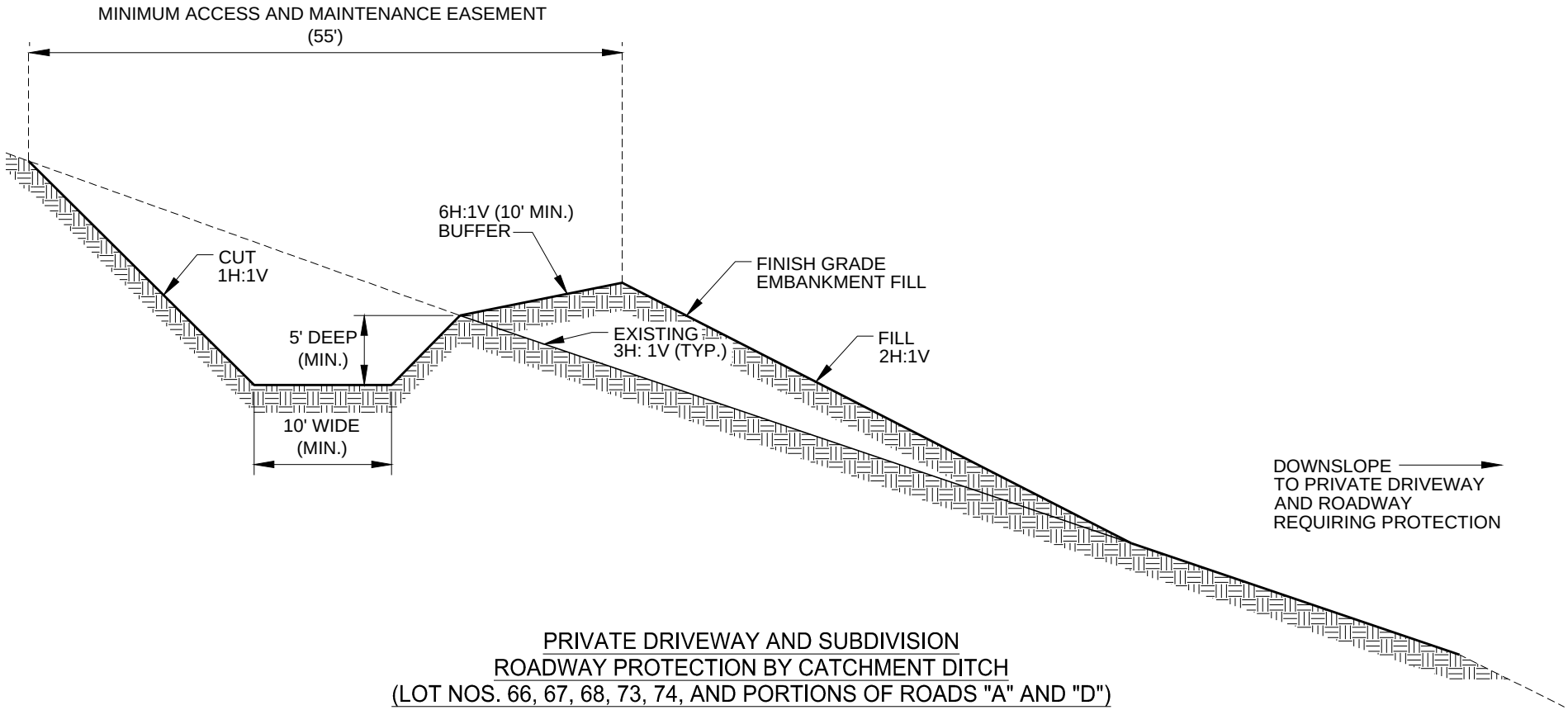


PRIVATE DRIVEWAY AND SUBDIVISION
ROADWAY PROTECTION BY CATCHMENT DITCH
(LOT NOS. 66, 67, 68, 73, 74, AND PORTIONS OF ROADS "A" AND "D")

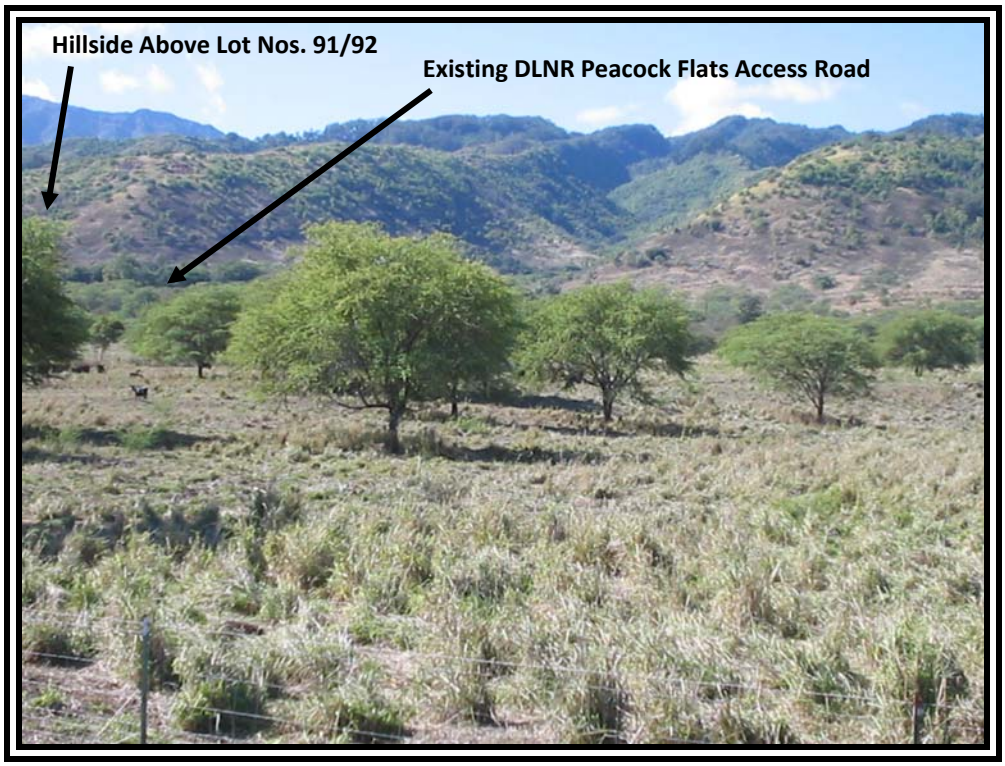
TYPICAL SECTION: ROCKFALL CATCHMENT DITCH

PHASE I ROCKFALL POTENTIAL AND
HILLSIDE SLOPE EVALUATION
DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, OAHU, HAWAII

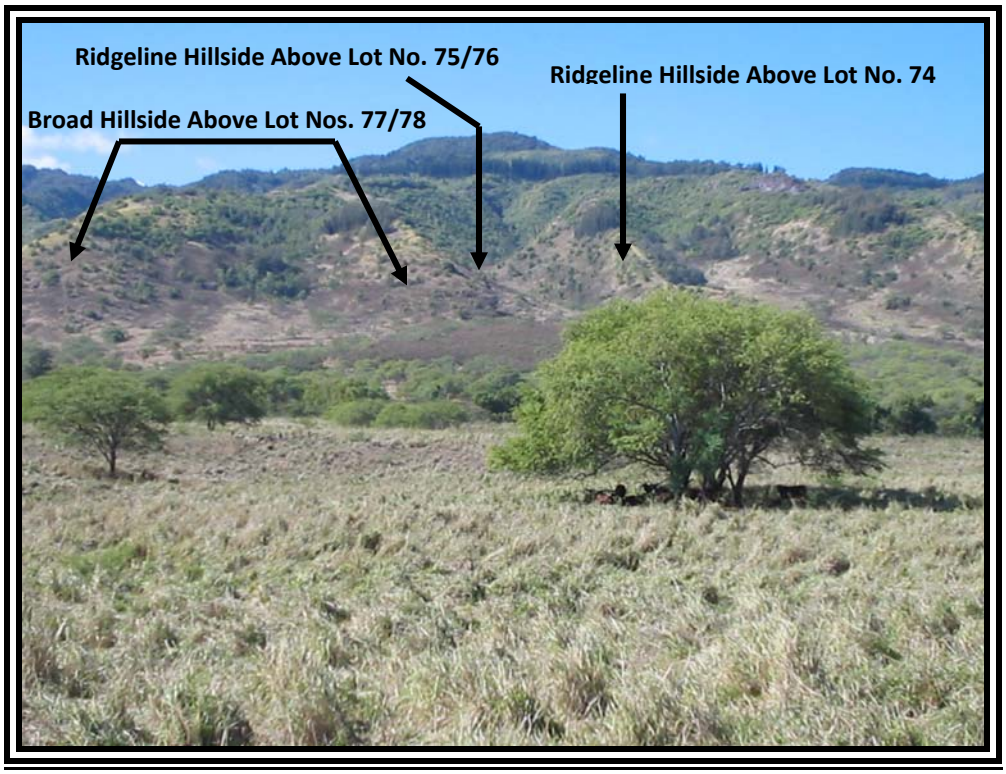
GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
JULY 2014	JRP	7
SCALE	W.O.	
NOT TO SCALE	5721-80	

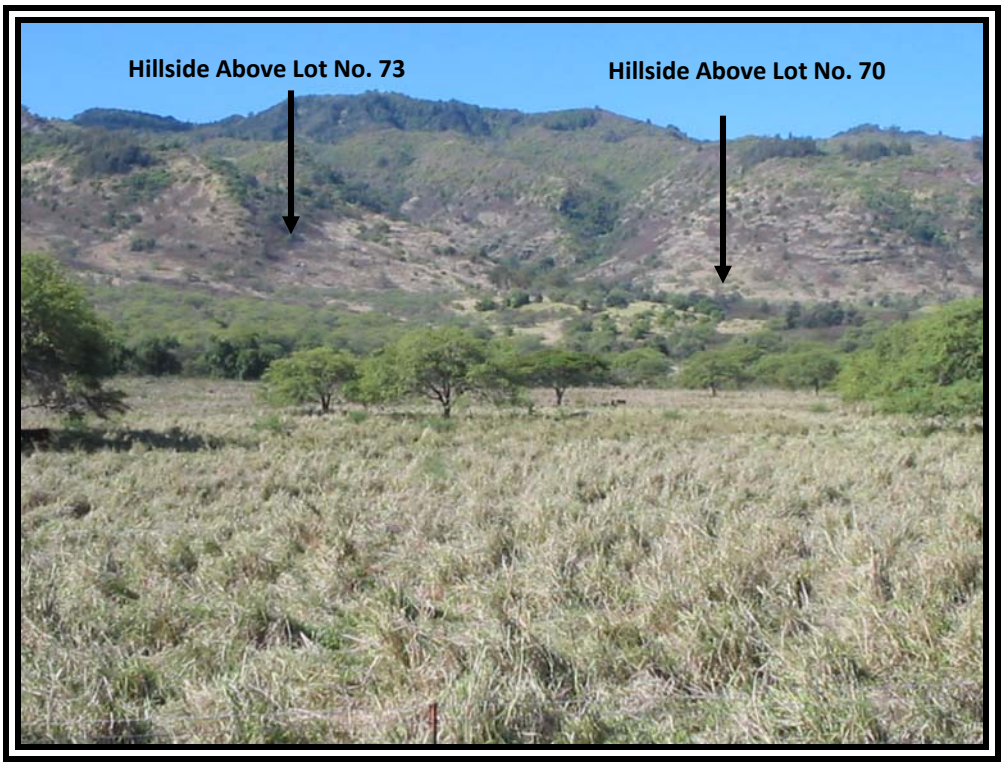
APPENDIX A



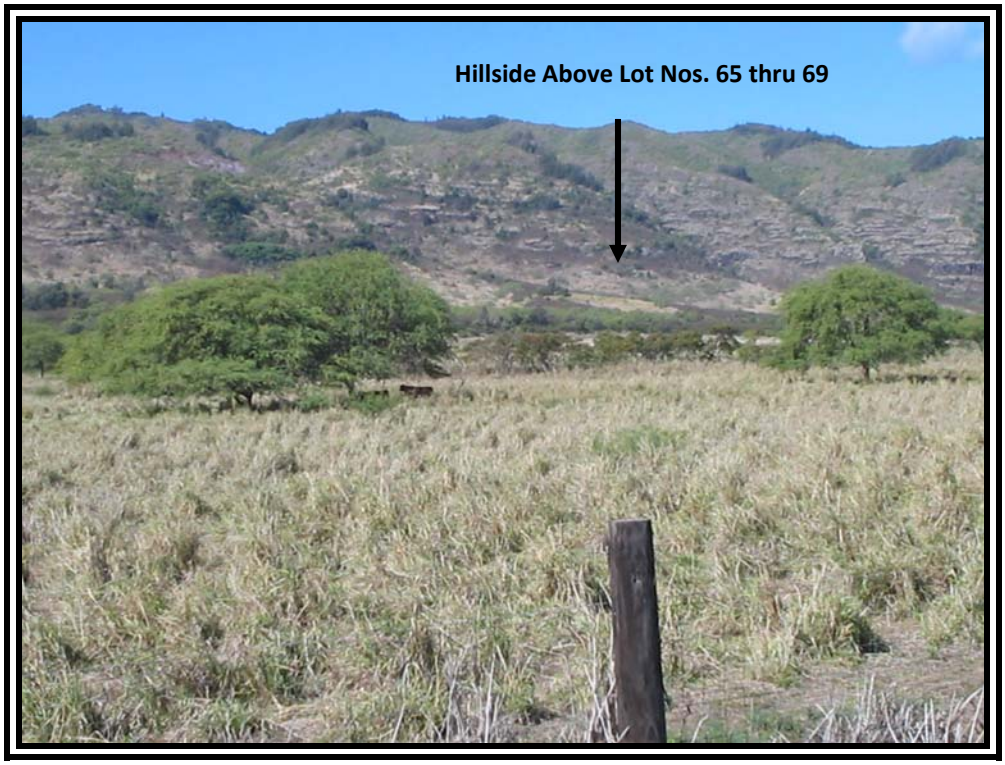
Photograph No. 1: *Panoramic view 1 of 4.* Distant general overview of mountain slopes above Lot No. 91 and the existing DLNR Peacock Flats access road. (1450)



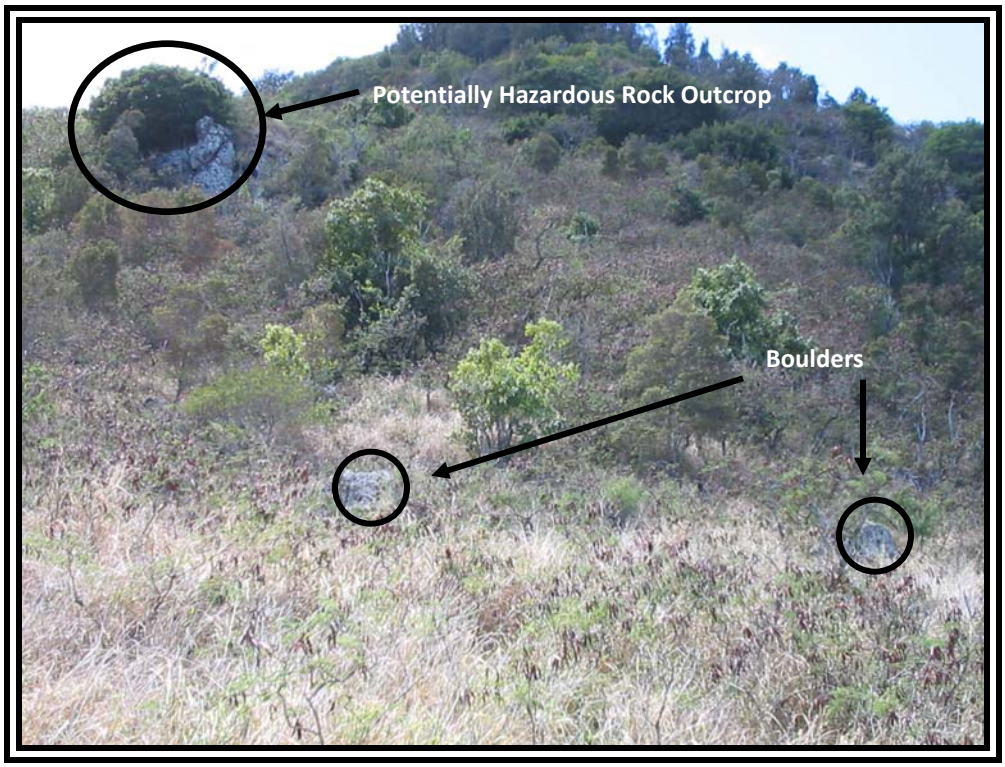
Photograph No. 2: *Panoramic view 2 of 4.* Distant general overview of mountain slopes above Lot Nos. 74 thru 78. (1451)



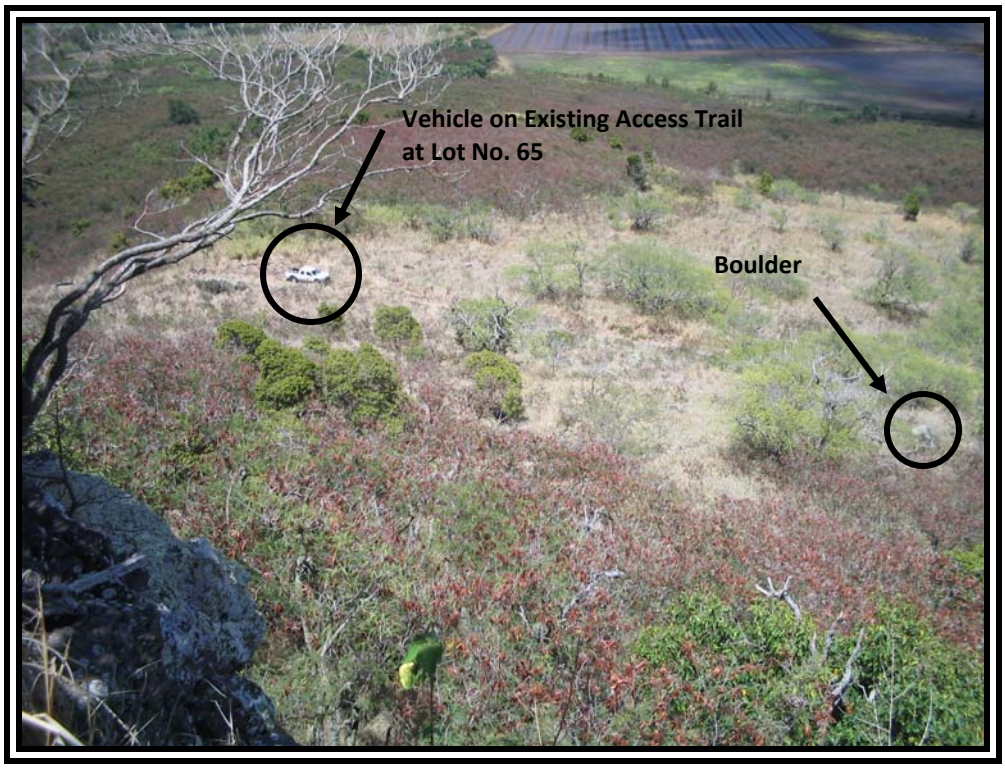
Photograph No. 3: *Panoramic view 3 of 4.* Distant general overview of mountain slopes upslope of Lot Nos. 70 thru 73. (1452)



Photograph No. 4: *Panoramic view 4 of 4.* Distant general overview of mountain slopes upslope of Lot Nos. 65 thru 69. (1453)



Photograph No. 5: Large potentially hazardous rock outcrop located upslope of Lot No. 65. (1459)



Photograph No. 6: View down slope of Lot No. 65 from existing rock ledge outcropping. (1474)

Photograph No. 7: Existing rock outcrop and boulder above Lot No. 66. (1480)

Photograph No. 8: Existing boulder above Lot No. 66. (1481)

Photograph No. 9: Typical slope and vegetation conditions with view down slope toward ravine and Lot No. 67 from existing rock outcroppings above Lot No. 66. (1483)

Photograph No. 10: Existing boulders on slope above Lot No. 68. (1485)

Photograph No. 11: View from Lot No. 71 of distant rock outcroppings on hillside above Lot Nos. 70 and 71. (1490)

Photograph No. 12: View down slope toward Lot Nos. 72 and 73 showing typical slope and vegetation conditions with generally few potential rockfall hazards. (1511)

Photograph No. 13: View upslope from Lot No. 74 showing the easterly facing ridgeline hillside containing some widely scattered boulders and rock outcroppings above the central and western side of Lot No. 74. (0606)

Photograph No. 14: Typical condition of existing widely scattered boulders on the ridgeline hillside above Subdivision Road "D" and Lot No. 74. (0603)

Photograph No. 15: Existing DLNR Peacock Flats access road traversing above Lot Nos. 82 thru 85. (1533)

APPENDIX B

Phase I Rockfall Evaluation, Dillingham Ranch Agricultural Subdivision

Summary of Results For Rockfall Impact Barrier										
Slope Profile No.	Diameter of Rock (ft)	Analysis Point No.	Elevation of AP (ft)	Rock Passing the Analysis Point (%)	Velocity (ft/sec)		Bounce Height (ft)		Kinetic Energy (ft-tons)	
					Average	90%	Average	90%	Average	90%
1 (Lot 65)	2	AP1	+330	82	38.3	55.1	3.1	9	11	20
	4	AP1	+330	84	38.3	55.0	3.1	8	92	162
	6	AP1	+330	85	38.6	55.9	3.0	9	316	562
2 (Lot 66)	2	AP1	+330	73	32.4	38.4	1.1	7	8	10
		AP2	+318	71	30.8	36.7	0.9	8	7	10
	4	AP1	+330	73	32.2	38.0	1.1	7	61	82
		AP2	+318	73	30.7	36.4	0.9	7	56	76
	6	AP1	+330	74	32.4	38.2	1.0	9	207	280
		AP2	+318	73	30.7	36.7	0.9	7	189	260
4 (Lot 67)	2	AP1	+320	26	32.0	37.5	1.0	7	7	10
		AP2	+340	27	32.0	37.6	1.0	8	8	10
	4	AP1	+320	27	32.3	37.7	1.1	8	61	80
		AP2	+340	27	32.4	38.1	0.9	8	61	82
	6	AP1	+320	27	32.5	38.0	1.1	7	208	275
		AP2	+340	28	32.3	38.1	1.1	7	279	251
5 (Lot 68)	2	AP1	+320	68	27.4	35.3	0.8	8	6	7
		AP2	+307	68	26.5	33.6	0.7	9	5	8
	4	AP1	+320	72	27.9	35.3	0.8	8	47	71
		AP2	+307	73	26.3	33.1	0.7	8	42	63
	6	AP1	+320	73	27.9	35.9	0.8	8	158	249
		AP2	+307	75	26.3	33.0	0.7	7	141	211
7 (Lot 69)	2	AP1	+310	47	21.6	28.1	0.5	8	4	6
		AP2	+294	39	14.1	21.3	0.3	11	2	3
	4	AP1	+310	48	21.5	28.2	0.5	8	28	46
		AP2	+294	41	14.0	20.7	0.2	11	13	25
	6	AP1	+310	49	21.5	28.5	0.5	8	97	156
		AP2	+294	41	14.1	20.8	0.2	12	45	85
8 (Lot 70)	2	AP1	+287	No Rocks Past Analysis Point 1						
		AP2	+285	No Rocks Past Analysis Point 2						
	4	AP1	+287	No Rocks Past Analysis Point 1						
		AP2	+285	No Rocks Past Analysis Point 2						
	6	AP1	+287	No Rocks Past Analysis Point 1						
		AP2	+285	No Rocks Past Analysis Point 2						
9 (Lot 71)	2	AP1	+293	No Rocks Past Analysis Point 1						
		AP2	+290	No Rocks Past Analysis Point 2						
	4	AP1	+293	No Rocks Past Analysis Point 1						
		AP2	+290	No Rocks Past Analysis Point 2						
	6	AP1	+293	No Rocks Past Analysis Point 1						
		AP2	+290	No Rocks Past Analysis Point 2						

Phase I Rockfall Evaluation, Dillingham Ranch Agricultural Subdivision

Summary of Results For Rockfall Impact Barrier										
Slope Profile No.	Diameter of Rock (ft)	Analysis Point No.	Elevation of AP (ft)	Rock Passing the Analysis Point (%)	Velocity (ft/sec)		Bounce Height (ft)		Kinetic Energy (ft-tons)	
					Average	90%	Average	90%	Average	90%
10 (Lot 72)	2	AP1	+289	No Rocks Past Analysis Point 1						
		AP2	+287	No Rocks Past Analysis Point 2						
	4	AP1	+289	No Rocks Past Analysis Point 1						
		AP2	+287	No Rocks Past Analysis Point 2						
	6	AP1	+289	No Rocks Past Analysis Point 1						
		AP2	+287	No Rocks Past Analysis Point 2						
11 (Lot 73)	2	AP1	+329	No Rocks Past Analysis Point 1						
		AP2	+325	No Rocks Past Analysis Point 2						
	4	AP1	+329	No Rocks Past Analysis Point 1						
		AP2	+325	No Rocks Past Analysis Point 2						
	6	AP1	+329	No Rocks Past Analysis Point 1						
		AP2	+325	No Rocks Past Analysis Point 2						
13 (Lot 74)	2	AP1	+360	30	24.6	33.1	0.7	8	5	8
		AP2	+350	29	19.4	28.2	0.4	12	3	6
	4	AP1	+360	32	25.2	34.2	0.7	6	40	67
		AP2	+350	30	20.0	28.6	0.4	13	26	47
	6	AP1	+360	31	24.9	33.6	0.7	8	132	220
		AP2	+350	29	19.4	28.3	0.4	11	84	155
14 (Lot 75)	2	AP1	+367	No Rocks Past Analysis Point 1						
		AP2	+363	No Rocks Past Analysis Point 2						
	4	AP1	+367	No Rocks Past Analysis Point 1						
		AP2	+363	No Rocks Past Analysis Point 2						
	6	AP1	+367	No Rocks Past Analysis Point 1						
		AP2	+363	No Rocks Past Analysis Point 2						
15 (Lot 76)	2	AP1	+390	No Rocks Past Analysis Point 1						
		AP2	+384	No Rocks Past Analysis Point 2						
	4	AP1	+390	No Rocks Past Analysis Point 1						
		AP2	+384	No Rocks Past Analysis Point 2						
	6	AP1	+390	No Rocks Past Analysis Point 1						
		AP2	+384	No Rocks Past Analysis Point 2						
17 (Lot 77)	2	AP1	+370	51	30.9	39.7	1.0	12	7	11
		AP2	+363	51	30.1	38.0	1.1	9	7	10
	4	AP1	+370	54	30.9	40.1	0.9	11	57	91
		AP2	+363	54	29.9	38.2	1.1	11	53	82
	6	AP1	+370	55	31.2	40.2	1.0	11	198	307
		AP2	+363	55	30.1	38.5	1.1	9	184	282

Phase I Rockfall Evaluation, Dillingham Ranch Agricultural Subdivision

Summary of Results For Rockfall Impact Barrier										
Slope Profile No.	Diameter of Rock (ft)	Analysis Point No.	Elevation of AP (ft)	Rock Passing the Analysis Point (%)	Velocity (ft/sec)		Bounce Height (ft)		Kinetic Energy (ft-tons)	
					Average	90%	Average	90%	Average	90%
18 (Lot 78)	2	AP1	+265	37	24.5	33.3	0.6	8	5	8
		AP2	+255	29	16.4	26.3	0.3	13	2	5
	4	AP1	+265	39	24.4	33.0	0.6	7	38	64
		AP2	+255	30	16.1	25.3	0.3	11	18	37
	6	AP1	+265	39	24.7	33.1	0.5	9	130	219
		AP2	+255	32	16.7	25.6	0.3	12	65	130
22 (Lot 90)	2	AP1	+262	73	31.1	42.7	0.9	8	8	12
		AP2	+241	63	22.1	30.8	0.5	11	4	7
	4	AP1	+262	74	31.1	42.8	0.9	9	61	100
		AP2	+241	65	22.1	30.8	0.5	10	32	53
	6	AP1	+262	76	31.4	42.9	0.9	8	209	337
		AP2	+241	66	21.7	30.4	0.5	10	103	174
19 (Lot 91)	2	AP1	+390	74	32.9	42.8	1.0	10	8	13
		AP2	+374	74	30.3	39.4	0.9	11	7	11
	4	AP1	+390	76	32.8	43.1	1.0	11	66	106
		AP2	+374	76	29.9	39.2	0.9	10	55	88
	6	AP1	+390	78	33.3	43.2	1.1	9	227	357
		AP2	+374	78	30.4	39.5	0.9	10	190	300
16 (Lot 77 Driveway)	2	AP1	+380	53	23.5	15.3	0.6	12	4	2
	4	AP1	+380	54	23.3	31.5	0.6	10	34	57
	6	AP1	+380	56	23.7	32.2	0.6	9	119	203
20 (DLNR Road)	2	AP1	+232	60	16.7	24.4	0.3	10	2	4
	4	AP1	+232	65	16.3	24.3	0.3	11	13	34
	6	AP1	+232	66	16.8	24.8	0.3	11	63	119
21 (DLNR Road)	2	AP1	+338	0.6	11.0	16.2	0.2	14	1	2
	4	AP1	+338	1.3	8.6	12.1	0.1	14	5	8
	6	AP1	+338	0.7	10.2	14.2	0.08	14	23	37

Phase I Rockfall Evaluation, Dillingham Ranch Agricultural Subdivision

Summary of Results for Rockfall Catchment Ditch					
Slope Profile No.	Diameter of Rock	Percentage of Retained at 10' Ditch	Elevation of Center of Ditch	No. of Passing at AP1 (upslope of ditch)	No. of Passing at AP2 (downslope of ditch)
	(feet)	(percent)	(feet MSL)		
3 (Rd. A)	2	98%	+320	726	12
	4	97%	+320	760	26
	6	98%	+320	779	16
6 (Rd. A)	2	98%	+300	607	14
	4	98%	+300	627	14
	6	99%	+300	627	6
12 (Rd. D)	2	100%	+313	667	0
	4	100%	+313	642	1
	6	100%	+313	667	1
14 (Rd. D)	2	No Rock Passing AP1	+287	330	324
	4	No Rock Passing AP1	+287	330	324
	6	No Rock Passing AP1	+287	330	324

APPENDIX C

100 kJ - 8000 kJ

MAINTENANCE MANUAL GBE-SERIES

GBE-100A-R

GBE-500A-R

GBE-500A

GBE-1000A-R

GBE-1000A

GBE-2000A

GBE-3000A

GBE-5000A

GBE-8000A

- Lifespan
- Inspections
- Criteria for repairs and replacement
- Emptying and clearing barriers
- Repairing and replacing components
- Inspection checklist

Issue: **199-N-FO / 01**
Date: **03.04.2012**

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PURPOSE AND ORGANIZATION OF THE MAINTENANCE MANUAL

This maintenance manual is intended for the proper maintenance and repair of a rockfall protection system, in order to ensure a long lifespan for the barrier, and its unrestricted and safe functioning following impacts and throughout its lifespan. The maintenance manual is to be understood as a recommendation. Only standard situations are described. In the event of unusual situations, this manual may under certain circumstances be inappropriate or inadequate for servicing or repairing the barrier. In certain cases, it is recommended that technical advice is obtained from the manufacturer.

This maintenance manual consists of the following sections:

- Lifespan
- Inspections
- Criteria for repairs and replacement
- Emptying and clearing of barriers
- Repairing and replacing components
- Inspection checklist
- ISO 9001 certificates

No claims are made that this document is complete. It is designed for general standard applications and does not take into account project-specific parameters. Geobrugg cannot be held liable for any extra costs that may be incurred for special cases. In the event of uncertainty, please contact the manufacturer. The General Terms of Business of Geobrugg AG apply.

Responsible for the content:
Geobrugg AG
Geohazard Solutions
Aachstrasse 11
P O Box
CH-8590 Romanshorn, Switzerland

Phone +41-71-466 81 55
Fax +41-71-466 81 50
E-mail info@geobrugg.com
www.geobrugg.com

Romanshorn, April 3, 2012

C. Wendeler M. Seeh ser

Geobrugg AG
Aachstrasse 11
CH-8590 Romanshorn
Switzerland

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I AREA OF APPLICATION

This maintenance manual applies for the Geobrugg rockfall barrier systems of the GBE series. Reference is made to the corresponding system drawings and system manuals:

GBE-100A-R	(100 kJ)	System drawing GS-1131	Product manual no. 169-N-FO
GBE-500A-R	(500 kJ)	System drawing GS-1122	Product manual no. 162-N-FO
GBE-500A	(500 kJ)	System drawing GS-1100	Product manual no. 156-N-FO
GBE-1000A-R	(1000 kJ)	System drawing GS-1128	Product manual no. 172-N-FO
GBE-1000A	(1000 kJ)	System drawing GS-1104	Product manual no. 158-N-FO
GBE-2000A	(2000 kJ)	System drawing GS-1109	Product manual no. 160-N-FO
GBE-3000A	(3000 kJ)	System drawing GS-1113	Product manual no. 164-N-FO
GBE-5000A	(3000 kJ)	System drawing GS-1125	Product manual no. 168-N-FO
GBE-8000A	(3000 kJ)	System drawing GS-1113	Product manual no. 170-N-FO

II QUALITY OF THE SYSTEM COMPONENTS

Geobrugg AG, Romanshorn, has been certified according to the quality management system requirements (ISO 9001: 2008, Rev. 2010) under registration number 34372 since August 22, 1995. The certifying body is the Swiss Association for Quality and Management Systems (SQS), a member of EQ-Net 9000. The quality manual describes in full how the individual system parts (input material, commercial products and end products) are comprehensively checked in order to exclude inadequate quality. The corresponding certificates can be found in the Annex.

III FUNCTIONAL EFFICIENCY OF THE BARRIER SYSTEMS

The functional efficiency of the systems is based on 1:1 rockfall tests, carried out and tested in accordance with the European Directive ETAG 027 “Falling Rock Protection Kits” in Walenstadt, Canton of St. Gallen (Switzerland). The 1:1 rockfall tests are carried out by dropping a block vertically into the central field of a three-field barrier with ten-meter post spacing in each case, with an impact velocity of at least 25 meters per second being reached. The trials are accepted by notified test centers, and are given an approval, called an ETA (European Technical Approval).

IV QUALITY CONTROL FOR MAINTENANCE

An inspection of damage should be made using the checklist in the maintenance manual. The maintenance manual describes in detail the individual steps for how the barriers must be maintained by local contractors. The recording of damage is, however, always subject to subjective criteria. In the event that doubts should arise for this reason, the manufacturer should be contacted in order to ensure the continued quality and functional efficiency of the barrier.

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V PRODUCT LIABILITY

Rockfall, landslides, debris flows or avalanches are sporadic and unpredictable. The cause may be human (buildings etc.), for example, or forces beyond human control (weather, earthquakes, etc.). The multiplicity of factors that may trigger such events means that guaranteeing the safety of persons and property is not an exact science.

However, the risks of injury and loss of property can be substantially reduced by appropriate calculations that apply good engineering practices, and by using predictable parameters along with the corresponding implementation of flawless protective measures in identified risk areas.

The monitoring and maintenance of such systems is an absolute requirement to ensure the desired safety level. System safety can also be compromised through events, natural disasters, inadequate dimensioning or failure to use standard components, systems and original parts, but also through corrosion (caused by environmental pollution or other man-made factors as well as other external influences).

In contrast to the 1:1 rockfall tests, which indeed test an extreme load case but still only demonstrate a standardized situation, in the field the layout and design of a protection system can vary greatly because of the topography. The influence of such alterations and adaptations cannot always be determined exactly. Critical points are, for example, post spacing, changes in direction, placement angle of the rope anchors, and the direction and velocity of impact.

Geobrugg can assist with estimating the influence of larger deviations and special situations, and can offer recommendations for feasible solutions. Geobrugg cannot, however, guarantee the same behavior as in the 1:1 rockfall tests. In critical cases, it is advisable to reinforce particular components as compared with the standard barrier.

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EXPLANATION OF THE SYMBOLS USED

Safety instruction: must be followed

Note / reminder, to ensure that the system is installed easily and correctly

Mountain side

Valley side

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1 LIFESPAN

1.1 Lifespan of the components in general

1.1.1 Individual parts

The lifespan of an individual part is defined by its load-bearing capacity. This includes e.g. the ropes, the rod anchors, the securing splints for the U-brake bolts etc.

1.1.2 Assemblies

The lifespan of an assembly is defined by its load-bearing capacity as well as by its mechanical functional efficiency. Typical assemblies include e.g. the installed barrier itself, the U-brakes and the running wheel groups.

1.1.3 Safety factors

If the functional efficiency or load-bearing capacity of the components is reduced as a result of damage or corrosion, such that the minimum required safety factors can no longer be fulfilled, the components must be replaced.

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2 INSPECTIONS

In order to ensure that no damage or advanced corrosion impairs the functional efficiency or load-bearing capacity of the components such that the minimum required safety factors can no longer be fulfilled, regular inspections of the barriers must be carried out.

2.1 Regular inspections

2.1.1 Interval for regular inspections

The appropriate interval depends primarily on the following parameters:

- Frequency of rockfalls
- Corrosion class of the area
- Vegetation

2.1.2 Minimum number of inspections

Under normal environmental conditions, two checks a year are sufficient. If frequent rockfalls occur, more inspections are appropriate. These should be carried out before the start of winter and after winter has ended.
A useful aid for the systematic checking of the barrier is the “Barrier Inspection” checklist in the Annex.

2.2 Inspection following incidents

An inspection must be carried out immediately following any notified or recorded incidents.
A useful aid for the systematic checking of the barrier is the “Barrier Inspection” checklist in the Annex.

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2.3 Accessibility

The barrier must be accessible so that all the components to be checked can be inspected without the risk of accidents. The infrastructure required for this depends on the terrain. The picture below shows an example of a secured climbing ladder.

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3 CRITERIA FOR REPAIR AND REPLACEMENT

If the functional efficiency or load-bearing capacity of the components is reduced as a result of damage or corrosion, such that the minimum required safety factors can no longer be fulfilled, the components must be replaced.

3.1 Debris in the barrier

Any debris that accumulates in the barrier should not exceed a maximum of a third of the usable height. Routine clearing of the barriers is essential to ensure unimpeded functioning.

3.2 Remaining usable height following an incident

The remaining usable height of the barrier following an incident is an initial indicator of the level of damage that has occurred. Clear sagging of the support rope or the net and a significant change in the angle of the posts indicate an elongation of one or more U-brakes, which may need to be replaced.

3.3 U-brakes

In the course of the EOTA certification tests, depending on their installation position the U-brakes became elongated to varying degrees. Accordingly, following several minor incidents their energy absorption capacity for a subsequent maximum incident varies.
For the sake of simplicity, for the U-150 an elongation of 30 cm has been set, and for the various U-300 modes the elongation of 60 cm is set as a maximum initial elongation. If the initial elongation exceeds this value, the brake must be replaced. Once the U-brakes have become elongated, the usable height of the barrier has decreased. By re-tightening the support ropes, the usable height can be restored to its original value.

3.4 Meshes and nets

Even in the case of distorted wires or strands, as a rule it is not necessary to replace whole fields.

3.4.1 TECCO

If there are compressed, heavily distorted or torn mesh loops, these areas should be repaired.

3.4.2 SPIDER

If there are compressed, heavily distorted or superficially or completely torn mesh loops, these areas should be repaired.

3.4.3 ROCCO

- If individual wires have slipped out of a clip, they should be secured with a wire rope clip of a suitable size.
- If there are compressed, heavily distorted, superficially or completely torn rings, these areas should be repaired.

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3.4.4 Wire mesh

If there are compressed, heavily distorted or torn mesh loops, these areas should be repaired.

3.5 Ropes as per the rope assembling drawings

3.5.1 Corrosion

Replacement of the rope, or a section thereof, is necessary if more than approx. 10% of the cross-section is affected.

3.5.2 Mechanical damage

Mechanical damage is indicated by sharp kinks and squashed or torn outer wires. Within a few years, the rope becomes brittle and loses the required load-bearing capacity. In cases of doubt, a section of the rope must be cut out in order to test the breaking strength of the rope. In the event of a poor test result, the entire rope must be replaced.
If one or more strands are torn, the rope, or this section thereof, must be replaced.

3.6 Posts

The posts hold the upper support ropes at the corresponding height and thus determine the usable height of the barrier. Slightly bent posts up to an angle of 15° do not need to be replaced.

3.7 Hinge bolt between post and base plate

In the event of impacts into the post, the hinge bolt between the post and the base plate may be bent or broken (predetermined breaking point, in order to avoid damage to the base plates and anchors). Bent or broken hinge bolts must be replaced.

3.8 Base plate

Plastic deformations to the base plate do not impair the functioning of the base plate significantly. Attention should therefore be focused on the weld seams. If weld seams are torn, the base plate must be replaced.

3.9 Rod anchor of the base plate or post foot

If a rod anchor (GEWI anchor) is significantly bent (>15°), if cracks are visible, or if the anchor is pulled out of the ground by more than 3cm, it must be replaced, since under certain circumstances its load-bearing capacity may no longer be sufficient.

3.10 Spiral rope anchor

Spiral rope anchors need only be replaced if there is serious damage to wires. If a steel pipe of an anchor head is damaged, this does not reduce the loading limit. However, this may lead to a shorter lifespan, because of the reduced corrosion protection. If the anchor is pulled out of the ground by more than 3 cm, it must be replaced, since under certain circumstances its load-bearing capacity may no longer be sufficient.

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4 CLEARING THE BARRIER

Various methods may be used for clearing stones, rubble or soil from rockfall barrier systems. The optimum method depends on the local framework conditions and the quantity and type of material in the nets.

A filled barrier is always under tension. The greatest care should be taken when releasing or separating components. See also section 7.1.

The barrier can be cleared using hand tools or a machine (e.g. a front-loader or similar). Care must be taken that the net is not damaged, and it must be ensured that stones rolling down the slope do not cause any damage (see illustration below).
Dug channels or large plastic pipes are useful for directing stones, debris and rubble safely towards the valley.

Lowering stones safely (secured with a rope)

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4.1 Breaking stones down

Large blocks that cannot be lifted out or transported away must be broken down. Depending on the situation, the following methods can be considered:

- Manual
- Explosives (see following illustration)
- Expanding cement (“cold explosives”). For this, the stones are drilled into and filled with the “propellant” (e.g. that manufactured by Betonamit) and water is added. After about one day, the stone is broken and can be cleared away.

Breaking a block down using explosives

If a crane is available, the stones can be fitted with a haulage anchor and brought down to the valley safely.

Fitting the block with haulage hooks

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Lifting the block out with the aid of a crane

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5 TOOLS FOR SERVICING ROCKFALL BARRIERS

The following tools should be kept available for servicing:

- One or two six-meter ladders
- Two cable pulley devices with 30 kN tensile strength (e.g. HABEGGER model)
- Two cable pulley devices with 7.5 kN tensile strength (e.g. LUGAL model)
- Various slings, each 1 meter in length
- 5/8” and 7/8” shackles
- Torque wrench, range 50-120 Nm
- Socket wrench or open-end wrench set
- Various tools, such as hammer, pliers, etc.
- Hemp ropes
- Measuring tape
- Angle spirit level
- Disk cutter
- Two rope clamps for ropes with a diameter of 8 to 16 mm
- Four rope clamps for ropes with a diameter of 14 to 26 mm
- Two complete sets of wrenches

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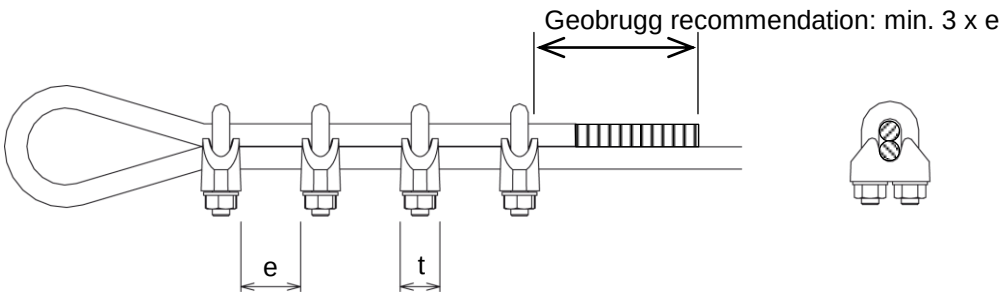
6 USE OF WIRE ROPE CLIPS

The first wire rope clip is attached close to the cable eye stiffener or loop. The wire rope clips must be spaced so that the distance **e** between them is between 1.5 and 3 times the width **t** of the wire rope clip.

The clip stirrups (“U-bolts”) are always applied to the unstressed rope end, the jaws (“saddle”) always on the stressed rope (“never saddle a dead horse”).

Extract from EN 13411-5 (DIN 1142)



Nominal size [mm]	Spacing e [mm]	Required tightening torque [N * m]	Required number of wire rope clips	Jaw size [mm]
13	50 – 80	35	4	19
16	50 – 90	55	4	22
19	50 – 90	75	4	22
22	50 – 90	120	5	24
22 GEOBINEX	50 – 90	120	10	24

The tightening torques shown above apply for greased screw/nut connections.

During assembly as well as before the system is put into use, the collar nuts must be brought to the prescribed tightening torque.

After the barrier has been assembled, the tightening torque of the rope connections at the lateral and mountain-side anchors must be checked and adjusted once again.

The tightening torques stated here are 10% higher than the torques stipulated by the standard. This is on account of the variance in the case of conventional torque wrenches.

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7 REPAIRING AND REPLACING COMPONENTS

7.1 Hazard information

7.1.1 Qualification of the group supervisor

Only a trained, experienced group supervisor may oversee repair work.

7.1.2 Net under tension

A filled barrier is always under tension. The greatest care should be taken whenever components are separated or released.

7.1.3 Ropes under tension

Personnel must never linger within the tension angle of two ropes.

7.1.4 Releasing parts under tension

Wherever possible, components under tension should not be separated or released. Where this is unavoidable, the greatest caution must be exercised.

7.2 Geometrical arrangement of the components

When carrying out repairs, the geometrical condition of the barrier must be restored to match that on initial acceptance. If this is no longer possible, a technically acceptable solution must be agreed with Geobrugg. The correct geometrical arrangement of the individual components can be found in the product manual.

