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STATEWIDE HIGHWAY SHORELINE PROTECTION STUDY

PROJECT NUMBER HWY-08-98

FINAL REPORT
NOVEMBER 2003

PREPARED BY:
EDWARD K. NODA AND ASSOCIATES, INC.
HONOLULU, HAWAII

PREPARED FOR:
STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
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GLOSSARY

Accretion. The buildup of land and/or beach by the action of natural forces, or by reason of man-made structures such as accretion formed by a groin or breakwater.

Beach Fill. Material placed on a beach to renourish eroding shores.

Beach nourishment. The process of replenishing a beach. It may be brought about naturally by longshore transport, or artificially by depositing fill material.

Erosion. The wearing away of land and/or beach by the action of natural forces. In the context of this study, the erosion that is caused by wave action.

Groin. A shore protection structure built perpendicular to the shoreline to trap littoral drift or retard erosion of the shore. A series of groins acting together to protect a section of the beach is called a groin field.

Revetment. A shore protection structure built on the shoreline to protect against erosion by wave action or currents. The structure is usually a facing of stone on a sloping embankment.

Seawall. A shore protection structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. Seawalls are usually near vertical structures constructed of concrete or other impervious material.

USGS. U.S. Geological Survey.

Wave setup. Superelevation of the water surface over normal surge elevation due to onshore mass transport of the water by breaking wave action.

1 - INTRODUCTION & SUMMARY

STUDY PURPOSE

The objective of this study effort is to develop a long-range master plan for protection and mitigation of wave and erosion damage to the statewide highway system. Throughout the state, a total of about 1,000 miles of highway are the responsibility of the State of Hawaii Department of Transportation, Highways Division (DOT-HWY). These are primarily major perimeter highways and roadways around each of the major islands. Major work activities included an inventory to identify the problem areas on each island, analysis of shoreline changes and development of recommendations for dealing with the erosion/wave problem at each priority area.

INVENTORY AND ASSESSMENT

Based on a review of GIS databases, review of contact prints of recent aerial photographs, and information provided by the DOT District Offices on each island, potential areas of concern were identified. Reconnaissance site visits were then conducted with District Office personnel during the months of August and September 2000. Baseline aerial photographs were obtained from the archives of Air Survey Hawaii for identified coastal segments, at enlarged scale of between 1"=200' to 1"=300', encompassing over 40 miles of shoreline. These aerial photos were reviewed together with the site reconnaissance photos, and about 30 miles of shoreline were identified as problem areas where the state highway is either in various stages of damage or disrepair due to shoreline erosion or wave overwash, or is potentially endangered due to shoreline erosion damage. These shoreline areas were primarily on Oahu and Maui, although problem areas were identified on all major islands. Table 1 (page 1-3) lists the shoreline segments identified during this phase of the study.