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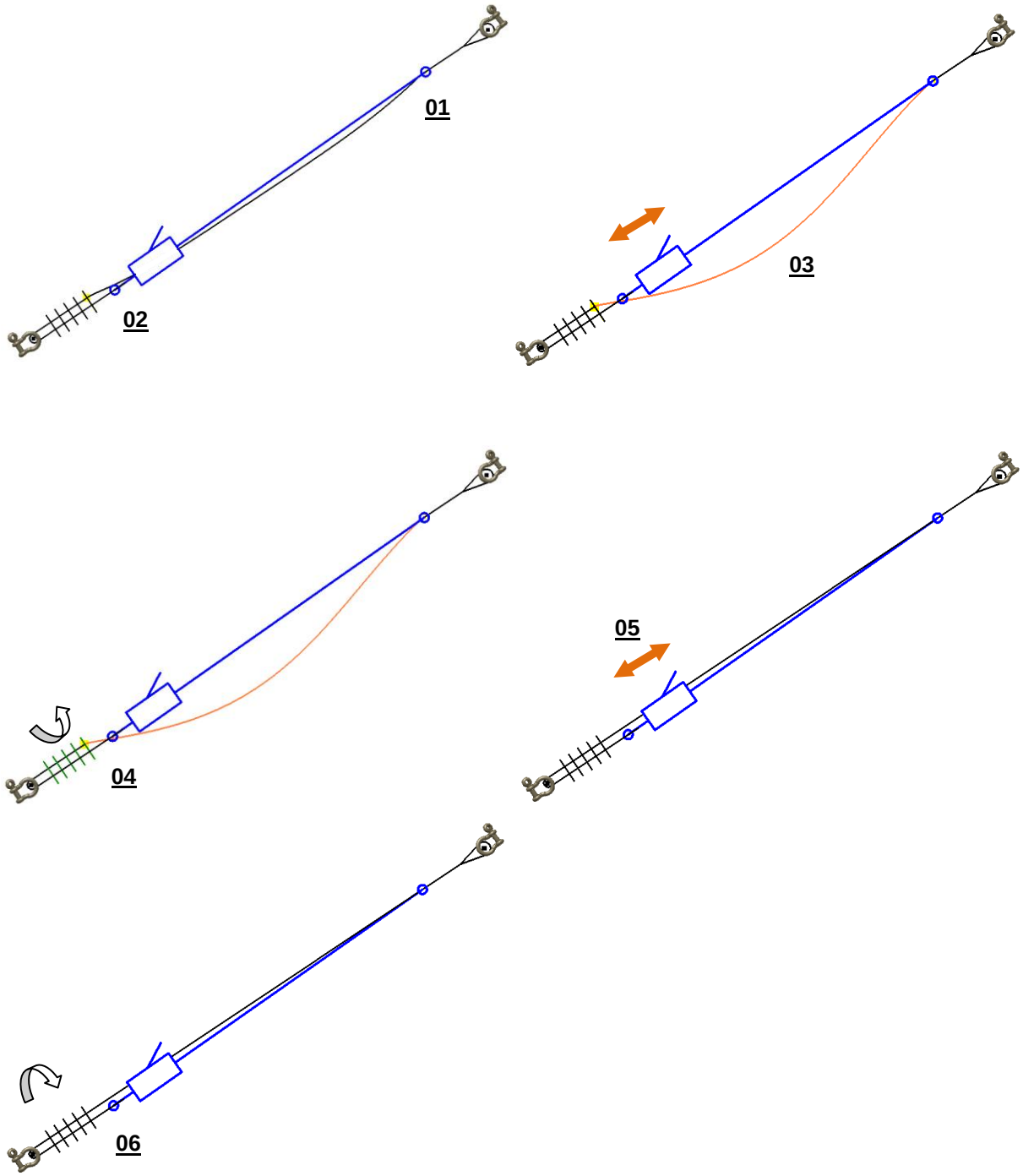
7.3 Tightening sagging ropes



- Fasten the clips of the cable pulley device on the rope **01** and its shackled end loop **02**.
- Actuate the cable pulley device until it is taut **03**.
- Release the wire rope clips of the rope **04**.
- Actuate the cable pulley device until the rope is tightened as desired **(05)**.
- Tighten the wire rope clips of the rope with the required tightening torque **(06)**.
- Detach the cable pulley device.

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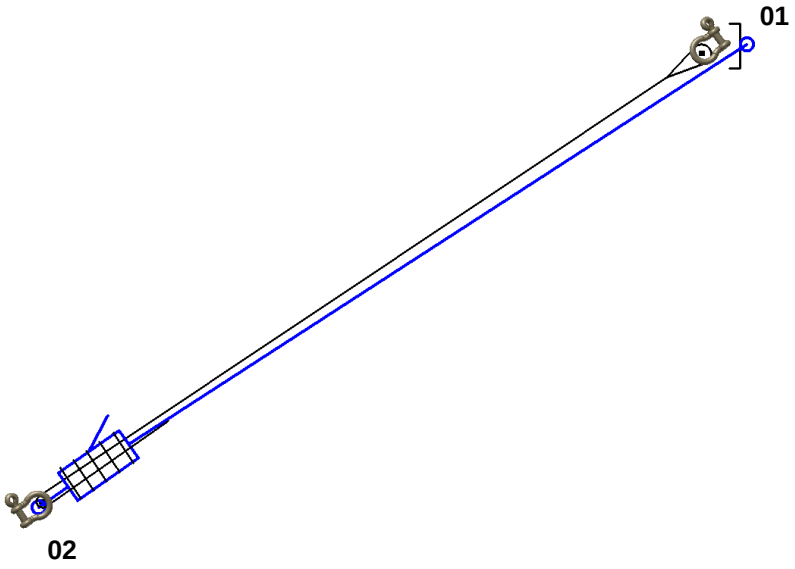
7.4 Replacing ropes



- Fit the clips of the cable pulley device to the post (e.g. with the auxiliary strap) **01** and to the fastening of the U-brake (e.g. rope anchor) **02**.

  Carry out the remaining steps as described in section 7.3:
- Actuate the cable pulley device until the rope that is to be replaced is loose.
- Release the wire rope clips of the rope and remove them.
- Fit the new rope.
- Tighten the wire rope clips for the new rope with the required tightening torque.
- Release the cable pulley device so that the tensile force is transferred to the new rope.
- Detach the cable pulley device.

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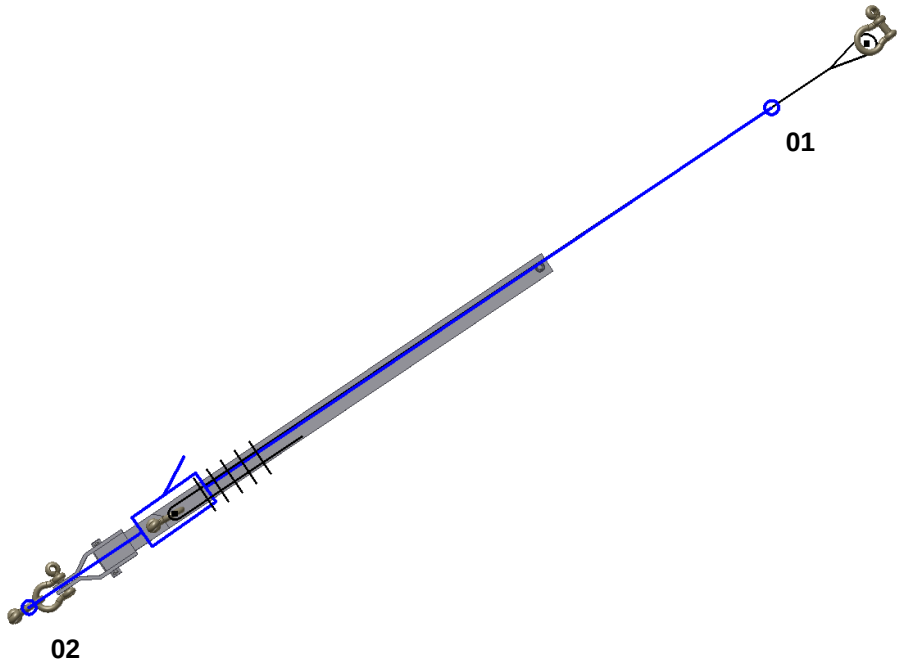
7.5 Replacing U-brakes



- Fit the clips of the cable pulley device to the rope of the U-brake **01** and the fastening of the U-brake (e.g. rope anchor) **02**.

  Carry out the remaining steps as described in section 7.3:
- Actuate the cable pulley device until the entire tensile force is on the cable pulley device.
- Remove the shackle of the U-brake from the loop of the rope.
- Replace the U-brake and return the shackle to the loop.
- Release the cable pulley device so that the tensile force is transferred to the U-brake rope.
- Detach the cable pulley device.

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7.6 Repairing nets and meshes

7.6.1 TECCO: repairing smaller mesh areas

If the mesh loops of a smaller mesh area have been pulled along in sympathy, a correspondingly small mesh can be laid over the damaged area and fastened to the intact mesh loops with shackles.
Care must be taken to ensure that the mesh loops are aligned horizontally as they are for intact meshes.

7.6.2 SPIDER: repairing smaller net areas

If the mesh loops of a smaller net area have been pulled along in sympathy, a correspondingly small net can be laid over the damaged area and fastened to the intact mesh loops with shackles.
Care must be taken to ensure that the mesh loops are aligned horizontally as they are for intact meshes.

7.6.3 ROCCO: repairing smaller net areas

If the rings of a smaller net area have been pulled along in sympathy, a correspondingly small net can be laid over the damaged area and fastened to the intact rings with shackles.
Care must be taken to ensure that each ring has four connection points to the next ring.

7.6.4 Wire mesh: repairing smaller mesh areas

If the mesh loops of a smaller mesh area have been pulled along in sympathy, a correspondingly small mesh can be laid over the damaged area and fastened to the intact mesh loops with wire binders.

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7.7 Replacing nets and meshes

7.7.1 TECCO: replacing a mesh field

As a basic principle, TECCO meshes are replaced in the same way as SPIDER nets. The replacement procedure is described in detail in 7.7.2 below.

a) Relieve the strain on the outermost spiral of the damaged area.

b) Open up the eyelet connection of the outermost spiral.

c) Unscrew the outermost spiral. ⇨ A separation is produced in the mesh area.

d) Cut open the mesh loops of the damaged mesh along the support rope and remove the damaged mesh.

e) Fasten the mesh loops of the new mesh to the support ropes with HELIX spirals (or shackles).

f) Connect the new mesh to the intact adjacent meshes with a TECCO spiral (or with shackles).

g) Connect the eyelets of the two TECCO spirals with a shackle and remove the strain relief.

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7.7.2 SPIDER: replacing a net field

The SPIDER net is replaced by unscrewing the outermost spirals of the damaged area, inserting the new net, and joining this to the intact nets with two new spirals (or with shackles).

a) Relieve the strain on the outermost spiral of the damaged area.

b) Cut open the eyelet connection of the outermost spiral.

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c) Unscrew the outermost spiral.

A separation is produced in the net area.

d) Cut open the mesh loops of the damaged net along the support rope and remove the damaged net.

e) Fasten the mesh loops of the new net to the support ropes with shackles.

f) Connect the new net to the intact adjacent nets with a spiral (or with shackles).

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g) Connect the eyelets of the two spirals with a shackle and remove the strain relief.

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7.7.3 ROCCO: replacing individual rings

The easiest way to replace individual rings is by fitting a replacement ring into the net with shackles. Corresponding prefabricated rings can be obtained via Geobrugg. The new ring is fastened to the adjacent rings with four shackles before the damaged ring is cut out.

If a ring is to be incorporated into the net, the following procedure is recommended:

a) Pull a piece of rope with a diameter of 4-8 mm through the 4 rings adjacent to the damaged ring and tighten it such that its diameter becomes smaller than that of the ring that is to be replaced.

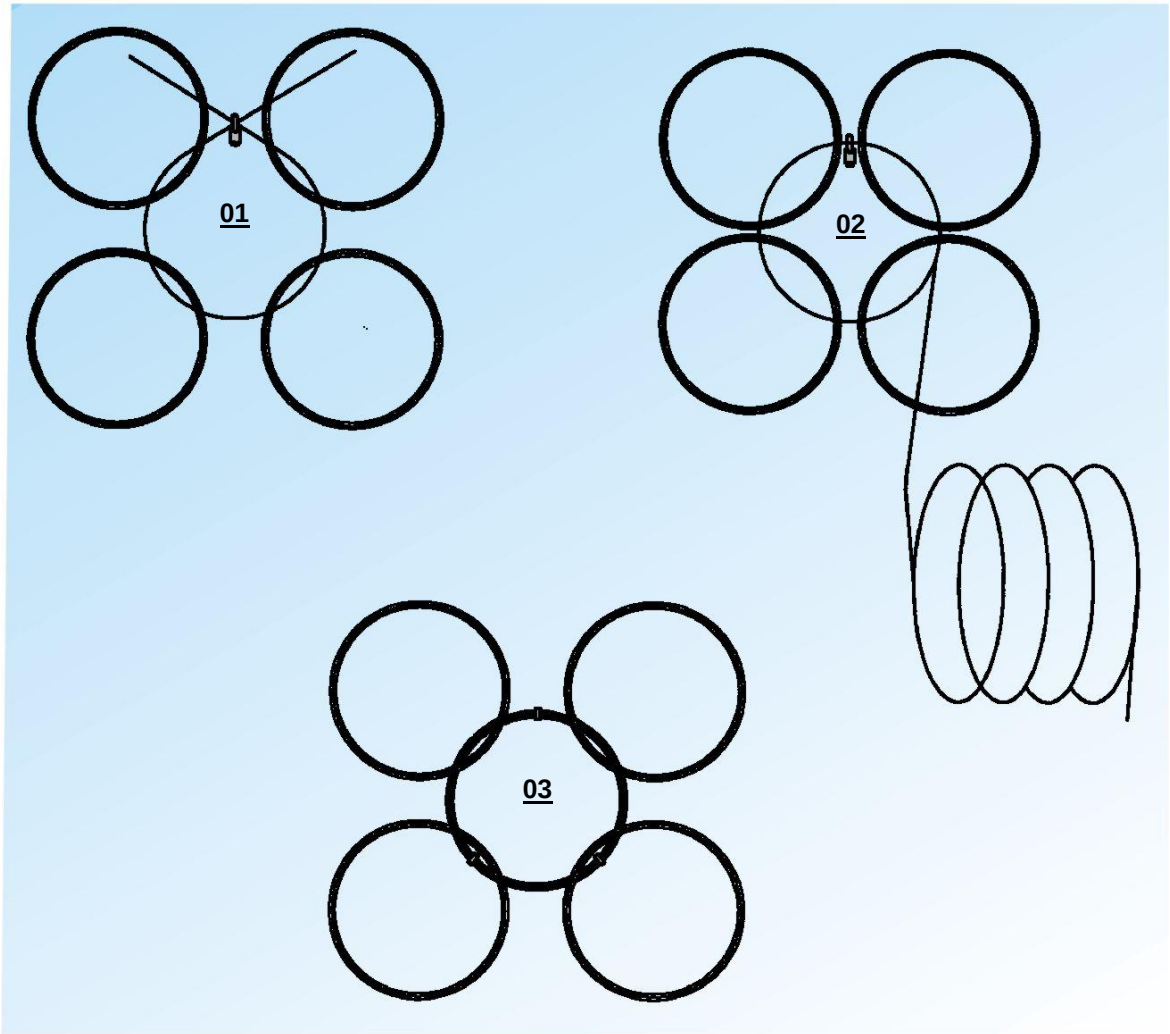
b) Secure the piece of rope that has been threaded through with a wire rope clip **01**.

c) Guide a piece of wire with a diameter of 3 mm and a tensile strength of at least 1770 N/mm^2 along the piece of rope that was threaded through and through the four rings **02**.

d) Repeat this until the number of turns of the adjacent rings has been reached.

e) Fix the circular shape of the resulting ring bundle with three wire rope clips **03**.

f) Remove the piece of rope that was threaded through.



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7.7.4 ROCCO: replacing a net field

a) Release the shackles to the adjacent nets.

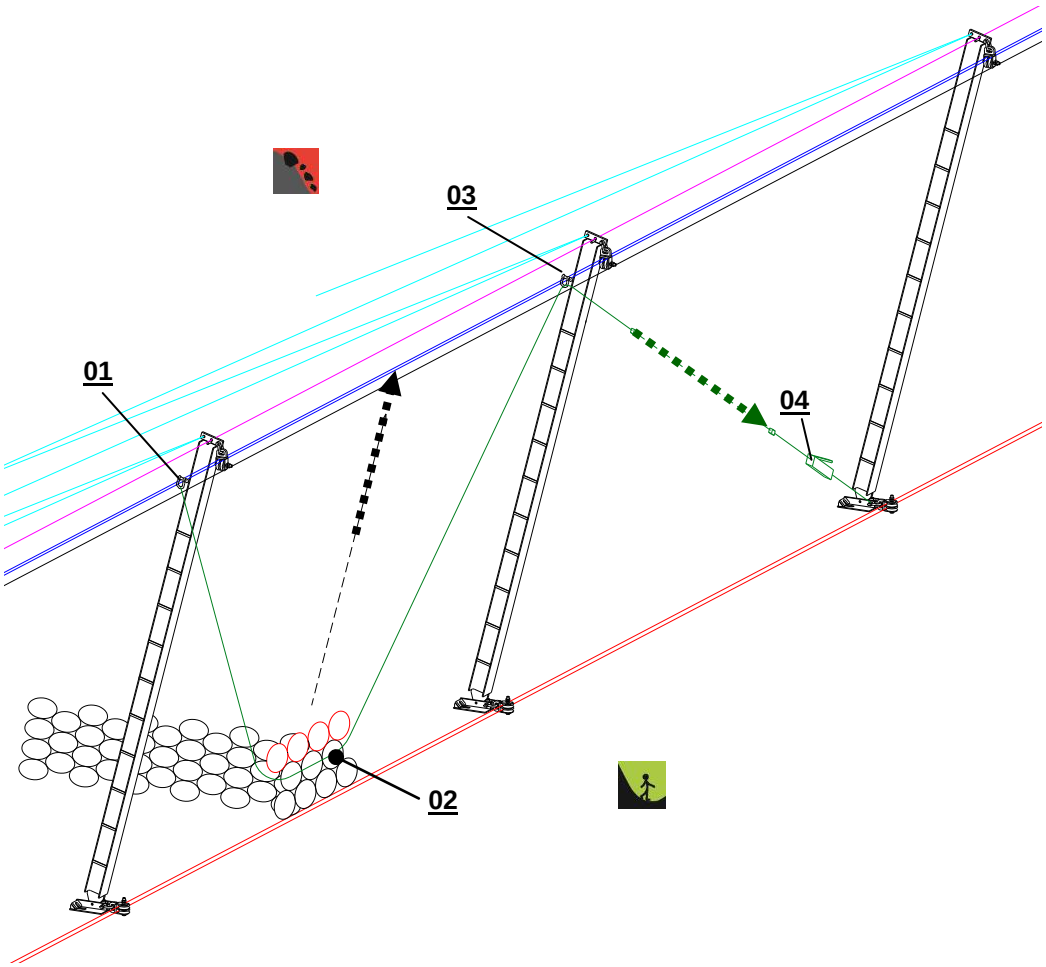
b) Cut open the rings on the support ropes and the arrestor cables, and remove the damaged net.

c) Lay the replacement net, still bundled, on the mountain side, between the two posts. The rows of rings for the support ropes and arrestor cables are marked in colour. Do not cut open the tied-up rows of rings yet.

d) Using a shackle, fasten an auxiliary rope to the top support rope next to the adjacent posts **01**, pull it through the rings in the second row of the replacement net **02**, and guide it through a second shackle **03** on the top support rope next to the other post, to the cable pulley device **04**. Tighten the rope until the first row of rings of the net is at the same height as the top support rope. Whilst pulling up, gradually cut open the tied-up rows of rings of the net.

e) Pull up the net like a curtain, and, using the corresponding shackles, join the net rings to the support ropes, the adjacent net fields and the arrestor cables.

f) Take care to ensure that the correct number of rings is fastened to the right and left of the post, not on the support ropes, but on the running rope. Detailed information can be found in the corresponding product manual.



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7.7.5 Wire mesh: replacing a length of mesh

a) Cut open the wire binders of the damaged length of mesh and remove the length of mesh.

b) Restore the geometric state of the barrier by e.g. tightening ropes, replacing U-brakes, etc.

c) Using wire binders, fasten the new length of mesh to the main net in accordance with the product manual.

7.8 Repairing ropes

As a basic principle, ropes are replaced rather than repaired.

7.9 Replacing ropes

Ropes must be replaced if the rope is damaged according to section 3.5. Often, only the elongated U-brakes need to be replaced.
Depending on the situation, replacement is done in accordance with to sections 7.3 / 7.4 / 7.5.
The required tightening torques are listed in section 6.

7.10 Replacing posts

7.10.1 Replacing middle posts

In most cases, the middle post can be replaced without dismantling the net or the ropes.

a) Secure the faulty post with auxiliary ropes.

b) Dismount the shackle with the running wheel on the post head.

c) Remove the hinge bolt of the post.

d) Lift the post out of the base plate using a winch, and place it, secured, on the ground on the mountain side.

e) Transfer the retaining ropes from the faulty post to the new post.

f) Place the post foot into the base plate and fit the hinge bolt.

g) Erect the post in a secured manner.

h) Refit the running wheel to the post head.

i) Remove the securing ropes.

7.10.2 Replacing edge posts

The lateral ropes brace the entire barrier via the edge posts on the slope. It is therefore essential to loosen the lateral ropes when replacing an edge post. Depending on the situation, the subsequent middle posts can be used to perform the function of the edge posts during repairs. In this case, the middle post is secured on the valley side and the lateral ropes are fixed to the middle post using suitable equipment. The edge post is then replaced as described in section 7.10.1. If this is not possible, a certain number of fields or the entire barrier must first be laid securely facing up the mountain until the edge post can be replaced.

7.11 Replacing the hinge bolt between post and base plate

The post is raised using a winch and the faulty bolt is removed and replaced by a new hinge bolt.

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7.12 Replacing a base plate

It is not possible to replace a base plate while it is still connected to the post. For this reason, first of all the post is removed as described in section 7.10. The running wheel of the bottom support rope is also dismounted. The faulty base plate is then replaced by a new one and the barrier is refitted.

7.13 Replacing base plate anchors

Replacing base plate anchors requires the base plate and the post to be removed in accordance with section 7.10 / 7.11 / 7.12. Depending on the type of damage to the foundation or the anchors, it may be necessary to recreate the foundation in a suitable location nearby in accordance with the product manual and the anchor forces sheet.

7.14 Replacing spiral rope anchors

To replace a rope anchor, it must first be relocated in a suitable location nearby in accordance with the product manual and the anchor forces sheet.

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8 FINAL CHECK

After servicing has been completed, above all the following points must be checked:

a) Are the support ropes and arrestor cables, as well as the lateral bracing, joined to the correct anchors?

b) Are the rope guides at the foot and head of the post laid out correctly?

c) Has the correct number of mesh loops or rings been left free to the left and right of the posts?

d) Is the net fitted correctly to the support ropes or running ropes?

e) If support ropes have been separated, are the bottom support ropes joined to the corresponding anchor and not to the base plate?

f) Is the number of wire rope clips on the rope end connections correct?

g) Are the wire rope clips fitted correctly?

h) Has the correct tightening torque been applied to the wire rope clips?

i) Have the nets been connected to one another correctly?

j) Have the border nets been fastened to the vertical ropes correctly?

k) Is the slack of the top support rope less than 3% of the post spacing?

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“BARRIER INSPECTION” CHECKLIST

This checklist is intended for the inspection of a barrier. Please enter your observations, tick the corresponding boxes, and take photographs or video recordings.

The paragraph numbers next to the boxes (e.g. no. 3.1) are reference numbers for the corresponding description in this maintenance manual.
The paragraph describes the criteria for repair and replacement.

Location:

General remarks:	**Impact area:**

Objects in the barrier

Leaves / soil / wood	Up to 20 cm	☐	
Rubble / pebbles	> 20 cm	☐	3.1
Stones	Up to 100 kg	☐	Stones up to approx. 35 cm in size
	> 100 kg	☐	3.1
	> 500 kg	☐	3.1 / 3.2 Stones over 60 cm in size
	.....	☐	

Visible damage:

A) Support and transmission ropes / U-brakes

Deformed rope	Yes	☐	3.5.2
	No	☐	
Net sags between posts	Up to 20 cm	☐	
	> 20 cm	☐	3.2 / 3.3
	> 50 cm	☐	3.2 / 3.3
	> 1 m	☐	3.2 / 3.3
Elongated brakes	Up to 30 cm	☐	3.3
	> 30 cm	☐	3.3
	> 60 cm	☐	3.3

B) Retaining ropes

Deformed rope	Yes	☐	3.5.2
	No	☐	
Angle between post and ground	approx. 70°	☐	
	approx. 80°	☐	3.2 / 3.3
	> 90°	☐	3.2 / 3.3

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C) Remaining ropes (without brakes)

Deformed rope	Yes	☐	3.2
	No	☐	

D) Spiral rope anchor

Damaged loop	Yes	☐	3.10
	No	☐	
Pulled out of the ground (in cm)	Up to 3 cm	☐	
	> 3 cm	☐	3.10

E) Mesh / net

Compressed mesh loops / rings	Yes	☐	3.4
Torn wires	Yes	☐	3.4
	No	☐	

F) Wire mesh

Torn down / punctured	Yes	☐	3.4.4
	No	☐	

G) Post / base plate

Deformed post	Yes	☐	3.6
	No	☐	
Hinge bolt bent / broken	Yes	☐	3.7
	No	☐	
Deformed base plate	Yes	☐	3.8
	No	☐	

Damaged rod anchor	Yes	☐	3.9
	No	☐	
Rod anchor pulled out of the ground	> 3 cm	☐	3.9

H) Wire rope clips

All wire rope clips have the right torque	Yes	☐	6
	No	☐	6

Remarks / Notes / Sketches:

Name of checker: ……..

Date: …… Signature: ……

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Appendix H

Wastewater Masterplan Report for
Dillingham Ranch Agricultural Subdivision
Mokule'ia, O'ahu, Hawai'i

Wastewater Masterplan Report

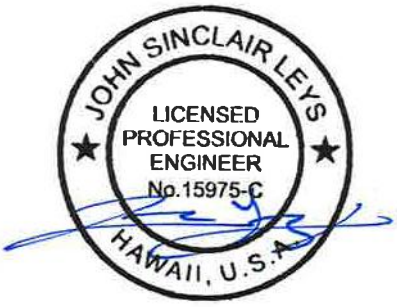
For Dillingham Ranch Agricultural Subdivision
Mokuleia, Oahu, Hawaii

Tax Map Key (1) 6-8-003

Prepared for:

Dillingham Ranch Aina, LLC

9701 Wilshire Boulevard, Suite 700
Beverly Hills, California 90212



Prepared July 31, 2014 by:

SHERWOOD
DESIGN ENGINEERS
58 Maiden Lane, Third Floor
San Francisco, CA 94108
www.sherwoodengineers.com

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- Leach Field

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  - Figure 2 – Conveyance from Dwelling to Collection System
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- Appendix C – Typical Section of Leach Field
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I. INTRODUCTION

a. Purpose and Scope of Report

This document presents the preliminary wastewater master plan for the agricultural subdivision at Dillingham Ranch Aina, Mokuleia, Hawaii. This report estimates the proposed demands per the Department of Health Wastewater Branch requirements and describes the sizing and layout of the collection network, system appurtenances, proposed wastewater treatment works, and disposal facility.

b. Existing Condition

Dillingham Ranch is a large land holding comprised of 2,721 acres bound between Farrington Highway and the Mokuleia Forest Reserve. Farrington Highway lies adjacent to the property's northern boundary and divides the ranch from the Mokuleai Community located approximately 800 feet northwest of the ranch entrance. Existing terrain on the property is defined by low coastal plains in the north and steep mountainous landscape to the south. The flat coastal plains are located between Farrington Highway and the old agricultural cane haul road with gentle slopes averaging 0% to 5%. The coastal plain is underlain by alluvial and marine sediments consisting of horizontal layers of clay, silt, sand, and coralline limestone.

Existing land use on the existing Ranch are governed by agricultural fields, coconut plantations equestrian uses, and cattle grazing. Various existing agricultural use structures are located in this region. In contrast to the flat coastal plain of the lower lands, the landscape *mauka* of the cane haul road ascends towards steep mountainous terrain. Slopes in this area start at 10% to 20% and continue to steepen up to 50% or greater *mauka* of the subdivision towards the Mokuleia Forest Reserve. Rockfall zones are present in the upper limits of the property.

There is very little existing development within the project area, the primary exceptions being the Dillingham Lodge, an access road to the Mokuleia Forest Reserve and a handful of private residences. Existing improvements treat wastewater through on-site systems that include a DOH-permitted aerobic treatment unit and subsurface disposal facility at the Lodge as well as traditional septic systems for the outlying private residences.

All the properties in the area around Dillingham Ranch Aina contain their own private systems, as no municipal wastewater mains or treatment plants are available within the region.

c. Proposed Condition

The proposed development is an agricultural subdivision comprised of 91, five-acre minimum lots with a 4-5 bedroom single family dwelling unit on each lot. The project will retain the existing historic Lodge building and its permitted functions and include a new Agricultural Cluster Development, which have 15 units.

The project will comply with DOH WWB, Title 11, Chapter 62, which mandates that a centralized wastewater treatment system is required for subdivisions with more than 50 lots. All of the wastewater infrastructure, components of which are located both on private lots and Ranch lots, will be maintained by the project's Home Owner's Association.

The proposed system will be comprised of septic tanks located at each lot for primary treatment prior to conveyance of the clarified effluent through a low pressure pipe network to the centralized wastewater treatment works. The wastewater treatment works will be comprised of a Cyclical Biological Treatment (CBT) Unit. The secondary treated effluent will then be disposed of through a centralized subsurface effluent disposal system or in combination with the treatment and use as R-2 recycled water.

II. METHODOLOGY

The wastewater analysis is governed by the Department of Health Wastewater Branch (DOH WWB), Title 11, Chapter 62, Appendix F-Table 1 which states the required estimated loading rates for various building uses. For residential uses a rate of 100 gallons per person per day (gpcd) with 2 people per bedroom is the required rate. Refer to the table below for the proposed wastewater generation rates.

Table 1. Proposed Wastewater Generation Rates

WASTEWATER LOADING RATES					AVG DAY FLOW (GPD)	MAX DAILY FACTOR	MAX DAY FLOW (GPD)
TYPE	# BEDROOM	GPD/BEDROOM	GPD/UNIT	# UNIT			
RESIDENTIAL	5	200	1,000	46	**46,000**	1.5	**69,000**
RESIDENTIAL	4	200	800	45	**36,000**		**54,000**
AG-CLUSTER (3 BDRM)[1]	3	200	600	10	**6,000**		**9,000**
AG-CLUSTER (2 BDRM)[1]	2	200	400	5	**2,000**		**3,000**
LODGE	8	200	1,600	1	**1,600**		**2,400**
TOTAL	-	-	-	-	**91,600**		**137,400**

Based on the demands summarized above, the design of the collection network and treatment works is described in more detail below.

III. COLLECTION SYSTEM

a. The Effluent Sewer System

The project proposes to use an effluent sewer system at each homesite prior to discharge into the project's wastewater collection network. With an effluent sewer system, raw sewage flows from the proposed residences to a watertight underground septic tank on each lot. Only the filtered liquid portion is discharged (by either pump or gravity) to shallow, small-diameter (3-4") collection lines located within the roadways. Solids remain in the underground tank, for passive, biological treatment, and need be pumped only every five to ten years. The effluent sewer for this project is referred to as the STEP (Septic Tank Effluent Pumping) system. These systems are found in residential communities across the United States.

The STEP systems are fully powered on electricity and concerns of operations during power outages are alleviated by increasing the septic system storage by up to 1.5 times the required capacity of each homesite. For example, 1,000 gal of storage is required for a typical 5 bedroom dwelling. To allow for a factor of safety in the system due to short duration power outages, the septic system may be increased to 1,500 gpd to account for maximum daily flow. The septic tanks at each lot will be located close to the home site, downstream of the dwelling unit. A 1/2 HP pump will be located downstream of the holding tank to discharge the liquid effluent into the low pressure force main within the roadway. The septic tanks will be maintained by the HOA, inspected regularly, and pumped periodically to remove the accumulated sludge. The low pressure force main will drain the wastewater to Lot 1005 where the centralized wastewater treatment works is located. (See Appendix A, Proposed Wastewater Layout)

IV. WASTEWATER TREATMENT WORKS AND DISPOSAL SYSTEMS

a. Aerobic Treatment Unit

Sherwood Design Engineers has worked with International Wastewater Technologies (IWT) to provide a package treatment unit which would be compact, yet modular to allow treatment of the proposed subdivision at full build out. A cyclical biological treatment (CBT) unit was proposed by IWT because there is the advantage of chemical oxidation, which provides a higher performance in wastewater treatment. The activated sludge technology maximizes the nitrogen and phosphorus removal. It is estimated two of the proposed units would be required for full-build-out, allowing treatment of the average and maximum daily flows. As phasing for the project is unknown at this time, the CBT units allow for modular expansion as phases of the project are built out.

The CBT unit will treat the domestic wastewater to an effluent level of 10mg/L of Biochemical Oxygen Demand (BOD_5) and 10 mg/L of Total Suspended Solids (TSS). This exceeds the WWB effluent concentration requirements for treatment units which are to not exceed 30mg/L of BOD_5 and 30mg/L of TSS. In addition, the pH of the effluent will be within the required limits of 6.0-9.0. The CBT unit will be located on Parcel 1005, just upstream of the proposed subsurface effluent disposal system. The wastewater will be consolidated at this point prior to dissipation in the leach field. The CBT unit will be no closer than 1000-ft from Existing Well 3410-01. Refer to Appendix A for location.

Refer to Appendix B for preliminary CBT product sheets.

b. Subsurface Effluent Disposal System

Subsequent to the CBT unit, the effluent will be discharged into a subsurface effluent disposal system where the wastewater will percolate into the soil. The subsurface effluent disposal system will largely occupy Parcel 1005. A portion of this lot is within the current 100-year flood plain, therefore the disposal system will be raised to avoid inundation during large flood events. Drainage will be routed around the disposal system as described in the 2014 Drainage Master Plan Report, prepared by Sherwood Design Engineers.

Percolation tests were performed by Geolabs in May 2014 and it was determined that Lot 1005 has a substrate with areas of sandy soil, albeit the substrate is not consistent. From the excavation and percolation tests performed, it is clear that coralline sand is

present at varying depths below existing grade, but is overlain by silty clay at varying depths. The percolation rates of the coralline sands are approximately 6 to 8.6 minutes per inch. The percolation rates through the clayey soils are unsuitable for subsurface effluent disposal system design as they exceed 60 minutes per inch (Refer to GeoLabs boring logs located in Appendix D of this report). The subsurface effluent disposal system will require removal of the clay layer and backfill of an engineered soil that will be designed to give a percolation rate of 6.0 minutes per inch. The Environmental Protection Agency (EPA) recommends wastewater application rates for the sandy soils to be 0.8 gpd/sf, based on designed soil percolation of 6.0 minutes per inch (USEPA Design Manual for Onsite Wastewater Treatment and Disposal Systems (DPA 625/1-80-012, table 7-2, p.214)).

Many options were considered in the design of the disposal system for the treated wastewater. The project has eliminated injection wells as a form of disposal due to its susceptibility to increase contamination to the groundwater aquifer among other environmental concerns. Leach fields were considered in the sizing of the disposal system; however, traditional gravel-filled leach fields require an expansive area for disposal, almost 5 acres for the peak flows of 137,400 gallons at the full-build out of the project.

The subsurface disposal system proposed is a chamber leach field, which is a similar mechanism for disposal of the treated effluent as a traditional leach field; however, the arched chambers allow for more efficient infiltration into the underlying soils via enhanced lateral distribution of the effluent. Chambered leachfields have been used for over 30 years in the United States (County of Santa Cruz Health Services Agency) and currently approximately 30% of leachfields installed employ leaching chambers. The chamber systems are comprised of fabricated corrugated arches, which are placed over soil. At full build-out flows of 137,400 gallons they will require 3.95 acres to adequately dispose of the treated effluent. To satisfy the 100% backup requirement of the WWT system, the chamber system will be 7.9 acres. This is approximately 80% of the area a traditional leach field would require. Please see Appendix C for sizing calculations.

The subsurface disposal system will be located within Parcel 1005. The chamber leaching beds will be placed with a minimum of 18-inches of cover. The final layout of the beds will be driven by various parameters for adequate setback distance to avoid potential impacts to existing water wells. Specifically, the leach field cannot encroach within 1000-ft of existing Well 3410-10, located in Parcel 1004.

V. WASTEWATER TREATMENT AND DISPOSAL ALTERNATIVES

a. R-2 Recycled Water Treatment

The recycled water system is an alternative to the chamber leach field system design. The recycled water would be used to drip irrigate adjacent grasslands and would be the primary disposal system of the treated effluent. The wastewater treatment works would be enhanced to meet Wastewater Branch's Guidelines for the Treatment and Use of Recycled Water dated May 15, 2002. This enhancement would be the disinfection of the treated wastewater. Note that the effluent meets the Wastewater Branch's requirements of 10 mg/L for both BOD_5 and TSS using the CBT unit. The disinfection of the recycled water would be comprised of UV disinfection or chlorination. Although the entire effluent design flow would be disposed of primarily using subsurface irrigation, the chamber

system would be provided to meet the 100% backup requirement (3.95 acres on Parcel 1005). The implementation of the system would reduce the over-excavation and placement of engineered soils.

Per the Wastewater Branch guidelines, the recycled water will be treated to R-2 standards, limiting its use at the development to subsurface irrigation for pastures and grasslands.

b. Ultra Violet (UV) Disinfection

Use of UV disinfection is preferred over other methods, as it requires no chemical additives and relies on absorption, reflection, refraction, and scattering of pathogen material when it interacts with the UV light. Disinfection results from interactions between the emitted UV light and UV reactor components. The influent entering the UV system which has been treated to 10 mg/L of BOD5 and TSS significantly improves the effectiveness of the UV system. The closed-channel disinfection system includes sensors, a quartz sleeve wrapped in the reactor casing. They can be located in-line with the pipe system and can rely on gravity to push the water through. The UV lamp parameters are assumed to be designed for about 45% UV Transmittance (UVT) and anticipated dose at 100 mJ/cm^2.

The closed-channel UV system is made of a 3-inch diameter tube, approximately 4-ft long. The residence time within the system can vary, which allows for flexibility for phasing of the development. A backup UV system would be provided in parallel for maintenance of system components. The disinfection system would be located downstream of the CBT unit.

c. Chlorine Disinfection

Chlorination is used as another form of disinfection to remove pathogenic organisms. Liquid chlorination is the preferred over powdered for this project, assuming that the system will be automated for better control of the dosing of chlorine. The chlorine dosing will be minimized to maintain a residual within the treated effluent to ensure that the stored recycled water does not turn septic prior to use. The minimum chlorine contact time will be 15 minutes to ensure that the residual during application of the treated water is no less than 2 mg/L.

d. Storage

All equipment, including the recycled water storage tank, will be stored in an at grade tank, located on Lot 1005, adjacent to the wastewater treatment equipment.

VI. MONITORING AND SAMPLING

The HOA will sample the wastewater treatment system to the satisfaction of the State of Hawaii Department of Health requirements and maintain the equipment in accordance with product and equipment specifications.

VII. CONCLUSION

The proposed wastewater treatment system for Dillingham Ranch Aina is composed of a robust, multi-stage set of proven technologies. Primary treatment is achieved through dispersed residential septic tanks located at each of the lots on the site. These tanks remove the solids from the waste stream before the wastewater enters the low pressure collection pipe network. The wastewater is then transported to a collection location downstream from the residences where secondary treatment is achieved in a cyclical biological treatment unit. Through these first two steps the wastewater will have been treated to levels far exceeding minimum code requirements and to a level where it can be disposed of in a leach field system or further treated through disinfection methods such that it can be disposed of via drip irrigation.

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APPENDIX A

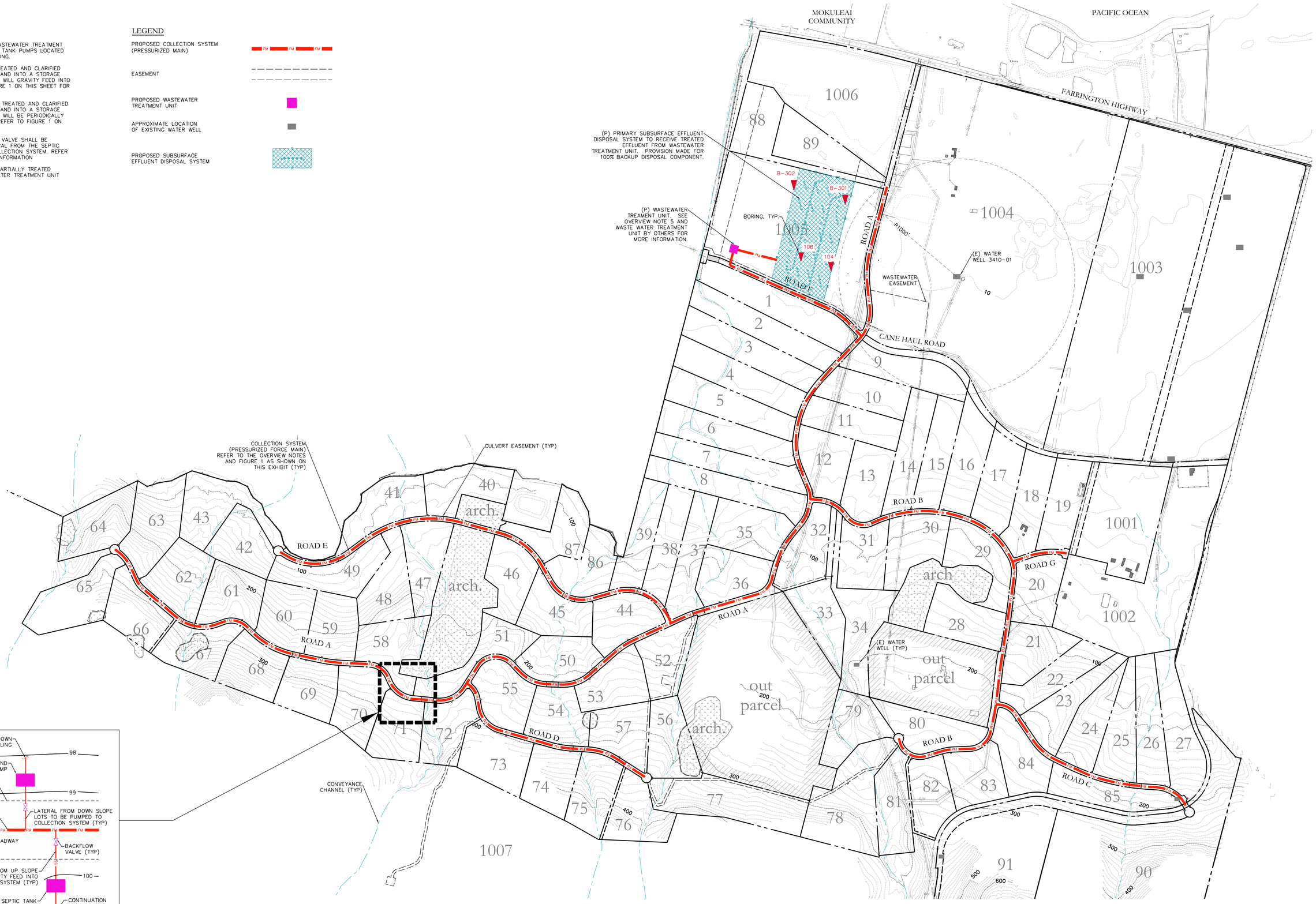
FIGURE 1 - PROPOSED WASTEWATER LAYOUT

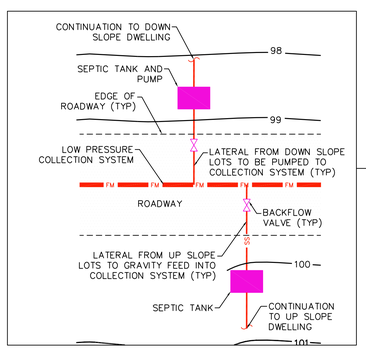
OVERVIEW NOTES

1. THE (P) COLLECTION SYSTEM FOR THE WASTEWATER TREATMENT WORKS WILL BE PRESSURIZED VIA SEPTIC TANK PUMPS LOCATED ADJACENT TO EACH DOWN SLOPED DWELLING.
2. FOR UP SLOPED LOTS, THE PARTIALLY TREATED AND CLARIFIED EFFLUENT WILL PASS THROUGH A FILTER AND INTO A STORAGE CHAMBER AT THE SEPTIC TANK WHERE IT WILL GRAVITY FEED INTO THE COLLECTION SYSTEM. REFER TO FIGURE 1 ON THIS SHEET FOR MORE INFORMATION.
3. FOR DOWN SLOPED LOTS, THE PARTIALLY TREATED AND CLARIFIED EFFLUENT WILL PASS THROUGH A FILTER AND INTO A STORAGE CHAMBER AT THE SEPTIC TANK WHERE IT WILL BE PERIODICALLY PUMPED INTO THE COLLECTION SYSTEM. REFER TO FIGURE 1 ON THIS SHEET FOR MORE INFORMATION.
4. A BACKFLOW PREVENTION (ANTI-SIPHON) VALVE SHALL BE INCORPORATED AT EACH OUTGOING LATERAL FROM THE SEPTIC TANK TO MAINTAIN PRESSURE IN THE COLLECTION SYSTEM. REFER TO FIGURE 1 ON THIS SHEET FOR MORE INFORMATION
5. THE COLLECTION SYSTEM CONVEYS THE PARTIALLY TREATED EFFLUENT DOWNSTREAM TO THE WASTEWATER TREATMENT UNIT LOCATED BELOW THE NO PASS LINE.