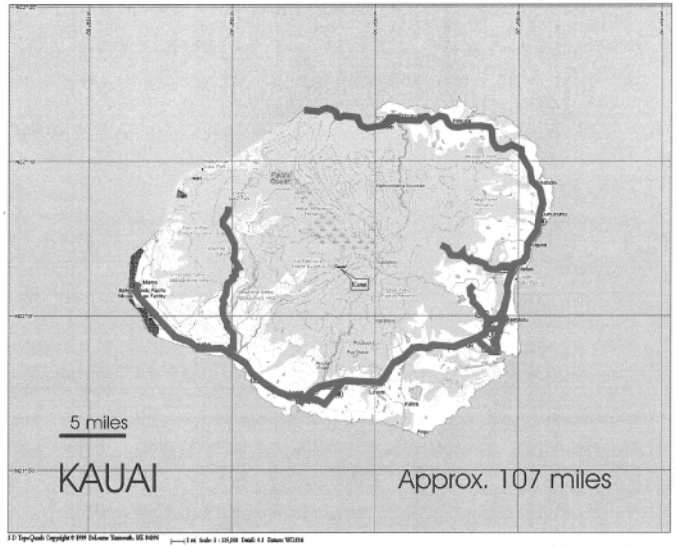
ANALYSIS OF SHORELINE CHANGES

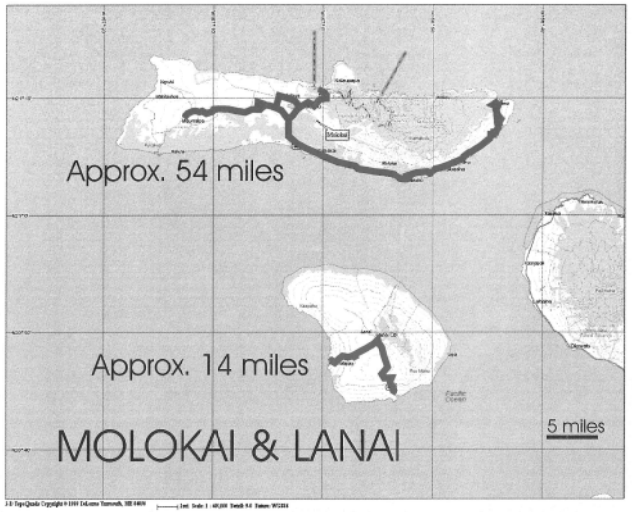
Based on the results of the inventory, historical aerial photographs were analyzed to determine the long-term shoreline changes at the problem areas. Typically, between 6 and 12 photos were selected for each site, spanning the time period between the oldest photo and most recent photo (about 50 years). Table 2 (page 1-3) lists the vertical aerial photos that were obtained from the archives of Air Survey Hawaii and R.M. Towill Corporation. The aerial photos were enlarged to a map scale of about 1 inch = 200 feet (or 1 inch = 300 feet, if limited by the scale of the original photos). The information that was desired from each photo was marked, and then digitized into an AutoCAD drawing file. Using target features (e.g. buildings, roads, bridges, etc.), the photo drawings were scaled and fitted to a USGS raster map background. The historic shoreline data from the photos were then superposed, and the changes in shoreline location calculated. The erosionary loss (-) or accretionary gain (−) of shoreline is quantified by calculating the change in area between the vegetation lines (or beach toe lines) of subsequent year photos. This area divided by the length of shoreline yields the average horizontal change per unit length of shoreline (i.e. square feet / linear feet = feet) for that shoreline reach over the time period between photos. The data are graphed to show the cumulative changes, starting with the earliest photo. Least squares fit of the data points yields a line where the slope is the average rate of shoreline change (i.e. feet / year).

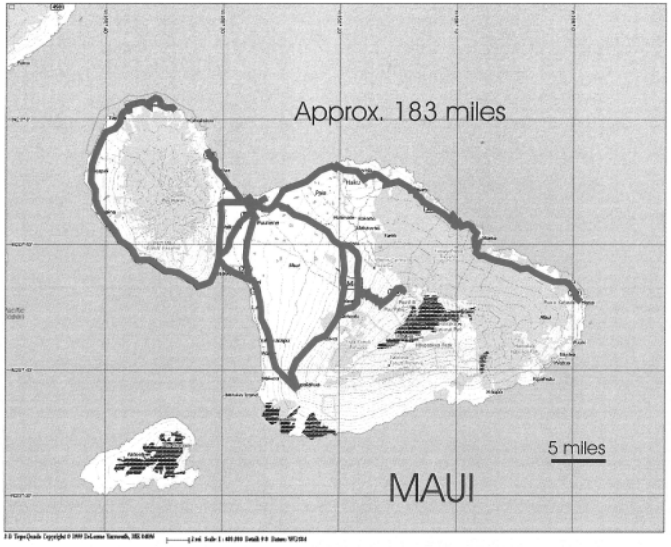
In this analysis, two representative shorelines were defined: the vegetation line and the beach toe line (or waterline). The vegetation line is an indicator of the seaward limit of fastlands (i.e. landward limit of the active beach zone). The beach toe line (or waterline) is an indicator of the seaward limit of the beach zone. The beach toe line is the point at which the beach slope intersects the shallow reef flat. Where there is not a shallow reef flat, then the waterline is selected, which is the point at which the water surface intersects the beach slope, and can vary depending on the tidal stage and wave activity. For several of the sites, there may not have been identifiable "beach" along the shoreline, in which case only the vegetation line was used. For many of the problem areas, there did not exist significant beach width fronting the shorelines historically, and shorelines have been artificially stabilized as part of the continuing maintenance of the highway system. Table 3 (page 1-4) summarizes the results of this analysis, and indicates those areas that were selected for the development of conceptual design alternatives.