LEGEND

- PROPOSED COLLECTION SYSTEM (PRESSURIZED MAIN)
- EASEMENT
- PROPOSED WASTEWATER TREATMENT UNIT
- APPROXIMATE LOCATION OF EXISTING WATER WELL
- PROPOSED SUBSURFACE EFFLUENT DISPOSAL SYSTEM





TYPICAL LATERAL CONNECTION

SCALE: NTS

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58 Maiden Lane, Third Floor
San Francisco, CA 94108
www.sherwoodengineers.com

WASTEWATER MASTER PLAN

DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, HAWAII

June 30, 2014

North

0 150' 300' 600'

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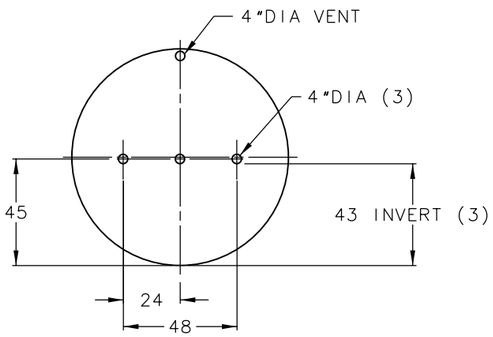
APPENDIX B

WASTEWATER TREATMENT CUT SHEETS

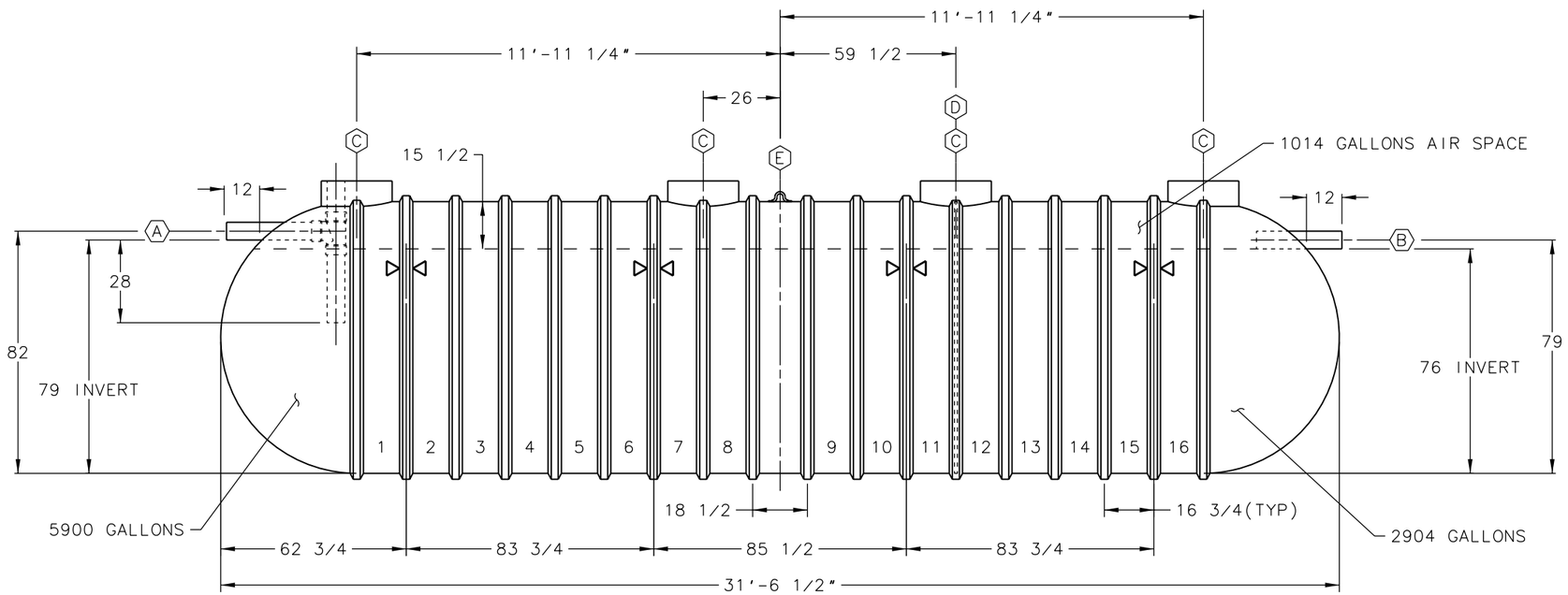
CYCLICAL BIOLOGICAL TREATMENT (CBT) UNIT

NOTE:

1 - SEE XERXES' ONE YEAR LIMITED WARRANTY FOR UNDERGROUND SEPTIC TANKS.
2 - INVERT DIMENSION FROM TANK I.D.



BAFFLE DETAIL
SCALE: 1/32



ACTUAL WORKING VOLUME = 8805 GALLONS

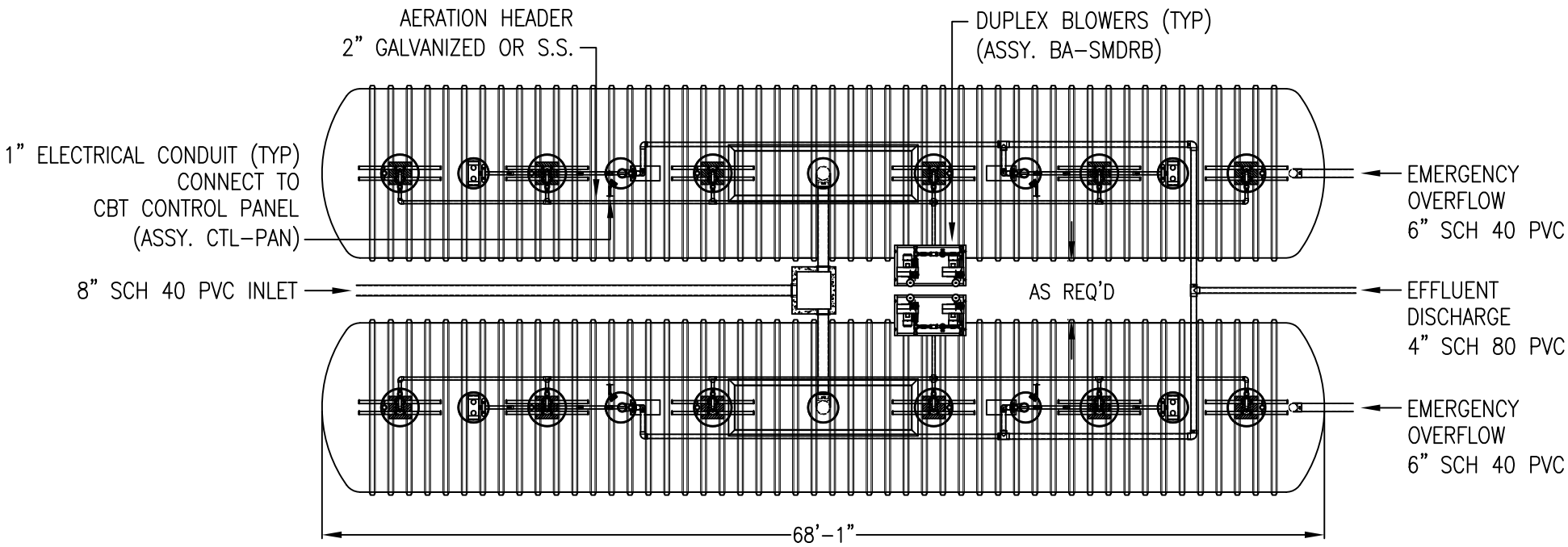
A	6"DIA SCH 40 PVC INLET PIPE WITH INTERNAL SANITARY TEE & PIPES
B	6"DIA SCH 40 PVC OUTLET PIPE
C	RISER PIPE, FOR 24"(NOMINAL) ACCESS OPENING
D	FULL PLATE BAFFLE WITH 3-4"DIA FLOW HOLES & 1-4"DIA VENT HOLE (43" INVERT)
E	LIFTING LUG
	HOLD DOWN STRAP LOCATION

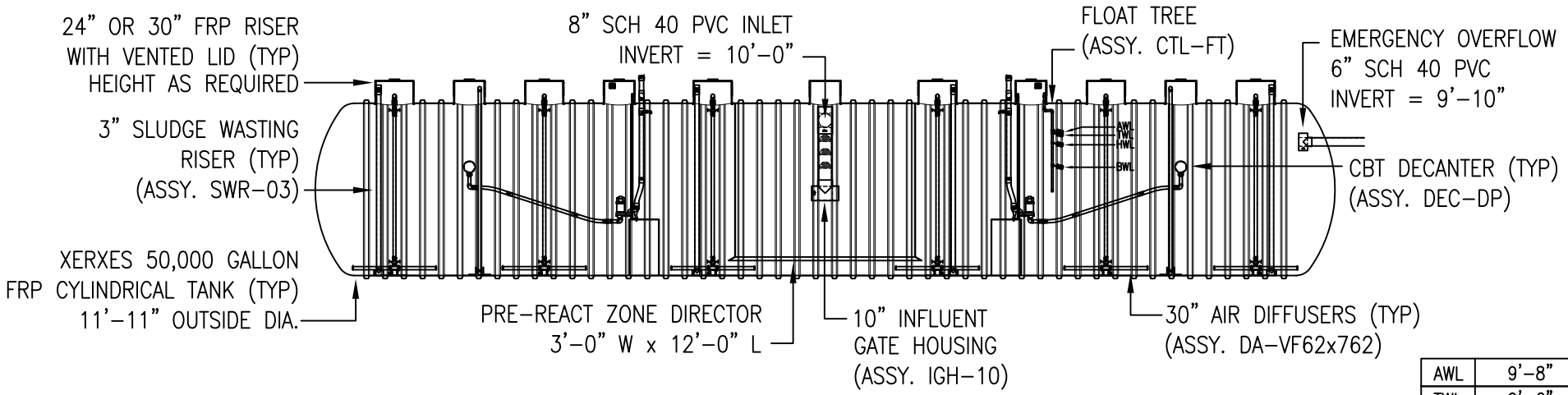
0	REVISION DESCRIPTION -	BY DATE

CHK'D	DATE	STD'S	DATE	APPR'D	DATE
-	-	-	-	-	-

XERXES® CORPORATION

DRN DAG	DATE 5-8-07	TITLE 8'DIA SWT CAP. 10,000 GALLONS INTERNATIONAL WASTEWATER	
CHK'D JWL	DATE 5-8-07		
STD'S	DATE	DR. SIZE D	DR. NUMBER 630-115 / REV 00
APPR'D JB	DATE 5-8-07		
SCALE: 1/2"=1'-0"		NEXT ASS'Y: -	SHT 1 OF 1





AWL	9'-8"
TWL	9'-6"
HWL	8'-10"
BWL	7'-4"

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INTERNATIONAL WASTEWATER TECHNOLOGIES, INC.
94-009 Waipahu Depot Street
Waipahu, Hawaii 96797
Phone - 808-677-7715
Fax - 808-677-7719
sales@internationalwastewater.com

MODEL	CBT 51.0KFX-200	TITLE	Sheet
CAPACITY	60,000 GPD	CBT 51.0KFX-200	W-1
SCALE	NOT TO SCALE	NOT FOR CONSTRUCTION	1 of 1
DATE	4/26/14		

POWER DESIGN

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Modular Enclosures

- Design versatility in 4′, 6′, 8′, 10′, 12′ 16′ and 20′ widths and a variety of lengths and heights

- Fire retardant 1/4″ fiberglass construction with UV protection
- Foam board insulation with a internal glass facer is available as an option

- Variety fiberglass door sizes and configuration all w/ stainless steel jamb, 3-point latch with padlocking provisions, and SS rain shield are available. Panic door hardware available as an option

- Internal seams are bolted and sealed for strength and water integrity

- Lift-off design with lifting eyes allows modular enclosure to be removed without disturbing enclosed equipment

- Special equipment such as air conditioners, heaters, exhaust fans, intake louvers, lights, etc can be installed at the factory
- Available in Light Grey, Willow Green, or Munsell Green colors. Special colors are available.

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POWER DESIGN INC.

Modular Enclosure Specification
Model # ME4-48-2424-L1-LG

1.0 Scope

This specification applies to fiberglass outdoor padmount modular enclosures. Unit shall be designed for mounting on a concrete pad by means of an internal flange completely around the base. Enclosure finish shall be in complete conformance with IEEE C57.12.28, Padmounted Equipment Enclosure Integrity Standard.

2.0 Construction

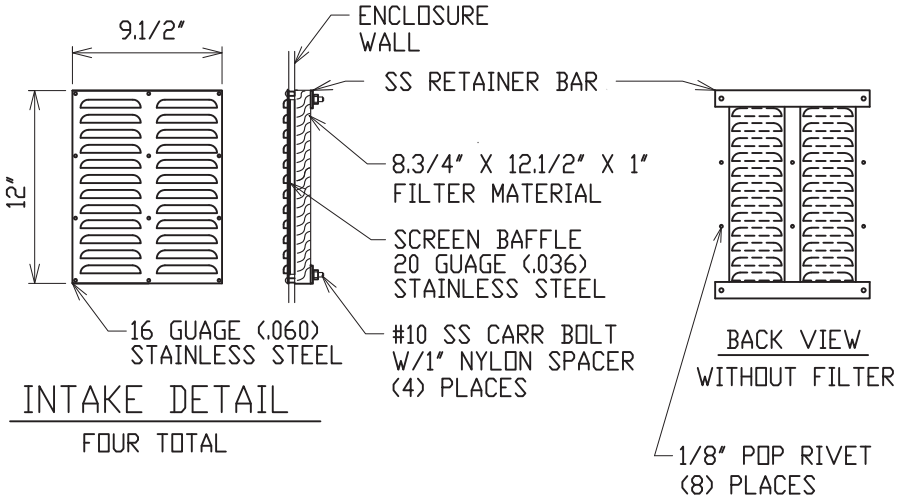
2.1 Fiberglass laminate shall be ¼" nominal thickness except where local reinforcement is required.
2.2 Fiberglass shall not support combustion and be self-extinguishing.
2.3 Enclosure exterior shall be gelcoated to .014 inch nominal thickness and be a standard white color.
2.4 Locking device shall provide three point latching and padlocking provisions.
2.5 All door and exterior hardware shall be made of 304 stainless steel.
2.6 Enclosure shall be removable without disturbing enclosed equipment.
2.7 A stainless steel identification plate shall be affixed outside the enclosure which identifies the manufacturer, model number of the equipment, and date of manufacture.
2.8 (4) SS Intake louvers shall be provided for adequate air flow and heat dissipation as required for enclosed equipment.
2.9 (4) 115 VAC 60 Hz 15 Watt Rotron fan with SS louver, guard & filter media.
2.10 (2) Adjustable 120 V snap disc fan & limit controls.
2.11 The enclosure components, dimensions, and construction shall be as shown on the drawings.
2.12 The enclosure shall be 4'W x 6'L x 5'6"H and have (2) 60" W x 50" H double doors.
2.13 The enclosure shall be shipped in one piece with four lifting eyes for setting over the equipment.
2.15 The enclosure components, dimensions, and construction shall be as shown on the drawings.

3.0 Testing & Standards

3.1 Certified test data for the finished laminate shall be as follows:

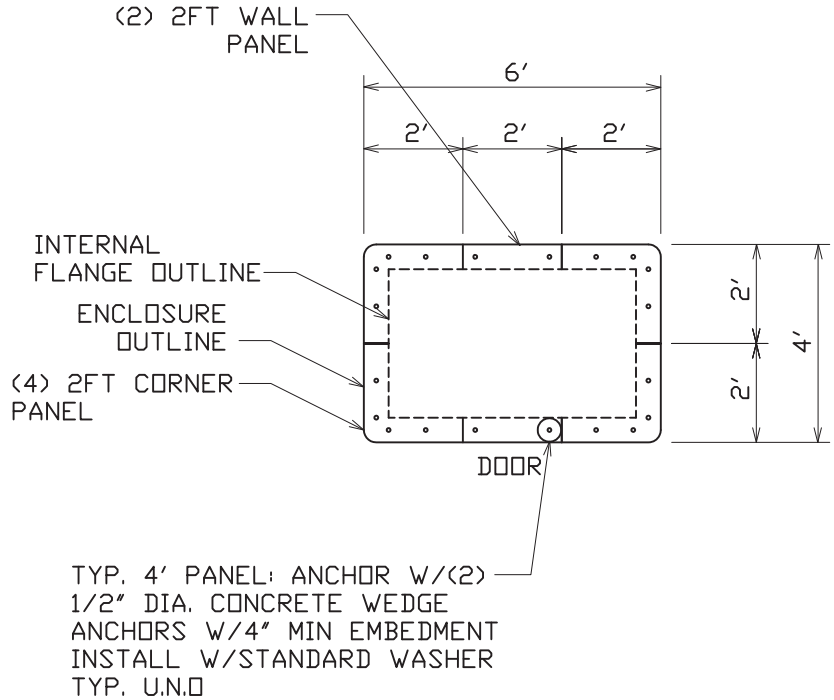
Tensile Strength	ASTM D638	11,120 psi
Flexural Strength	ASTM D790	25,380 psi
Flexural M.O.E.	ASTM D790	1.182×10^6
Comp Strength	ASTM D695	23,980 psi
Charpy Impact	ASTM D256	4.6 ft lbs/in
Impact Resistance	ASTM D2444	46 in lbs
Water Absorption	ASTM D570	0.092%
Flammability	ANS Z124.2	self-ext'g

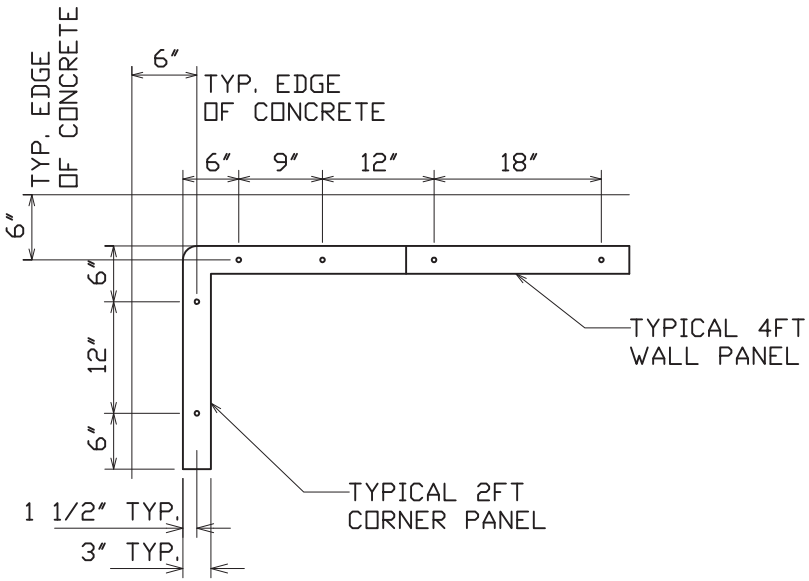
3.2 The enclosure finish shall meet or exceed ANSI C57.12.28 Padmounted Equipment Enclosure Integrity Standard.



INTAKE DETAIL

FOUR TOTAL





FLANGE & TRUSS MOUNTING BOLT DETAIL

NOTE:

WEDGE ANCHORS AND PLATE WASHERS SUPPLIED BY CUSTOMER

FIBERGLASS MODULAR ENCLOSURE

4 FT WIDE x 5 FT 6 IN HIGH x 6 FT LONG

TWO DOUBLE DOORS (4) EXHAUST FANS FILTERED INTAKE LOUVER

POWER DESIGN INC.

ODELL, OREGON

DRAWN:	PAGE	DATE	DRAWING NO.
RB	2 OF2	3-4-09	2424

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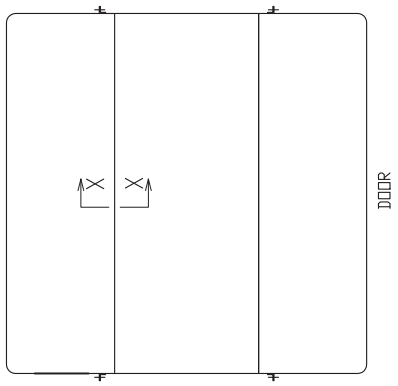
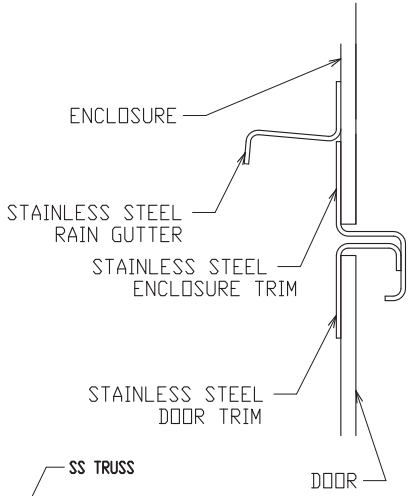
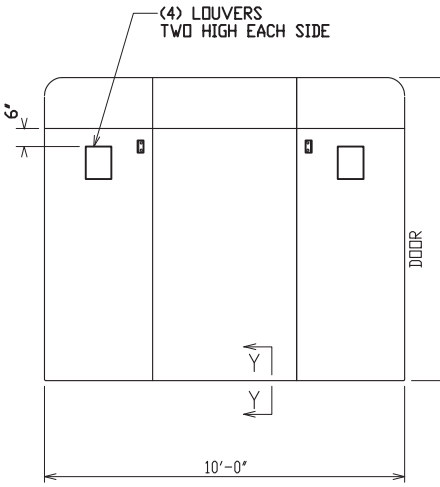


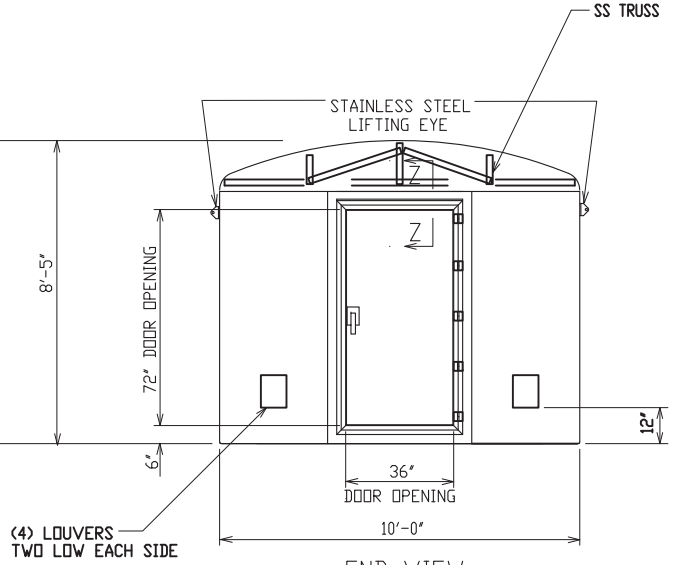
TOP VIEW



SECTION Z-Z



FRONT VIEW



END VIEW

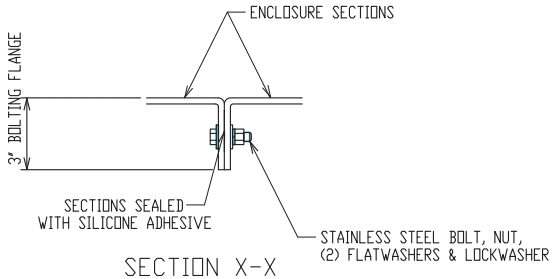
ORDERING INFORMATION:

ME 1 - 120 - 2425 - L1 - LG

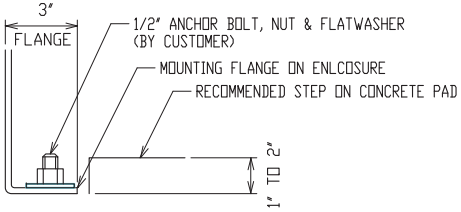
- MODEL
- NUMBER OF DOORS
- NOMINAL WIDTH
- DETAILS AS SHOWN ON THIS DRAWING
- COLOR:
  - LG - LIGHT GRAY
  - WG - LIGHT GREEN
  - MG - MUNSELL GREEN
  - OTHER COLORS AVAIL. CONSULT FACTORY
- L1 - PROVISION FOR PADLOCKING ONLY
- L2 - PROVISION FOR PADLOCKING & PENTA HEAD BOLT
- L4 - PROVISION FOR PADLOCKING, PENTA HEAD BOLT & INNER DOORS

NOTE:

1. MATERIAL:
   1) FIBERGLASS LAMINATE 1/4" NOMINAL THICKNESS
   2) EXTERIOR UV STABILIZED GELCOAT - 14 MIL NOMINAL THICKNESS
   3) FIRE RETARDANT - DOES NOT SUPPORT COMBUSTION
   4) STAINLESS STEEL HARDWARE
2. STANDARDS:
   1) CERTIFIED TEST DATA OF ASTM STRUCTURAL STANDARDS AVAILABLE UPON REQUEST



SECTION X-X



SECTION Y-Y

FILE REF:

FIBERGLASS MODULAR ENCLOSURE

10 FT WIDE x 8 FT 5 IN HIGH x 10 FT LONG

ONE ACCESS DOOR

POWER DESIGN INC.

ODELL, OREGON

DRAWN:	PAGE	DATE	DRAWING NO.
RB	1 OF 2	3-5-09	2425

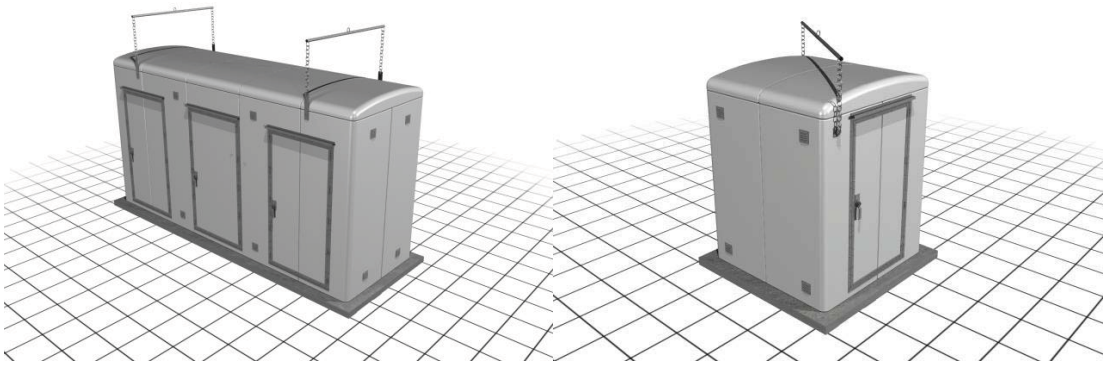
POWER DESIGN INC.
PO BOX 147 ODELL, OR 97044 TEL: (541) 354-3222 FAX: (541) 354-3366

MODULAR ENCLOSURE
Installation Instructions

UNLOADING
Typically the 4’ and 6’ wide modular enclosures can be picked up with a single forklift. Verify the pallet is set up to support the weight before attempting to lift with a single forklift. Units that are 8’ wide and larger generally require two forklifts or a crane to lift them off the truck. Large units are typically loaded by lifting on either side with a forklift and then having the truck back underneath the unit. Unloading can be done in the same way. When using a crane a spreader bar is required so that the force on the lifting eyes is straight up. The length required is the width of the enclosure (4’, 6’, 8’, 10’ or 12’). Adjustment in the spreader bar assembly may be required due to uneven weight distribution such as doors or wall mounted equipment.

After unloading, inspect the unit for any shipping damage and note any damage on the bill lading. Some equipment may be shipped on the pallet inside the enclosure. It is important to review and inspect this equipment for shipping damage as well.

PLACEMENT
The modular enclosure can be lifted by the lifting eyes provided on the enclosure. There are 1” diameter holes in the end of the bars for attachment. A spreader bas assembly is required for lifting so that the force is straight up on the bar and not off at an angle. The length required is the width of the enclosure (4’, 6’, 8’, 10’ or 12’). There are no other special tools needed to lift the enclosure.



Remove the lag bolts from the internal flange to release the modular enclosure from the pallet. If any doors need to be opened while placing the unit make sure the doorstop rod is in place. Adjustment in the spreader bar assembly may be

required due to uneven weight distribution due to doors or wall mounted equipment.

PAD

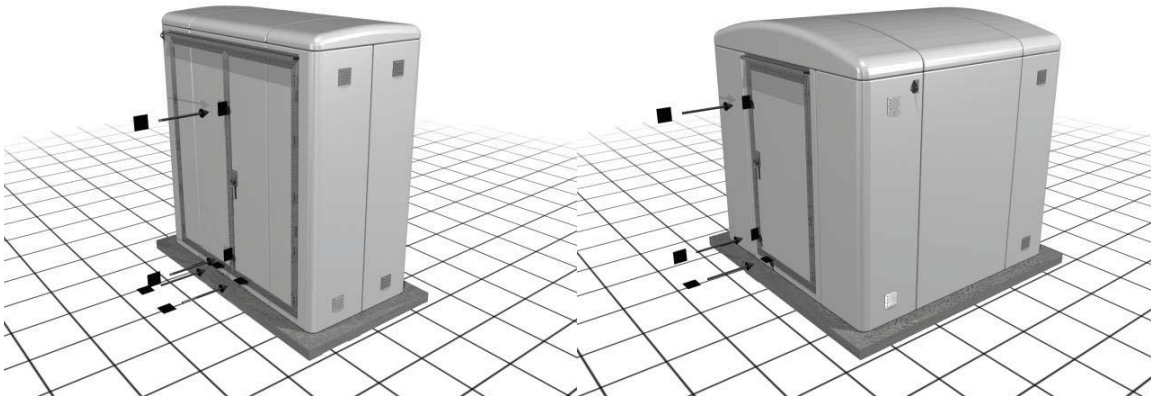
It is recommended to put the enclosure on a housekeeping pad where the flange is 1-2” below the interior floor. The base does not need to be sealed in this approach and allows any water, which might get inside to drain out. The pad should be at least 8” larger than the enclosure on each side for anchorage.

ATTACHMENT

The base mounting flange is nominally 3/8” thick with 7/8” diameter holes on approximately 14” centers. Recommended anchor bolt size is 5/8” diameter extending 1 ½” above and 5” into the pad. Drilled in place stainless steel bolts or wedge anchors are recommended due to variations in pads, door placement, equipment mounting, etc. It is not necessary to use all anchor bolt holes provided. The extra holes are provided in case floor or wall mounted equipment is in the way. Each wall or corner section should have at least two anchor bolts and they should be equally spaced around the enclosure. Single doors should have at least (2) anchor bolts underneath the opening and double doors should have (3-4) depending on the width.

ADJUSTMENT

After the enclosure is securely bolted to the pad, the door may require some adjustment. This can be accomplished by loosening the ¼” bolts holding the hinges. The door should then be shimmed on the bottom and side opposite the hinges. Retighten the ¼” bolts on the inside with the shims in place. If the pad in not completely level it may be necessary to shim under the enclosure flange for the door to operate correctly.



Muffin XL AC - MX2A3 - 028316

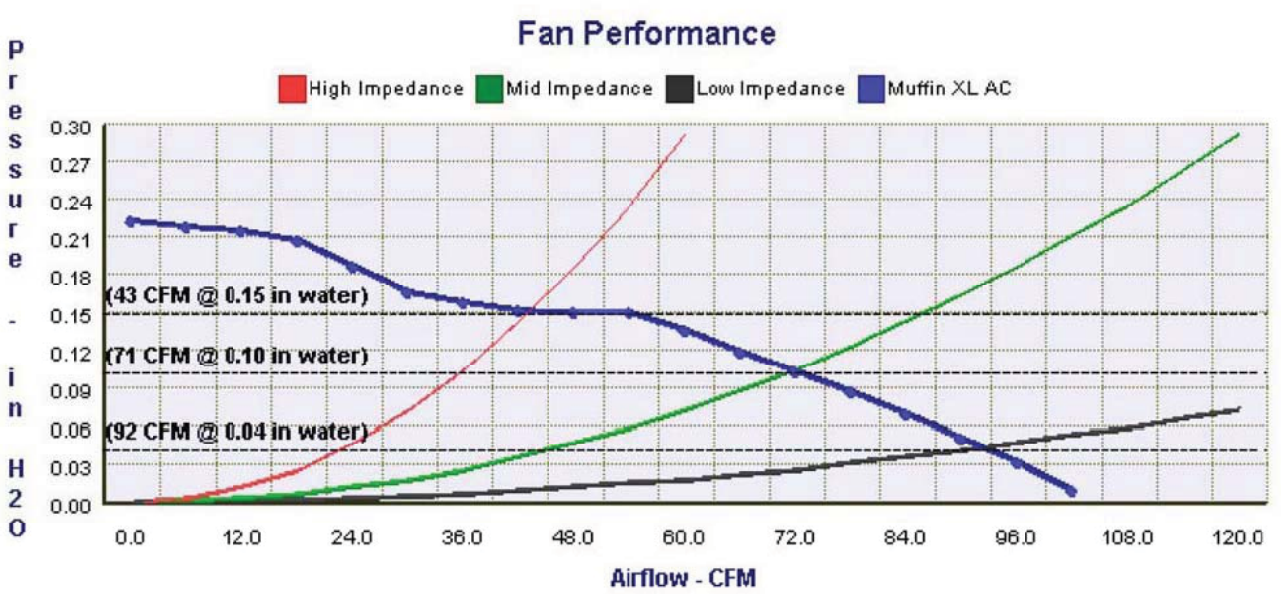
(Family) (Model) (Part Number)

Electrical Specifications

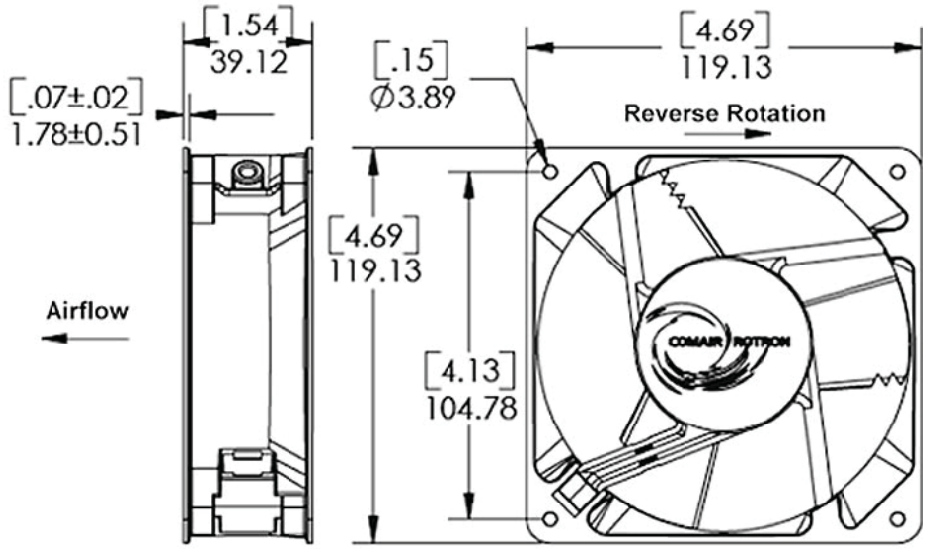
Rated Voltage:	115 VAC
AC Frequency:	60 Hz
Power Supply:	15.0 Watts
Line Current:	0.18 Amps
Locked Rotor Current	0.27 Amps
Nominal Speed:	3100 RPM

Mechanical Specifications

Dimensions:	4.72in x 1.50in
Weight	21.0 oz
Max Airflow @ 0 in H_2O	105.0 CFM
Max Pressure @ 0 CFM	0.223 in H_2O
Noise	47.6 dBA



Mechanical Drawing



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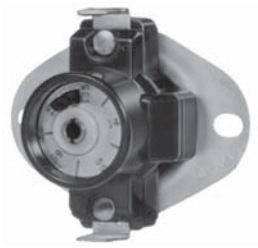

3L05-1

F6-1798 (1 per pack)

ADJUSTABLE SNAP DISC FAN & LIMIT CONTROLS

Adjustable Snap Disc Thermostat Allows You to Set the Temperature Set Point to Match Your Specific Needs Which Simplifies Inventory

FEATURES

- ¼″ quick connect terminals are standard.
- Reduces inventory while providing coverage for a wide range of temperature applications.
- Replaces the majority of fixed disc thermostats now on heating equipment and various appliances.
- 2 adjustable fan control models replace 7 fixed snap disc models.
- 5 adjustable limit control models replace 10 fixed snap disc models.

SPECIFICATIONS

ELECTRICAL RATINGS

VAC	Resistive (Non-Inductive)	Motor Rating (Inductive)		Pilot Duty
		Full Load	Locked Rotor	
120	25.0A	14.0A	72.0A	125 VA
240	25.0A	10.0A	60.0A	125 VA

PARTS AND ACCESSORIES

- F6-1798 Adapter plates (Order separately) — 1 per pack

Model Number	Temperature Range	Differential	Switch Action	Function	Accessories	Therm-O-Disc	
						Style	Type
3F05-1	90 to 130°F	20°F	SPST	Fan Controls	Includes thermostat and tab-to-screw terminals.	74T12	310708
3F05-2	140 to 180°F	20°F	SPST	(Close on Rise)		74T12	310709
3L05-1	135 to 175°F	40°F	SPST	Limit Controls		74T11	310710
3L05-2	175 to 215°F	40°F	SPST	(Open on Rise)		74T11	310711
3L05-3	210 to 250°F	40°F	SPST			74T11	310712
3L05-10	135 to 175°F	20°F	SPST			74T11	310724
3L05-13	250 to 290°F	40°F	SPST			74T11	310730

PROJECT:	Dillingham Ranch WWTP V1
MODEL NUMBER:	CBT102KFX-200
DATE:	04/26/14
SITE LOCATION:	Dillingham Ranch North Shore Oahu, Hawaii
ELECTRIC:	230-V, 3-Phase minimum with 120-V for Controls.
	San Francisco, CA 94108
BASIN:	4-ea Xerxes 50,000 Gallon 12'D x 68'-1" L
BLOWERS:	3BA7620-OAT46
DIFFUSERS:	EDI FLEXAIR 62 x 762
PUMPS:	50DWXU6.75

International Wastewater Technologies, Inc.
94-009 Waipahu Depot Street
Waipahu, HI 96797

INFLUENT PROCESS PARAMETERS

AVERAGE DAILY WASTEWATER FLOW	0.025500	MGD
PEAK FLOW (4 HOUR DURATION)	0.038250	MGD
pH	6 -9	
BOD_5	200.00	mg/l
	42.53	lb/day
TSS	200.00	mg/l
	42.53	lb/day
NH_3-N	25.00	mg/l
	5.32	lb/day
TKN	45.00	mg/l
OIL & GREASE	< 100	mg/l
MINIMUM ALKALINITY ($CaCO_3$)	150.00	mg/l
MINIMUM PHOSPHORUS	2.00	mg/l
WASTEWATER TEMPERATURE	20	^oC
AIR TEMPERATURE	0 - 40	^oC
SITE ELEVATION	20	feet

EFFLUENT PROCESS PARAMETERS

AVERAGE DAILY WASTEWATER FLOW	0.025500	MGD
PEAK FLOW (4 HOUR DURATION)	0.038250	MGD
pH	6 -9	
BOD_5	10.00	mg/l
	2.13	lb/day
TSS	10.00	mg/l
	2.13	lb/day
NH_3-N	1.00	mg/l
	0.21	lb/day
TKN	10.00	mg/l

DESIGN PARAMETERS

MLVSS, @ BOTTOM WATER LEVEL (BWL)	2,636	mg/l
F:M RATIO	0.056	lb BOD_5 / lb MLVSS
SLUDGE AGE	70	days
CYCLES/DAY	6	cycles / day
LENGTH PER CYCLE	4	hours cycle
SLUDGE PRODUCTION	0.27	lb / lb BOD_5 removed
TOTAL SLUDGE PRODUCTION	10.91	lb / day

BASIN GEOMETRY

INSIDE DIAMETER	11.50	feet
OUTSIDE LENGTH	68.00	feet
BOTTOM WATER LEVEL (BWL)	7.33	feet
HIGH WATER LEVEL (HWL)	8.83	feet
TOP WATER LEVEL (TWL)	9.50	feet
ALARM WATER LEVEL (AWL)	9.75	feet
INFLUENT INVERT	10.00	feet
VOLUME @ BWL	34,739	gallons
VOLUME @ HWL	42,558	gallons
VOLUME @ TWL	45,601	gallons
DETENTION TIME @ BWL	32.70	hours
INFLUENT GATE HOUSING DIAMETER	8.00	inches
PRE-REACT ZONE WIDTH	3.00	feet
PRE-REACT ZONE LENGTH	12.00	feet
PRE-REACT ZONE BOTTOM HEIGHT	1.00	feet
INFLUENT GATE HOUSING BOTTOM HEIGHT	4.75	feet
NUMBER OF GATES	3	gates
SLUDGE STORAGE @ 8,500 mg/l	156	days
SLUDGE PRODUCTION @ 8,500 mg/l	154	gallons / day

AIR SUPPLY

TOTAL OXYGEN REQUIREMENT (SOR)	150.25	lb / day
AIR SUPPLIED (FOR BIOLOGICAL REMOVAL)	78.62	scfm
BRAKE HP REQUIRED	3.13	brake HP
NUMBER OF OPERATING BLOWERS	1	blower(s)
NUMBER OF STANDBY BLOWERS	1	blower(s)
BLOWER HP	6.20	HP / blower
INSTALLED DIFFUSER LENGTH	29.92	inches
INSTALLED DIFFUSERS	24	diffuser(s)

DECANTER

NORMAL DECANT TIME	30	- 60 minutes
PEAK DECANT TIME	45	- 60 minutes
DECANT RATE	142	gal / min
NORMAL DECANT VOLUME	4,250	gallons
PEAK DECANT VOLUME	6,375	gallons
NUMBER OF PORTS PROVIDED	4	ports
EMERGENCY SETTLE TIME	114.58	min
TOTAL NUMBER OF PUMPS	2	pump(s)
BRAKE HP PER PUMP	1.00	HP / pump

MOTOR REQUIREMENTS

REACTOR BASIN AIR BLOWER(S)	55.80	KWH / day
EFFLUENT DECANTER PUMP	4.50	KWH / day
BLOWER HEAT OUTPUT	15,760	BTU

58 MAIDEN LANE, 3RD FLOOR, SAN FRANCISCO, CA 94108
(415) 677-7300 WWW.SHERWOODENGINEERS.COM

APPENDIX C

TYPICAL LEACH FIELD CALCULATIONS

APPENDIX C - DILLINGHAM RANCH - LEACH FIELD DESIGN

ASSUMPTIONS

TYPE	VALUE	UNIT
AVERAGE DAY WASTEWATER FLOW	91,600	GPD
MAXIMUM DAY WASTEWATER FLOW	137,400	GPD
PERCOLATION RATE	6	MIN/IN
EPA APPLICATION RATE	0.80	GPD/FT^2

LEACH FIELD CALCULATIONS

TYPE	VALUE	UNIT
LEACH FIELD AREA	171,750	SF
AREA WITH 100% DISPOSAL COMPONENT[1]	343,500	SF

1. SEE SUBCHAPTER 62-25-B
2. LEACH FIELD SIZED BY: MAX DAY FLOW / EPA APPLICATION RATE

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(415) 677-7300 WWW.SHERWOODENGINEERS.COM

APPENDIX D

SUPPORTING DOCUMENTS

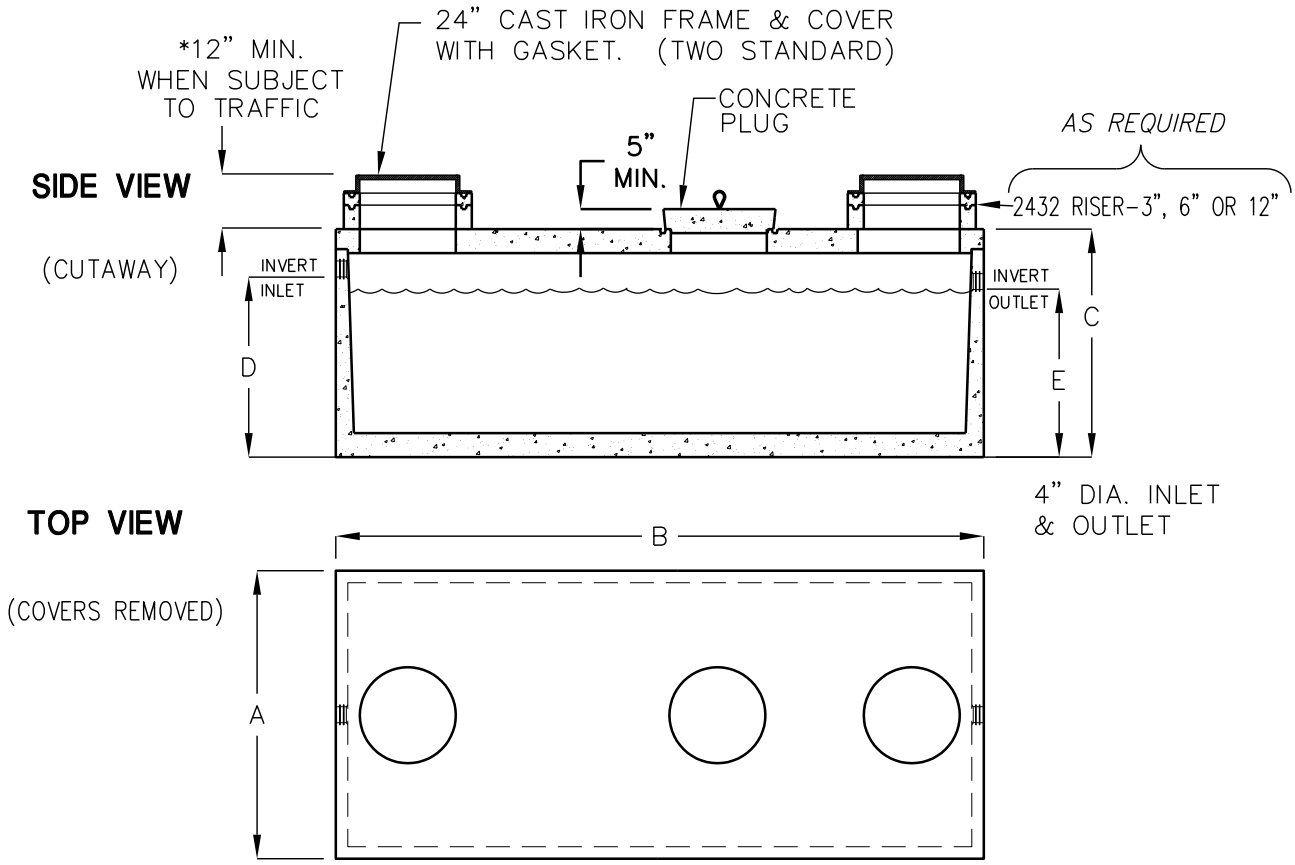
DOH WWB TITLE 11
UV FILTRATION SYSTEM
CHLORINE DOSING TANK
CHLORINE DOSING PUMP
CHLORINE CONTACT TANK

CHAPTER 11-62 APPENDIX F

TABLE 1
April 15, 1997

Type of Establishment	Gallons Per Person Per Day (Unless Otherwise Noted)
Airports (per passenger)	5
Camps:	
Campground with central comfort stations	32
With flush toilets, no showers	25
Construction camps (semi-permanent)	50
Day camps (no meals served)	15
Resort camps (night and day) with limited plumbing	50
Luxury camps	100
Church	
With kitchen	10
Without kitchen	5
Cottages and small dwellings with seasonal occupancy (2 persons per bedroom minimum)	100
Country clubs (per resident member)	100
Country clubs (per non-resident member present)	25
Dentist per chair	200
Doctor per patient	5
Dwelling (2 persons per bedroom minimum)	100
Factories (gallons per person, per shift, exclusive of industrial waste)	35
Hair salon, including barber shops and beauty salons	150
Hospitals (per bed space)	250+
Hotels with private baths (2 person per bedroom minimum)	100
Hotels without private baths	50
Institutions other than hospitals (per bed space)	125
Laundries, self-service (per machine)	300
Mobile home parks (per space)	250
Motels with bath, toilet, and kitchen waste (per bed space)	50
Motels (bed space)	60
Picnic parks (toilets wastes only) (per picnicker)	5
Picnic parks with bathhouses, showers, and flush toilets	10
Restaurants	
Average, per seat	80
Fast food, per seat	100
Additional kitchen wastes per take out meals	3
Additional for bars and cocktail lounges, per seat	15
Schools:	
Boarding	100
Day, without gyms, cafeteria, or showers	15
Day, with gyms, cafeteria, and showers	25
Day, with cafeteria, but without gyms or showers	20
Service station (per vehicle served)	10
Swimming pools and bathhouses	10
Theaters:	
Movie (per auditorium seat)	5
Drive-in (per car space)	5
Workers (in addition to above):	
Construction (at semi-permanent camps)	50
Day, at schools and offices (per shift)	20
Employee (per shift)	20

HJ1000-HJ1500 GALLON HOLDING TANKS-HAWAII



NOTE: NOT RECOMMENDED FOR POTABLE WATER OR ABOVE GROUND USE. NO WARRANTIES EXPRESSED OR IMPLIED FOR MERCHANTIBILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

MODEL NUMBER	LIQUID CAPACITY GALLONS	WIDTH 'A'	OVERALL LENGTH 'B'	TANK HEIGHT 'C'	INLET 'D'	OUTLET 'E'	MINIMUM EXCAVATION WIDTH	MINIMUM EXCAVATION LENGTH	✳DEPTH OF BURY	TANK WEIGHT LBS.
HJ1000HT	1000	6'-0"	9'-4"	4'-9"	3'-9"	3'-6"	7'-0"	10'-4"	6' MAX.	13,300
HJ1250HT	1250	6'-0"	11'-6"	4'-9"	3'-9"	3'-6"	7'-0"	12'-6"	6' MAX.	15,850
HJ1500HT	1500	6'-0"	13'-6"	4'-9"	3'-9"	3'-6"	7'-0"	14'-6"	6' MAX.	18,500

- TANK DESIGNED FOR H-20 TRAFFIC WHEEL LOAD WITH 1' TO 6' MAX. EARTH COVER AND WATER TABLE AT ONE FOOT BELOW GRADE.
- SUITABLE NATIVE SOIL OR GRANULAR SUB-BASE SHALL BE COMPACTED AND LEVELED TO HANDLE ANTICIPATED LOADS. SEE INSTALLATION PROCEDURES SHEET FOR ADDITIONAL INFO.
- EXTERIOR AND INTERIOR CONCRETE SURFACES TO BE COATED WITH AN APPROVED BITUMINOUS MATERIAL.
- FOR COMPLETE DESIGN AND PRODUCT INFORMATION CONTACT JENSEN PRECAST.

THE DESIGN AND DETAIL OF THIS DRAWING ARE THE PROPERTY OF JENSEN PRECAST AND NOT TO BE USED EXCEPT IN CONNECTION WITH ITS OWN WORK. DESIGN AND INVENTION RIGHTS ARE RESERVED.

04-11-03
HJ1000-HJ1500_HT-H.dwg
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JENSEN PRECAST®

CHLORINE STORAGE TANK OPTION

OR-1000 antioxidant surface required.

~7 liters per day of 12.5% sodium hypochlorite solution needed for 2mg/l residual in 138kgal of irrigation water (~56 gallons per month)

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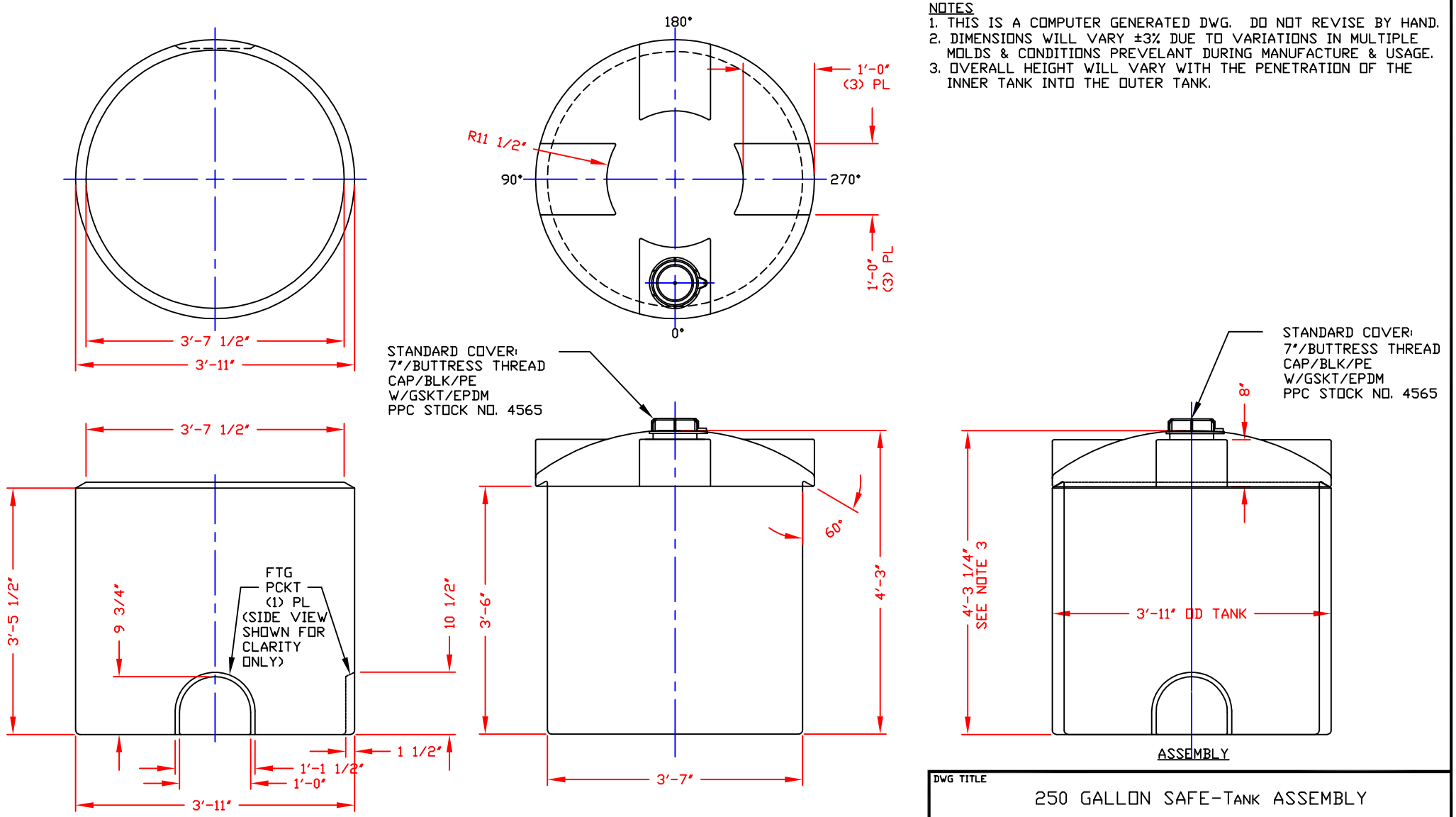
NOTES
1. THIS IS A COMPUTER GENERATED DWG. DO NOT REVISE BY HAND.
2. DIMENSIONS WILL VARY ±3% DUE TO VARIATIONS IN MULTIPLE MOLDS & CONDITIONS PREVELANT DURING MANUFACTURE & USAGE.
3. OVERALL HEIGHT WILL VARY WITH THE PENETRATION OF THE INNER TANK INTO THE OUTER TANK.



CALCULATED CAPACITIES/ VOLUME IN U.S. GALLONS			
TANK	SHELL CAP	DOME VOL	TOTAL VOL
INNER	258	25	283
OUTER	304	N/A	304

CONFIDENTIAL PROPERTY OF POLY PROCESSING COMPANY NOT FOR REPRINT OR USE WITHOUT PERMISSION

DWG TITLE: 250 GALLON SAFE-TANK ASSEMBLY

SCALE: 3/4"=1'-0"

DATE: 11/12/12

POLY PROCESSING COMPANY LLC
Central Region
P.O. Box 4159 (71211)
2201 Old Sterlington Rd.
Monroe, LA 71203
(318) 343-7565
FAX (318) 343-8795

DR: B. THURMON

CK:

SHEET: 1 OF 1

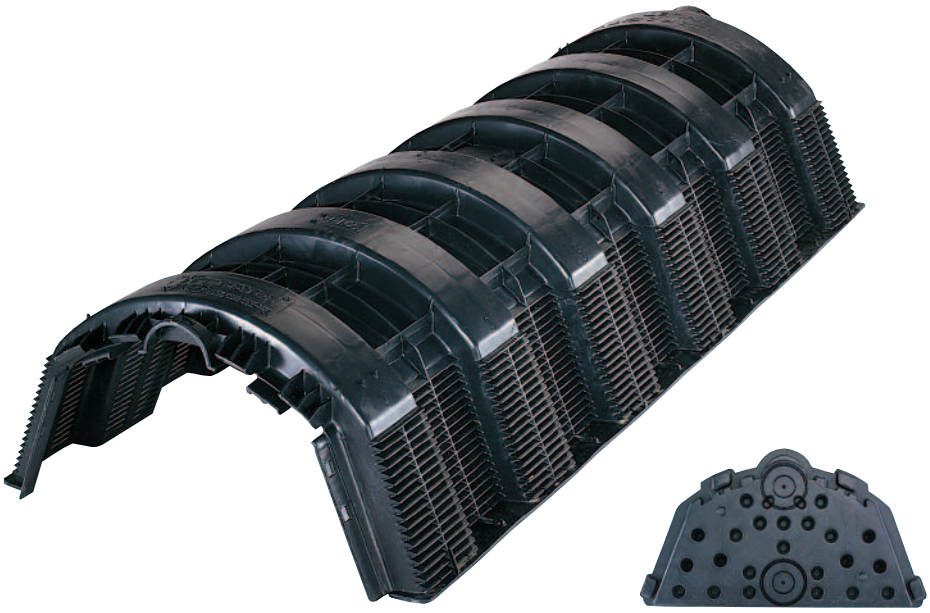
COMPUTER FILE: 2000250

REV: -

The High Capacity **Infiltrator®** Chamber H-20

INFILTRATOR® SYSTEMS INC

Environmental Onsite Wastewater Solutions℠



The High Capacity Infiltrator Chamber H-20 offers maximum internal volume per linear foot for extra temporary storage capacity. The 10" louvered sidewalls facilitate infiltration and evapotransporation, while reducing fines in the system. The High Capacity H-20 chamber gets an H-20 load rating with 18" of compacted cover when installed per installation requirements.

The High Capacity Infiltrator Chamber H-20 System Offers These Unique Benefits:

- More temporary storage capacity
- Maximum internal volume per linear foot
- Easy assembly and installation with as few as two people, a back-hoe and a pickup truck
- Inspection port option for easy access to leachfield with no site disruption
- **OVERALL REDUCED COST**

Tested and Proven with More than One Million Installed

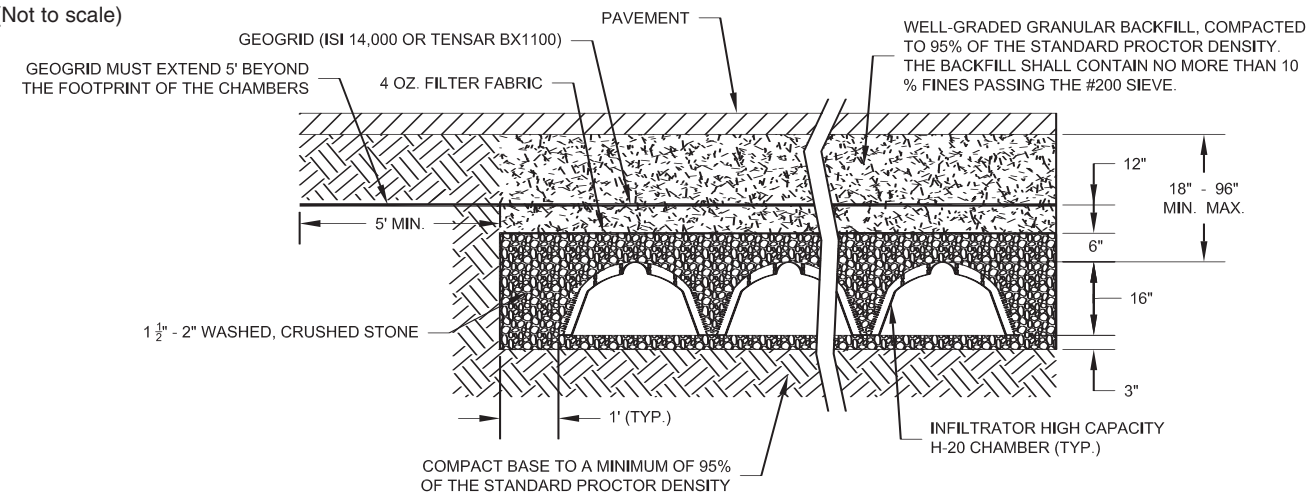
- Infiltrator is the number-one septic leachfield chamber system in the onsite industry.
- More than one million systems installed, with over 27 million units in-ground in all 50 states and 24 countries.
- Infiltrator's established history of performance and reliability began in 1987.
- Field surveys show that Infiltrator chambers systems are more resistant to hydraulic failure than stone and pipe systems.
- Infiltrator is ISO 9001:2000 certified and is IAPMO and UPC approved.

Approved in _____

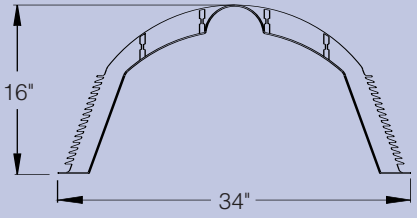
The High Capacity **Infiltrator®** Chamber H-20

HIGH CAPACITY INFILTRATOR H-20 CHAMBER TYPICAL CROSS SECTION

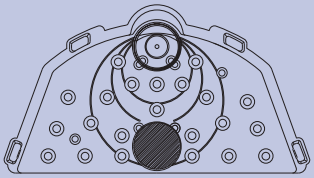
(Not to scale)



Chamber End View



PosiLock™ End Plate



Specifications

Size (W x L x H)	34" x 75" x 16"
Storage Capacity	110 gal/14.3 ft^3
Weight	38 lbs
Louvered Sidewall Height	10"

Note: For traffic loading applications please contact Infiltrator Systems Technical Services Department for current design and installation specifications.

INFILTRATOR SYSTEMS, INC. STANDARD LIMITED WARRANTY

INFILTRATOR SYSTEMS, INC., ("Infiltrator") STANDARD LIMITED WARRANTY FOR SEPTIC PRODUCTS

(a) The structural integrity of each chamber and end plate manufactured by Infiltrator (collectively referred to as "Units"), when installed and operated in a leachfield of an onsite septic system in accordance with Infiltrator's installation instructions, is warranted to the original purchaser ("Holder") against defective materials and workmanship for one (1) year from the date upon which a septic permit is issued for the septic system containing the Units; provided, however, that if a septic permit is not required for the septic system by applicable law, the one (1) year warranty period will begin upon the date that installation of the septic system commences. In order to exercise warranty rights, Holder must notify Infiltrator in writing at its corporate headquarters in Old Saybrook, Connecticut, within fifteen (15) days of the alleged defect. Infiltrator will supply replacement Units for those Units determined by Infiltrator to be defective and covered by this Limited Warranty. Infiltrator's liability specifically excludes the cost of removal and/or installation of the Units.

(b) THE LIMITED WARRANTY AND REMEDIES IN SUBPARAGRAPH (a) ARE EXCLUSIVE. THERE ARE NO OTHER WARRANTIES WITH RESPECT TO THE UNITS, INCLUDING NO IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

(c) The Limited Warranty does not extend to incidental, consequential, special or indirect damages. Infiltrator shall not be liable for penalties or liquidated damages, including loss of production and profits, labor and materials, overhead costs, or other losses or expenses incurred by the Holder or any third party. Specifically excluded from Limited Warranty coverage is damage to the Units due to ordinary wear and tear, alteration, accident, misuse, abuse or neglect of the Units; the Units being subjected to vehicle traffic or other conditions which are not permitted by the installation instructions; failure to maintain the minimum ground covers set forth in the installation instructions; the placement of improper materials into the system containing the Units; failure of the Units or the septic system due to improper siting, improper sizing, excessive water usage, improper grease disposal or improper operation or any other event not caused by Infiltrator. This Limited Warranty shall be void if the Holder fails to comply with all of the terms set forth in this Limited Warranty.

Further, in no event shall Infiltrator be responsible for any loss or damage to the Holder, the Units, or any third party resulting from installation or shipment, or from any product liability claims of Holder or any third party. For this Limited Warranty to apply, the Units must be installed in accordance with all site conditions required by state and local codes, all other applicable laws and Infiltrator's installation instructions.

(d) No representative of Infiltrator has the authority to change this Limited Warranty in any manner whatsoever, or to extend this Limited Warranty. No warranty applies to any party other than the original Holder.

* * * * * * *

The above represents the standard Limited Warranty offered by Infiltrator. A limited number of states and counties have different warranty requirements. Any purchaser of Units should contact Infiltrator's corporate headquarters in Old Saybrook, Connecticut, prior to such purchase, to obtain a copy of the applicable warranty and should carefully read that warranty prior to the purchase of Units.

Infiltrator Systems does not recommend installing onsite systems under pavement.
Chambers must be installed according to manufacturer's instructions. Failure to install according to manufacturer's instructions will void warranty.
Infiltrator Systems recommends the use of septic tank filters and laundry filters with all onsite septic systems.

INFILTRATOR® SYSTEMS INC

Environmental Onsite Wastewater Solutions℠

6 Business Park Road • P.O. Box 768
Old Saybrook, CT 06475
860-577-7000 • FAX 860-577-7001

www.infiltratorsystems.com

1-800-221-4436

For technical assistance, installation instructions or customer service, call Infiltrator Systems at 1-800-221-4436.

U.S. Patents: 4,759,661; 5,017,041; 5,156,488; 5,336,017; 5,401,116; 5,401,459; 5,511,903; 5,716,163; 5,588,778; 5,839,844 Canadian Patents: 1,329,959; 2,004,564 Other patents pending.
Infiltrator, Equalizer, Quick4 and SideWinder are registered trademarks of Infiltrator Systems Inc. Infiltrator is a registered trademark in France. Infiltrator Systems Inc. is a registered trademark in Mexico.
ChamberSpacer, Contour, MicroLeaching, MultiPort, PolyTuff, PosiLock, QuickCut, QuickPlay and SnapLock are trademarks of Infiltrator Systems Inc.
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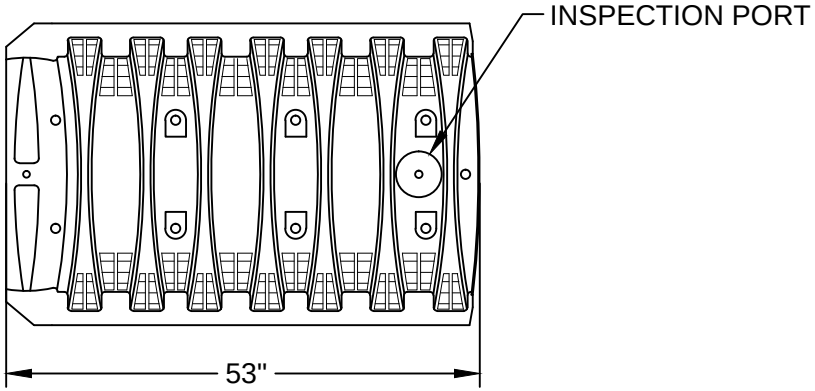
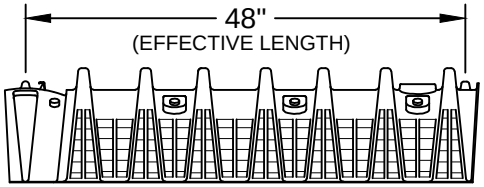
C550306ISI-1

INFILTRATOR SYSTEMS INC.
QUICK4 STANDARD CHAMBER
PRODUCT SPECIFICATION
(NOT TO SCALE)

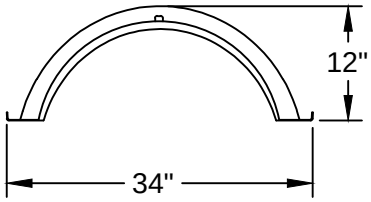
TOP VIEW



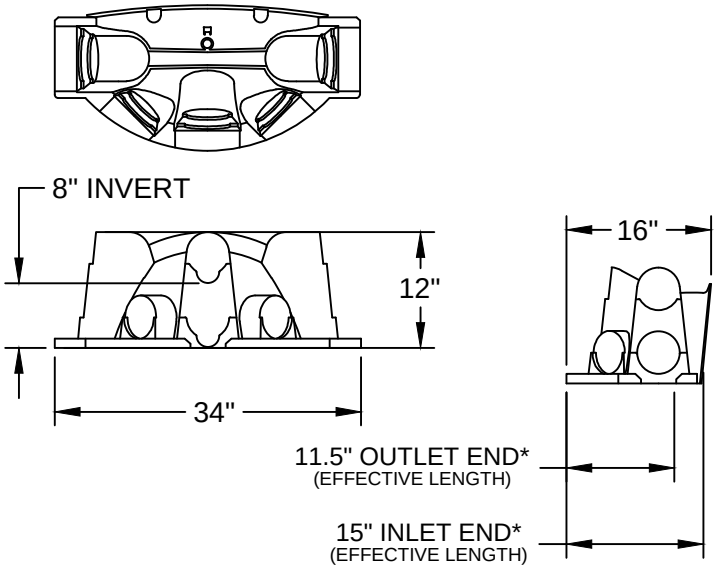
SIDE VIEW



END VIEW



QUICK4 STANDARD MULTIPORT END CAP



* ALL VIEWS = INSTALLED LENGTH.

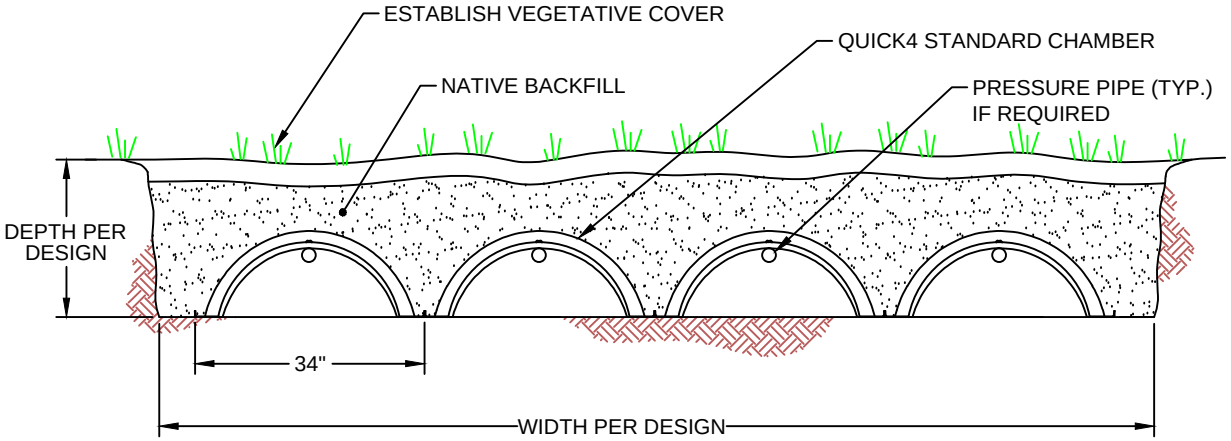
INFILTRATOR®
systems inc.

INFILTRATOR SYSTEMS INC.
4 Business Park Rd. Old Saybrook, CT 06475
(800) 221-4436

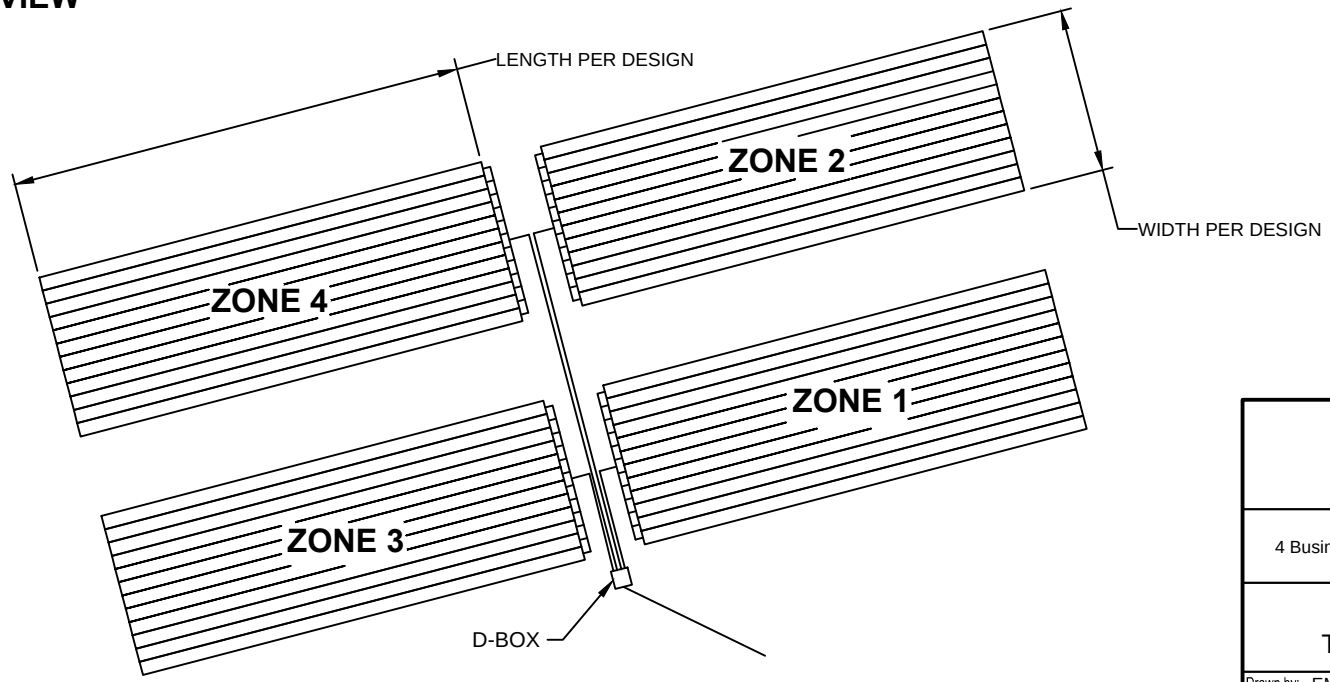
QUICK4 STANDARD CHAMBER
PRODUCT SPECIFICATION

Drawn by: EMB		Date: 07/24/2013
Scale: NOT TO SCALE	Checked by: DFH	Sheet: 1 of 1

SECTION VIEW



PLAN VIEW



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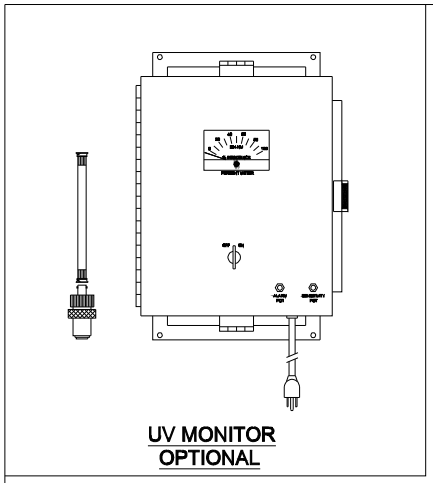
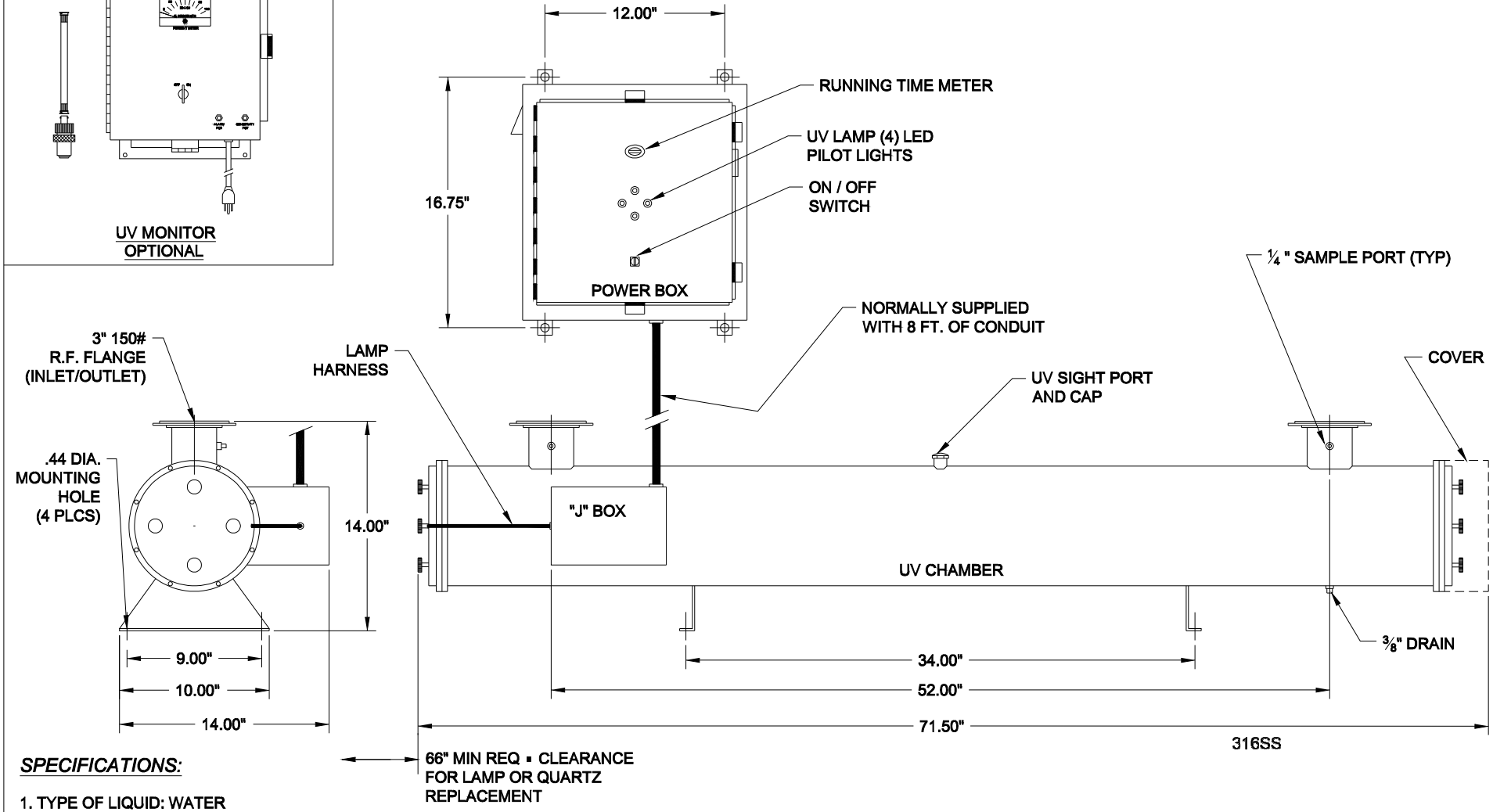
QUICK4 STANDARD
TYPICAL BED DESIGN

Drawn by: EMB		Date: 06/20/2014
Scale: NOT TO SCALE	Checked by: DFH	Sheet: 3 of 3





SPECIFICATIONS:

1. TYPE OF LIQUID: WATER
2. FLOW RATE: 105 GPM Clear Waste Water, 135 GPM Clear Fresh Water, 165 GPM High Purity Water
3. PRESSURE DROP: LESS THAN 1 PSIG MAX.
4. U.V. DOSAGE: 30,000 MW SEC / CM2
5. OPERATING PRESSURE: 150 PSIG MAX.
6. ELECTRICAL: 120 VAC / 60 HZ - 3.2 AMPS
   220 VAC / 50 HZ - 1.7 AMPS
7. POWER SUPPLY: Fan Cooled Nema Style Enclosure
8. LAMP TYPE: 254 NM High Output UV Lamps

GWT Genesis Water Technologies, Inc.

ULTRAVIOLET DISINFECTION SYSTEM

GWT I Series: GWT-135

DATE: 1/5/12	DRAWN BY: JM	MATERIAL: 316 SS FINISH: ELECTROPOLISH

GWT I-Series

Genesis Water Technologies, Inc.– High Performance Ultraviolet Light Disinfection Systems

UV System Specification Sheet

Standard Features:

- 316 Stainless Steel Electro-polished & Passivated UV Chamber Construction
- UV Lamp Status Indicator
- Fan Cool Feature
- Simple Dual Compression Seals
- UV Sensor Port and Drain Port
- UV System Run Time Meter
- UV Resistant O-Rings and Gaskets
- High Output UV Lamps
- System capable of using 185nM or 254nM UV Lamps
- Horizontal or Vertical mountable
- Remote power enclosure
- Removable Flanged Heads
- Low Power Usage

Optional Features:

- Automatic Wiper System
- Sanitary System Connections
- UV Monitor
- 4-20mA dry contact for UV Monitor relay to PLC controls
- Custom Application Design

Performance:

- System provides in excess of 30,000 mw/Sec/cm2 dosage – 254nm UV spectrum standard
- High Output UV Lamps rated for over 12,0000 hours of continuous usage
- Operating Pressure Rated at 125 PSI
- System Engineered Pressure at 150 PSI
- Water Pressure Drop At Rated Flow Rate Is Less Than 1 PSI
- Innovative Chamber Design to maximize inactivation of contaminants
- Capable of inactivating 99.9% of microbiological organisms

Applications:

- Pre or Post Reverse Osmosis Treatment
- Storage Tank Sterilization
- Pre-Treatment before Ultrafiltration systems
- Recirculating Loop Systems
- Ozone Destruction
- TOC (Total Organic Carbon) Reduction

Industries:

Pharmaceuticals, Electronics, Laboratories, Universities, Kidney dialysis clinics, Hospitals, Food industries, Dairy processing, Cosmetics industry, Medical clinics.

System Specifications:

Model#	Flow Rate GPM	Inlet	UV Wavelength	Dimensions	# UV Lamps
GWT-75	75 GPM	2” NPT	254 nm	37” x 14” x 14”	4
GWT-135	135 GPM	3” Flange	254 nm	72” x 10” x 14”	4
GWT-195	195 GPM	4” Flange	254 nm	72” x 10” x 14”	6
GWT-265	265 GPM	6” Flange	254 nm	76” x 16” x 20”	8
GWT-530	530 GPM	6” Flange	254 nm	76” x 16” x 20”	16

Genesis Water Technologies, Inc.
“Using Innovation To Meet The Water Needs of The World”
Toll Free: 877 267 3699 * Tel: +1 407 721 4857 * Fax: +1 407 792 2603
Email: sales@genesiswatertech.com * Web: www.genesiswatertech.com

TABLE 2
April 15, 1997

Minimum Horizontal Distance From	Cesspool (ft)	Treatment Unit (ft)	Seepage Pit (ft)	Soil Absorption System (ft)
Wall line of any structure or building	5	5	5	5
Property line	9	5	9	5
Stream, the ocean at the vegetation line, pond, lake, or other surface water body	50	50	50	50
Large trees	10	5	10	10
Treatment unit	5	5	5	5
Seepage pit	18	5	12	5
Cesspool	18	5	18	5
Soil absorption system	5	5	5	5
Potable water sources serving public water systems	1000	500	1000	1000

TABLE III
April 15, 1997

Percolation Rate (min/inch) Less than or equal to	Required Absorption Area (ft2/bedroom or 200 gallons)	Percolation Rate (min/inch) Less than or equal to	Required Absorption Area (ft2/bedroom or 200 gallons)
1	70	31	253
2	85	32	257
3	100	33	260
4	115	34	263
5	125	35	267
6	133	36	270
7	141	37	273
8	149	38	277
9	157	39	280
10	165	40	283
11	170	41	287
12	175	42	290
13	180	43	293
14	185	44	297
15	190	45	300
16	194	46	302
17	198	47	304
18	202	48	306
19	206	49	308
20	210	50	310
21	214	51	312
22	218	52	314
23	222	53	316
24	226	54	318
25	230	55	320
26	234	56	322
27	238	57	324
28	242	58	326
29	246	59	328
30	250	60	330

TABLE IV
April 15, 1997

Pollutant	Pollutant Ceiling Concentration Limit (dry weight basis, mg/kg)
Arsenic	20
Cadmium	15
Chromium	200
Copper	1500
Lead	300
Mercury	10
Molybdenum	15
Nickel	100
Selenium	25
Zinc	2000

TABLE V
April 15, 1997

Amount of Wastewater Sludge (Metric Ton per 365 day period, dry weight basis)	Frequency
Greater than zero but less than 290	Once per year
Equal to or greater than 290 but less than 1500	Once per quarter
Equal to or greater than 1500 but less than 15,000	Once per 60 days
Equal to or greater than 15,000	Once per month
Amount of Wastewater Sludge (English Ton per 365 day period, dry weight basis)	Frequency
Greater than zero but less than 320	Once per year
Equal to or greater than 320 but less than 1650	Once per quarter
Equal to or greater than 1650 but less than 16,500	Once per 60 days
Equal to or greater than 16,500	Once per month

TABLE VI
April 15, 1997

Horizontal Distance From	Feet
Waters of the United States, state waters, the ocean at the vegetation line, or any other surface water body	50
Property line	50
Occupied building or dwelling	500
Potable water source serving public water systems	1000

TABLE VII
April 15, 1997

Pollutant	Pollutant Ceiling Concentration Limit (dry weight basis, mg/kg)
Arsenic	20
Chromium	200
Nickel	100

GEOLABS, INC.

Geotechnical Engineering

DILLINGHAM RANCH DEVELOPMENT
LEACH FIELD - ADDITIONAL WORK
MOKULEIA, OAHU, HAWAII

Log of Boring

B-301

DRAFT

Approximate Ground Surface Elevation : N/A

Laboratory				Field							
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
										CH	Brown **SILTY CLAY**, very stiff, dry
					19	4.5					
					14						
					23	4.5	5				
					45		10			SW-SM	Brownish tan **GRAVELLY SAND (CORALLINE)** with some silt, dense
					9		15				grades to loose
											Boring terminated at 16.5 feet
							20				
							25				
							30				
							35				

Date Started:	July 15, 2014	Water Level: ▽	10.1 ft. 07/15/2014 1132 HRS	Plate
Date Completed:	July 15, 2014			
Logged By:	David Gremminger	Drill Rig:	CME-55GY	
Total Depth:	16.5 feet	Drilling Method:	4" Solid Stem Auger	A - 8
Work Order:	5721-50(C)	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC.

Geotechnical Engineering

DILLINGHAM RANCH DEVELOPMENT
LEACH FIELD - ADDITIONAL WORK
MOKULEIA, OAHU, HAWAII

Log of Boring

B-302

DRAFT

Approximate Ground Surface Elevation : N/A

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Laboratory: Core Recovery (%)	Laboratory: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
										CH	Brown **SILTY CLAY**, very stiff, dry
					33	4.5					
					33						grades to hard
					43	4.5	5				
					2		10			SP	Tan **SAND (CORALLINE)** with a little gravel (coralline) and silt, very loose
					5		15				grades to loose
											Boring terminated at 16.5 feet
							20				
							25				
							30				
							35				

Date Started:	July 15, 2014	Water Level: ▽	10.3 ft. 07/15/2014 1216 HRS	Plate
Date Completed:	July 15, 2014			
Logged By:	David Gremminger	Drill Rig:	CME-55GY	
Total Depth:	16.5 feet	Drilling Method:	4" Solid Stem Auger	A - 9
Work Order:	5721-50(C)	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC.

Geotechnical Engineering

DILLINGHAM RANCH DEVELOPMENT
LEACH FIELD
MOKULEIA, OAHU, HAWAII

Log of Boring

104

Approximate Ground Surface Elevation (feet): 15 *

Laboratory			Field								Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	
										MH	Brown **CLAYEY SILT** with sand, very stiff, dry (alluvium)
	19	90			29	>4.5					
	19				25						
										SW	Tan **GRAVELLY SAND (CORALLINE)**, very dense, damp (coralline detritus)
					15/1"		5				Boring terminated at 5 feet
							10				
							15				

Date Started:	October 3, 2008	Water Level: ▽	Not Encountered
Date Completed:	October 3, 2008		
Logged By:	D. Gremminger	Drill Rig:	CME-45C
Total Depth:	5 feet	Drilling Method:	4" Auger
Work Order:	5721-50	Driving Energy:	140 lb. wt.,30 in. drop

Plate

A - 4

GEOLABS, INC. Geotechnical Engineering	DILLINGHAM RANCH DEVELOPMENT LEACH FIELD MOKULEIA, OAHU, HAWAII	Log of Boring 106

Approximate Ground Surface Elevation (feet): 19 *

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
										CL	Brown **SILTY CLAY AND SAND**, very stiff, damp (alluvium)
	20	82			19	>4.5					
	26				6	2.0					grades to stiff
LL=48 PI=26	28	90			11	2.5	5				grades to moist
	14				7						
										SP	Brownish tan **SAND (CORALLINE)** with some gravel, loose, moist (beach deposit)
							10				Boring terminated at 10 feet
							15				

Date Started:	October 3, 2008	Water Level: ▽	Not Encountered
Date Completed:	October 3, 2008		
Logged By:	D. Gremminger	Drill Rig:	CME-45C
Total Depth:	10 feet	Drilling Method:	4" Auger
Work Order:	5721-50	Driving Energy:	140 lb. wt.,30 in. drop

Plate

A - 6

Appendix I

Water System Masterplan Report for
Dillingham Ranch Agricultural Subdivision
Mokule'ia, O'ahu, Hawai'i

Water System Masterplan Report

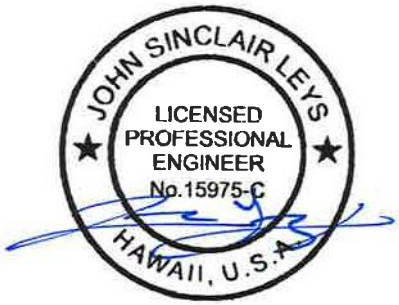
For Dillingham Ranch Agricultural Subdivision
Mokuleia, Oahu, Hawaii

Tax Map Key (1) 6-8-003

Prepared for:

Dillingham Ranch Aina, LLC

9701 Wilshire Boulevard, Suite 700
Beverly Hills, California 90212



Prepared July 31, 2014 by:

SHERWOOD
DESIGN ENGINEERS
58 Maiden Lane, Third Floor
San Francisco, CA 94108
www.sherwoodengineers.com

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Distribution System and Water Tank
Pipe and Appurtenances

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Tank Sizing Summary
Water Demand Summary

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Lower Model Report
Upper Model Report

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I. Introduction

A. Purpose and Scope of Report

This document presents the water master plan for the agricultural subdivision at Dillingham Ranch Aina, Mokuleia, Hawaii. The report covers the design of the domestic and fire water systems including the proposed storage and distribution infrastructure for the Dillingham Ranch Aina Project (DRA) as well as the service connection to the adjacent Mokuleia Community.

II. Existing Condition

A. Existing Site Features

Dillingham Ranch, herein referred to as the "Ranch", is a large land holding comprising 2,721 AC bound by Farrington Highway, lands owned by Pioneer Ili-Bred International, the Mokuleia Forest Reserve, and lands owned by Castle & Cooke. Farrington Highway is the property's northern boundary and the Mokuleai Community is located approximately 800 feet northwest of the Ranch entrance. Topography of the property is defined by low coastal plains in the north and steep mountainous terrain to the south. The flat coastal plains are located between Farrington Highway and the old agricultural Cane Haul Road with gentle slopes averaging 0% to 5%. The coastal plain is underlain by alluvial and marine sediments consisting of horizontal layers of clay, silt, sand, and coralline limestone[1].

Land use in this area is governed by agricultural fields, primarily coconut trees and equestrian polo grounds. This area also has paddocks, open pasture and an equestrian center with corrals.

In contrast to the flat coastal plain, the landform *mauka* (towards the mountains) of the Cane Haul Road transitions into steeper sloping terrain. Slopes in this area start at 10% to 20% slopes and steepen to 20-50% mauka of the subdivision, but the terrain is very irregular. Rockfall zones are present in the upper limits of the property. There is very little existing development within the Ranch, the primary exceptions being the Dillingham Lodge and a handful of private residences. Historically, the Ranch has used the lands above the Cane Haul Road for cattle production.

Refer to Appendix A, "Existing Site Conditions" for existing topography and structure locations.