CONCEPTUAL ALTERNATIVE PLANS

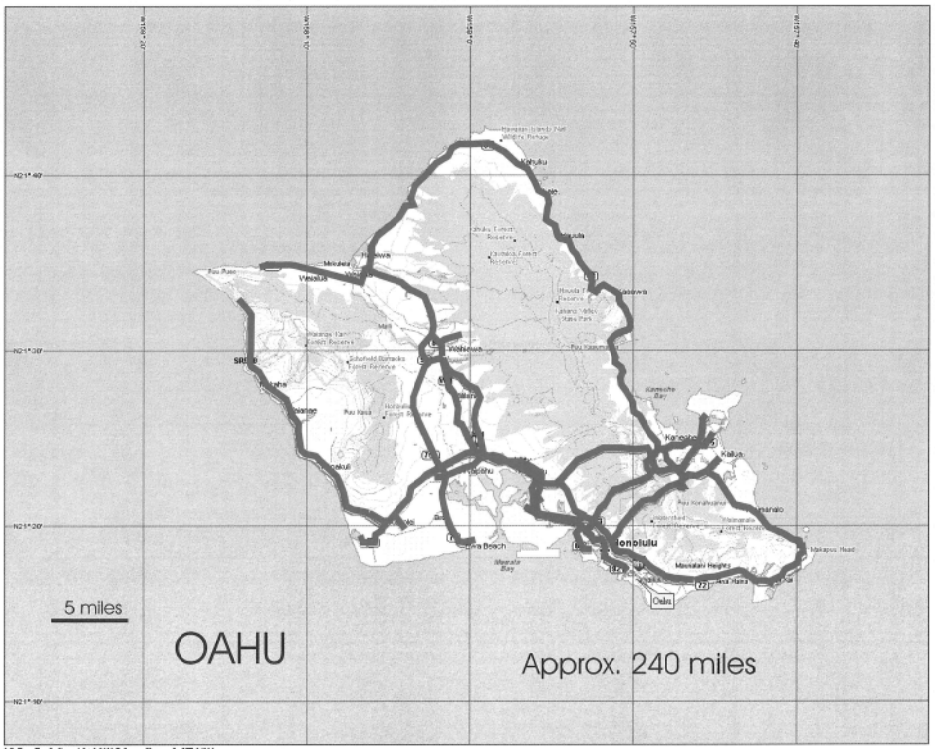
For those selected high priority shoreline areas, conceptual design alternatives for erosion protection or mitigation of wave damage were developed and assessed with respect to feasibility of implementation. Alternatives included hardening (i.e. shore protection structures), relocation or realignment of the highway, beach fill/nourishment, or other less conventional design concept if appropriate. Table 3 (page 1-4) identifies the types of alternatives for each priority site. Shoreline profiles and the vegetation line were surveyed for some of the areas to locate the present shoreline in relation to the highway and other shoreline properties and to establish "baseline" conditions for the design of conceptual plans. Coastal engineering analysis of storm wave exposure established the design wave parameters and design stillwater levels for the development of shore protection and beach fill alternatives. Budgetary cost estimates were developed for each alternative, and recommendations formulated with respect to implementation. Table 4 (page 1-5) summarizes the costs for each alternative.







STATEWIDE HIGHWAY SYSTEM



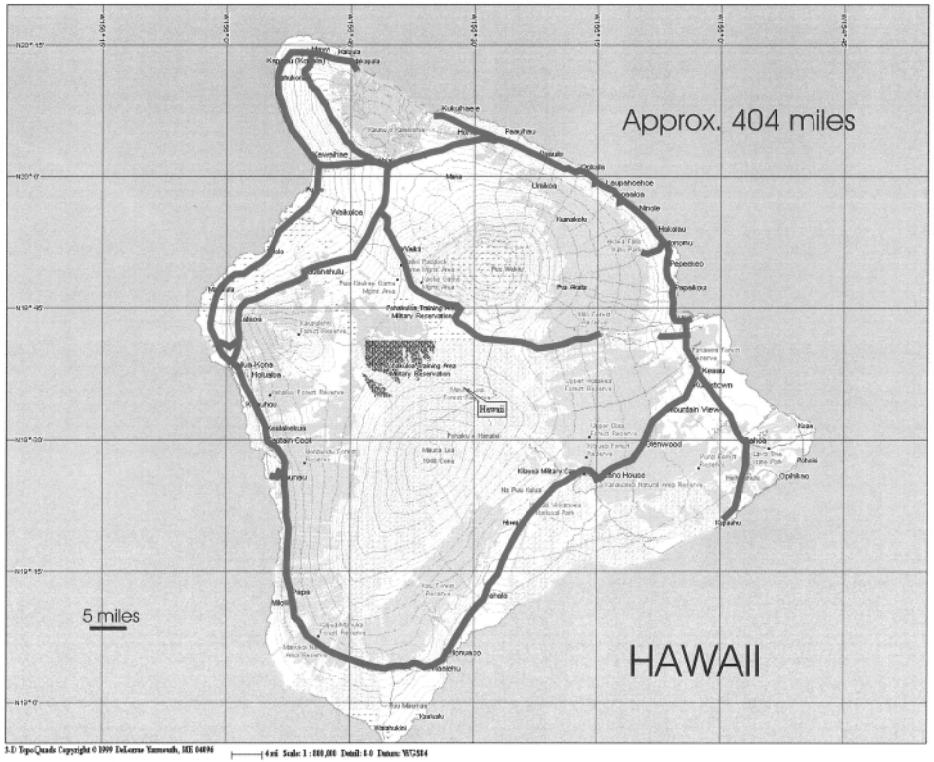


TABLE 1: AERIAL PHOTOGRAPHS FOR IDENTIFIED SHORELINE SEGMENTS

		BASELINE AERIAL PHOTOS				Multiple Years	
ISLAND	LOCATION	Feet	Miles	Photo Date	Scale	Feet	Miles
OAHU	KAWAILOA BEACH	4000		Jul 27, 92	1"=300'	4000	
	WAIMEA BAY	3000		Sep 23, 00	1"=200'		
	SUNSET BEACH	3000		Jan 30, 00	1"=300'	3000	
	HAUULA	4000		Jan 30, 00	1"=300'	4000	
	PUNALUU	4000		Jan 30, 00	1"=300'	4000	
	KAHANA BAY	4000		Jan 30, 00	1"=300'	4000	
	KAAAWA PT	5000		Aug 22, 96	1"=200'	5000	
	KAAAWA BEACH PARK-KAOLO PT	10000		Aug 22, 96	1"=200'	10000	
	KAOLO PT-KUALOA PARK	7000		Aug 22, 96	1"=200'	7000	
	KAIONA BEACH PARK	4000		Aug 22, 96	1"=200'	4000	
	MAKAPUU PIER	4000		Aug 22, 96	1"=200'	4000	
	NANAKULI	10000		Sep 14, 96	1"=300'		
	MAILI BEACH PARK-ULEHAWA B.P.	10000		Aug 25, 96	1"=200'		
	MAUNA LAHILAHI BEACH PARK	3000		Aug 25, 96	1"=200'	3000	
	MAKAHA BEACH PARK	3000		Aug 25, 96	1"=200'	3000	
	KEAAU	3000		Jul 27, 92	1"=300'	3000	
	MAKUA	6000		Jul 27, 92	1"=300'	6000	
		87000	16.5			64000	12.1
KAUAI	HAENA BAY	2000		Mar 14, 95	1"=300'		
	WAINIHA BAY	4000		Mar 14, 95	1"=300'	4000	
	HANALEI BAY	5000		Mar 14, 95	1"=300'	5000	
	WAILUA BAY	3000		Sep 18, 92	1"=300'	3000	
	KEKAHA	10000		Sep 18, 92	1"=300'		
		24000	4.5			12000	2.3
MOLOKAI	KAMILOLOA	4000		Jan 24, 00	1"=200'	4000	
	KAWELA	4000		Jan 24, 00	1"=200'	4000	
	PAHOA-KIPAPA	5000		Jan 24, 00	1"=200'		
	NIAUPALA FISHPOND	3000		Jan 24, 00	1"=200'	3000	
	KUPEKE FISHPOND	5000		Jan 24, 00	1"=200'	5000	
	PAUWALU-WAIALUA	6000		Jan 24, 00	1"=200'	6000	
	WAIALUA-KALAEKAPU	11000		Jan 24, 00	1"=200'	11000	
		38000	7.2			33000	6.3
MAUI	KAHULUI BAY SHORELINE	5000		Sep 28, 99	1"=300'	5000	
	HOOKIPA	5000		Oct 8, 90	1"=300'	5000	
	KEALIA POND SHORELINE	8000		Mar 7, 98	1"=200'	8000	
	UKUMEHAME BEACH	5000		May 19, 97	1"=200'	5000	
	UKUMEHAME PARK-HEKILI POINT	10000		May 19, 97	1"=200'	10000	
	HEKILI PT-EASTWARD	4000		Sep 28, 99	1"=300'	4000	
	OLOWALU	6000		Sep 28, 99	1"=300'	6000	
	LAUNIUPOKO	8000		Sep 28, 99	1"=300'	8000	
	WAHIKULI	3000		Sep 28, 99	1"=300'		
		54000	10.2			51000	9.7
HAWAII	HILO BAYFRONT BEACH	7000		Oct 12, 91	1"=200	7000	
	WAINAKU-HILO	4000		Oct 10, 91	1"=200'		
	PELEULI POINT	4000		Dec 2, 82	1"=200'	4000	
	LAUPAHOEHOE	4000		Dec 2, 82	1"=200'	4000	
	NAALEHU	3000		Oct 21, 91	1"=200'		
		22000	4.2			15000	2.8
	TOTAL PHOTO MILES		42.6				33.2