B. Existing Water System

Existing domestic water utilities and appurtenances are managed by the North Shore Water Company. There are a total of 10 existing wells within the Dillingham Ranch

[1] Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)

property. Six wells are located in the lowlands encompassed by proposed parcels 1003, 1004, and 1005 while the remaining four are situated *mauka* of the Cane Haul Road. Dillingham Ranch is underlain by an aquifer that is situated in permeable basalts. Within the low-lying coastal area, the basalt is covered by a 200 to 600 foot layer of caprock sediment, therefore, wells must penetrate below this zone to reach potable water[2]. Wells drilled further mauka, including the sites for the proposed new wells, will penetrate directly into the basalt.

Two of the 10 existing wells are currently used for potable and non-potable sources, while the rest are sealed or not permitted for use[2]. Well #3410-01 provides water to the Mokuleia Community. Previous studies conducted by Water Resource Associates (2003) and R.M. Towill (2008) have confirmed that this source has insufficient pressure and pumping capacity to provide the minimum required fire flow. Well #3410-03 functions as the site's irrigation supply source and has a permit from the State Commission of Water Resource Management (CWRM) for pumping 1.5 MGD. The agricultural well is a privately owned and maintained by the Ranch.

The following list provides a brief description of each well by geographic location:

Makai Wells (North of Cane Haul Road):

Well #3410-01 (Permitted for 0.5 MGD)
This well was constructed over 100 years ago (dating prior to 1911) and has 4 pumps; two 3 HP, one 7.5 HP, and one 15 HP[3]. Corrosion and age have played a substantial factor in the condition of this structure. Consequently #3410-01 had to be re-cased from its original 10 inch casing down to 6 inches. Well 3410-01 is owned by the North Shore Water Company, LLC, which is subject to oversight by the Public Utilities Commission. It currently serves the Mokuleia Community through an agreement with the Ranch.

It is contemplated that this well may be abandoned when the North Shore Water Company is provided with a connection to the new water system as outlined in Section III of this report.

Well #3410-02 (Sealed)

Well #3410-03 (Permitted for 1.5 MGD Agricultural Use Only)
This well was constructed over 80 years ago (dating prior to 1934). #3410-03 has a historical casing diameter of 10 inches, although this may now be smaller. It should be noted that #3410-03 is an agricultural use only well with a permit for 1.5 MGD.

Well #3410-04 (Sealed)

Well #3410-05 (Sealed)

Well #3410-06 (Sealed)

[2] Water Resource Associates, "Preliminary Hydrogeological Evaluation of Dillingham Ranch Wells" (May, 2003)
[3] R.M. Towill Corporation, "Prelminary Water System Report" (Feb, 2008)

Mauka Wells (South of Cane Haul Road)

Well #3410-10 (Not Permitted for Use)
The casing for this well is at ground level and subject to contamination. It will be sealed with cement in accordance with local requirements.

Well #3310-01 (Permitted for 1.25 MGD):
Situated at 470 feet, this is the highest elevation existing well on site. #3310-01 was drilled in 1980 and pump tested the same year for 25 hours at a rate of 885 GPM. The well is fitted with a 12 inch casing and has a water use permit of 1.25 MGD for irrigation and domestic use[1].

Well #3310-02 (Permitted for 0.85 MGD):
#3310-02 is situated at 367 feet and represents the second highest elevation well on site. This well was drilled in 1980 and pump tested for 45 hours at 1400 GPM. #3310-02 has a 14 inch case and is permitted for 0.85 MGD for irrigation and domestic use[1].

Well #3310-03 (Not Permitted for Use):

Refer to Appendix A, "Existing Site Conditions" for existing well locations.

III. Proposed Concept

A. Proposed Water System

The proposed program for the Dillingham Ranch subdivision includes the construction of 91 (4-5 bedroom) dwellings on lots with a minimum size of 5-acres. Most of these dwellings will be situated *mauka* of the Cane Haul Road with the exception of lots 88 and 89 adjacent to Farrington Highway. Parcel 1001 will encompass the Dillingham Lodge while Parcel 1002 will include a future agricultural cluster development of 15 farm dwellings each with 2 to 3 bedrooms, linked to fields located below the Cane Haul Road. Parcel 1003 will contain the agricultural fields for the Agricultural Cluster Parcel (Parcel 1002), which will be planted with mango, citrus, coconut, farm-to-table crops, and a landscape plant nursery. The existing equestrian polo grounds and coconut farms (Parcels 1003 and 1004) located *makai* of the Cane Haul Road will remain relatively unchanged with the exception of Parcel 1005 - which will be designated for the subdivision's wastewater treatment works and a subsurface effluent disposal system.

Access to the proposed subdivision will be provided by a series of new roadways labeled alphabetically from A to G (see Appendix B "Proposed Water System"). Road A will follow the property's existing main access road from the intersection of Farrington Highway to the Cane Haul Road, then continue south into the site with secondary roads branching outwards to access the rest of the development. Most of the proposed water network will be placed within these roadway corridors although some dedicated utility easements through individual parcels will be required for access to tanks and to link distribution pipelines.

Because elevations vary widely across the project site, the water distribution system necessitated the creation of three pressure service zones. Two new water tanks

(referred to as Tank 1 at Elevation 220 and Tank 2 at Elevation 500 in this report) will provide a combination of fire suppression and operational storage while maintaining required minimum distribution pressures. Tank 1 serves Pressure Zone 1 while Tank 2 serves Pressure Zones 2 and 3. Pressure reducing valves at the points of connection between Zones 2 and 3 will be used to prevent pressures within Zone 2 from exceeding the design maximum.

Pressure reducing valves will also connect Zones 1 and 2, to provide a back-up water supply for Zone 1 in the event the tank runs low during emergencies or other supply problems. Refer to Table 2 of this report for pressure zone summaries.

The Ranch's irrigation demands are described in detail in the Project's Agricultural Feasibility Report and generally include two zones, Growing Zones One and Two. Growing Zone One is the lower zone and is not supplied by the Ranch's domestic water system. Growing Zone One contains 28 orchard lots, 3 pasture lots, the Agricultural Cluster Parcel, managed pastures, the Lodge, agricultural cluster dwellings, and the Lake surroundings. Growing Zone One will be supplied by the existing Ranch-owned Well #3410-03. This well has been permitted to pump 1.5 MGD and is the current supply source for the main ranch areas. Growing Zone Two will be supplied by the development's domestic water system and contains 45 pasture lots and 15 grazing lots. The water needed to irrigate personal landscape on all 91 residential parcels of the project will be provided by the development's proposed domestic water system as well.

Two new wells will be drilled to supply all domestic demands for the project site and the Mokuleia community. The wells have been preliminarily located as shown on Appendix B "Proposed Water System", separated by a minimum of 750 feet as recommended by the project's geohydrologist, Tom Nance Water Resource Engineering. Both wells will pump to Tank 1, where the water will be chlorinated, and booster pumps will then draw from this tank to supply Tank 2. This water will either flow through a dedicated line to Tank 2, or it will be injected directly into the Zone 2/3 distribution system, which in turn will fill Tank 2 when Zone 3 demands are lower than the pumping rates. Additional system modeling will be performed to determine if the latter option would potentially inhibit the circulation required to maintain acceptable water quality.

Although the proposed water system design meets BWS requirements in terms of minimum water pressure, it is anticipated that certain homesites may be situated above each Zone's maximum service elevation, and so may require private booster pumps to deliver the pressure needed to reach upper floor water fixtures. Similarly, homesites at the low end of each zone may require pressure reducing at the meter to minimize impacts of high pressure water on the interior plumbing.

Refer to the Section V Conclusions and Appendix B "Proposed Water System" for more information.

IV. Methodology

A. Design Parameters

The proposed water layout abides by the Board of Water Supply's Water System Standards (WSS) 2002. In particular, Division 100 of the manual provides requirements for fire and domestic flow demands, peak factors, and pipe sizing amongst other guidelines. These parameters were instrumental in determining many of the water system factors such as the elevation and storage capacity of the water tank and the placement of pressure reducing valves (PRVs).

i. Fireflow Parameters

Fireflow parameters are outlined in Table 100-19 of the Water System Standards. The proposed homes for the agricultural subdivision are designated under the "agriculture" type land use. Therefore these structures must meet a fire flow demand of 1,000 gallons per minute (gpm) for 30 minutes as stipulated in the manual. Multifamily units, such as occurs within the Mokuleia Community (Camp Mokuleia), and the Dillingham Lodge are categorized under "commercial structures" and require 2,000 gpm for 2 hours.

ii. Irrigation Design Parameters

The irrigation demands can be characterized as either agricultural/pastoral (managed by the HOA) or personal (managed by the home owner). The domestic water system will be the supply of irrigation water for agricultural/pastoral demands on lots in the upper pressure zones (Pressure Zones 2&3, which is coincident with Growing Zone Two), as well as for all private landscaping on all proposed lots within both service zones. A separate water system, strictly agricultural and utilizing existing Ranch infrastructure, will be utilized for agricultural demands on lots in the lower pressure zone (Pressure Zone 1, which is coincident with Growing Zone One as defined in the Agricultural Feasibility Report). Except to provide water for cattle and horses, lots designated for grazing will not be irrigated.

The Dillingham Ranch's HOA will be responsible for managing application of the agricultural/pastoral irrigation water on individual lots. Per the Agricultural Feasibility Report, this irrigation supply is assumed to be applied on a consistent basis throughout the day, thereby allowing peak agricultural irrigation demands to be estimated as the daily average demand for storage tank design purposes. Because agricultural uses will be supplied by the domestic system within Pressure Zones 2 & 3 (Growing Zone 2), non-landscape irrigation demands will at all times be subject to water availability within the system. In the event that supplies within the storage tanks fall to predetermined minimum thresholds (due to a power failure for example) the irrigation system will not be used.

Refer to Appendix B "Water Demand Calculations" and Table 1 below for more information including design parameters described above.

TABLE 1 – WATER DESIGN PARAMETERS		
Type	**Rate / Value**	**Comment / Source**
Fire Flow (Agricultural Lots)	1000 gpm @ 30 min duration (30,000 gal)	Storage within Tank 1 and Tank 2. Per WSS Table 100-19
Fire Flow (Lodge & Mokuliea Community)	2000 gpm @ 2hr duration (240,000 gal)	Storage within Tank 1 and Tank 2. Per WSS Table 100-19
Fire Flow (Residual Pressure Min)	20 psi	During fire flow with max daily domestic demand flow. Per WSS Table 100-19
Domestic Water Demand	500 gpd/single-family dwelling 2000 gpd for the Lodge	Per WSS Table 100-18
Irrigation Water Demand Orchard Pasture Grazing Personal Landscaping	 20,818 gpd/lot 20,818 gpd/lot 75 gpd/head 1,145 gpd/lot	From project irrigation consultant
Design Static Pressure Range Maximum	55 psi – 110 psi.	Per Industry standard
Design Peak Hour Residual Pressure Min (Pipelines)	40 psi.	Per WSS Section 111.06
Max Daily Peaking Factor	1.5 x Average Day Domestic Demand (ADD) + Average Day Domestic Irrigation Demand	Per WSS Table 100-20
Peak Hour Factor	3.0 x Domestic ADD + [Average Day Irrigation Demand ÷ (2 assumed hours of irrigation/day ÷ 24)]	Per WSS Table 100-20
TankReservoir Storage	Maximum Day domestic demand + Average Day irrig. demand + fire demand Criterion 1: Meet Max Day Consumption with Reservoir full at start of 24hr Period. Criterion 2: Meet Max Day Rate plus Fire Flow for duration of Fire w/ Reservoir 75% full at start of Fire, and inflow from Well Pump.	Per WWS
Pipe Velocity	6 fps max (without fire flow) 12 fps max (with fire flow)	6 fps per WSS page 111-5. 12 fps based industry standard.

iii. Domestic Water Parameters

Interior domestic water demand is assumed at 500 gpd per single family dwelling. This design parameter is used for the 91 dwellings on the agricultural lots as well as the 15 single family dwellings for the Agricultural Cluster located on Lot 1002. The existing Dillingham Lodge is a commercial facility with an average demand of 2,000 gpd. The Mokuleia Community is estimated to have an average demand of 133,600 gpd, based upon historical records submitted to CWRM.

Refer to Appendix B “Water Demand Calculations” for additional information and design parameters.

iv. Estimated Project Demands

Based on the parameters set forth above, total project water demands are estimated below. The proposed domestic water system will be separated into three pressure zones, supplied by two storage tanks, so the following calculations are broken down into the two tank Service Zones as shown in Table 2 below.

TABLE 2 - ESTIMATED PROJECT WATER DEMANDS TABLE				
Service Zone 1				
Domestic Demand	Residential:	25 single family homes @ 500 gpd =	12,500	gpd
		13 ancillary homes @ 500 gpd =	6,500	gpd
		15 cluster homes @ 500 gpd =	7,500	gpd
	Commercial:	Existing Lodge @ 2000 gpd =	2,000	gpd
Offsite Demand:	Existing Mokuleia community =		133,600	gpd
Irrigation Demand	Livestock:	100 horses @ 75 gpd =	7,500	gpd
	Personal Landscaping:	25 lots @ 1,145 gpd/lot =	28,625	gpd
Average Day Demand =			**198,225**	gpd
Service Zone 2/3				
Domestic Demand	Residential:	66 single family homes @ 500 gpd =	33,000	gpd
		33 ancillary homes @ 500 gpd =	16,500	gpd
Irrigation Demand	Pasture:	7 lots @ 20,818 gpd/lot =	142,752	gpd
	Livestock:	250 head cattle @ 75 gpd =	18,750	gpd
	Personal Landscaping:	66 lots @ 1,145 gpd/lot =	75,570	gpd
Average Day Demand =			**286,572**	gpd
Total Domestic System Demand =			**484,797**	**gpd**
Max Domestic System Demand* =	Total Domestic x 1.5 +Pasture Irrigation		**655,820**	**gpd**
WELL PUMP SIZE	Sized for Max System Demand over 16 Hours		**683**	**gpm**

B. Water Supply and Pumping

Water will be supplied by two proposed wells, whose preliminary locations are shown on Figure 2 – Proposed Water System. The wells will be fitted with pumps capable of pumping 700 GPM and will be run for a maximum of 16 hours per day. This pumping rate and time is within the range recommended by the project geohydrologist. Booster pumps will be sized at a similar rate to pump water from Tank 1 to Tank 2 over a similar time period.

C. Distribution and Storage

As noted above, topographical constraints require separation of the proposed domestic water distribution system into three pressure zones. Pressure Zone 1 covers water services within the elevation range of 10 feet to 90 feet and is served by Tank 1 under normal operating conditions and by a combination of Tank 1 and 2 during fire flow events. Pressure Zones 2 and 3 provide service to all dwellings between elevation 90 and 370 feet and is served by Tank 2 (located at elevation 500'). The reservoirs (tanks) have been designed to provide a minimum static pressure of 55 psi throughout each pressure zone, although, as noted above, topographic conditions may require the installation of individual booster pumps for some homes. In addition, the reservoirs and distribution infrastructure have been designed to ensure there will be at least 40 psi of residual pressure at all home sites during peak hour (non-fire flow) demand conditions, and 20 psi of residual pressure at all fire hydrants under fire flow conditions. A typical 20' utility easement, as shown in Appendix B "Proposed Water System", will be provided to maintain access to each tank.

The tanks were sized using WSS Criterion 1 and 2. Criterion 1 uses the combined daily personal irrigation and max daily domestic demands to determine a required tank volume. This Criterion is assuming a power outage condition where the well pumps are not operating. Criterion 2 sizes the tank for fire flow conditions and is assuming that one of the well pumps is running. This is done by assuming that the tank is ¾ full and that the demand is the combination of max daily domestic demand and fire flow demand. For both Tank 1 and Tank 2 Criterion 1 determined the required size.

Refer to Table 2 below for the pressure zone summary.

D. Modeling

A simulation of the Dillingham Ranch Water System was conducted using WaterCAD by Haested Methods. This simulation was broken into two models, a Lower Model, which reflects areas services by Tank 1, and an Upper Model, which reflects areas serviced by Tank 2 (Refer to Tables 2 and 3 for sizing). Water design guidelines set forth by local agencies, and as outlined in Table 1 of this report, were used as inputs into both models. The WaterCAD model confirms water system pipe sizes and provides pipe pressures and velocities throughout the water system.

Each model was created by placing junctions along the water mains to account for peak hourly domestic water and irrigation demands centered at groupings of lots. The sum of these demands constitute total normal flow conditions. The Lower Model's analysis

includes peak hour domestic demands only, since irrigation in this service area is supplied by existing Well #3410-03.

Additionally, a second set of models were designed to simulate fire flow by pairing normal flow conditions with fire flow demands for both the Tank 1 and Tank 2 service areas. In both scenarios, the analysis was compared against the design parameters outlined in Table 1 of this report. Specifically, the program checked that residual pressures did not drop below 40 psi under peak hour flow conditions or drop below 20 psi under fire flow conditions. The simulation also confirmed that maximum pipeline flow velocities were not exceeded.

Refer to Appendix C "WaterCAD Report" for additional information regarding the WaterCAD calculations.

Table 3: Pressure Zone Summary
Refer to Appendix A – Figure 2 "Proposed Water System" for Lot locations

Pressure Zone	Elevation Range	Lots Included	Comments
1	10ft - 90ft	1-20, 29-32, 1001,1002, 88, 89, Mokuleia Community	Lots in Pressure Zone 1 to be supplied by Tank 1 under normal operating conditions. Tank 2 will feed Pressure Zone 1 in the event of a pressure drop.
2	90ft - 246ft	21-28, 33-50, 51-53, 84-92	Lots in Pressure Zone 2 to be supplied by Tank 2.
3	246ft – 370ft	51, 54-83	Lots in Pressure Zone 3 to be supplied by Tank 2

V. Conclusions

A. Distribution System

The water distribution system will consist of an upper and lower service area encompassing three pressure zones. The lower service area will be supplied by Tank 1 and will provide domestic water and fire water to Pressure Zone 1 in addition to the Mokuleia Community *makai* of Farrington Highway. The upper service zone will be supplied by Tank 2 and will provide domestic water to Pressure Zones 2 and 3 while also providing supplemental fire water storage for Pressure Zone 1 and Irrigation water to the majority of Pressure Zones 2 and 3.

The size of the distribution mains identified in the WaterCAD modeling analysis varies between 10 and 12 inches in the Lower Model distribution network and between 8 and 10 inches in the Upper Model distribution network. Pressure reducing valves will be required at the two locations where Pressure Zone 2 connects to Pressure Zone 3, and two additional locations where the interconnection occurs between Pressure Zone 1 and Pressure Zone 2. Refer to Appendix B "Proposed Water System" for an exhibit detailing these locations.

B. Water Tanks

The WaterCAD Model has substantiated that the proposed tank elevations (220 feet above sea level for Tank 1 and 500 feet above sea level for Tank 2) will maintain the desired range of static and residual pressures throughout the distribution network. As noted in Section IV, the tanks were sized under the assumption that each must maintain a permanent reservoir of the required fire storage in addition to the daily domestic maximum water demand and 2 hours of daily irrigation storage. These criteria resulted in a required 371,000 gallon volume for Tank 1 and a 216,000 gallon volume for Tank 2. Preliminary tank dimensions were selected in an effort to minimize the visibility and site impact.

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APPENDIX A

FIGURE 1 - EXISTING SITE CONDITIONS

FIGURE 2 - PROPOSED WATER SYSTEM

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FIGURE 1 - EXISTING SITE CONDITIONS

DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, HAWAII

July 29, 2014

North

0 150' 300' 600'

LEGEND

- PRESSURE ZONE LIMIT
- WATER LINE – UPPER (DW, FW, IRR)
- WATER LINE – LOWER (DW, FW)
- DISTRIBUTION LINE FROM SUPPLY SOURCE TO TANK
- PROPOSED WATER TANK
- APPROXIMATE LOCATION OF EXISTING WATER WELL
- PROPOSED WELL
- PRESSURE REDUCING VALVE
- EASEMENT
- PROPERTY LINE
- ARCHEOLOGICAL ZONE

WATER SUMMARY

TOTAL LENGTH OF WATER MAIN:
- 31,000 LF

PRVS (MAIN LINE):
- 3

PRESSURE ZONES:
- PRESSURE ZONE 1 (RD A): (10'–90')
- PRESSURE ZONE 1 (RD B): (10'–120')
- PRESSURE ZONE 2 (RD A): (90'–246')
- PRESSURE ZONE 2 (RD B): (120'–246')
- PRESSURE ZONE 3 (TO TANK #2): (246'–350')

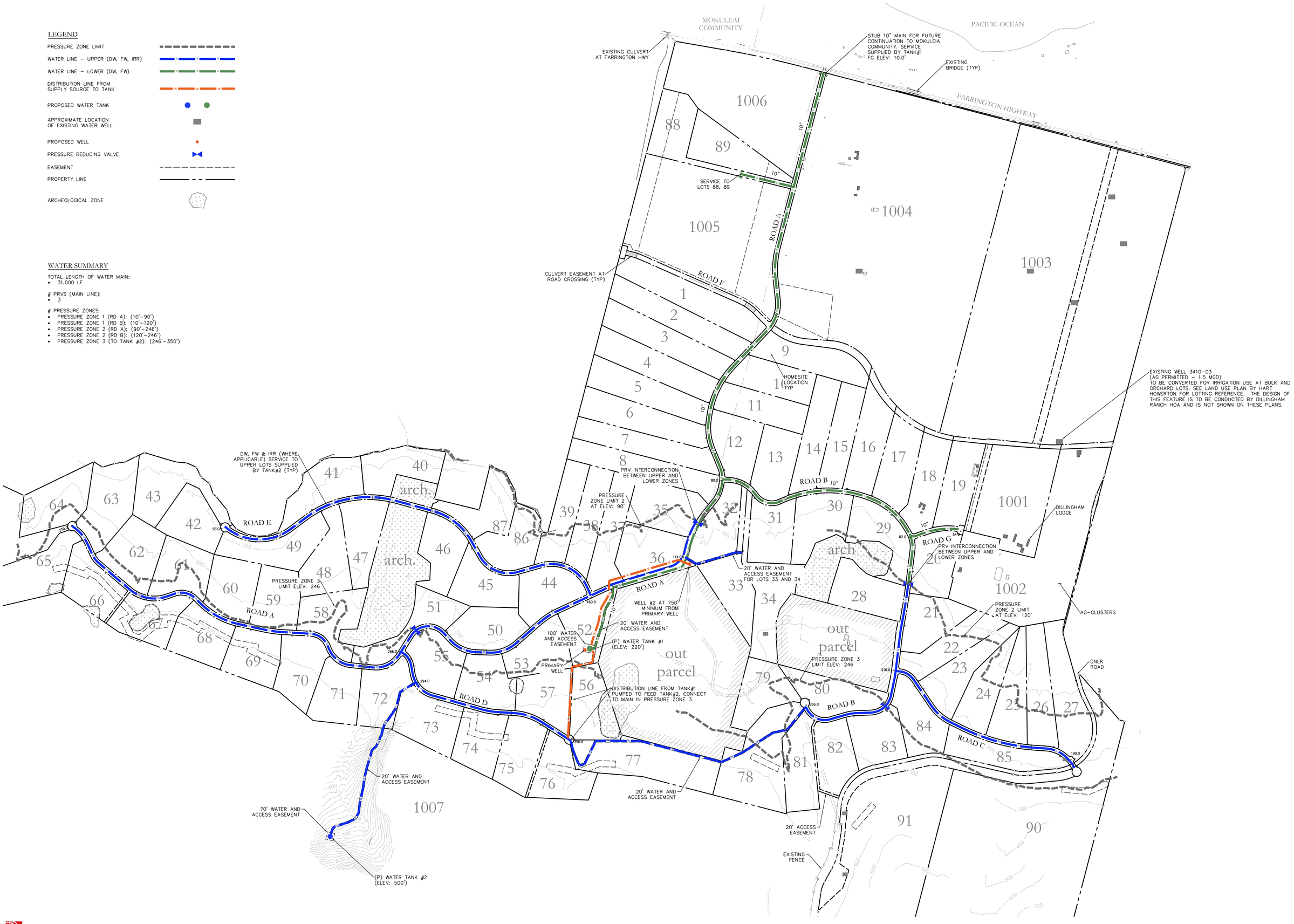

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FIGURE 2 - PROPOSED WATER SYSTEM

DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, HAWAII

July 29, 2014

North 0 150' 300' 600'

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APPENDIX B

TANK SIZING SUMMARY

WATER DEMAND CALCULATIONS

TANK SIZING SUMMARY

INPUT DATA

ASSUMPTIONS AND INPUT DATA				
ITEM	TYPE	RATE	UNIT	COMMENTS
Gallon to Cubic Foot	Conversion Factor	0.1337	-	CONVERSION FACTOR FOR TANK SIZING (DIAMETER)
IRR Demand (Tank #1)	Storage Capacity	2.0	hours	ASSUME 2 HOURS OF STORAGE IN TANK#1 TO BE USED FOR UPPER LOTS
IRR Demand (Tank #2)	Storage Capacity	2.0	hours	ASSUME 2 HOURS OF STORAGE IN TANK#2 TO BE USED FOR UPPER LOTS
IRR Demand	Irrigation Demand	1,080,468	GPD	IRRIGATION DEMANDS FOR UPPER LOTS TO BE HELD BY TANK1 AND TANK2

TANK SIZING CALCULATIONS (LARGER OF TWO CRITERIA GOVERNS)

CRITERION 1 CALCULATIONS

DESCRIPTION	2 HR IRR-DEMAND (GAL)	PERSONAL IRRIGATION (GAL)	MAX DAILY WATER DEMAND (GAL)	MOKULEAI MAX DAILY (GAL)	TANK VOLUME (GAL)	
TANK 1 (LOWER)	90,039	46,945	33,000	200,400	**370,384**	**CRITERION 1 GOVERNS**
TANK 2 (UPPER)	90,039	75,570	49,500	-	**215,109**	**CRITERION 1 GOVERNS**

1. Meet maximum day consumption.
2. Reservoir full at start of the 24 hour period. No credit for pump.

CRITERION 2 CALCULATIONS

DESCRIPTION	FIRE DEMAND (GAL)	PUMP CAPACITY (GPM)	TANK VOLUME(GAL)	
TANK 1 (LOWER)	240,000	700	249,154	**CRITERION 1 GOVERNS**
TANK 2 (UPPER)	30,000	700	14,975	**CRITERION 1 GOVERNS**

1. Meet maximum day use rate plus fire flow for duration of the fire.
2. Reservoir at 3/4 full at start of fire. Credit for pump (assumed at 700 gpm)

TANK SIZING SUMMARY

DESCRIPTION	TANK 1 (LOWER)	TANK 2 (UPPER)	TOTAL	COMMENT
MAX DAILY TOTAL (GPD)[1]	370,384	215,109	585,493	CRITERION 1 SIZING CALC
TANK HEIGHT (FT) - ASSUMED	30	20	-	
TANK DIAMETER (FT)[2]	46	43	-	BASED ON CYLINDRICAL TANK

WATER DEMAND CALCULATIONS

INPUT DATA

ITEM	TYPE	RATE	UNIT	COMMENTS
DW Demand	Domestic	500	GPD/Unit	Per Recommendation by Local Agency
DW Demand (Lodge)	Domestic	2,000	GPD/Unit	
FW Demand	Typical Unit	1,000	GPM	See Reference HI tab (111-4) - 1000 gpm/hr for 0.5 hour
FW Demand	Large Unit	2,000	GPM	See Reference HI tab (111-4) - 2000 gpm/hr for 2 hours
IRR Demand (Livestock)	Animal	75	GPD/Head	75 GPD/head at 250 total heads spread over 15 lots
IRR Demand (Pasture / Orchard)	Residential Unit	20,818	GPD/Unit	Per Calvin Oda
IRR Demand (Personal Pasture)	Residential Unit	1,145	GPD/Unit	Per Calvin Oda
Peaking Factor	Peak Hour	3	-	State of HI design guidelines - see Reference HI tab (111-5)
Peaking Factor	Max Daily	1.5	-	State of HI design guidelines - see Reference HI tab (111-5)

*Refer to '***REF-IRR***' tab for Irrigation rate calculation tables. All Irrigation rates based on peak monthly flows.

TANK 1 - LOWER TANK

GENERAL		DOMESTIC WATER DEMANDS					FIRE WATER DEMAND		
LOT TYPE	NO. UNITS	RATE (GPD/UNIT)	PERSONAL IRRIGATION (GPD)	DOM DEMAND (GPD)	MAX DAILY (GPD)	PEAK HR (GPD)	RATE (GPM)	DURATION (HR)	FIRE DEMAND (GAL)
ORCHARD	23	500	26,335	11,500	17,250	34,500	2000	2	240,000
PASTURE (LOT 88, 89)	2	500	2,290	1,000	1,500	3,000			
LODGE	1	2,000	1,145	2,000	3,000	6,000			
CLUSTER UNIT	15	500	17,175	7,500	11,250	22,500			
TOTAL	-	-	**46,945 (GPD)**	**22,000 (GPD)**	**33,000 MAX DAILY (GPD)**	**66,000 PEAK DAILY (GPD)**	-	-	**240,000 FIRE DEMAND (GAL)**

MOKULEAI COMMUNITY	
DOM DEMAND (GPD)	MAX DAILY (GPD)
133600	200400
133,600 AVG (GPD)	**200,400 MAX DAILY (GPD)**

Per CWRM Data from 2012

TANK 2 - UPPER TANK

GENERAL		IRRIGATION DEMAND [2]	DOMESTIC WATER DEMANDS					FIRE WATER DEMAND		
LOT TYPE	NO. UNITS	DEMAND (GPD)	RATE (GPD/UNIT)	PERSONAL IRRIGATION (GPD)	DOM DEMAND (GPD)	MAX DAILY (GPD)	PEAK HR (GPD)	RATE (GPM)	DURATION (HR)	FIRE DEMAND (GAL)
PASTURE	45	936,810	500	51,525	22,500	33,750	67,500	1,000	0.5	30,000
ORCHARD	6	124,908	500	6,870	3,000	4,500	9,000			
GRAZING LOT	15	18,750	500	17,175	7,500	11,250	22,500			
TOTAL	-	**1,080,468 IRR DEMAND (GPD)**	-	**75,570 (GPD)**	**33,000 AVG DEMAND (GPD)**	**49,500 MAX DAILY (GPD)**	**99,000 PEAK HR (GPD)**	-	-	**30,000 FIRE DEMAND (GAL)**

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APPENDIX C

WATERCAD REPORTS

WATERCAD - LOWER MODEL

WATERCAD LOWER MODEL REFERENCE

JUNCTION DEMAND ASSUMPTIONS

ITEM	RATE	UNIT	COMMENTS
DW Demand Rate (Residence)	500	GPD/Lot	Per WSS Table 100-19
Peak Hour Factor	3	-	Per WSS Table 100-20
DW Demand (Mokuleia)	139.2	GPM	Based on 200,400 GPD
DW Demand (Residence)	0.3	GPM/Lot	
DW Demand (Ranch)	1.4	GPM/Lot	
FW Demand	2,000	GPM	See Reference HI tab (111-4) - 1000 gpm/hr for 1 hour

JUNCTION TABLE - LOWER (WATER FLOW ONLY)			
LABEL	DEMAND (GPM)[3]	#LOTS SERVED	CONTRIBUTING LOT #
J-1[1]	0.0	0	-
J-2[1]	0.0	0	-
J-3[1]	0.0	0	-
J-4	0.3	1	8
J-5	0.7	2	7,12
J-6	1.0	3	5,6,11
J-7	1.4	4	2,3,4,10
J-8	0.7	2	1,9
J-9	0.7	2	88,89
J-10	139.2	1	Mokuleia
J-4A	0.7	2	13, 31
J-4B	1.0	3	14, 15, 30
J-4C	0.7	2	16, 17
J-4D	0.7	2	18, 29
J-4E (Lodge)	7.3	4	19, 20, Lodge, Ag-Cluster
TOTAL	**154.4**	**28**	**-**

WATERCAD LOWER MODEL

GENERAL NOTES & ASSUMPTIONS

1. Lower Model refers to the pipe network servicing lots makai of Cane Haul Road (represented by Pressure Zone 1 in the Water Exhibit)
2. Static Flow Conditions assume no demands in the water main
3. Water Flow Conditions assume a pressure range of 40-110 psi
4. Fireflow Conditions require a minimum pressure of 20 psi
5. The maximum velocity in the pipe without fireflow is 6 ft/s
6. There is no irrigation component in the lower model.
7. Refer to State of Hawaii's Water System Standards page 111-5 for more information on these criteria
8. All pipes assumed to be ductile iron with Hazen-Williams Coef of 130

STATIC FLOW CALCULATIONS

JUNCTION TABLE

LABEL	ELEVATION (FT)	DEMAND (GPM)[3]	PRESSURE (PSI)
R-1 (Reservoir)	220	0.0	0
J-1[1]	150	0.0	30.3
J-2[1]	120	0.0	43.3
J-3	85	0.0	58.4
J-4	72	0.0	64
J-5	65	0.0	67.1
J-6	50	0.0	73.6
J-7	29	0.0	82.6
J-8	20	0.0	86.5
J-10 (Mokuleia)[2]	8	0.0	91.7
J-09	10	0.0	90.9
J-4A	86	0.0	58
J-4B	84	0.0	58.8
J-4C	82	0.0	59.7
J-4D	82	0.0	59.7
J-4E (Lodge)	54	0.0	71.8

WATER DEMAND FLOW CALCULATIONS

JUNCTION TABLE

LABEL	ELEVATION (FT)	DEMAND (GPM)[3]	PRESSURE (PSI)
R-1 (Reservoir)	220	0.0	0
J-1[1]	150	0.0	30.3
J-2[1]	120	0.0	43.2
J-3	85	0.0	58.3
J-4	72	0.3	63.9
J-5	65	0.7	66.9
J-6	50	1.0	73.3
J-7	29	1.4	82.4
J-8	20	0.7	86.3
J-09	10	0.7	91.2
J-10 (Mokuleai)	8	139.2	90.5
J-4A	86	0.7	57.8
J-4B	84	1.0	58.7
J-4C	82	0.7	59.5
J-4D	82	0.7	59.5
J-4E (Lodge)	54	7.3	71.7

[1]Demand is entered as zero at these Junctions since they do not serve any houses
[2]Mokuleia Community is assumed to have a max daily demand of 200,400 GPD
[3]Refer to the Model Lower Reference Tab for more information

PIPE TABLE

LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	398	R-2	J-1	10	154	0.63
P-2	647	J-1	J-2	10	154	0.63
P-3	699	J-2	J-3	10	154	0.63
P-4	230	J-3	J-4	10	154	0.63
P-5	233	J-4	J-5	10	144	0.59
P-6	412	J-5	J-6	10	143	0.58
P-7	652	J-6	J-7	10	142	0.58
P-8	286	J-7	J-8	10	141	0.57
P-9	1210	J-8	J-09	10	140	0.57
P-10	1721	J-09	J-10	10	139	0.57
P-4A	476	J-4	J-4A	10	10	0.04
P-4B	573	J-4A	J-4B	10	10	0.04
P-4C	508	J-4B	J-4C	10	9	0.04
P-4D	328	J-4C	J-4D	10	8	0.03
P-4E	542	J-4D	J-4E	10	7	0.03

[1]Demand is entered as zero at these Junctions since they do not serve any houses
[2]Mokuleia Community is assumed to have a max daily demand of 200,400 GPD

FIRE FLOW CALCULATIONS

JUNCTION TABLE - FIRE AT JUNCTION J-4E			
LABEL	ELEVATION (FT)	DEMAND (GPM)	PRESSURE (PSI)
R-1 (Reservoir)	220	0.0	0
J-1[1]	150	0.0	25.9
J-2[1]	120	0.0	31.8
J-3	85	0.0	39.3
J-4	72	0.3	42.4
J-5	65	0.7	45.4
J-6	50	1.0	51.8
J-7	29	1.4	60.9
J-8	20	0.7	64.8
J-10 (Mokuleia)[2]	8	139.2	69.7
J-09	10	0.7	69
J-4A	86	0.7	31.7
J-4B	84	1.0	27.1
J-4C	82	0.7	23
J-4D	82	0.7	21.7
J-4E (Lodge - Assigned Fireflow)	54	2000.0	28.6

[1]Demand is entered as zero at these Junctions since they do not serve any houses

[2]Mokuleia Community is assumed to have a demand of 100,000 GPD

PIPE TABLE - FIRE AT JUNCTION J-4E						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	398	R-2	J-1	10	2,147	8.77
P-2	647	J-1	J-2	10	2,147	8.77
P-3	699	J-2	J-3	10	2,147	8.77
P-4	230	J-3	J-4	10	2,147	8.77
P-5	233	J-4	J-5	10	144	0.59
P-6	412	J-5	J-6	10	143	0.58
P-7	652	J-6	J-7	10	142	0.58
P-8	286	J-7	J-8	10	141	0.57
P-9	1210	J-8	J-09	10	140	0.57
P-10	1721	J-09	J-10	10	139	0.57
P-4A	476	J-4	J-4A	10	2,003	8.18
P-4B	573	J-4A	J-4B	10	2,002	8.18
P-4C	508	J-4B	J-4C	10	2,001	8.18
P-4D	328	J-4C	J-4D	12	2,001	5.68
P-4E	542	J-4D	J-4E	10	2,000	8.17

JUNCTION TABLE - FIRE AT JUNCTION J-10			
LABEL	ELEVATION (FT)	DEMAND (GPM)	PRESSURE (PSI)
R-1 (Reservoir)	220	0.0	0
J-1[1]	150	0.0	26.4
J-2[1]	120	0.0	33.1
J-3	85	0.0	41.4
J-4	72	0.3	44.8
J-5	65	0.7	45.6
J-6	50	1.0	48.1
J-7	29	1.4	50.9
J-8	20	0.7	52
J-10 (Mokuleia - Assigned Fireflow)[2]	8	2000.0	29
J-09	10	0.7	44.7
J-4A	86	0.7	38.7
J-4B	84	1.0	39.6
J-4C	82	0.7	40.4
J-4D	82	0.7	40.4
J-4E (Lodge)	54	7.3	52.6

PIPE TABLE - FIRE AT JUNCTION J-10						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	398	R-2	J-1	10	2,015	8.23
P-2	647	J-1	J-2	10	2,015	8.23
P-3	699	J-2	J-3	10	2,015	8.23
P-4	230	J-3	J-4	10	2,015	8.23
P-5	233	J-4	J-5	10	2,004	8.19
P-6	412	J-5	J-6	10	2,004	8.19
P-7	652	J-6	J-7	10	2,003	8.18
P-8	286	J-7	J-8	10	2,001	8.18
P-9	1210	J-8	J-09	10	2,001	8.17
P-10	1721	J-09	J-10	10	2,000	8.17
P-4A	476	J-4	J-4A	10	10	0.04
P-4B	573	J-4A	J-4B	10	10	0.04
P-4C	508	J-4B	J-4C	10	9	0.04
P-4D	328	J-4C	J-4D	10	8	0.02
P-4E	542	J-4D	J-4E	10	7	0.03

WATERCAD - UPPER MODEL

WATERCAD UPPER MODEL REFERENCE

JUNCTION DEMAND ASSUMPTIONS

1. Assumed all lots have irrigation demand
2. Irrigation demands assumed to be carried continuously over 24 hours

ITEM	RATE	UNIT	COMMENTS
DW Demand (Residence)	500	GPD/Lot	Per WSS Table 100-19
DW Demand (Residence)	0.3	GPM/Lot	
Peak Hour Factor	3.0	-	Per WSS Table 100-20
IRR: Pasture Demand	14.5	GPM/lot	Use for pasture lots only. Based on 20,818 gpd/lot
IRR: Personal Demand	0.8	GPM/Lot	Use for both grazing and pasture lots. Based on 1,145 gpd/lot
IRR: Grazing Demand	0.9	GPM/Lot	Use for grazing lots only. Based on 75 gpd/head at 250 heads spread across 15 grazing lots
IRR: Total Grazing Demand	1.7	GPM/Lot	Total Grazing Demand: Grazing Demand + Personal Demand
IRR: Total Pasture Demand	15.3	GPM/Lot	Total Pasture Demand: Pasture Demand + Personal Demand
FW Demand	1,000	GPM	See Reference HI tab (111-4) - 1000 gpm/hr for 30 min

JUNCTION TABLE - LOWER (WATER FLOW ONLY)								
LABEL	IRR GRAZING (GPM)	IRR PASTURE (GPM)	DOM DEMAND (GPM)[3]	TOTAL DEMAND (GPM)	GRAZING LOT	PASTURE LOT	TOTAL LOTS	CONTRIBUTING LOT #
J-1	1.7	15.3	0.7	17.6	*1*	*1*	*2*	55, 73(G)*
J-2	**0.0**	**0.0**	**0.0**	**0.0**	***0***	***0***	***0***	**Dummy Node**
J-4	3.3	30.5	1.4	35.2	*2*	*2*	*4*	54, 57, 74(G), 75(G)
J-5 (Highest Lot)	3.3	15.3	1.0	19.6	*2*	*1*	*3*	56, 76(G), 77(G)
J-6	**0.0**	**0.0**	**0.0**	**0.0**	***0***	***0***	***0***	**Dummy Node**
J-7	0.0	30.5	0.7	31.2	*0*	*2*	*2*	78, 79
J-8	0.0	45.8	1.0	46.8	*0*	*3*	*3*	80, 81, 82
J-9	0.0	15.3	0.3	15.6	*0*	*1*	*1*	83
J-10 (Interconnect to Lower)	0.0	30.5	0.7	31.2	*0*	*2*	*2*	21, 28
J-11	0.0	15.3	0.3	15.6	*0*	*1*	*1*	22
J-12	0.0	45.8	1.0	46.8	*0*	*3*	*3*	23, 24, 84
J-13	0.0	45.8	1.0	46.8	*0*	*3*	*3*	25, 26, 27
J-14	1.7	0.0	0.3	2.0	*1*	*0*	*1*	90(G)
J-15	1.7	15.3	0.7	17.6	*1*	*1*	*2*	85, 91(G)
J-16	3.3	45.8	1.7	50.8	*2*	*3*	*5*	62, 63, 64, 65(G), 66(G)
J-17	1.7	15.3	0.7	17.6	*1*	*1*	*2*	61, 67(G)
J-18	3.3	30.5	1.4	35.2	*2*	*2*	*4*	59, 60, 68(G), 69(G)
J-19	1.7	15.3	0.7	17.6	*1*	*1*	*2*	58, 70(G)
J-20	1.7	0.0	0.3	2.0	*1*	*0*	*1*	71(G)
J-21	1.7	15.3	0.7	17.6	*1*	*1*	*2*	51, 72(G)
J-22	0.0	0.0	0.3	0.3	*0*	*0*	*1*	36(N)
J-23	0.0	30.5	0.7	31.2	*0*	*2*	*2*	44, 53
J-24	0.0	15.3	0.3	15.6	*0*	*1*	*1*	50
J-25	**0.0**	**0.0**	**0.0**	**0.0**	***0***	***0***	***0***	**Dummy Node**
J-26	0.0	30.5	0.7	31.2	*0*	*2*	*2*	42, 43
J-27	0.0	30.5	0.7	31.2	*0*	*2*	*2*	48, 49
J-28	0.0	45.8	1.0	46.8	*0*	*3*	*3*	40, 41, 47
J-29	0.0	30.5	0.7	31.2	*0*	*2*	*2*	46, 87
J-30	0.0	30.5	0.7	31.2	*0*	*2*	*2*	45, 86
J-31	0.0	0.0	0.7	0.7	*0*	*0*	*2*	38(NI), 39(N)
J-33	0.0	15.3	0.7	15.9	*0*	*1*	*2*	37(N), 52
J-34	0.0	30.5	0.7	31.2	*0*	*2*	*2*	33, 34
J-36 (Interconnect to Lower)	0.0	0.0	0.7	0.7	*0*	*0*	*2*	32(N), 35(N)
TOTAL	**24.9**	**686.3**	**22.9**	**734.2**	**15.0**	**45.0**	**66.0**	**-**

[1]Refer to the image below for a graphical representation of the junction demand

[2]Irrigation is not required for the lower zone. Demands in this Table reflect only basic domestic water demands. Refer to Model Lower tab for Fireflow scenarios

*(G) Grazing Lot / (N) No Irrigation

DILLINGHAM RANCH WATERCAD UPPER MODEL

GENERAL NOTES & ASSUMPTIONS

1. Lower Model refers to the pipe network servicing lots makai of Cane Haul Road (represented by Pressure Zone 1 in the Water Exhibit)
2. Static Flow Conditions assume no demands
3. Normal Flow Conditions assume a pressure range of 40-110 psi
4. Fireflow Conditions require a minimum pressure of 20 psi
5. The maximum velocity in the pipe without fireflow is 6 ft/s
7. Refer to State of Hawaii's Water System Standards page 111-5 for more information on these criteria
8. All pipes assumed to be ductile iron with Hazen-Williams Coef of 130

PRESSURE REDUCING VALVE

PRV CALCULATIONS			
LABEL	**ELEVATION**	**REDUCED PRESSURE (PSI)**	**COMMENT**
PRV-1	246	55.0	BETWEEN NODE J-9 & NODE J-11
PRV-2	246	41.0	BETWEEN NODE J-2 & NODE J-25

STATIC FLOW CALCULATIONS

JUNCTION TABLE - UPPER			
LABEL	**ELEVATION (FT)**	**DEMAND (GPM)**	**PRESSURE (PSI)**
R-1 (Reservoir)	500	0.0	0
J-1	294	0.0	89
J-2	266	0.0	101
J-4	318	0.0	79
J-5 (Highest Lot)	342	0.0	68
J-6	290	0.0	91
J-7	264	0.0	102
J-8	282	0.0	94
J-9	246	0.0	110
J-10 (Interconnect to Lower)	120	0.0	110
J-11	210	0.0	71
J-12	213	0.0	69
J-13	186	0.0	81
J-14	204	0.0	73
J-15	228	0.0	63
J-16	270	0.0	100
J-17	274	0.0	98
J-18	266	0.0	101
J-19	266	0.0	101
J-20	264	0.0	102
J-21	268	0.0	100
J-22	120	0.0	96
J-23	190	0.0	65
J-24	212	0.0	56
J-25	236	0.0	45
J-26	94	0.0	107
J-27	88	0.0	109
J-28	110	0.0	100
J-29	132	0.0	90
J-30	136	0.0	89
J-31	128	0.0	92
J-33	160	0.0	78
J-34	126	0.0	93
J-36 (Interconnect to Lower)	100	0.0	104

WATER DEMAND FLOW CALCULATIONS

JUNCTION TABLE - UPPER			
LABEL	ELEVATION (FT)	DEMAND (GPM)[1]	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	17.6	83
J-2	266	0.0	94
J-4	318	35.2	71
J-5 (Highest Lot)	342	19.6	61
J-6	290	0.0	82
J-7	264	31.2	93
J-8	282	46.8	85
J-9	246	15.6	101
J-10 (Interconnect to Lower)	120	31.2	109
J-11	210	15.6	71
J-12	213	46.8	69
J-13	186	46.8	81
J-14	204	2.0	73
J-15	228	17.6	63
J-16	270	50.8	92
J-17	274	17.6	90
J-18	266	35.2	94
J-19	266	17.6	94
J-20	264	2.0	95
J-21	268	17.6	93
J-22	120	0.3	93
J-23	190	31.2	64
J-24	212	15.6	55
J-25	236	0.0	45
J-26	94	31.2	104
J-27	88	31.2	106
J-28	110	46.8	97
J-29	132	31.2	88
J-30	136	31.2	86
J-31	128	0.7	90
J-33	160	15.9	76
J-34	126	31.2	91
J-36 (Interconnect to Lower)	100	0.7	102

Assumes demands from Water and Irrigation running concurrently at every lot as a worse case scenario.