TABLE 2: HISTORICAL AERIAL PHOTOS FOR PRIORITY AREAS

HISTORICAL PHOTOS FOR OAHU

Kawailoa Beach	Hauula	Kahana Bay	Kaiona Beach - Makapuu Pier	03-30-75	Keaau
05-08-49	09-28-49	10-29-49		12-05-82	11-22-49
04-12-56	12-29-59	10-14-64	10-29-49	12-15-89	05-19-59
08-24-62	10-14-64	02-06-71	06-18-59	07-27-92	12-22-65
01-23-71	10-24-67	06-03-75	11-20-63	08-25-96	02-06-71
04-11-75	02-06-71	12-05-82	05-14-67		03-30-75
12-05-82	04-13-75	01-30-00	03-17-71	Makaha Beach Park	12-15-82
02-16-89	12-05-82		04-13-75		12-15-89
07-27-92	12-16-89	Kaaawa Pt - Kualoa	12-05-82	02-16-49	07-27-92
01-13-96	01-30-00		05-24-86	05-19-59	07-03-99
		10-29-49	02-24-89	12-22-65	
Sunset Beach	Punaluu	11-01-69	03-05-93	02-06-71	Makua
09-24-52	01-19-59	12-11-72	08-22-96	03-30-75	05-08-49
12-04-62	10-14-64	04-13-75		12-05-82	12-22-65
01-23-71	02-06-71	12-05-82	Mauna Lahilahi Beach Park	12-15-89	03-30-75
04-11-75	04-13-75	02-15-89		07-27-92	12-05-82
12-05-82	12-05-82	08-22-96	02-16-49	08-25-96	02-15-89
06-02-89	12-16-89		05-19-59	07-03-99	07-27-92
07-27-92	01-30-00		12-22-65		
01-30-00			02-06-71		

HISTORICAL PHOTOS FOR MOLOKAI

Kamiloloa	Niaupala Fishpond	Pauwalu - Waialua
05-23-49		
05-19-64	11-21-49	03-15-61
03-09-72	03-15-61	01-26-71
07-04-75	05-12-75	05-12-75
10-25-82	10-19-82	10-19-82
02-09-88	07-31-88	07-09-87
05-19-97	01-24-00	01-24-00
01-24-00		
	Kupeke Fishpond	Waialua - Kalaekapu
Kawela		
05-23-49	11-21-49	11-21-49
05-19-64	01-26-71	01-26-71
03-09-72	05-12-75	05-12-75
05-12-75	10-19-82	10-19-82
10-25-82	07-09-87	07-09-87
07-31-88	01-24-00	01-24-00
05-09-97		
01-24-00		

HISTORICAL PHOTOS FOR MAUI

Kahului Bay	Kealia Pond	Olowalu
09-13-53	11-21-49	01-26-71
12-30-59	06-07-55	03-26-75
01-28-64	06-02-64	10-25-82
12-22-70	12-22-70	03-10-88
03-26-75	03-26-75	09-24-91
10-19-82	10-25-82	09-28-99
09-16-86	07-17-87	
11-23-89	09-28-91	Launiupoko
09-28-99	03-07-98	11-21-49
		12-22-62
Hookipa	Ukumehame	01-14-68
02-27-50	11-21-49	01-26-71
07-23-59	04-11-63	03-26-75
10-27-64	01-23-71	10-25-82
12-22-70	03-26-75	03-10-88
10-19-82	10-25-82	09-24-91
10-08-90	03-11-88	09-28-99
	09/28/91	
	02-27-95	
	05-19-97	

HISTORICAL PHOTOS FOR KAUAI

Wainiha Bay	Hanalei Bay	Wailua
11-22-50	11-22-50	11-22-50
09-15-57	09-15-57	05-02-62
10-13-63	10-13-63	08-31-71
04-10-75	04-10-75	04-10-75
01-03-83	05-30-79	01-03-81
03-04-88	01-05-83	05-19-88
09-17-92	03-04-88	09-18-92
03-14-95	03-14-95	

HISTORICAL PHOTOS FOR HAWAII

Laupahoehoe	Hilo Bayfront	
08-10-71	02-22-49	
05-31-75	12-13-52	
12-02-82	05-23-60	
07-24-87	09-15-64	
	10-10-69	
Peleuli Point	01-05-72	
10-07-71	01-22-76	
05-31-75	12-03-82	
12-02-82	05-09-88	
07-24-87	10/12/91	
	02-24-92	
	02-07-98	