PIPE TABLE - UPPER						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	1462	R-1	J-1	8	737	4.7
P-2	354	J-1	J-2	8	410	2.6
P-4	1069	J-1	J-4	8	309	2.0
P-5	574	J-4	J-5	10	274	1.1
P-6	1362	J-5	J-6	8	254	1.6
P-7	795	J-6	J-7	8	254	1.6
P-8	241	J-7	J-8	8	223	1.4
P-9	585	J-8	J-9	8	176	1.1
P-12	800	J-11	J-10	8	31	0.2
P-13	634	J-11	J-12	10	113	0.5
P-14	1139	J-12	J-13	10	66	0.3
P-15	101	J-13	J-14	10	20	0.1
P-16	658	J-14	J-15	10	18	0.1
P-17	927	J-16	J-17	8	51	0.3
P-18	670	J-17	J-18	8	68	0.4
P-19	970	J-18	J-19	8	104	0.7
P-20	330	J-19	J-20	8	122	0.8
P-21	379	J-20	J-21	8	124	0.8
P-22	247	J-21	J-2	8	141	0.9
P-24	655	J-23	J-24	8	253	1.6
P-25	642	J-24	J-25	8	269	1.7
P-27	385	J-26	J-27	8	31	0.2
P-28	847	J-27	J-28	8	62	0.4
P-29	937	J-28	J-29	8	109	0.7
P-30	753	J-29	J-30	8	140	0.9
P-31	503	J-30	J-31	8	172	1.1
P-33	862	J-22	J-33	6	33	0.4
P-34	422	J-33	J-23	6	222	2.5
P-35	374	J-31	J-33	6	173	2.0
P-37	773	J-34	J-22	6	32	0.4
P-44	86	J-9	PRV-1	6	161	1.8
P-45	259	PRV-1	J-11	8	161	1.0
P-47	249	J-2	PRV-2	6	269	3.1
P-48	52	PRV-2	J-25	6	269	3.1
P-49	397	J-22	J-36	6	1	0.0

FIRE FLOW CALCULATIONS - FIRE FLOW AT J-15

JUNCTION TABLE - J-15			
LABEL	ELEVATION (FT)	DEMAND (GPM)[1]	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	17.6	61
J-2	266	0.0	73
J-4	318	35.2	39
J-5 (Highest Lot)	342	1.0	23
J-6	290	0.0	32
J-7	264	31.2	35
J-8	282	46.8	25
J-9	246	15.6	35
J-10 (Interconnect to Lower)	120	31.2	85
J-11	210	15.6	46
J-12	213	1.0	40
J-13	186	1.0	43
J-14	204	2.0	34
J-15 (Assigned Fireflow)	**228**	**1000.0**	**22**
J-16	270	50.8	71
J-17	274	17.6	69
J-18	266	35.2	73
J-19	266	17.6	73
J-20	264	2.0	74
J-21	268	17.6	72
J-22	120	0.3	93
J-23	190	31.2	64
J-24	212	15.6	55
J-25	236	0.0	45
J-26	94	31.2	104
J-27	88	31.2	106
J-28	110	46.8	97
J-29	132	31.2	88
J-30	136	31.2	86
J-31	128	0.7	90
J-33	160	15.9	76
J-34	126	31.2	91
J-36 (Interconnect to Lower)	100	0.7	102

*Turned off irrigation demands in J-13, J-12, and J-5 to meet 20 psi minimum. Assumes irrigation runs in all other lots to be conservative.

PIPE TABLE - J-15						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	1462	R-1	J-1	8	1,609	10.3
P-2	354	J-1	J-2	8	410	2.6
P-4	1069	J-1	J-4	8	1,181	7.5
P-5	574	J-4	J-5	8	1,146	7.3
P-6	1362	J-5	J-6	8	1,145	7.3
P-7	795	J-6	J-7	8	1,145	7.3
P-8	241	J-7	J-8	8	1,114	7.1
P-9	585	J-8	J-9	8	1,067	6.8
P-12	800	J-11	J-10	8	31	0.2
P-13	634	J-11	J-12	8	1,004	6.4
P-14	1139	J-12	J-13	8	1,003	6.4
P-15	101	J-13	J-14	8	1,002	6.4
P-16	658	J-14	J-15	10	1,000	4.1
P-17	927	J-16	J-17	8	51	0.3
P-18	670	J-17	J-18	8	69	0.4
P-19	970	J-18	J-19	8	104	0.7
P-20	330	J-19	J-20	8	122	0.8
P-21	379	J-20	J-21	8	124	0.8
P-22	247	J-21	J-2	8	141	0.9
P-24	655	J-23	J-24	8	253	1.6
P-25	642	J-24	J-25	8	269	1.7
P-27	385	J-26	J-27	8	31	0.2
P-28	847	J-27	J-28	8	62	0.4
P-29	937	J-28	J-29	8	109	0.7
P-30	753	J-29	J-30	8	140	0.9
P-31	503	J-30	J-31	8	172	1.1
P-33	862	J-22	J-33	6	33	0.4
P-34	422	J-33	J-23	6	222	2.5
P-35	374	J-31	J-33	6	173	2.0
P-37	773	J-34	J-22	6	32	0.4
P-44	86	J-9	PRV-1	6	1,051	11.9
P-45	259	PRV-1	J-11	8	1,051	6.7
P-47	249	J-2	PRV-2	6	269	3.1
P-48	52	PRV-2	J-25	6	269	3.1
P-49	397	J-22	J-36	6	1	0.0

FIRE FLOW CALCULATIONS - FIRE FLOW AT J-26

JUNCTION TABLE - J-26			
LABEL	ELEVATION (FT)	DEMAND (GPM)[1]	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	18.0	58
J-2	266	0.0	65
J-4	318	35.0	47
J-5 (Highest Lot)	342	20.0	36
J-6	290	0.0	58
J-7	264	31.0	68
J-8	282	47.0	60
J-9	246	16.0	76
J-10 (Interconnect to Lower)	120	31.0	109
J-11	210	16.0	71
J-12	213	47.0	69
J-13	186	47.0	81
J-14	204	2.0	73
J-15	228	18.0	63
J-16	270	51.0	63
J-17	274	18.0	61
J-18	266	35.0	65
J-19	266	18.0	65
J-20	264	2.0	66
J-21	268	18.0	64
J-22	120	0.0	56
J-23	190	31.0	44
J-24	212	16.0	42
J-25	236	0.0	39
J-26 (Assigned Fireflow)	**94**	**1000.0**	**21**
J-27	88	31.0	27
J-28	110	47.0	24
J-29	132	31.0	23
J-30	136	32.0	29
J-31	128	1.0	37
J-33	160	16.0	39
J-34	126	32.0	53
J-36 (Interconnect to Lower)	100	1.0	64

PIPE TABLE - J-26						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	1462	R-1	J-1	8	1,707	10.9
P-2	354	J-1	J-2	8	1,379	8.8
P-4	1069	J-1	J-4	8	310	2.0
P-5	574	J-4	J-5	8	275	1.8
P-6	1362	J-5	J-6	8	255	1.6
P-7	795	J-6	J-7	8	255	1.6
P-8	241	J-7	J-8	8	224	1.4
P-9	585	J-8	J-9	8	177	1.1
P-12	800	J-11	J-10	8	31	0.2
P-13	634	J-11	J-12	8	114	0.7
P-14	1139	J-12	J-13	8	67	0.4
P-15	101	J-13	J-14	8	20	0.1
P-16	658	J-14	J-15	10	18	0.1
P-17	927	J-16	J-17	8	51	0.3
P-18	670	J-17	J-18	8	69	0.4
P-19	970	J-18	J-19	8	104	0.7
P-20	330	J-19	J-20	8	122	0.8
P-21	379	J-20	J-21	8	124	0.8
P-22	247	J-21	J-2	8	141	0.9
P-24	655	J-23	J-24	8	1,222	7.8
P-25	642	J-24	J-25	8	1,238	7.9
P-27	385	J-26	J-27	8	1,000	6.4
P-28	847	J-27	J-28	8	1,031	6.6
P-29	937	J-28	J-29	8	1,078	6.9
P-30	753	J-29	J-30	8	1,109	7.1
P-31	503	J-30	J-31	8	1,141	7.3
P-33	862	J-22	J-33	6	33	0.4
P-34	422	J-33	J-23	6	1,191	13.5
P-35	374	J-31	J-33	6	1,142	13.0
P-37	773	J-34	J-22	6	32	0.4
P-44	86	J-9	PRV-1	6	161	1.8
P-45	259	PRV-1	J-11	8	161	1.0
P-47	249	J-2	PRV-2	6	1,238	14.1
P-48	52	PRV-2	J-25	6	1,238	14.1
P-49	397	J-22	J-36	6	1	0.0

FIRE FLOW CALCULATIONS - FIRE FLOW AT J-16

JUNCTION TABLE - J-16			
LABEL	ELEVATION (FT)	DEMAND (GPM)[1]	PRESSURE (PSI)
R-1 (Reservoir)	500	0.0	0
J-1	294	17.6	59
J-2	266	0.0	66
J-4	318	35.2	47
J-5 (Highest Lot)	342	19.6	37
J-6	290	0.0	58
J-7	264	31.2	69
J-8	282	46.8	61
J-9	246	15.6	76
J-10 (Interconnect to Lower)	120	31.2	109
J-11	210	15.6	71
J-12	213	46.8	69
J-13	186	46.8	81
J-14	204	2.0	73
J-15	228	17.6	63
J-16 (Assigned Fireflow)	**270**	**1000.0**	**34**
J-17	274	17.6	40
J-18	266	35.2	49
J-19	266	17.6	57
J-20	264	2.0	61
J-21	268	17.6	63
J-22	120	0.3	93
J-23	190	31.2	64
J-24	212	15.6	55
J-25	236	0.0	45
J-26	94	31.2	104
J-27	88	31.2	106
J-28	110	46.8	97
J-29	132	31.2	88
J-30	136	31.2	86
J-31	128	0.7	90
J-33	160	15.9	76
J-34	126	31.2	91
J-36 (Interconnect to Lower)	100	0.7	102

PIPE TABLE - J-16						
LABEL	LENGTH (FT)	START NODE	STOP NODE	DIAMETER (IN)	FLOW (GPM)	VELOCITY (FT/S)
P-1	1462	R-1	J-1	8	1,687	10.8
P-2	354	J-1	J-2	8	1,359	8.7
P-4	1069	J-1	J-4	10	310	2.0
P-5	574	J-4	J-5	10	275	1.8
P-6	1362	J-5	J-6	8	255	1.6
P-7	795	J-6	J-7	8	255	1.6
P-8	241	J-7	J-8	8	224	1.4
P-9	585	J-8	J-9	8	177	1.1
P-12	800	J-11	J-10	8	31	0.2
P-13	634	J-11	J-12	12	114	0.7
P-14	1139	J-12	J-13	12	67	0.4
P-15	101	J-13	J-14	8	20	0.1
P-16	658	J-14	J-15	10	18	0.1
P-17	927	J-16	J-17	10	1,000	6.4
P-18	670	J-17	J-18	8	1,018	6.5
P-19	970	J-18	J-19	8	1,053	6.7
P-20	330	J-19	J-20	8	1,071	6.8
P-21	379	J-20	J-21	8	1,073	6.9
P-22	247	J-21	J-2	8	1,090	7.0
P-24	655	J-23	J-24	8	253	1.6
P-25	642	J-24	J-25	8	269	1.7
P-27	385	J-26	J-27	8	31	0.2
P-28	847	J-27	J-28	8	62	0.4
P-29	937	J-28	J-29	8	109	0.7
P-30	753	J-29	J-30	8	140	0.9
P-31	503	J-30	J-31	8	172	1.1
P-33	862	J-22	J-33	8	33	0.4
P-34	422	J-33	J-23	8	222	2.5
P-35	374	J-31	J-33	8	173	2.0
P-37	773	J-34	J-22	8	32	0.4
P-44	86	J-9	PRV-1	8	161	1.8
P-45	259	PRV-1	J-11	8	161	1.0
P-47	249	J-2	PRV-2	6	269	3.1
P-48	52	PRV-2	J-25	6	269	3.1
P-49	397	J-22	J-36	6	1	0.0

58 MAIDEN LANE, 3RD FLOOR, SAN FRANCISCO, CA 94108
(415) 677-7300 WWW.SHERWOODENGINEERS.COM

APPENDIX D

SUPPORTING DOCUMENTS

Table 100-18 - DOMESTIC CONSUMPTION GUIDELINES				
AVERAGE DAILY DEMAND*				
ZONING DESIGNATION	HAWAII	KAUAI	MAUI	OAHU
RESIDENTIAL:				
Single Family or Duplex	400 gals/unit	500 gals/unit	600 gals/unit or 3000 gals/acre	500 gals/unit or 2500 gals/acre
Multi-Family Low Rise	400 gals/unit	350 gals/unit	560 gals/unit or 5000 gals/acre	400 gals/unit or 4000 gals/acre
Multi-Family High Rise	400 gals/unit	350 gals/unit	560 gals/unit	300 gals/unit
COMMERCIAL:				
Commercial Only	3000 gals/acre	3000 gals/acre	6000 gals/acre	3000 gals/acre
Commercial/Industrial Mix	--	5000 gals/acre	140 gals/1000 sq. ft.	100 gals/1000 sq. ft.
Commercial/Residential Mix	--	3000 gals/acre	140 gals/1000 sq. ft.	120 gals/1000 sq. ft.
RESORT (To include hotel for Maui only)	400 gals/unit (1)	350 gals/unit	350 gals/unit or 17000 gals/acre	350 gals/unit or 4000 gals/acre
LIGHT INDUSTRY:	4000 gals/acre	4000 gals/acre	6000 gals/acre	4000 gals/acre
SCHOOLS, PARKS:	4000 gals/acre or 60 gals/student	4000 gals/acre or 60 gals/student	1700 gals/acre or 60 gals/student	4000 gals/acre or 60 gals/student
AGRICULTURE:		2,500 gals/acre	5000 gals/acre	4000 gals/acre

* - Where two or more figures are listed for the same zoning, the daily demand resulting in higher consumption use shall govern the design unless specified otherwise.

(1) - Subject to special review and control by the Manager.

Table 100-19 - FIRE FLOW REQUIREMENTS				
LAND USE	FLOW (GPM)/DURATION (HRS)/FIRE HYDRANT SPACING (FT.)			
	HAWAII	KAUAI	MAUI	OAHU
Agriculture	500/0.5/600 (1)	250/1/500	500/2/500	1000/0.5/700
Rural			1000/2/500	
Single Family	(2)	(4)	1000/2/350	1000/1/350
Duplex	1500/1/300	(4)	1250/2/350	1000/1/350
PUD Townhouse and Low Rise Apartments	1500/1/300	(4)	(5)	1500/1/250
Schools, Neighborhood Businesses, Small Shopping Centers, Hotels (except Maui), and High Rise Apartments	2000/2/300	2000/2/350	2000/2/250	2000/2/250
Light Industry, Downtown Business, Large Shopping Center, and Hospitals	2,000/2/300	3000/3/350	2000/2/250	4000/3/250
Heavy Industry, Hotels	2,000/2/300	3000/3/350	2,500/2/ 250	(3)

(1) - Applies to one acre lot size or less
(2) - 10,000 sq. ft. or larger lot size = 500/2/600; Less than 10,000 sq. ft. lot size = 1000/1/600
(3) - Subject to special review and control by Manager
(4) - R-2 = 500/1/500 R-4 = 750/2/500 R-6 = 1000/2/500 R-10 = 1250/2/350
R-20 = 1500/2/350 RR-10 = 1500/2/350 RR-20 = 2000/2/350
(5) - A-1 = 1500/2/250 A-2 = 2000/2/250

Note:
1. On dead end streets, the last F.H. shall be located at one half the spacing distance for F.H.s from the last house/unit (frontage property line or to the driveway/access for the property).
2. Spacing of fire hydrant shall be measured along the roadway.

Table 100-20 - DEMAND FACTORS		
Island	Maximum Daily Demand	Peak Hour
Hawaii	1.5 x Average Day	5.0 x Average Day
Kauai, Maui, Oahu	1.5 x Average Day	3.0 x Average Day

111.06 PIPELINE SIZING.

Pipelines shall be sized to meet the following requirements:

1. Maximum daily flow plus fire flow with a residual pressure of 20 psi at critical fire hydrant.

2. Peak hour flow with a minimum residual pressure of 40 psi.

3. In determining the carrying capacity of the mains, the "C"* values to be applied are shown in Table 100-21.

Table 100-21 - "C"* FACTORS	
Pipe Diameter (In.)	"C"
4", 6"	100
8", 12"	110
16", 20"	120
24" and Larger	130

* Not for metallic non-cement lined pipe.

4. Maximum velocity in distribution main (without fire flow) is 6 feet per second.

5. *For Maui Only: In addition, the maximum velocity in mains shall apply as follows:*

   a. *Distribution mains - 10 feet per second with fire flow at max day domestic flow.*

   b. *Transmission mains without water services or fire flow - 20 feet per second.*

   c. *Fire lines - 13 feet per second.*

Appendix J

Drainage Masterplan Report for
Dillingham Ranch Agricultural Subdivision
Mokule'ia, O'ahu, Hawai'i

Drainage Masterplan Report

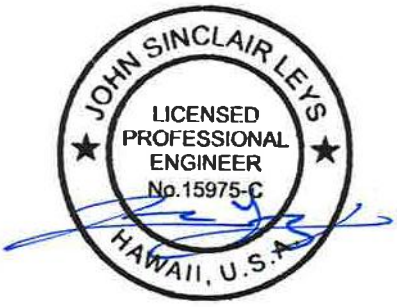
For Dillingham Ranch Agricultural Subdivision
Mokuleia, Oahu, Hawaii

Tax Map Key (1) 6-8-003

Prepared for:

Dillingham Ranch Aina, LLC

9701 Wilshire Boulevard, Suite 700
Beverly Hills, California 90212



Prepared July 31, 2014 by:

SHERWOOD
DESIGN ENGINEERS
58 Maiden Lane, Third Floor
San Francisco, CA 94108
www.sherwoodengineers.com

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I. Introduction

A. Purpose and Scope of Report

The purpose of this report is to describe the overall drainage plan for the Dillingham Ranch Agricultural Subdivision. This report includes a discussion of drainage conditions during major storm events, provides sizing criteria for proposed drainage conveyance structures, and presents flood elevation data from the 2004 FEMA Flood Insurance Rate Study, as amended by the 2008 flood determination study by R.M. Towill and a 2011 Letter of Map Revision issued by FEMA that covers a major portion of the project site.

This report conforms to the methodologies set forth in the City and County of Honolulu Department of Planning and Permitting *Rules Relating to Storm Drainage Standards,* and presents computed results for peak stormwater flow rates generated within the various watersheds of the subject parcels. It is demonstrated through the included analysis that there will be no post-development increase in flow rate at the site's five major drainage discharge points. As a result, it is anticipated there will be no adverse impacts to downstream properties or existing drainage conveyance structures under Farrington Highway as a result of development.

B. Overall Project Description

The proposed STET 938 acre agricultural subdivision enclosed in a 2,721 acre property with a contributing watershed area of approximately 3,500 acres. The subdivision consists of 91 total lots dedicated for construction of single family homes. Full-buildout of the project also includes separate lots for centralized wastewater effluent disposal, the existing Dillingham Lodge, an existing pond adjacent to Farrington Highway, equestrian/pasture use, and a future agricultural cluster subdivision. Approximately 4.5 miles of proposed roadway and associated utility networks will serve the subdivision. All roadways and drainage infrastructure will remain private and will be maintained by the subdivision's home owner's association (HOA).

The project covers portions of several parcels located in Mokuleia, Hawaii, on the northwestern coast of the island of Oahu. The project is bounded by Farrington Highway (Route 930) to the North, the Mokuleia Forest Reserve to the South, and lands under separate private ownership to the East and West.

The project parcels are identified on Oahu Tax Map Key (TMK) (1) 6-8-02:6 and (1) 6-8-03:5, 6, 15,19, 20, 30, 31, 33, 35, and 40 (Appendix C). Parcel lands are included on the 1998 Kaena, HI 7.5-minute United States Geological Survey (USGS) Quadrangle (Appendix A).

II. Existing Condition

A. Existing Site Features

i. Site

The existing ranch consists of largely undeveloped woods and range land that varies in topography from steep ridges and wide, deep valleys in the south to low-lying flatlands in the north, adjacent to Farrington Highway. The Dillingham Lodge and two residential outparcels, containing single family homes and associated outbuildings, are the only significant improvements located within the boundaries of the ranch.

ii. Slopes

The overall project is characterized by significantly variable topography, beginning with gradual slopes averaging between 0 and 5% in the flat (*makai)* lands within the northern portion of the existing ranch parcels. Slopes gradually increase in steepness moving in the southerly direction across the project, with slopes between 10% and 20% average at the rear (*mauka)* lot lines of the proposed subdivision lots. There are some smaller portions of the site along the *mauka* lot lines with 25% or greater slopes. Slopes continue to steepen to 50% or greater south of the subdivision and into the upper reaches of the Mokuleia Forest Reserve.

iii. Soils

The site soils are identified as Hydrologic Soil Group (HSG) D soils (Appendix C). Based on the US Soil Conservation Service Soil Survey (1972), site soils are classified as follows:

Soil Classification	Slope Range
Ewa Silty Clay Loam (EaC)	-
Ewa Stony Silty Clay (EwC)	3 to 6%
Kaena Clay (KaB)	6 to 12%
Kaena Very Stony clay (KanE)	6 to 12%
Kaena Stony Clay (KaeB)	-
Kaena Stony Clay (KaC)	-
Kawaihapai Clay Loam (KIA)	0 to 2%
Kawaihapai Stony Clay Loam (KlaA)	0 to 2%
Kawaihapai Stony Clay Loam (KlaB)	0 to 2%
Kawaihapai Very Stony Clay (KlbC)	0 to 2%
Pulehu Stony Clay Loam (PuB)	-

III. Proposed Condition

A. Proposed Site Features

i. Site

The proposed Dillingham Ranch Subdivision includes 91 single family, 5 acre minimum residential lots. It is assumed each lot will be developed within a 5,000 square foot area with an average 200 foot long by 12.5 foot wide driveway for a total estimated 7,500 square feet of impervious area per lot. The majority of these lots will be located *mauka* of the existing cane haul road, with the exception of lower lots 88 and 89.

Additional Bulk lots 1001 through 1005 will host other existing or proposed uses. Lot 1001 will be preserved for the Dillingham Lodge, while 1002 and 1003 will be subdivided as an agricultural cluster and will host 15 smaller residential agricultural cluster units. The existing equestrian polo grounds and coconut farms (Lots 1003 and 1004) *makai* of the cane haul road will remain relatively unchanged. Lot 1005 will be designated for a subsurface effluent disposal system (outlined in the Wastewater Master Plan Report by Sherwood Design Engineers, 2014) and ancillary equestrian uses such as stables.

The proposed impervious area resulting from development will include 14 acres on new lots, 1 acre of miscellaneous structures (water tanks, pumps houses, etc.), and 16 acres of pavement to construct the approximately 4.5 miles of proposed subdivision roads.The remainder of the site will be comprised of agricultural fields, pasture land or open space on the individual subdivision lots, farmed coastal flatlands, and undeveloped mountainous terrain located *Mauka* of the new lots. This equates to a total increase in impervious area from new development of approximately 31 acres within the 2,721 acre property, an increase of approximately 1 percent. Furthermore, because the upper watersheds of the streams that cross the site lie entirely within the Mokuleia Forest Reserve, this project-caused increase of impervious surface represents an even smaller change in actual runoff conditions on each stream, and would never be part of a larger cumulative drainage impact since neither the Forest lands nor the remainder portions of the ranch parcels can ever be developed Refer to Table 1 below for a summary of areas by land use.

Table 1: Increase to Post Development Impervious Areas

Land Use	Area (AC)
Impervious – Roadway (Pavement w/in ROW)	14
Impervious – Lots (Driveways, Structures, Hardscape)	16
Impervious – Miscellaneous	1
Total On-Site Area	2,800
Total Watershed Boundary (includes areas from the off site Mokuleia Forest Reserve)	3,500

Access to the proposed subdivision will be provided by a series of new roadways labeled alphabetically from A to G. This roadway network begins at Farrington Highway entrance to the site and branches outwards to reach all new lots and to provide continued access to the few outparcels within the project boundary. Swales will be constructed on the uphill side of roads to intercept overland drainage and direct it to culverts that will take it under the road. Swales on the downhill side will then carry this runoff to either existing or proposed swales that will run across residential parcels as required to eventually reach one of the site's existing major stream channels. Refer to Figure 1 for detailed information regarding the location of these conveyance structures.

IV. Pre - Development Drainage Conditions

A. Major Channels and Drainage Outlet Points

The subject parcels are included within an overall watershed that is bounded to the south by the uppermost mountain ridgeline of the Mokuleia Forest Reserve. Drainage from the ridgeline is directed *makai* through the Reserve and on to the ranch through existing stream channels that run either entirely through the project site or through the site and adjacent lands to the west that abut Farrington Highway. Flows carried by all of these channels are ultimately conveyed to the Pacific Ocean after crossing under Farrington Highway through existing bridges and culverts. (Figure 2).

There are seven major intermittent stream channels that begin their courses on the upper slopes of the Waianae Mountains and drain through the site, conveying runoff to the coastline. The largest of these is the only named channel, Makaleha Stream (designated Channel 5 for the purposes of this report). This stream,

originates east of the site, cuts across the easterly ranch boundary in the vicinity of the cane haul road (an existing gravel farm road), continues east for approximately 1000 feet, and then flows north to an existing culvert of unknown size underneath Farrington Highway before discharging to the ocean.

Channel 4 runs through the middle of the project, and is actually comprised of three channels that converge into a single stream just before the uplands give way to the flat lowlands covering the north end of the site. This natural channel meanders across gently rolling terrain until crossing cane haul road, where it enters a graded section that parallels the property's westerly property line to a 12 x 8 foot culvert under Farrington Highway. A short section of channel then carries the stream to its ocean outfall.

The three remaining major channels (numbered 1 – 3, from west to east) cross the southwestern portion of the ranch from south to north. At the northerly ranch boundary, they flow onto neighboring agricultural parcels located between this end of the ranch (which is not proposed for development) and Dillingham Airfield. At the edge of the airfield, it appears all three channels converge on a culvert that runs under the east end of the airfield runway, and then through a second culvert under Farrington Highway to the ocean. However, trace channels likely provide a high flow connection to Channel 4, just upstream of its highway culvert. It is expected this connection allows runoff to spread across the lowlands located south of the highway as floodwaters begin backing up behind the highway crossings.

In addition to the two highway crossings on the project frontage described above, there is an unnamed bridge at the existing polo fields that drains the northern portion of Lot 1004 and is located between Makaleha Stream and the channel that runs along the westerly property line.

In total, five points of analysis were used in the computation of pre-development drainage flows (Table 2). These points of analysis are labeled as Comparison Points 1 through 5 on the Pre-Development Watershed Exhibit, corresponding to the designation for each stream channel. All are located where the respective streams cross the downstream ranch boundary, so Points 1 through 3 are located along the section of northerly property line that is set back from Farrington Highway, Point 4 is the existing Farrington Highway box culvert at the northwestern corner of the parcel, and Comparison Point 5 is at Farrington Highway between the unnamed polo grounds bridge and the Makaleha Stream bridge.

Discharge rates for each of the Comparison Points are presented in Table 2. Rates for the first four points were determined using *Plate 6: Design Curves for Peak Discharge vs. Drainage Area,* from The Department of Planning and Permitting, City and County of Honolulu (DPP) *Rules Relating to Storm Drainage Standards* (See Methodology). The discharge rate for Comparison Point 5 was taken from the previously referenced Makaleha Stream LOMR.

Table 2: Comparison Point Discharge

Comparison Point	Off-site Watershed (AC)	On-site Watershed (AC)	Total Watershed (AC)	100-Year Q From Plate 6 (CFS)
1	151	179	330	1,300
2	30	205	235	900
3	459	346	805	2,250
4	554	842	1396	3,500
5	1,768	732	2,500	5,200

In addition to these watersheds that define the major stream channels, several areas of the existing ranch do not flow directly to any of the existing channel comparison points, but instead contribute overland flow to the adjacent agricultural lands to the north. At the far western end of the site, an area of approximately 460 acres discharges to the west of Comparison Point 1, while much smaller areas of 26 acres and 76 acres drain to the offsite lands located between Comparison Points 1 & 2 and Comparison Points 2 & 3, respectively. The last of the overland discharges is located between Comparison Point 3 and the westerly ranch boundary that runs north to Farrington Highway. Runoff from the large, far western area collects into an intermittent stream channel that also runs to the south side of the airfield runway, but is not part of this study because no development is planned on this portion of the ranch. Runoff from the smaller overland discharges described above likely flows into the adjacent agricultural fields and makes its way into the stream channels as they continue north toward the runway.

Similar to many of the drainage conveyance channels throughout Oahu which direct stormwater from *mauka* lands to the island's ocean waters, the channel section between Farrington Highway and the shoreline is periodically blocked by sand, leading to stormwater accumulation and stagnation within the channel, particularly after major storm events. Data is currently unavailable regarding either the typical depth of sand accumulation or how often these channels are cleaned and maintained by City and County of Honolulu personnel.

i. Existing Flood Event Conditions

Based on hydraulic analyses performed by FEMA and by local engineering firms, during a 100-year storm and other major rainfall events, runoff that cannot be accommodated by the existing Farrington Highway crossings is expected to collect within the flats along the northerly end of the site and ultimately overflow the Highway. This is illustrated on the effective FEMA Flood Insurance Rate Map

(FIRM) and on the more recent Letter of Map Revision (LOMR) prepared for Makaleha Stream. Both studies show the 100 year flood zone covering all of the project site located north of the cane haul road for an area of about 277 acres between the site access road (future Road A) and the westerly property line. Within this flood zone, FEMA has also delineated a floodway that begins at the point where Makaleha Stream crosses the cane haul road and widens to nearly 1,300 feet at Farrington Highway, centered on the polo field bridge. Flood elevations have been defined within the floodway and for a short distance on either side, ranging from approximately 21 feet at the cane haul road to elevation 10 at the Highway.[1] Outside the limits of this detailed study, flood elevations are not defined, but the mapped flood zone extends east along the highway approximately 2,950 feet beyond the westerly project boundary covering the east end of the airfield runway. North of the highway, the entire coastline is also projected to be inundated by the 100 year flood, although elevations in this area suggest the flooding is caused by tidal inundation and not stream flow. Please refer to Figure 1.

Makua of the cane haul road, the 2004 FEMA mapped flood zone for Channel 4 extends south into the site for a distance of approximately 2,500 feet, narrowing to a width of about 400 feet at the southerly limit of the flood study. West of this point, the flood zone for Channel 2 also extends a short distance into the site, covering an area mapped as approximately 65 feet wide. As part of R.M. Towill's work for the Dillingham Ranch Aina in 2008, a flood determination study was completed for Channels 1 through 4. This study included HEC-RAS analysis for these channels through the residential development area and further refined the limits of the 100 year flood zone.

Although the revised Makaleha Stream floodway at Farrington Highway stretches from just east of the future Road A to the point where the main stream channel crosses the highway, the existing highway grade steadily decreases moving from east to west across the project frontage, reaching a low point of-Elevation 9+/- in the vicinity of a Road A. The width of the floodway combined with the depth of flow below the flood elevation of 10 indicates a significant portion of the 100-year flood cannot be accommodated by the three bridges/culverts in this vicinity, but instead overflows the road. Since the low point of the highway is apparently centered on Road A, it is expected the area of actual inundation would extend a minimum of 700 feet on either side of this point, at least to the limits of the floodway.
Within this area of projected 100-year inundation, there is an existing permanent wet pond on the site located between Road A and Channel 4, adjacent to Farrington Highway. This pond is apparently fed by overland runoff from the south and possibly by overflow from Channel 4. During severe rains, though, flooding spreads throughout this entire area, causing the pond to essentially disappear. Overflows to the north from the area of the pond are likely limited by a berm along the highway that extends to elevation 12, but this berm does not cover the pond's entire highway frontage, so it is unknown to what extent it influences the highway overflows that prevent flood elevations from rising higher on the site and throughout the immediate vicinity.

[1]The flood elevation at the highway was 11 when first mapped by FEMA, but the LOMR which was prepared by RM Towill Engineering and certified by FEMA on DATE, lowered this elevation to 10.

To support the lowering of the Makaleha Stream flood elevation at Farrington Highway from 11 to 10 feet above sea level in the LOMR, RM Towill, the Engineer of Record for the previously approved application for Dillingham Agricultural Subdivision, performed a new HECRAS analysis. This analysis utilized the previously determined 100-year flow rate at the highway of 5200 cfs. The results of the LOMR analysis will be included in any subsequent Makaleha Stream studies needed to accurately evaluate the impacts of project-related grade modifications in the areas north of Cane Haul Road.

V. Post - Development Drainage Conditions

A. Peak Runoff Rates

The areal extent and boundaries for each of the watersheds draining to Comparison Points 1 through 5 across the project site will not be altered as a result of proposed development, except to an insignificant extent in the Channel 1 watershed. Proposed roadway design has been planned such that topographic ridgelines will be matched with roadway highpoints as necessary to preserve existing drainage patterns. Since the computation of runoff using Plate 6 is solely based on area, this indicates there would be no change in pre and post-development flow rates (Table 3). However, because any changes could adversely affect existing flooding conditions on the site and at Farrington Highway, a closer examination of the post-development conditions is provided below.

With no change in the existing watershed boundaries, the only project-related activities that would affect drainage will be the construction of impervious surfaces, primarily buildings and pavement. In general, the density of development will be very low, as can be illustrated by looking at the watershed draining to Comparison Point 4. It is projected that 38 lots (each generating 7,500 square feet of new impervious surfaces), 8500 linear feet of 26 foot wide roadways (24 feet of pavement, plus an additional one foot on either side assumed to be impervious), and an estimated 5000 square feet of ancillary structures (water tanks, etc.) will be located within this zone, resulting in 11.75 acres of impervious surfaces. As previously described, soils on the ranch are classified as Hydrologic Soil Group D by the Soils and Conservation Service (SCS), so it is conservatively estimated the undeveloped condition rainfall retention factor would equal 2.5 inches.[2] By contrast, the retention factor for impervious areas would be 0.2 inches. Taking the weighted average (by area) of these factors results in a post-development composite on-site retention factor of

[2] Calculation of the retention factor, a measure of the volume of rain projected to not run off a site during a design storm, is based on the methodology set forth in *Urban Hydrology for Small Watersheds, TR-55*, by the US Soils and Conservation Service's TR-55. In this procedure, land areas are assigned a Curve Number (CN) based on several factors such as soil type, slope and vegetative cover. This number is then translated into a runoff retention factor (S) by the equation S = (1000/CN)-10. The CN for the undeveloped portions of the ranch is conservatively estimated to equal 80, while the CN for impervious areas equals 98.

2.4 inches. Inserting these values in the SCS runoff equation yields the following pre and post-development runoff volumes:

$Q_{pre} = (P - 0.2xS_{pre})^2/(P + 0.8x(80S_{pre})$
$Q_{pre} = (12 - 0.2x2.5)^2/(12 + 0.8x2.5) = 9.45$ inches of runoff

$Q_{post} = (P - 0.2xS_{post})^2/(P + 0.8xS_{post})$
$Q_{post} = (12 - 0.2x2.4)^2/(12 + 0.8x2.4) = 9.53$ inches of runoff

Percentage increase = (9.53-9.45)/9.45 = 0.85

Where P = 12 inches of rain in 24 hours (per NOAA)

Although the SCS method does not calculate peak runoff rates, the anticipated volume of runoff can serve as a proxy for the runoff coefficient in the Rational Equation. Consequently, if the watershed area and rainfall intensity are held constant in a pre and post-development analysis, the calculated increase in total runoff would be equivalent to a 0.85 percent increase in peak runoff rate. It is noted this calculation is actually quite conservative, because the impact would be even smaller if the composite post-development retention factors were based on the entire upstream watershed, both on the ranch and within the forest reserve, and not just on the area within the proposed development boundary. In addition, the computations did not account for the fact that the project's impervious areas will be highly disconnected, so the composite retention factor would be higher than estimated, resulting in an even smaller difference between pre and post-development conditions. Consequently, it can be concluded development of the proposed project would have an insignificant impact on runoff volumes, peak runoff rates or existing flooding conditions.

It is further noted that project-related modification of existing drainage conditions within all of the watersheds draining through the site, except for Makaleha Stream, represent the end of potential development. Development rights within the remaining portions of the ranch located south and west of the proposed project will be surrendered as part of the subdivision approval, and the lands located within the Mokuleia Forest Reserve can never be developed. As a result, the proposed project can never be part of a larger cumulative drainage impact resulting from continued watershed development.

Table 3: Pre and Post Development Discharge Rates

Comparison Point	Watershed Area (AC)	Q (CFS)
1	330	1,300
2	235	900
3	805	2,250
4	1396	3,500
5	2,500	5,200

B. Roadway Crossings

Existing stream channels will be routed into new drainage structures at all proposed roadway crossings. These major crossings, plus a multitude of additional, smaller crossings, will require a combination of bridges, and box, arched or circular culverts to adequately convey stormwater from the upper reaches of the Waianae Mountains/Mokuleia Forest Reserve through the subdivision, to the coastline without flooding proposed roadways.

Most of the existing streams will be crossed at only one location by the roadway network. There are two exceptions: Channel 4 is crossed three times (by Roads A, D, and E), and Channel 3 is crossed two times (by Roads A and E) (Figure 3). Cul-de-sacs have been designed to terminate prior to stream channels at the eastern and western-most ends of the site to avoid additional channel crossings to the maximum extent practical.

The cane haul road will be upgraded to subdivision road standards between Road A and the westerly property line of the project, and will become Road F. The existing 9ft x 4.75ft box culvert under the cane haul Road adjacent to the western property line will remain, and additional culvert capacity will be installed to increase the conveyance capacity sufficient to accommodate peak discharges within this large upstream watershed. A swale will be constructed on the downstream (north) side of the road on the project site to contain these flows and protect the wastewater treatment facility and effluent disposal field planned for Lot 1005. The swale will parallel the road and discharge back to the main stream channel just west of the site property line.

ii. Stream Routing

The existing streams will continue to follow their current routes through the site, crossing individual residential lots as required. Channels will not be improved except at road crossings, as needed to conform with new drainage structures. Consequently, potential homesites on affected lots will be limited to those areas located outside the floodway determined necessary for conveyance of peak flows. In addition, smaller existing drainage swales will be retained as needed to carry tributary drainage to the main channels, and new swales will be created where roadway construction will result in minor realignment of existing runoff patterns.

Covenants, Conditions, and Restrictions (CCRs) imposed on all lots at the time of purchase will codify these limitations on private lot development, and ensure any modifications proposed by future property owners must be designed by a registered engineer and do not impact conveyance capacity. In addition, permanent easements will be established at each road crossing to permit continued maintenance by the homeowners' association in the event the private roadway system is publicly maintained in the future.

C. Proposed Flood Conditions

Since there will be no significant change is post-development runoff rates, drainage will continue to collect within the low-lying flats and overflow the Farrington Highway intersection during the 100-year flood and other major rainfall events. The existing pond adjacent to Farrington Highway will continue to overflow in large storm events, and stormwater will overtop the highway as determined by FEMA during a 100-year event. The existing pond berm will not be modified, so there will be no obstructions that might confine the floodway and cause flood elevations to rise higher than now projected by FEMA.

It is expected that future maintenance performed by the City and County of Honolulu on the existing stream channels downstream of Farrington Highway will affect flooding conditions at the north end of the project site. Sand accumulation from major storm events frequently blocks the channels' ocean outlets, impounding stagnant water. More importantly, this condition could worsen minor flooding on the ranch property by raising tailwater elevations. It is not expected this would significantly affect major flood events, because flood elevations are determined by the overflow depth at Farrington Highway, but it could result in more frequent or more widespread flooding during minor events that would otherwise remain in the respective stream channels.

All proposed project roads will be constructed above effective 100-year flood elevations. The exception to this rule will be the north end of Road A, where it intersects Farrington Highway. Since the highway elevation of 9(+/-) is below the revised 100-year flood elevation at this location (Elevation 10), Road A will have to match it. The grade will climb to a minimum of one foot above the flood elevation within a distance of approximately 1000 feet, to provide safe egress for proposed Lots 88 and 89. This gradual change in elevation will help ensure there will be no interference with the movement of floodwaters across the north end of the site adjacent to the highway. Since the end of Road A will be impassable under these conditions, access to the site would have to be through the development to the DLNR access road via Road C and then *makai* to Farrington Highway.

Almost the entirety of proposed Lots 88 and 89 will be located within the extensive 100-year flood zone at Farrington Highway. Furthermore, portions of Lots 1 to 8, 32 to 35, and 40 and 41 will be located with the upland flood zones associated with Stream Channels 2, 3 and 4. The home sites at the highway will have to be elevated on fill to at least one foot above the effective flood elevation, and removed from the flood zone through preparation of a Letter of Map Revision Based on Fill (LOMR-F), while the home sites on the other affected lots will be situated outside the defined flood boundary. These prospective locations are shown on Figure 2. In addition, the FIRM limits will need to be updated throughout the *mauka* portions of the property to reflect the results of the 2008 flood determination study prepared by R.M. Towill.

i. Individual Lot Drainage Provisions

Project topography and the proposed subdivision lot layout will place many subdivision lots downslope of adjacent lots. Therefore, runoff generated on a typical uphill lot during a storm event is anticipated to drain downhill onto a neighboring lot. The use of Best Management Practices (BMPs) on the lower side of upslope lots will help promote sheet flow and replicate existing runoff conditions as a way to mitigate potentially adverse drainage effects. A typical measure anticipated to be employed entails the use of infiltration trenches with level lip spreaders, installed on the downhill side of uphill lots. The infiltration trenches will run parallel to the existing topography and will intercept runoff from impervious and landscaped areas, releasing it gradually over the level lip spreader length. Trenches will not be constructed in such a way as to impede the flow of existing drainage channels. The individual infiltration areas will be centered within dedicated drainage easements, and the CCRs of the homeowners association will include language covering the construction and maintenance of infiltration trenches and level lip spreaders.

Existing drainage patterns will also be maintained by minimizing driveway crossings of natural drainage channels. Where possible, runoff will be directed away from driveways to promote infiltration and dispersion. When driveway culverts must be installed, though, the discharge will be routed into infiltration trenches as described above to reduce and slow flow rates before runoff reaches a parcel boundary.

ii. Roadway Drainage

In general, roadway runoff will be carried within open swales located adjacent to the pavement. These swales will carry the flow until intersecting either a major stream or a minor existing drainage swale that is tributary to a stream. In some locations, though, additional piped conveyances will be required to conform with the existing topography. For example, a significant length of Road B will be constructed on a steep gradient in a cut section. This will prevent direct connection to adjacent swales and may result in erosive velocities within open channels next to the road. As a result, runoff will be collected at discrete locations and routed into a pipe system that will parallel the road until it can daylight at an appropriate outfall location. The need for such measures has not been fully determined, but preliminary designs indicate the Road B system would daylight into two or three different swales, with most flow concentrated into an outfall on the uphill side of Road G that will ultimately discharge to Makaleha Stream through a new swale between Lot 19 and the Dillingham Lodge property (Figure 3).

D. Storm Water Quality Treatment of Roadway Runoff

The City and County of Honolulu does not currently require the treatment of storm water runoff generated onsite, because there is currently no existing Municipal Separate Storm Sewer System (MS4) within Farrington Highway. However, one of the primary goals of this project is to treat pollutants generated on the asphalt surfaces of the subdivision roadways to the greatest extent practical.

Two main approaches are currently being proposed for treatment of pavement runoff: vegetated roadside swales and grass filter strips. The crowned road section will direct runoff into swales, where infiltration is expected to reduce the volume of flow and filtration through the grass cover will remove a large percentage of contaminants. In areas where roads are constructed on fill or where all natural runoff is via overland flow, the swales on the downhill side of the road will be replaced with grass strips that will also remove contaminants while dispersing flow across the adjacent landscape rather than concentrating it into newly cut swales through private lots. These two passive LID measures will provide highly effective treatment for the majority of the site's roadway runoff.

Treatment on individual lots is not as critical an issue, since fewer contaminants would be expected to accumulate in the absence of regular vehicle traffic. However, the infiltration trenches and level lip spreaders described in a previous section will provide passive water quality treatment while also reducing runoff volumes through retention.

VI. Methodology

A. Design Parameters

The Department of Planning and Permitting, City and County of Honolulu (DPP) *Rules Relating to Storm Drainage Standards* (December 2012) sets forth the drainage design standards for development within the county.

Standards state that multiple requirements be met according to various site characteristics. As described in Section 1-4.1 of the document, separate hydrologic criteria for determining both recurrence interval (Tm) and runoff quantity are required for drainage areas dependent on acreage. Recurrence interval criteria are presented in Table 4 below:

Table 4: Recurrence Interval

Drainage Area	Recurrence Interval (Tm)
100 acres or less	10 years, unless otherwise specified
100 acres or less with sump, or tailwater effect and for the design of roadway culverts and bridges	50 years
Greater than 100 acres and all streams, design curves based upon the USGS data on flood magnitude and frequency	100 years

In accordance with Table 4, all project roadway culverts and bridges with 100 acres or less of contributing drainage area have been designed for the 50-year storm recurrence interval. Culverts and bridges draining areas of greater than 100 acres have been designed for the 100-year recurrence interval.

Table 5 presents methodology requirements correlating to drainage acreage:

Table 5: Runoff Quantity

Drainage Area	Method to be Used
100 acres or less	Rational Method
Greater than 100 acres	Plate 6 titled, “Design Curves for Peak Discharge vs. Drainage Area” should be used to determine the 100-year peak discharge.

In accordance with Table 3, the Rational Method has been used to determine runoff quantity to site outlet points 100 acres or less in size, and Plate 6 has been used to determine runoff quantity to site outlet points greater than 100 acres in size. See Appendix B for equations, assumptions, and calculation of runoff quantity based on each of these methods.

Drainage areas were delineated using a combination of 2-foot topographical contours within the proposed development, and using the USGS quadrangle for land north of the development.

B. Culvert Modeling

Sherwood Design Engineers produced a computer simulation of all proposed and one existing culvert using HydraFlow software. HydraFlow is an extension of Civil3D exclusively designed for hydrologic and hydraulic modeling. Specifically, the program generates profile sections at each culvert based on various input data such as flow, structure dimension, and shape. In addition to displaying the culvert size, these resulting profiles also illustrate the relationship between the roadway elevation and the top of the structure therefore ensuring that the conveyance system abides by a minimum cover. All analysis conducted in Hydraflow was performed in accordance with the criteria set forth by DPP's *Storm Drainage Standards* as summarized in Tables 4 and 5.

Refer to Table 6 of this report for the methodology used in sizing a typical culvert:

Table 6: Typical Culvert Sizing Procedure

Step	Description
1	Determine the contributing watershed for the select culvert
2	Determine the flow to culvert as defined in Tables 4 and 5
3	Determine all inverts and road elevations at the culvert location
4	Enter inputs (including culvert size, shape, and information from Steps 1, 2, 3) into HydraFlow and run the resulting profile
5	Check the profile to ensure elevations do not conflict and that the culvert meets minimum design standards

Refer to Appendix B for additional information regarding culvert calculations and modeling.

VII. Conclusion

Offsite peak flow rates will be equal for pre and post development conditions. This is due to the preservation of watershed boundaries, ridgelines, and contributing areas to Comparison Points 1 through 5.

Increases in impervious area due to project development are very minor in relation to the overall watershed area, comprising less than 1% of the total contributing land area. Combined with the existing underlying clayey Hydrologic Soil Group D soils with low infiltration rates, impervious coverage will not adversely affect drainage flow rates or water surface elevations during the 100-year flood or other major rainfall events.

Site construction will be out of the 100-year floodplain as designated on the 2011 Letter of Map Revision, except for Lots 88 and 89, which will be constructed above the 100-year water surface elevation. Road A will be below the water surface elevation between Farrington Highway and the driveway to Lot 89, as it climbs from existing grade 9 +/- ft at the Highway to Elevation 12+/- ft at the

driveway to Lot 89. All lots will have egress capability at the 100-year flood event through the subdivision roads and DLNR Road.

Existing drainage structures under Farrington Highway will not be adversely impacted due to development. Existing flooding patterns along Farrington Highway and the most Makai areas of the site will remain as they are today.

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APPENDIX A

FIGURE 1 – PRE DEVELOPMENT WATERSHED

FIGURE 2 – PROPOSED SUBDIVISION MAP

FIGURE 3 – DRAINAGE CONVEYANCE EXHIBIT

LOCATION MAP
NTS

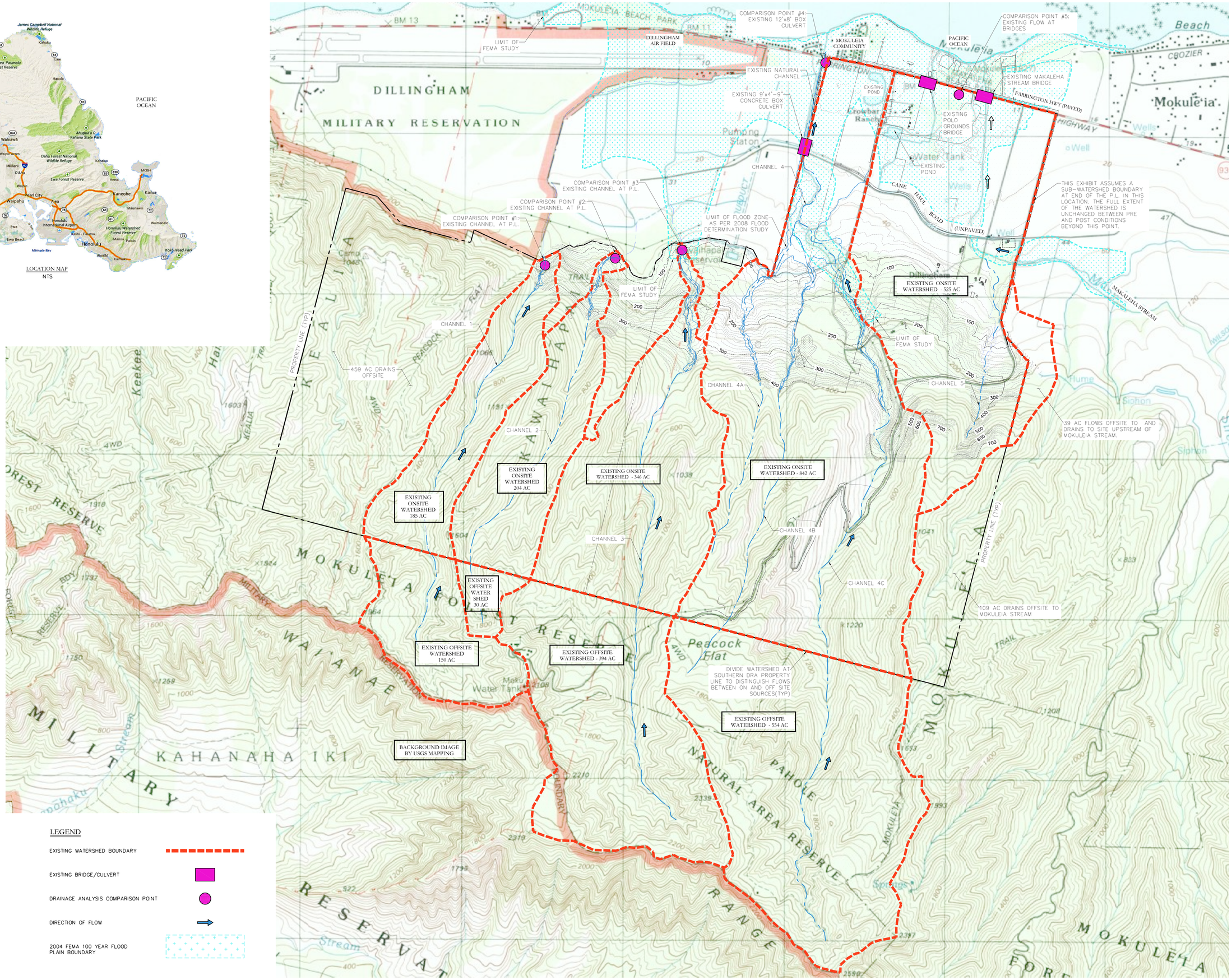

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FIGURE 1 - PRE-DEVELOPMENT WATERSHED EXHIBIT

DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, HAWAII

June 30, 2014

North 0 350' 700' 1400'

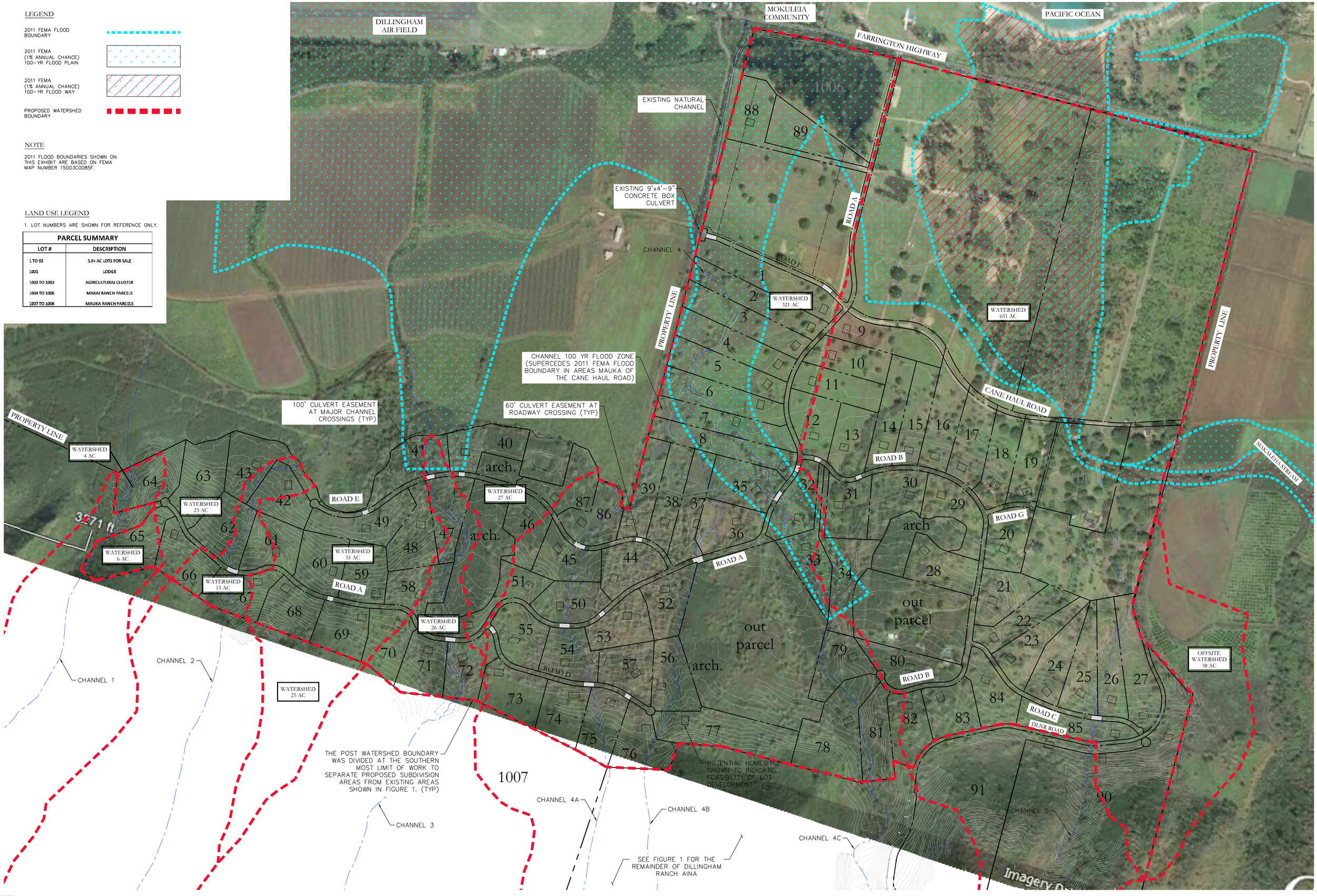

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FIGURE 2 - PROPOSED SUBDIVISION MAP

DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULEIA, HAWAII

June 30, 2014

North

0 150' 300' 600'

CULVERT SUMMARY										
GENERAL					DIMENSIONS				ELEVATION	
CULVERT #	WATERSHED (AC)	Q (CFS)	INV_DN (FT)	INV_US (FT)	LENGTH (FT)	RISE (FT)	SPAN (FT)	NO. BARRELS	Hw ELEV (FT)	FG Road (FT)[1]
A-1	910	2400	85.0	86.0	64.0	**8.0**	**24.0**	2	92.8	**95.5**
A-2	196	900	130.0	137.0	80.0	**6.0**	**14.0**	2	143.2	**145.0**
A-3	100	317	206.0	207.0	60.0	**5.0**	**14.0**	1	211.8	**213.0**
A-4	726	2000	242.0	248.0	90.0	**7.0**	**24.0**	2	254.3	**258.0**
A-5	226	950	255.0	260.0	120.0	**6.0**	**16.0**	2	270.2	**271.5**
C-1	95	302	161.0	169.0	100.0	**4.0**	**24.0**	1	172.8	**173.5**
D-1	23	74	271.0	274.0	80.0	**3.0**	**12.0**	1	273.9	**275.0**
D-2	57	180	302.0	305.0	60.0	**4.0**	**14.0**	1	309.6	**311.0**
E-1	117	600	117.0	120.0	73.0	**4.0**	**24.0**	2	123.5	**125.3**
E-2	739	2100	111.0	117.0	90.0	**7.0**	**24.0**	2	121.1	**123.2**
F-1	1340	2750	12.0	16.0	40.0	**6.0**	**22.0**	4	121.1	**22.0**

[1]FG elevations are assumed at the centerline of the road.

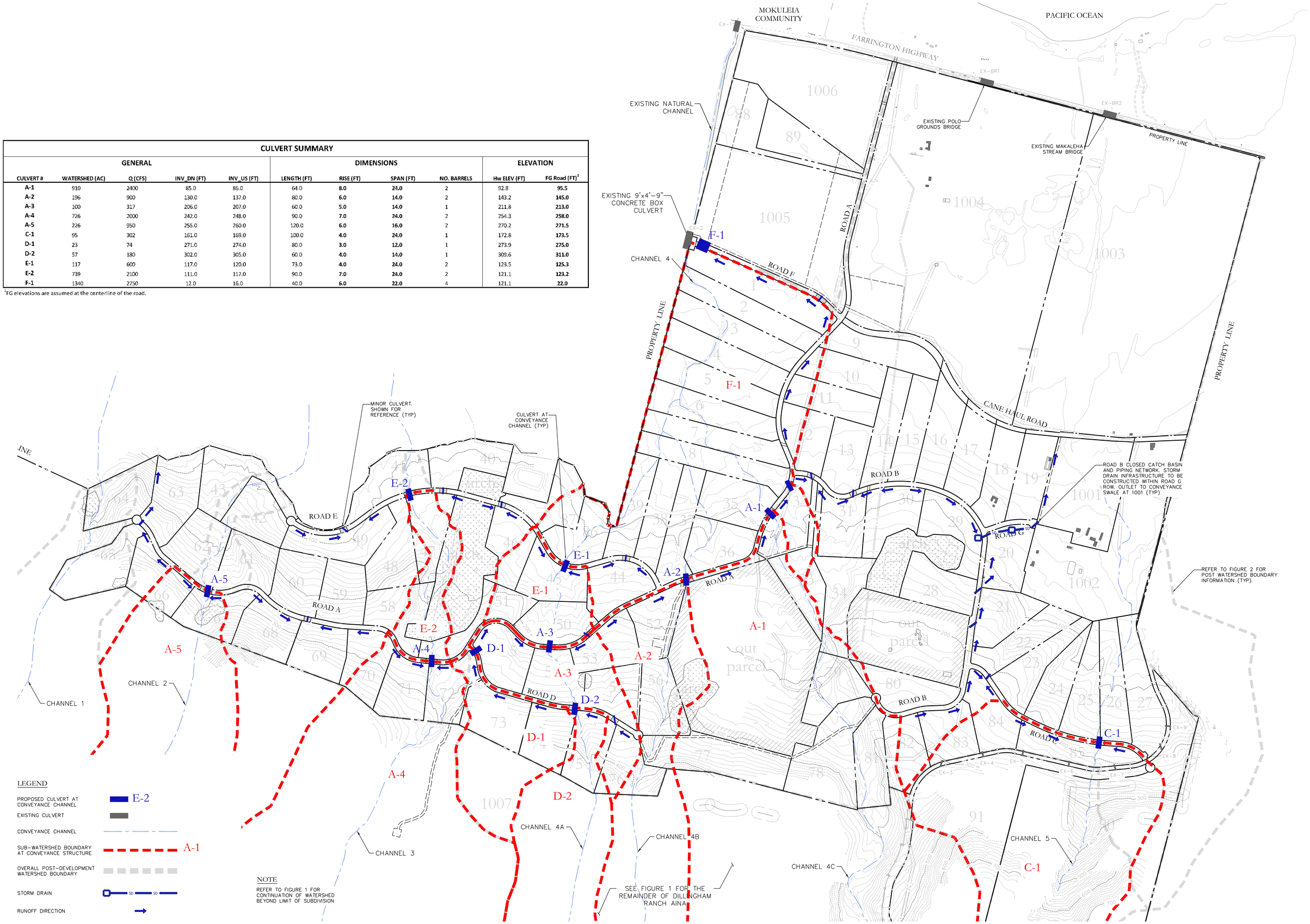

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FIGURE 3 - DRAINAGE CONVEYANCE EXHIBIT

DILLINGHAM RANCH AGRICULTURAL SUBDIVISION
MOKULELA, HAWAII

June 30, 2014

North

0 150' 300' 600'

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APPENDIX B

CULVERT SUMMARY
HYDRAFLOW REPORT

DILLINGHAM RANCH - CULVERT CALCULATIONS SUMMARY

1) REFER TO FIGURE 4A , 4B FOR CULVERT LOCATIONS AND WATERSHED BOUNDARIES

2) REFER TO THE HYDRAFLOW REPORT FOR DETAILED CULVERT INFORMATION

CULVERT SUMMARY										
GENERAL					DIMENSIONS				ELEVATION	
CULVERT #	WATERSHED (AC)	Q (CFS)	INV_DN (FT)	INV_US (FT)	LENGTH (FT)	RISE (FT)	SPAN (FT)	NO. BARRELS	Hw ELEV (FT)	FG Road (FT)[1]
A-1	910	2400	85.0	86.0	64.0	**8.0**	**24.0**	2	92.8	**95.5**
A-2	196	900	130.0	137.0	80.0	**6.0**	**14.0**	2	143.2	**145.0**
A-3	100	317	206.0	207.0	60.0	**5.0**	**14.0**	1	211.8	**213.0**
A-4	726	2000	242.0	248.0	90.0	**7.0**	**24.0**	2	254.3	**258.0**
A-5	226	950	255.0	260.0	120.0	**6.0**	**16.0**	2	270.2	**271.5**
C-1	95	302	161.0	169.0	100.0	**4.0**	**24.0**	1	172.8	**173.5**
D-1	23	74	271.0	274.0	80.0	**3.0**	**12.0**	1	273.9	**275.0**
D-2	57	180	302.0	305.0	60.0	**4.0**	**14.0**	1	309.6	**311.0**
E-1	117	600	117.0	120.0	73.0	**4.0**	**24.0**	2	123.5	**125.3**
E-2	739	2100	111.0	117.0	90.0	**7.0**	**24.0**	2	121.1	**123.2**
F-1	1340	2750	12.0	16.0	40.0	**6.0**	**22.0**	4	121.1	**22.0**

[1]FG elevations are assumed at the centerline of the road.

Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT A-1

Invert Elev Dn (ft)	=	85.00
Pipe Length (ft)	=	64.00
Slope (%)	=	1.56
Invert Elev Up (ft)	=	86.00
Rise (in)	=	96.0
Shape	=	Box
Span (in)	=	288.0
No. Barrels	=	2
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

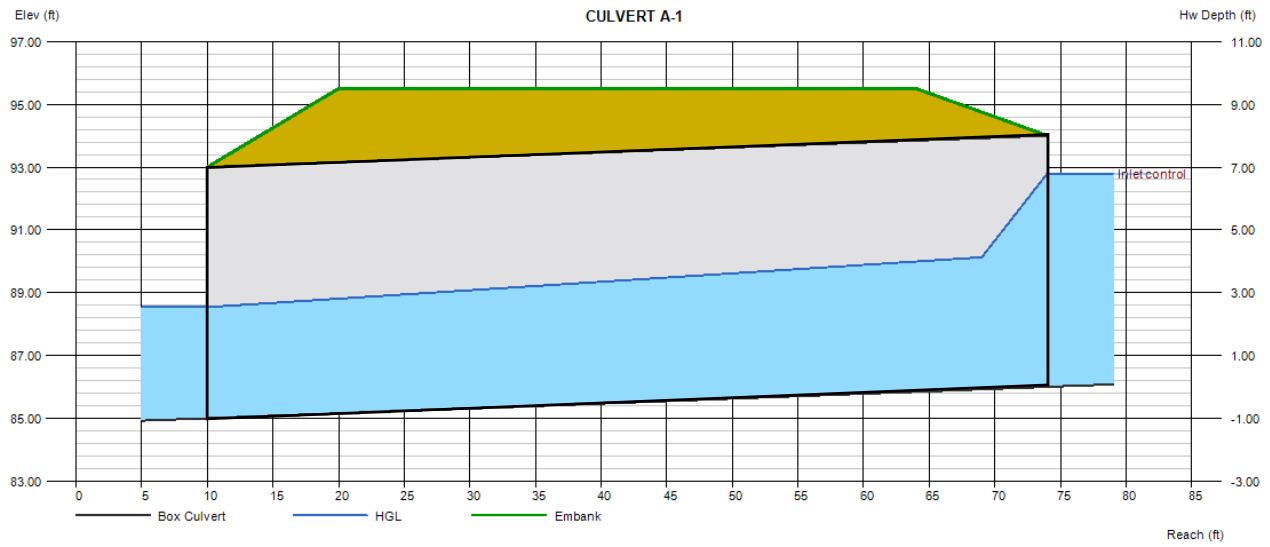
Top Elevation (ft)	=	95.50
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	2400.00
Qmax (cfs)	=	2400.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	2400.00
Qpipe (cfs)	=	2400.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	14.12
Veloc Up (ft/s)	=	11.73
HGL Dn (ft)	=	88.54
HGL Up (ft)	=	90.26
Hw Elev (ft)	=	92.80
Hw/D (ft)	=	0.85
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT A-2

Invert Elev Dn (ft)	=	130.00
Pipe Length (ft)	=	80.00
Slope (%)	=	8.75
Invert Elev Up (ft)	=	137.00
Rise (in)	=	72.0
Shape	=	Box
Span (in)	=	168.0
No. Barrels	=	2
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

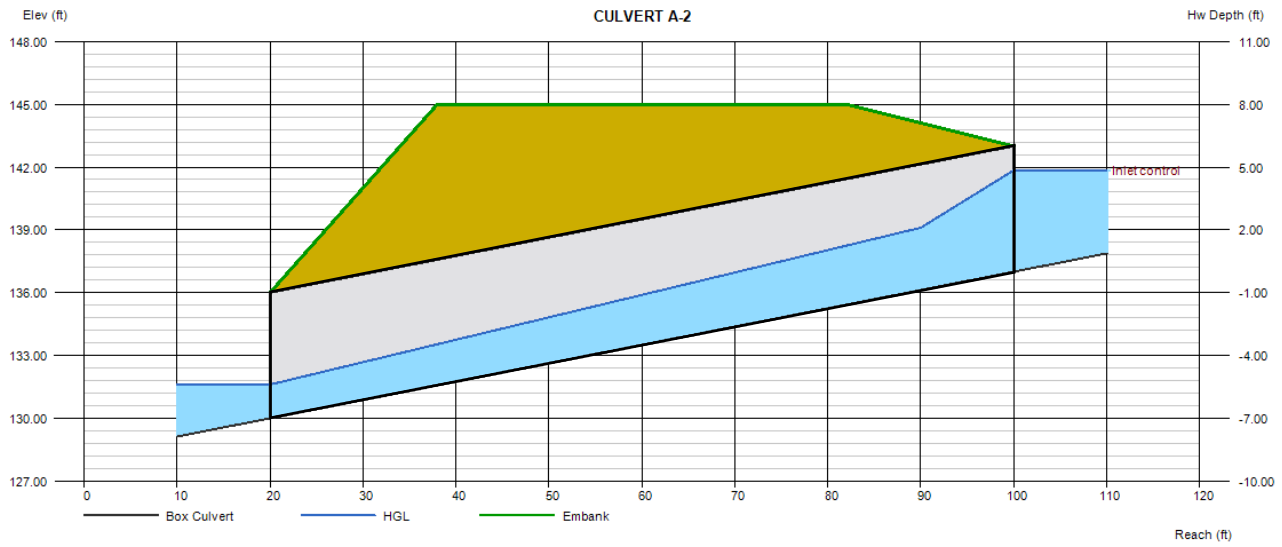
Top Elevation (ft)	=	145.00
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	900.00
Qmax (cfs)	=	900.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	900.00
Qpipe (cfs)	=	900.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	19.96
Veloc Up (ft/s)	=	10.12
HGL Dn (ft)	=	131.61
HGL Up (ft)	=	140.18
Hw Elev (ft)	=	141.85
Hw/D (ft)	=	0.81
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT A-3

Invert Elev Dn (ft)	=	206.00
Pipe Length (ft)	=	60.00
Slope (%)	=	1.67
Invert Elev Up (ft)	=	207.00
Rise (in)	=	60.0
Shape	=	Box
Span (in)	=	168.0
No. Barrels	=	1
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

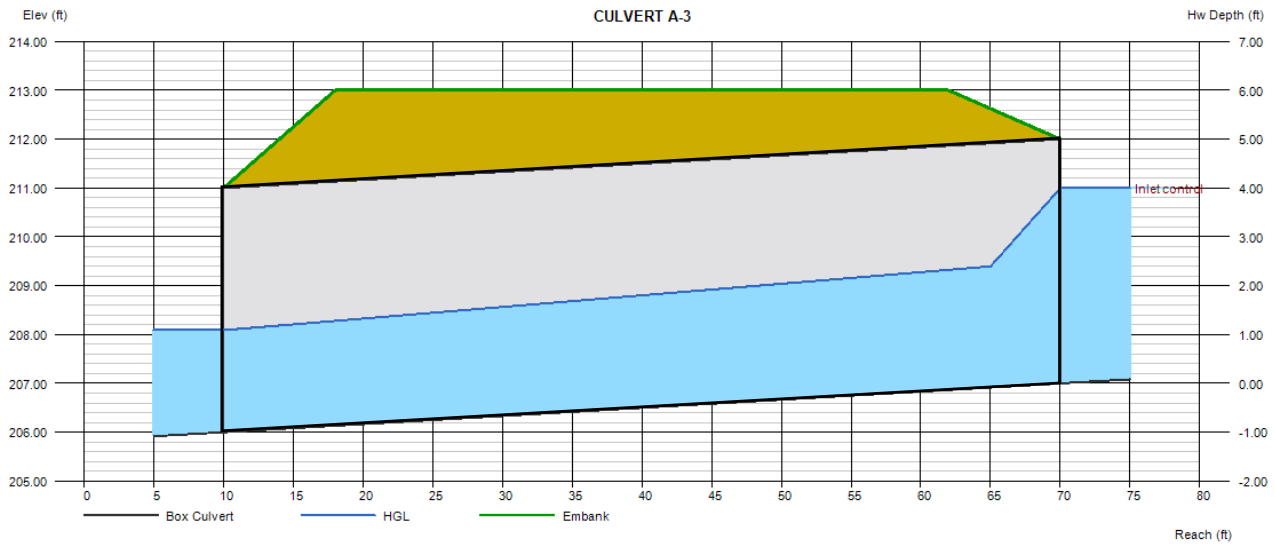
Top Elevation (ft)	=	213.00
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	317.00
Qmax (cfs)	=	317.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	317.00
Qpipe (cfs)	=	317.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	10.83
Veloc Up (ft/s)	=	9.00
HGL Dn (ft)	=	208.09
HGL Up (ft)	=	209.51
Hw Elev (ft)	=	211.00
Hw/D (ft)	=	0.80
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT A-4

Invert Elev Dn (ft)	=	242.00
Pipe Length (ft)	=	90.00
Slope (%)	=	6.67
Invert Elev Up (ft)	=	248.00
Rise (in)	=	84.0
Shape	=	Box
Span (in)	=	288.0
No. Barrels	=	2
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

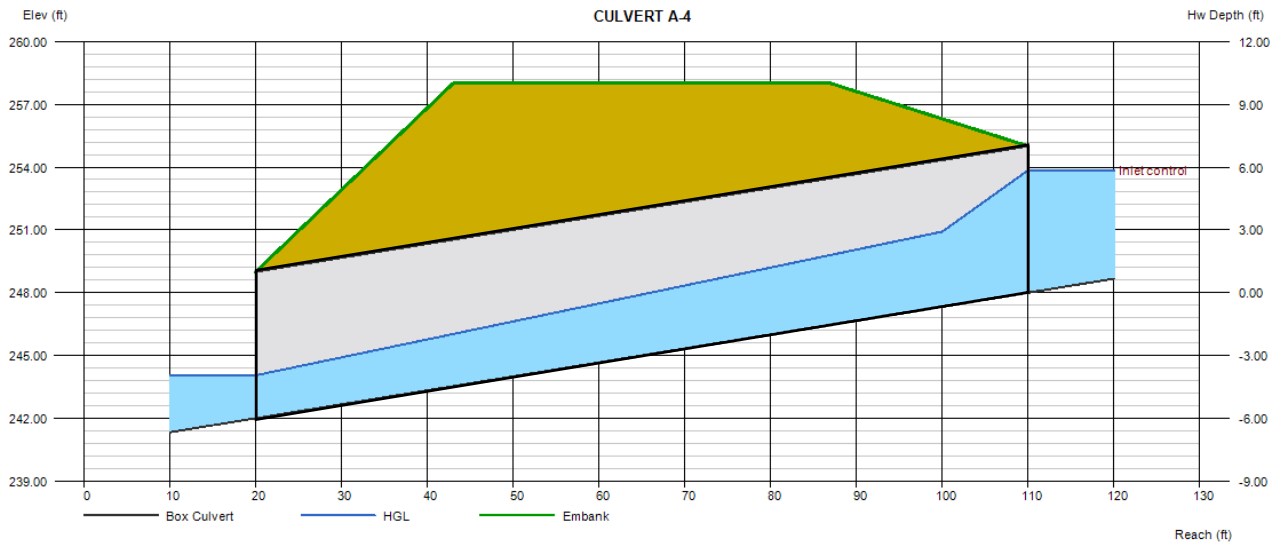
Top Elevation (ft)	=	258.00
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	2000.00
Qmax (cfs)	=	2000.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	2000.00
Qpipe (cfs)	=	2000.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	20.33
Veloc Up (ft/s)	=	11.04
HGL Dn (ft)	=	244.05
HGL Up (ft)	=	251.77
Hw Elev (ft)	=	253.85
Hw/D (ft)	=	0.84
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT A-5

Invert Elev Dn (ft)	=	255.00
Pipe Length (ft)	=	120.00
Slope (%)	=	4.17
Invert Elev Up (ft)	=	260.00
Rise (in)	=	72.0
Shape	=	Box
Span (in)	=	192.0
No. Barrels	=	2
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

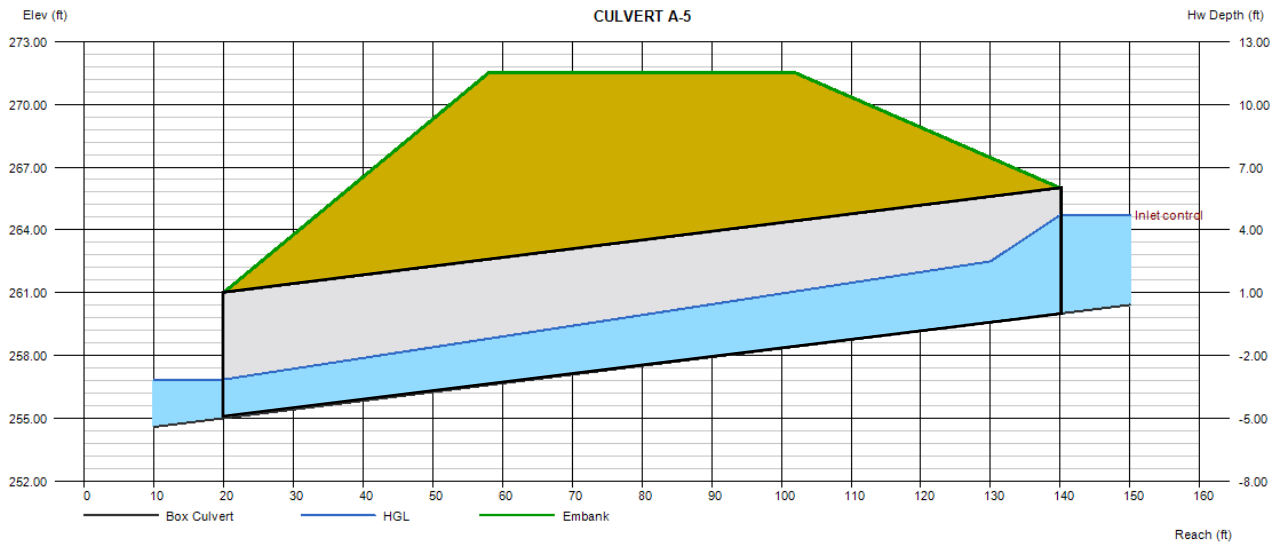
Top Elevation (ft)	=	271.50
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	950.00
Qmax (cfs)	=	950.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	950.00
Qpipe (cfs)	=	950.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	16.05
Veloc Up (ft/s)	=	9.86
HGL Dn (ft)	=	256.85
HGL Up (ft)	=	263.01
Hw Elev (ft)	=	264.71
Hw/D (ft)	=	0.79
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT C-1

Invert Elev Dn (ft)	=	161.00
Pipe Length (ft)	=	100.00
Slope (%)	=	8.00
Invert Elev Up (ft)	=	169.00
Rise (in)	=	48.0
Shape	=	Box
Span (in)	=	288.0
No. Barrels	=	1
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

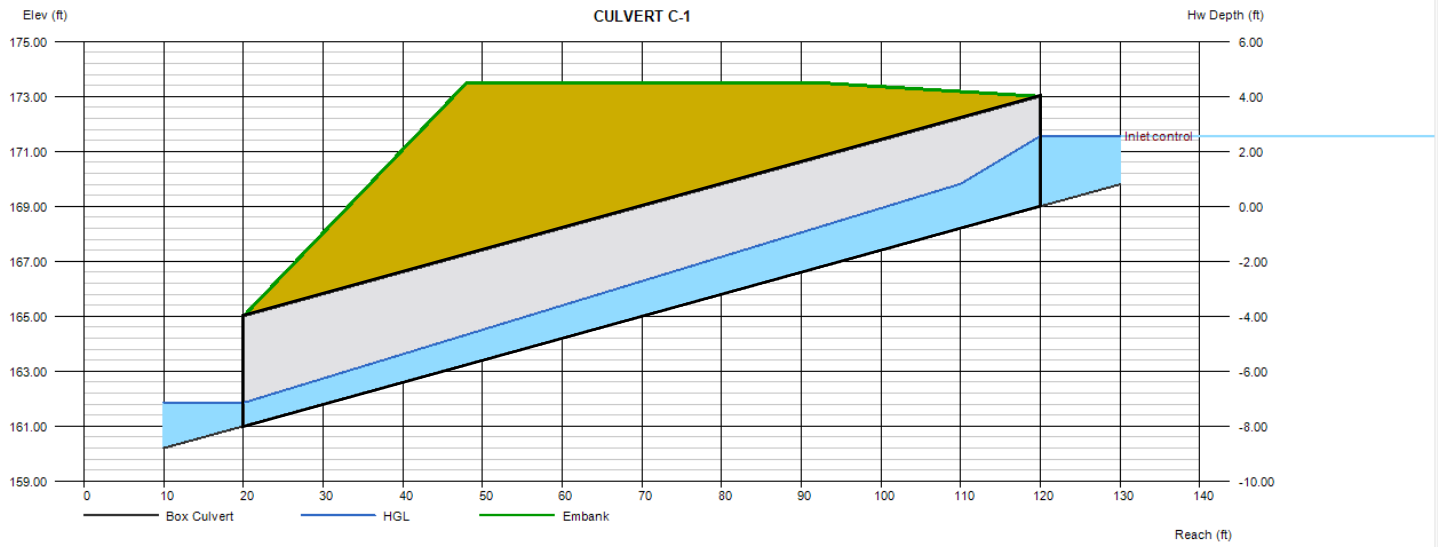
Top Elevation (ft)	=	173.50
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	303.00
Qmax (cfs)	=	303.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	303.00
Qpipe (cfs)	=	303.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	14.85
Veloc Up (ft/s)	=	7.41
HGL Dn (ft)	=	161.85
HGL Up (ft)	=	170.70
Hw Elev (ft)	=	171.56
Hw/D (ft)	=	0.64
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT D-1

Invert Elev Dn (ft)	=	271.00
Pipe Length (ft)	=	80.00
Slope (%)	=	3.75
Invert Elev Up (ft)	=	274.00
Rise (in)	=	36.0
Shape	=	Box
Span (in)	=	144.0
No. Barrels	=	1
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

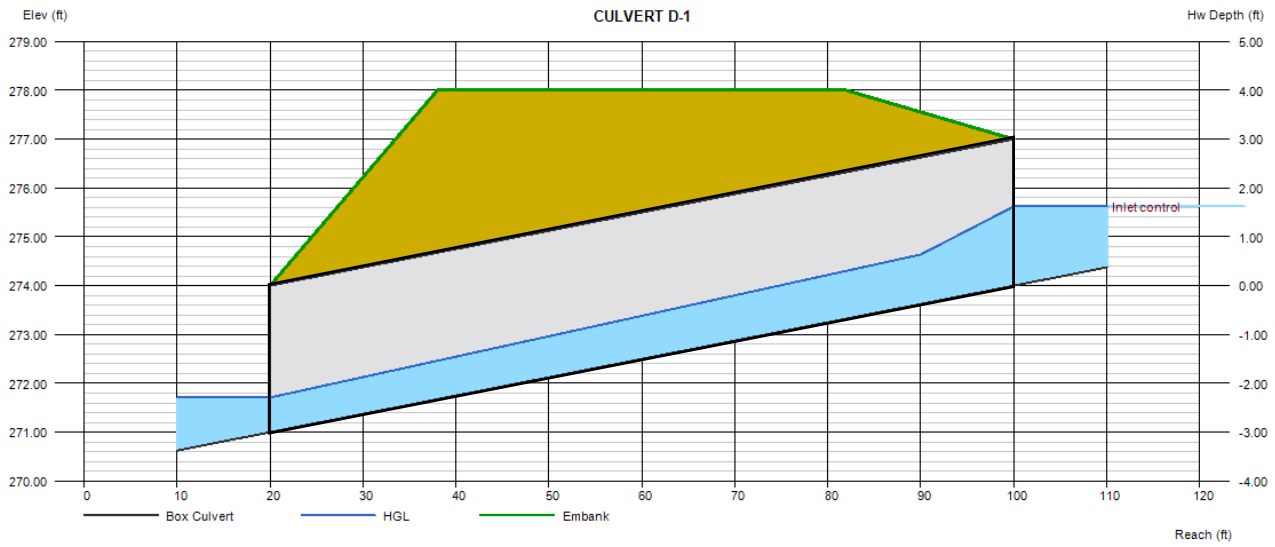
Top Elevation (ft)	=	278.00
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	74.00
Qmax (cfs)	=	74.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	74.00
Qpipe (cfs)	=	74.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	8.69
Veloc Up (ft/s)	=	5.83
HGL Dn (ft)	=	271.71
HGL Up (ft)	=	275.06
Hw Elev (ft)	=	275.62
Hw/D (ft)	=	0.54
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT D-2

Invert Elev Dn (ft)	=	302.00
Pipe Length (ft)	=	60.00
Slope (%)	=	5.00
Invert Elev Up (ft)	=	305.00
Rise (in)	=	48.0
Shape	=	Box
Span (in)	=	168.0
No. Barrels	=	1
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

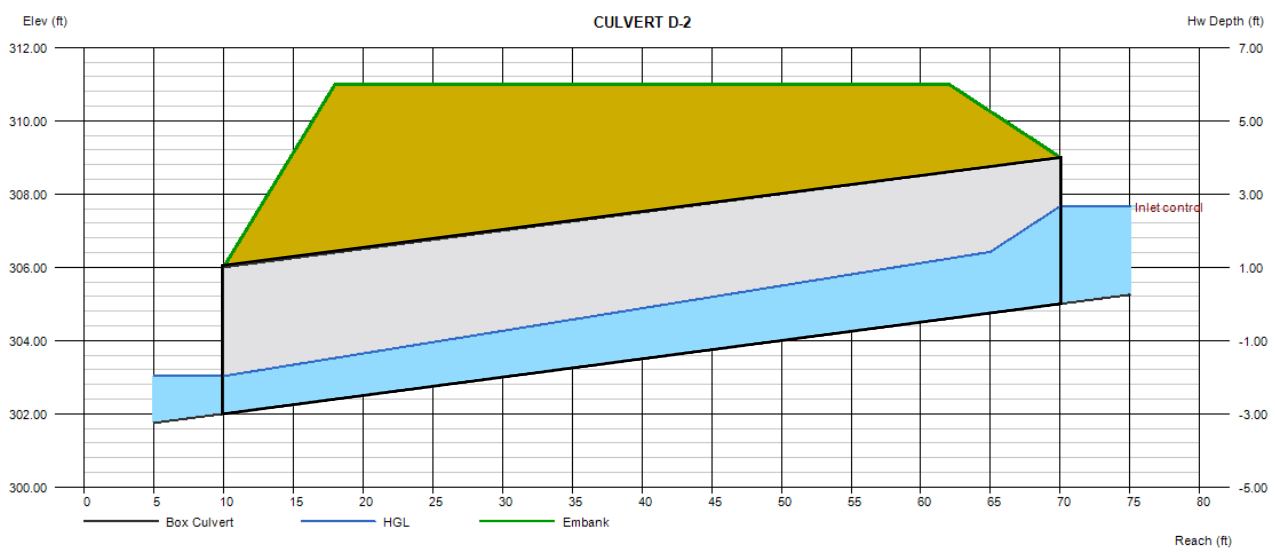
Top Elevation (ft)	=	311.00
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	181.00
Qmax (cfs)	=	181.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	181.00
Qpipe (cfs)	=	181.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	12.55
Veloc Up (ft/s)	=	7.47
HGL Dn (ft)	=	303.03
HGL Up (ft)	=	306.73
Hw Elev (ft)	=	307.67
Hw/D (ft)	=	0.67
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT E-1

Invert Elev Dn (ft)	=	117.00
Pipe Length (ft)	=	70.00
Slope (%)	=	4.29
Invert Elev Up (ft)	=	120.00
Rise (in)	=	48.0
Shape	=	Box
Span (in)	=	288.0
No. Barrels	=	2
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

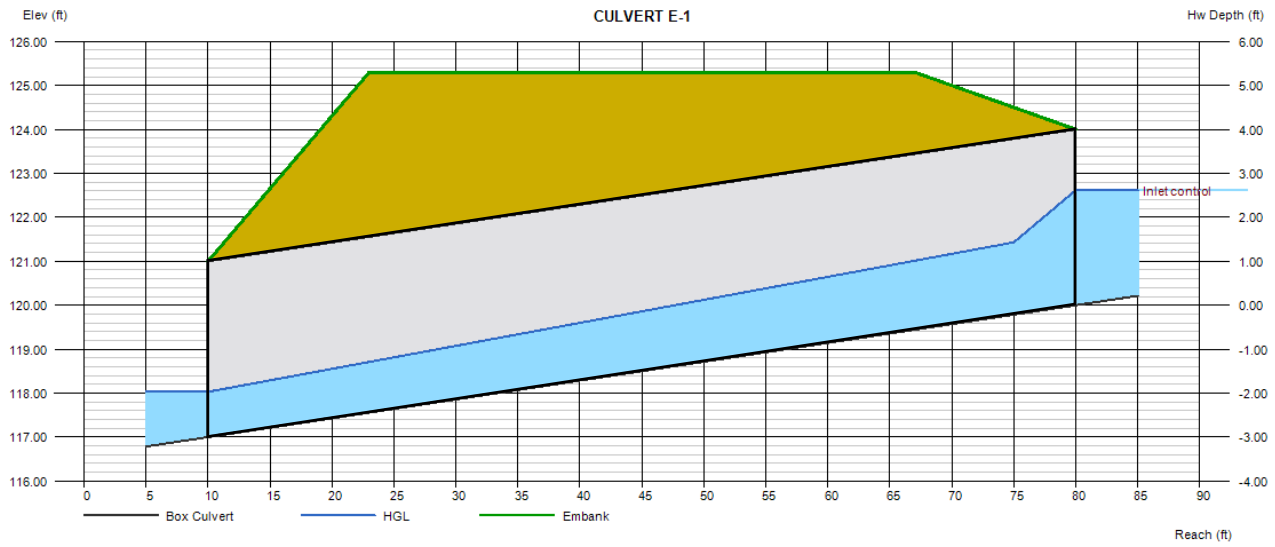
Top Elevation (ft)	=	125.30
Top Width (ft)	=	44.00
Crest Width (ft)	=	44.00

Calculations

Qmin (cfs)	=	600.00
Qmax (cfs)	=	600.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	600.00
Qpipe (cfs)	=	600.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	12.14
Veloc Up (ft/s)	=	7.38
HGL Dn (ft)	=	118.03
HGL Up (ft)	=	121.69
Hw Elev (ft)	=	122.62
Hw/D (ft)	=	0.65
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT E-2

Invert Elev Dn (ft)	=	111.00
Pipe Length (ft)	=	90.00
Slope (%)	=	6.67
Invert Elev Up (ft)	=	117.00
Rise (in)	=	84.0
Shape	=	Box
Span (in)	=	288.0
No. Barrels	=	2
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

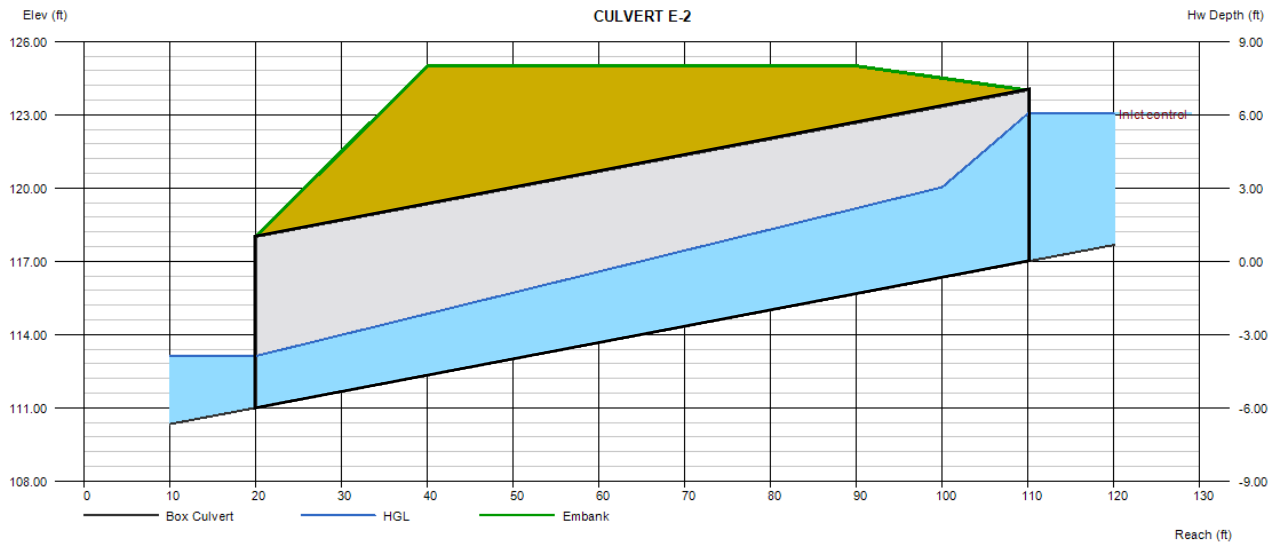
Top Elevation (ft)	=	125.00
Top Width (ft)	=	50.00
Crest Width (ft)	=	50.00

Calculations

Qmin (cfs)	=	2100.00
Qmax (cfs)	=	2100.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	2100.00
Qpipe (cfs)	=	2100.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	20.64
Veloc Up (ft/s)	=	11.22
HGL Dn (ft)	=	113.12
HGL Up (ft)	=	120.90
Hw Elev (ft)	=	123.05
Hw/D (ft)	=	0.86
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Jun 24 2014

CULVERT F-1

Invert Elev Dn (ft)	=	10.00
Pipe Length (ft)	=	40.00
Slope (%)	=	7.50
Invert Elev Up (ft)	=	13.00
Rise (in)	=	72.0
Shape	=	Box
Span (in)	=	264.0
No. Barrels	=	4
n-Value	=	0.024
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

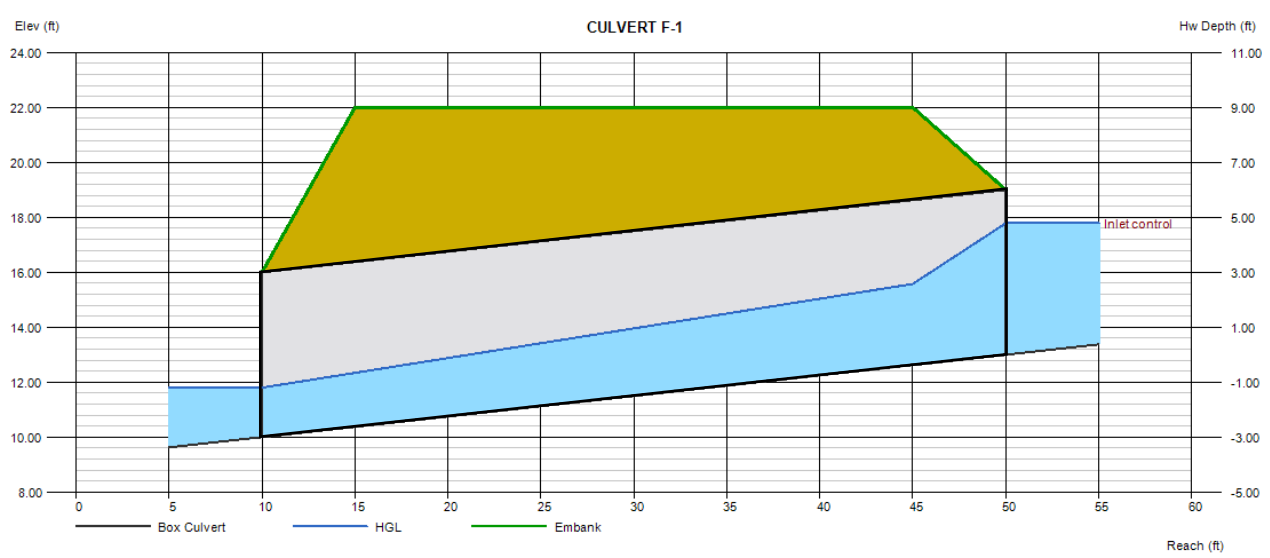
Top Elevation (ft)	=	22.00
Top Width (ft)	=	30.00
Crest Width (ft)	=	30.00

Calculations

Qmin (cfs)	=	2750.00
Qmax (cfs)	=	2750.00
Tailwater Elev (ft)	=	0.00

Highlighted

Qtotal (cfs)	=	2750.00
Qpipe (cfs)	=	2750.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	17.36
Veloc Up (ft/s)	=	10.03
HGL Dn (ft)	=	11.80
HGL Up (ft)	=	16.12
Hw Elev (ft)	=	17.79
Hw/D (ft)	=	0.80
Flow Regime	=	Inlet Control



DILLINGHAM RANCH - ROAD A CULVERT CALCULATIONS

GENERAL NOTES & ASSUMPTIONS

1. All watershed boundaries are based on existing surveyed topography and the contours shown on the UCGS quandangle.
2. The rational method was used to determine flows for watershed boundaries less than 100 AC, and Plate 6 was referenced for flows at watershed boundaries over 100 AC in area.
3. Refer to the Conveyance Structure Watershed Exhibit and the Hydraflow Culvert Report within this Appendix for detailed culvert location and sizing.
4. Assumed a 50 year 15 minute storm of .46 was applicable to all structural watershed Q calculations.

RATIONAL METHOD INPUTS				
ITEM	TYPE	RATE	UNIT	COMMENT
Intensity	Rational Method	6.97	in/hr	Refer to Reference Tab for more information
C-Value	Runoff Coefficient	0.45	-	Type D Soil. Rural Spacing
SF TO AC	Conversion Factor	43,560	-	

WEIGHTED C-CALCULATION[1]						
	AREA (SF)	AREA (AC)	TYPE	C	AREA-Weighted (AC)	C-Weighted
	1,001,880	23.0	IMPERVIOUS - ROAD	0.90	20.7	
	479,160	11.0	IMPERVIOUS - HOUSING	0.90	9.9	
	147,232,800	3,380.0	LANDSCAPE	0.45	1,521.0	
TOTAL		3,414	-		1,552	**0.45**

[1]Refer to P-C_Value.dwg located in: ***P:\2013\13-231_Dillingham_Ranch\04_Design\Exhibits\Proposed*** for additional information

WATERSHED CALCULATIONS

WATERSHED AT ROAD A CULVERTS			
CULVERT #	WATERSHED AREA (SF)[1]	WATERSHED (AC)	FLOW METHOD
A-1	39,655,156	910	Plate 6
A-2	8,559,012	196	Plate 6
A-3	4,356,000	100	Rational Method
A-4	31,642,833	726	Plate 6
A-5	9,854,173	226	Plate 6

[1]Refer to P-Watershed-Structure.dwg for additional calculations:

P:\2013\13-231_Dillingham_Ranch\04_Design\01_Tentative Map\Proposed

FLOW CALCULATIONS

FLOW AT ROAD A CULVERTS					
CULVERT #	WATERSHED AREA (AC)	I	C_Weighted	Q (CFS)	COMMENTS
A-1	**910.4**	**n/a**	**n/a**	**2,300**	Plate 6
A-2	**196.5**	**n/a**	**n/a**	**900**	Plate 6
A-3	**100.0**	**6.97**	**0.45**	**317**	Rational Method
A-4	**726.4**	**n/a**	**n/a**	**2,000**	Plate 6
A-5	**226.2**	**n/a**	**n/a**	**950**	Plate 6

[1]Refer to reference tab for more information regarding intensity rates

[2]Refer to HydraFlow Report for more information regarding culvert dimensions

DILLINGHAM RANCH - ROAD C CULVERT CALCULATIONS

GENERAL NOTES & ASSUMPTIONS

1. All watershed boundaries are based on existing surveyed topography and the contours shown on the UCGS quandangle.
2. The rational method was used to determine flows for watershed boundaries less than 100 AC, and Plate 6 was referenced for flows at watershed boundaries over 100 AC in area.
3. Refer to the Conveyance Structure Watershed Exhibit and the Hydraflow Culvert Report within this Appendix for detailed culvert location and sizing.
4. Assumed a 50 year 15 minute storm of .46 was applicable to all structural watershed Q calculations.

RATIONAL METHOD INPUTS				
ITEM	**TYPE**	**RATE**	**UNIT**	**UNIT**
Intensity	Rational Method	6.97	in/hr	Refer to Reference Tab for more information
C-Value	Runoff Coefficient	0.45	-	Type D Soil. Rural Spacing
SF TO AC	Conversion Factor	43,560	-	

WEIGHTED C-CALCULATION[1]						
	AREA (SF)	**AREA (AC)**	**TYPE**	**C**	**AREA-Weighted (AC)**	**C-Weighted**
	1,001,880	23.0	IMPERVIOUS - ROAD	0.90	20.7	
	479,160	11.0	IMPERVIOUS - HOUSING	0.90	9.9	
	147,232,800	3,380.0	LANDSCAPE	0.45	1,521.0	
TOTAL		3,414	-		1,552	**0.45**

[1]Refer to P-C_Value.dwg located in: ***P:\2013\13-231_Dillingham_Ranch\04_Design\Exhibits\Proposed*** for additional information

WATERSHED CALCULATIONS

WATERSHED AT ROAD C CULVERTS			
CULVERT #	**WATERSHED AREA (SF)[1]**	**WATERSHED (AC)**	**FLOW METHOD**
C-1	4,147,144	95	Rational Method

[1]Refer to P-Watershed-Structure.dwg for additional calculations:

P:\2013\13-231_Dillingham_Ranch\04_Design\01_Tentative Map\Proposed

FLOW CALCULATIONS

FLOW AT ROAD C CULVERTS					
CULVERT #	**WATERSHED AREA (AC)**	**I**	**C_Weighted**	**Q (CFS)**	**COMMENTS**
C-1	**95.2**	**6.97**	**0.45**	**302**	Rational Method

[1]Refer to reference tab for more information regarding intensity rates

[2]Refer to HydraFlow Report for more information regarding culvert dimensions

DILLINGHAM RANCH - ROAD D CULVERT CALCULATIONS

GENERAL NOTES & ASSUMPTIONS

1. All watershed boundaries are based on existing surveyed topography and the contours shown on the UCGS quandangle.
2. The rational method was used to determine flows for watershed boundaries less than 100 AC, and Plate 6 was referenced for flows at watershed boundaries over 100 AC in area.
3. Refer to the Conveyance Structure Watershed Exhibit and the Hydraflow Culvert Report within this Appendix for detailed culvert location and sizing.
4. Assumed a 50 year 15 minute storm of .46 was applicable to all structural watershed Q calculations.

RATIONAL METHOD INPUTS				
ITEM	**TYPE**	**RATE**	**UNIT**	**UNIT**
Intensity	Rational Method	6.97	in/hr	Refer to Reference Tab for more information
C-Value	Runoff Coefficient	0.45	-	Type D Soil. Rural Spacing
SF TO AC	Conversion Factor	43,560	-	

WEIGHTED C-CALCULATION[1]						
	AREA (SF)	**AREA (AC)**	**TYPE**	**C**	**AREA-Weighted (AC)**	**C-Weighted**
	1,001,880	23.0	IMPERVIOUS - ROAD	0.90	20.7	
	479,160	11.0	IMPERVIOUS - HOUSING	0.90	9.9	
	147,232,800	3,380.0	LANDSCAPE	0.45	1,521.0	
TOTAL		3,414	-		1,552	**0.45**

[1]Refer to P-C_Value.dwg located in: ***P:\2013\13-231_Dillingham_Ranch\04_Design\Exhibits\Proposed*** for additional information

WATERSHED CALCULATIONS

WATERSHED AT ROAD D CULVERTS			
CULVERT #	**WATERSHED AREA (SF)[1]**	**WATERSHED (AC)**	**FLOW METHOD**
D-1	1,012,748	23	Rational Method
D-2	2,480,942	57	Rational Method

[1]Refer to P-Watershed-Structure.dwg for additional calculations:

P:\2013\13-231_Dillingham_Ranch\04_Design\01_Tentative Map\Proposed

FLOW CALCULATIONS

FLOW AT ROAD D CULVERTS					
CULVERT #	**WATERSHED AREA (AC)**	**I**	**C_Weighted**	**Q (CFS)**	**COMMENTS**
D-1	**23.2**	**6.97**	**0.45**	**74**	Rational Method
D-2	**57.0**	**6.97**	**0.45**	**180**	Rational Method

[1]Refer to reference tab for more information regarding intensity rates

[2]Refer to HydraFlow Report for more information regarding culvert dimensions

DILLINGHAM RANCH - ROAD E CULVERT CALCULATIONS

GENERAL NOTES & ASSUMPTIONS

1. All watershed boundaries are based on existing surveyed topography and the contours shown on the UCGS quandangle.
2. The rational method was used to determine flows for watershed boundaries less than 100 AC, and Plate 6 was referenced for flows at watershed boundaries over 100 AC in area.
3. Refer to the Conveyance Structure Watershed Exhibit and the Hydraflow Culvert Report within this Appendix for detailed culvert location and sizing.
4. Assumed a 50 year 15 minute storm of .46 was applicable to all structural watershed Q calculations.

RATIONAL METHOD INPUTS				
ITEM	**TYPE**	**RATE**	**UNIT**	**UNIT**
Intensity	Rational Method	6.97	in/hr	Refer to Reference Tab for more information
C-Value	Runoff Coefficient	0.45	-	Type D Soil. Rural Spacing
SF TO AC	Conversion Factor	43,560	-	

WEIGHTED C-CALCULATION[1]						
	AREA (SF)	**AREA (AC)**	**TYPE**	**C**	**AREA-Weighted (AC)**	**C-Weighted**
	1,001,880	23.0	IMPERVIOUS - ROAD	0.90	20.7	
	479,160	11.0	IMPERVIOUS - HOUSING	0.90	9.9	
	147,232,800	3,380.0	LANDSCAPE	0.45	1,521.0	
TOTAL		3,414	-		1,552	**0.45**

[1]Refer to P-C_Value.dwg located in: ***P:\2013\13-231_Dillingham_Ranch\04_Design\Exhibits\Proposed*** for additional information

WATERSHED CALCULATIONS

WATERSHED AT ROAD E CULVERTS			
CULVERT #	**WATERSHED AREA (SF)[1]**	**WATERSHED (AC)**	**FLOW METHOD**
E-1	5,096,520	117	Plate 6
E-2	32,183,161	739	Plate 6

[1]Refer to P-Watershed-Structure.dwg for additional calculations:

P:\2013\13-231_Dillingham_Ranch\04_Design\01_Tentative Map\Proposed

FLOW CALCULATIONS

FLOW AT ROAD E CULVERTS					
CULVERT #	**WATERSHED AREA (AC)**	**I**	**C_Weighted**	**Q (CFS)**	**COMMENTS**
E-1	**117.0**	**n/a**	**n/a**	**600**	Plate 6
E-2	**738.8**	**n/a**	**n/a**	**2,100**	Plate 6

[1]Refer to reference tab for more information regarding intensity rates

[2]Refer to HydraFlow Report for more information regarding culvert dimensions

DILLINGHAM RANCH - ROAD F CULVERT CALCULATIONS

GENERAL NOTES & ASSUMPTIONS

1. All watershed boundaries are based on existing surveyed topography and the contours shown on the UCGS quandangle.
2. The rational method was used to determine flows for watershed boundaries less than 100 AC, and Plate 6 was referenced for flows at watershed boundaries over 100 AC in area.

WATERSHED CALCULATIONS

WATERSHED AT ROAD E CULVERTS			
CULVERT #	WATERSHED AREA (SF)[1]	WATERSHED (AC)	FLOW METHOD
EX-2	58,369,601	1,340	Plate 6
F-1	58,369,601	1,340	Plate 6

[1]Refer to P-Watershed-Structure.dwg for additional calculations:

P:\2013\13-231_Dillingham_Ranch\04_Design\01_Tentative Map\Proposed

FLOW CALCULATIONS

FLOW AT ROAD E CULVERTS				
CULVERT #	WATERSHED AREA (AC)	Q CFS)	Max Q Allowed (CFS)	COMMENTS
EX-2	**1,340**	**3,000**	**300**	Max Q that can flow through EX-2 is 300 CFS
F-1	**1,340**	**2,750**	**n/a**	F-1 shall convey remaining flow from EX-2

[1]Refer to reference tab for more information regarding intensity rates

[2]Refer to HydraFlow Report for more information regarding culvert dimensions

58 MAIDEN LANE, 3RD FLOOR, SAN FRANCISCO, CA 94108
(415) 677-7300 WWW.SHERWOODENGINEERS.COM

APPENDIX C

SUPPORTING DOCUMENTS

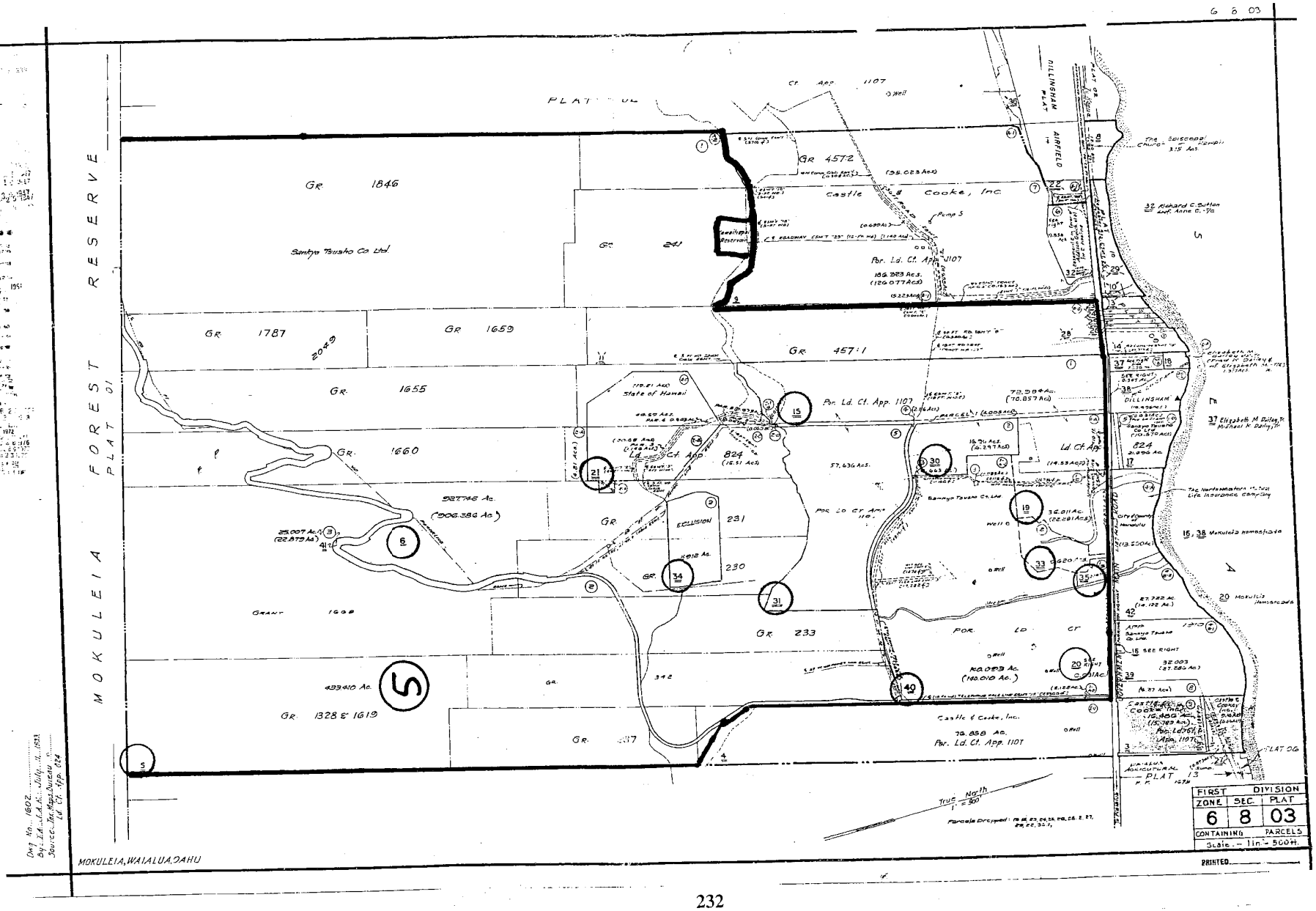
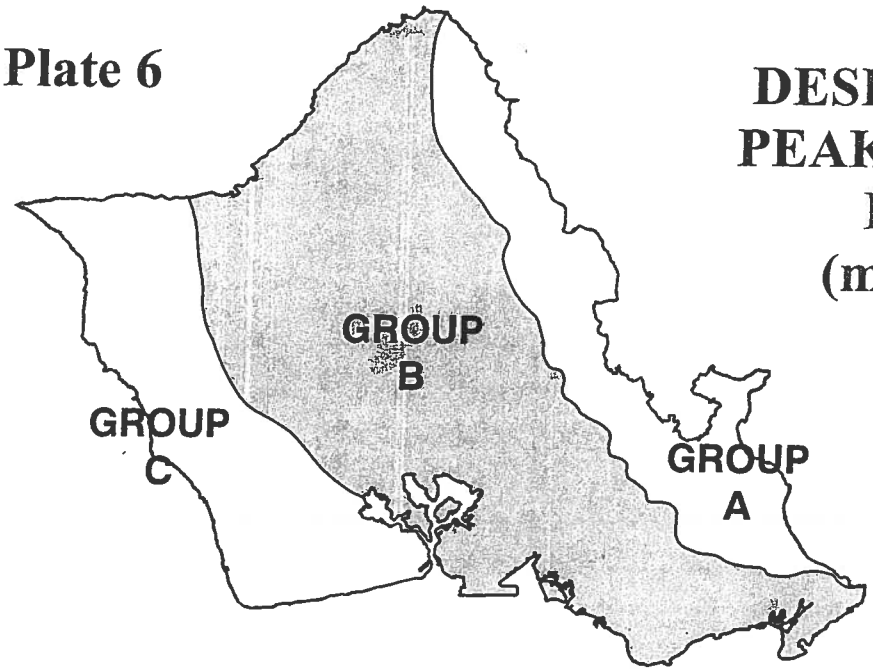
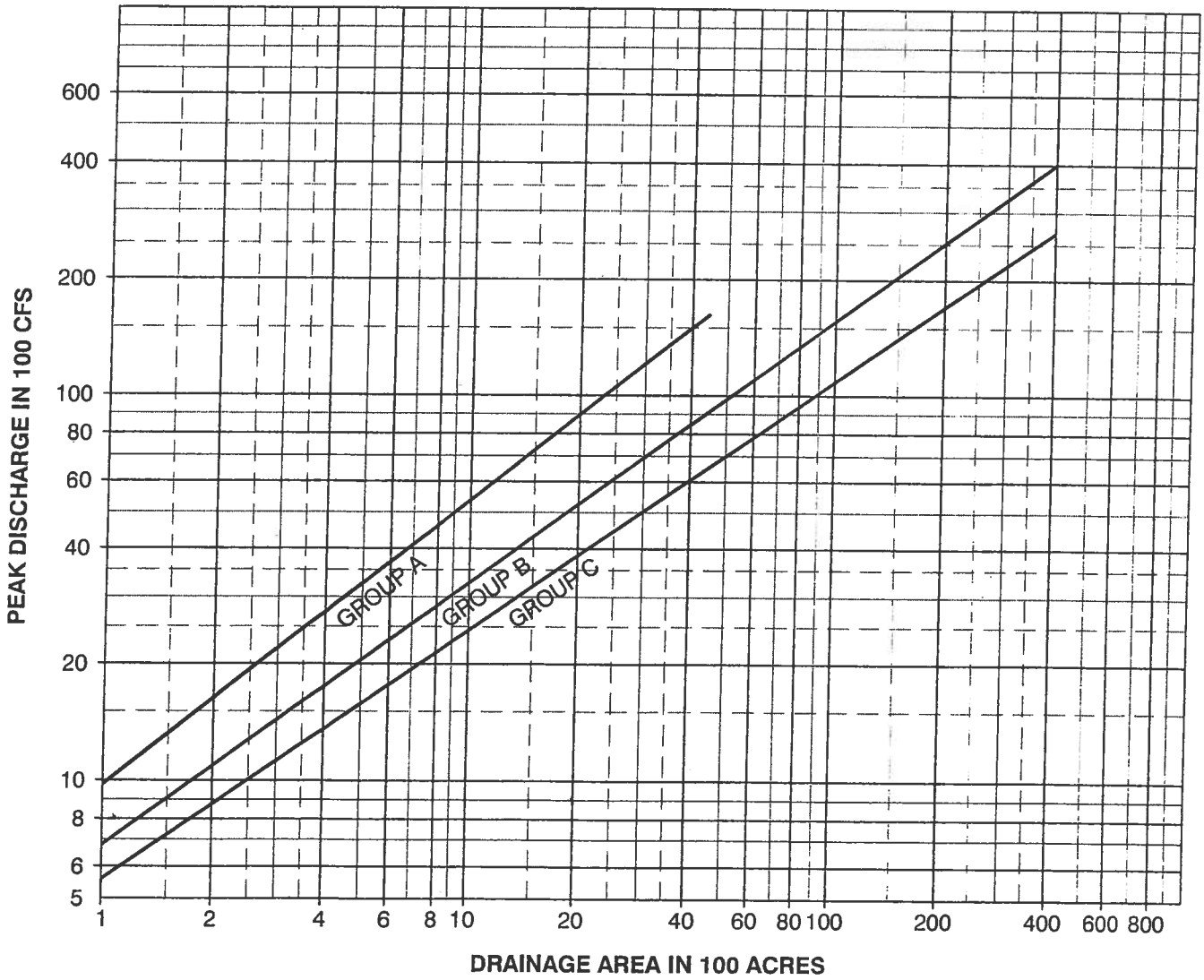

6 8 03
MOKULEIA FOREST RESERVE
PLAT 01
PLAT 01
GR 1846
Santya Busho Co Ltd
GR 1787
GR 1659
GR 1655
GR 1660
GR 4572
Castle & Cooke, Inc.
GR 4571
State of Hawaii
Por. Ld. Ct. App. 1107
Ld. Ct. App. 824
ECLUSION 231
GR 233
GR 342
GRANT 1608
GR 1328 & 1619
GR 237
Santya Tusho Co Ltd
Castle & Cooke, Inc.
DILLINGHAM AIRFIELD
DILLINGHAM PLAT
PLAT 06
PLAT 13
True North
1" = 500'
FIRST DIVISION
ZONE 6
SEC. 8
PLAT 03
CONTAINING PARCELS
Scale - 1in = 500ft.
PRINTED
MOKULEIA, WAIALUA, OAHU

Plate 6

DESIGN CURVES FOR PEAK DISCHARGE VS. DRAINAGE AREA (more than 100 acres)



● CURVES ARE FOR STREAM CHANNELS AND DRAINAGE STRUCTURES.



SOURCE: DATA FROM U.S. GEOLOGICAL SURVEY REV. FEB 2003.

jsb - D:\PROJECTS\26537218_000B1\DC-DA.DWG - Mon, 21 Jun 2010

[Eff: APR 08 2011] (Auth: Sec 14-12.31, ROH) (Imp: Sec 14-12.31, ROH)

Federal Emergency Management Agency

Washington, D.C. 20472

LETTER OF MAP REVISION DETERMINATION DOCUMENT

COMMUNITY AND REVISION INFORMATION		PROJECT DESCRIPTION	BASIS OF REQUEST
COMMUNITY	City and County of Honolulu County Hawaii	NO PROJECT	FLOODWAY HYDRAULIC ANALYSIS NEW TOPOGRAPHIC DATA
	COMMUNITY NO.: 150001		
IDENTIFIER	Flood Hazard Analysis for Makaleha Stream	APPROXIMATE LATITUDE & LONGITUDE: 21.573, -158.169 SOURCE: USGS QUADRANGLE DATUM: NAD 27	

ANNOTATED MAPPING ENCLOSURES	ANNOTATED STUDY ENCLOSURES
TYPE: FIRM* NO.: 15003C0085F DATE: September 30, 2004	DATE OF EFFECTIVE FLOOD INSURANCE STUDY: January 19, 2011 PROFILE(S): 59P FLOODWAY DATA TABLE: 9

Enclosures reflect changes to flooding sources affected by this revision.
* FIRM - Flood Insurance Rate Map; ** FBFM - Flood Boundary and Floodway Map; *** FHBM - Flood Hazard Boundary Map

FLOODING SOURCE(S) & REVISED REACH(ES)

Makaleha Stream - from the confluence with the Pacific Ocean to just downstream of Cane Haul Road

SUMMARY OF REVISIONS

Flooding Source	Effective Flooding	Revised Flooding	Increases	Decreases
Makaleha Stream	BFEs*	BFEs	NONE	YES
	Zone AE	Zone AE	NONE	YES
	Floodway	Floodway	YES	YES
	Zone AE	Zone X (shaded)	NONE	YES

* BFEs - Base Flood Elevations

DETERMINATION

This document provides the determination from the Department of Homeland Security's Federal Emergency Management Agency (FEMA) regarding a request for a Letter of Map Revision (LOMR) for the area described above. Using the information submitted, we have determined that a revision to the flood hazards depicted in the Flood Insurance Study (FIS) report and/or National Flood Insurance Program (NFIP) map is warranted. This document revises the effective NFIP map, as indicated in the attached documentation. Please use the enclosed annotated map panels revised by this LOMR for floodplain management purposes and for all flood insurance policies and renewals in your community.

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Map Information eXchange (FMIX) toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 7390 Coca Cola Drive, Suite 240, Hanover, MD 21076. Additional Information about the NFIP is available on our website at http://www.fema.gov/nfip.

Beth A. Norton

Beth A. Norton, Program Specialist
Engineering Management Branch
Federal Insurance and Mitigation Administration

122451 PT202.BKR.11090171P.H15 102-D-A

Federal Emergency Management Agency
Washington, D.C. 20472

LETTER OF MAP REVISION DETERMINATION DOCUMENT (CONTINUED)

COMMUNITY INFORMATION

APPLICABLE NFIP REGULATIONS/COMMUNITY OBLIGATION

We have made this determination pursuant to Section 206 of the Flood Disaster Protection Act of 1973 (P.L. 93-234) and in accordance with the National Flood Insurance Act of 1968, as amended (Title XIII of the Housing and Urban Development Act of 1968, P.L. 90-448), 42 U.S.C. 4001-4128, and 44 CFR Part 65. Pursuant to Section 1361 of the National Flood Insurance Act of 1968, as amended, communities participating in the NFIP are required to adopt and enforce floodplain management regulations that meet or exceed NFIP criteria. These criteria, including adoption of the FIS report and FIRM, and the modifications made by this LOMR, are the minimum requirements for continued NFIP participation and do not supersede more stringent State/Commonwealth or local requirements to which the regulations apply.

We provide the floodway designation to your community as a tool to regulate floodplain development. Therefore, the floodway revision we have described in this letter, while acceptable to us, must also be acceptable to your community and adopted by appropriate community action, as specified in Paragraph 60.3(d) of the NFIP regulations.

COMMUNITY REMINDERS

We based this determination on the base (1-percent-annual-chance) flood discharges computed in the FIS for your community without considering subsequent changes in watershed characteristics that could increase flood discharges. Future development of projects upstream could cause increased flood discharges, which could cause increased flood hazards. A comprehensive restudy of your community's flood hazards would consider the cumulative effects of development on flood discharges subsequent to the publication of the FIS report for your community and could, therefore, establish greater flood hazards in this area.

Your community must regulate all proposed floodplain development and ensure that permits required by Federal and/or State/Commonwealth law have been obtained. State/Commonwealth or community officials, based on knowledge of local conditions and in the interest of safety, may set higher standards for construction or may limit development in floodplain areas. If your State/Commonwealth or community has adopted more restrictive or comprehensive floodplain management criteria, those criteria take precedence over the minimum NFIP requirements.

We will not print and distribute this LOMR to primary users, such as local insurance agents or mortgage lenders; instead, the community will serve as a repository for the new data. We encourage you to disseminate the information in this LOMR by preparing a news release for publication in your community's newspaper that describes the revision and explains how your community will provide the data and help interpret the NFIP maps. In that way, interested persons, such as property owners, insurance agents, and mortgage lenders, can benefit from the information.

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Map Information eXchange (FMIX) toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 7390 Coca Cola Drive, Suite 240, Hanover, MD 21076. Additional Information about the NFIP is available on our website at http://www.fema.gov/nfip.

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Federal Insurance and Mitigation Administration

Federal Emergency Management Agency

Washington, D.C. 20472

LETTER OF MAP REVISION
DETERMINATION DOCUMENT (CONTINUED)

We have designated a Consultation Coordination Officer (CCO) to assist your community. The CCO will be the primary liaison between your community and FEMA. For information regarding your CCO, please contact:

Ms. Sally M. Ziolkowski
Director, Mitigation Division
Federal Emergency Management Agency, Region IX
1111 Broadway Street, Suite 1200
Oakland, CA 94607-4052
(510) 627-7175

STATUS OF THE COMMUNITY NFIP MAPS

We will not physically revise and republish the FIRM and FIS report for your community to reflect the modifications made by this LOMR at this time. When changes to the previously cited FIRM panel(s) and FIS report warrant physical revision and republication in the future, we will incorporate the modifications made by this LOMR at that time.

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Map Information eXchange (FMIX) toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 7390 Coca Cola Drive, Suite 240, Hanover, MD 21076. Additional Information about the NFIP is available on our website at http://www.fema.gov/nfip.

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Federal Insurance and Mitigation Administration

Federal Emergency Management Agency

Washington, D.C. 20472

LETTER OF MAP REVISION
DETERMINATION DOCUMENT (CONTINUED)

PUBLIC NOTIFICATION OF REVISION

PUBLIC NOTIFICATION

FLOODING SOURCE	LOCATION OF REFERENCED ELEVATION	BFE (LOCAL TIDAL DATUM)		MAP PANEL NUMBER(S)
		EFFECTIVE	REVISED	
Makaleha Stream	Just upstream of Farrington Highway	11	10	15003C0085F
	Approximately 1,250 feet upstream of Farrington Highway	12	11	15003C0085F

Within 90 days of the second publication in the local newspaper, any interested party may request that we reconsider this determination. Any request for reconsideration must be based on scientific or technical data. This revision is effective as of the date of this letter. However, until the 90-day period has elapsed, the revised BFEs presented in this LOMR may be changed.

A notice of changes will be published in the *Federal Register*. A short notice also will be published in your local newspaper on or about the dates listed below. Please refer to FEMA's website at https://www.floodmaps.fema.gov/fhm/Scripts/bfe_main.asp for a more detailed description of proposed BFE changes, which will be posted approximately within a week of the date of this letter.

LOCAL NEWSPAPER Name: *The Honolulu Start-Advertiser*
Dates: 3/25/2011 and 4/1/2011

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Map Information eXchange (FMIX) toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 7390 Coca Cola Drive, Suite 240, Hanover, MD 21076. Additional Information about the NFIP is available on our website at http://www.fema.gov/nfip.

Beth A. Norton

Beth A. Norton, Program Specialist
Engineering Management Branch
Federal Insurance and Mitigation Administration

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE [1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Makaleha Stream								
A	860	2,040	2,112	2.3	9.8	9.8	10.6	0.8
B	1,365	1,823	4,066	1.1	10.2	10.2	10.9	0.7
C	2,055	1,458	4,298	1.2	11.2	11.2	11.2	0.0
D	3,810	51	333	14.6	29.6	29.6	29.6	0.0
E	4,203	42	433	11	35.8	35.8	35.8	0.0
F	5,235	75	551	8.4	49.1	49.1	49.1	0.0
G	5,705	281	1,106	4.1	54.7	54.7	54.7	0.0
H	6,790	44	296	14.8	73.6	73.6	73.6	0.0
I	8,345	74	335	12.5	111.8	111.8	111.8	0.0
Unnamed Stream								
A	2,575	1,573	2,825	1.4	9.4	9.4	9.9	0.5
B	3,585	1,016	3,591	1.1	9.9	9.9	10.3	0.4
C	4,269	850	2,218	1.7	10.0	10.0	10.8	0.8
D	6,505	2,016	4,742	0.7	10.9	10.9	11.9	1.0
E	7,538	950	1,865	1.7	21.3	21.3	21.3	0.0
F	8,300	862	1,040	2.9	24.4	24.4	24.4	0.0
Malaekahana Stream								
A	2,081	1,652	5,957	2.8	13.1	13.1	13.3	0.2
B	2,675	4,100	21,107	0.8	13.5	13.5	13.8	0.3
C	3,750	3,000	21,852	0.7	13.6	13.6	13.9	0.3
D	5,490	733	2,835	5.2	14.4	14.4	15.0	0.6
E	6,304	971	4,053	3.5	20.2	20.2	21.1	0.9
F	8,032	681	3,932	3.3	35.8	35.8	36.3	0.5
G	8,437	440	2,148	6.0	38.9	38.9	39.3	0.4

[1]Feet above confluence with Pacific Ocean

REVISED DATA

TABLE 9

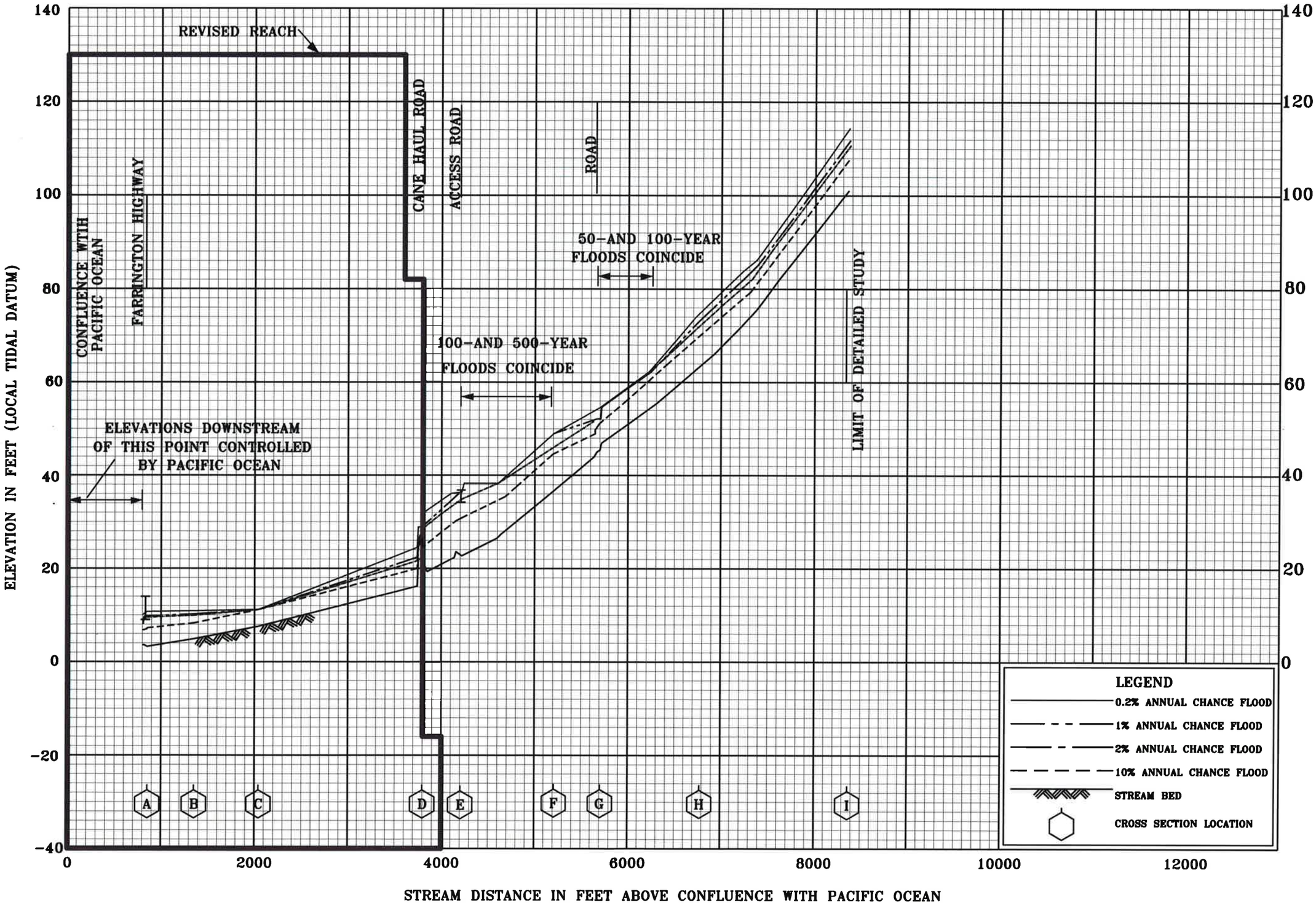
FEDERAL EMERGENCY MANAGEMENT AGENCY

REVISED TO REFLECT LOMR EFFECTIVE: March 21, 2011

CITY AND COUNTY OF HONOLULU, HI

FLOODWAY DATA

MAKALEHA STREAM-UNNAMED STREAM-MALAEKAHANA STREAM



FLOOD PROFILES

MAKALEHA STREAM

REVISED TO REFLECT LOMR EFFECTIVE: March 21, 2011

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY AND COUNTY OF HONOLULU, HI

Legend

1% annual chance (100-Year) Floodplain

1% annual chance (100-Year) Floodway

0.2% annual chance (500-Year) Floodplain

MAP SCALE 1" = 1000'

500 0 1000 FEET

300 0 300 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0085F

FIRM

FLOOD INSURANCE RATE MAP

CITY AND COUNTY OF HONOLULU, HAWAII

PANEL 85 OF 395

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

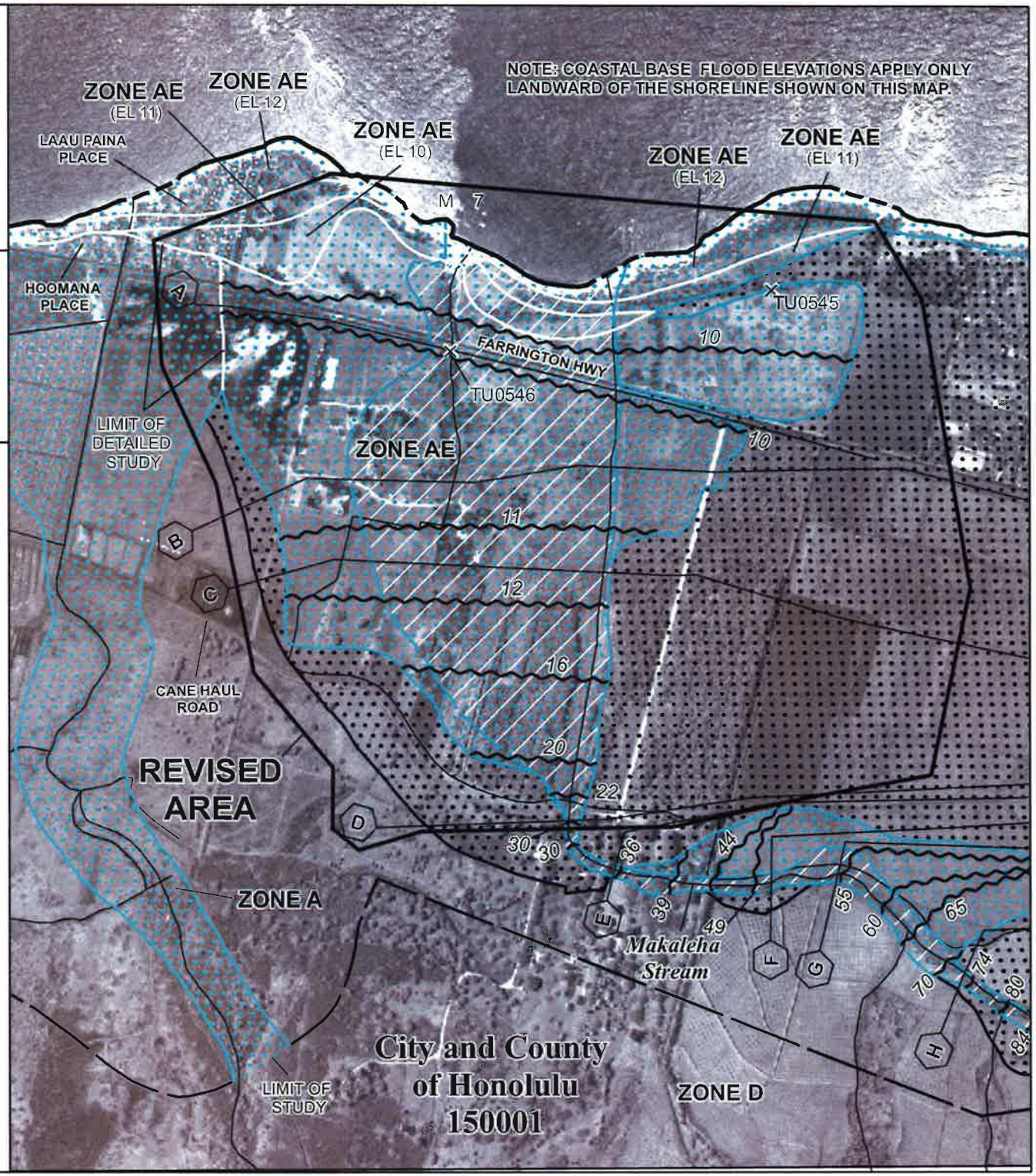
CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
HONOLULU, CITY AND COUNTY OF	150001	0085	F

REVISED TO REFLECT LOMR EFFECTIVE: March 21, 2011

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER 15003C0085F

EFFECTIVE DATE SEPTEMBER 30, 2004

Federal Emergency Management Agency