TABLE 3: SUMMARY TABLE OF RESULTS FROM ANALYSIS OF AERIAL PHOTOS AND RECOMMENDED HIGH PRIORITY SITES

ISLAND	Time Span of Photo Coverage			Shoreline (Vegetation) Long-Term Change			Significant	Alternatives	
SHORELINE LOCATION	Start Yr	End Yr	Span Years	Net (feet)	Avg Rate (ft/yr)	Length (ft)	Beach Loss?	H - R - B - O	Other Comments
OAHU									
Kawailoa Beach (P)	1949	1996	47	8.9	0.21	1730	No	H - R - B	(S) overwash during winter surf + undermining of road along short reach
Sunset Beach	1952	2000	48	-0.6	-0.24	2390	No	No action	overwash during winter surf
Hauula (P)	1949	2000	51	-1.4	0.03	3110	No	H - R	(S) overwash during winter surf + undermining of road
Punaluu (P)	1959	2000	41	22	0.58	3070	No	H - R - B	(S) north of Punaluu B. P., overwash during high surf
Kahana Bay	1949	2000	51	95	1.78	2480	No	No action	accretion within bay; maintain shore protection along west side
Kaaawa Pt - Kualoa (P)	1949	1996	47	14 to -10	0.43 to -0.41	14990	Yes	H - R - B	(S) Section 4 is the worst (Corps project reach and southward)
Kaiona Beach	1949	1996	47	0.1	0.03	3650	No	No action	significant beach accretion; maintain existing shore protection as precaution
Makapuu Pier (P)	1971	1996	25	16	0.22	3200	No	H - R	road shoulder now gone along short reach; similar to Wainaku (Hilo)
Mauna Lahilahi B.P.	1949	1996	47	-17	-0.11	1860	Yes	O	overwash during winter surf; provide higher tier on retaining wall
Makaha B.P. (P)	1949	1999	50	-12	-0.45	2180	Yes	R - B - O	(S) overwash during winter surf
Keaau	1949	1999	50	indeterminate from photos			?	H	erosion problem at bridges; beachrock along shoreline
Makua	1949	1992	43	indeterminate from photos			No	H	rocky cliff shoreline-shoulder is eroding where unprotected
KAUAI									
Wainiha Bay	1950	1995	45	-70	-0.22	1500	No	H	erosion within bay; implement recommendations of 7-21-2000 engrg.rpt
Hanalei Bay (P)	1950	1995	45	-3.7	0.12	2040	No	H - R	(S) shoreline erosion is very localized at north end
Wailua	1950	1992	42	2.7	0.24	2340	No	No action	no chronic erosion; large fluctuations in beach line
MOLOKAI									
Kamiloloa	1949	2000	51	-16	-0.26	1460	No	H	
Kawela	1949	2000	51	-20	-0.38	2930	No	H	
Niaupala Fishpond (P)	1949	2000	51	39	0.72	1650	No	H - B	fishpond wall at roadway is deteriorating; cultural/archaeological issues
Kupeke Fishpond	1949	2000	51	-2.3	0.01	471	No	H	short section of fishpond wall at roadway is deteriorating
Pauwalu-Kalaekapu (P)	1949	2000	51	3.9	0.07	9140	No	H - R - B	approx. 1000' reach at Kumimi Point is high priority
MAUI									
Kahului Bay (P)	1953	1999	46	21 west	0.5 west	2290	No	H	(S) Section 1 (west side) is high priority; need to address seaweed problem
Hookipa	1950	1990	40	indeterminate from photos			No	H - R	rocky cliff shoreline; short segment similar to Makua
Kealia Pond (P)	1949	1998	49	-14 avg	-0.31 avg	7280	Yes	H - B - O	(S) located within wildlife refuge
Ukumehame (P)	1949	1997	48	-28 max	-0.73 max	15120	No	H - R - B	(S) Section 2 & 3 are worse
Olowalu (P)	1971	1999	28	8.1	0.24	3910	No	H	(S) erosion is very localized at south end; cobble beach
Launiupoko	1949	1999	50	-43 avg	-1.01 avg	6850	No	H - R	significant beach erosion only at north end
HAWAII									
Laupahoehoe	1971	1987	16	indeterminate from photos			No	R	very high cliff shoreline
Peleuli Point	1971	1987	16	indeterminate from photos			No	R	very high cliff shoreline
Hilo Bayfront (P)	1949	1998	49	-36 west	-0.9 west	2950	No	H - R - B - O	Section 1 (west half of bayfront) is eroding; Section 2 (east half) is accreting

Notes: (P) indicates areas that are the subject of the conceptual design alternatives analysis.

Shoreline (Vegetation) Long-Term Change: positive values indicate accretion; negative values indicate erosion.

The length of shoreline affected by any conceptual alternative plan is not the same as the length of shoreline evaluated using the historical aerial photos. The latter generally encompasses a larger area.

Significant beach loss indicates average rate of recession of at least 0.5 feet per year or greater over time span of photo coverage.

Alternative Plans include H=hardening (shore protection structures), R=relocation (highway realignment), B=beach fill/nourishment, O=other

(S) indicates that additional topographic survey data have been acquired.

TABLE 4: SUMMARY TABLE OF ALTERNATIVE PLANS FOR RECOMMENDED HIGH PRIORITY SITES

ISLAND SHORELINE LOCATION	ALTERNATIVE PLAN ALONG ENTIRE REACH	R/W Acquisition	Planning, Permitting, Design	Construction Cost	Total First Cost for Specified Reach	Beach Nourishment Annual Cost	Beach Nourishment Estimated Frequency
OAHU							
Kawailoa Beach	Revetment	$0	$247,800	$1,049,200	$1,297,000	$0	
	CRM Seawall *	$0	$290,600	$1,230,700	$1,521,300	$0	
	Highway Realignment	$100,000	$1,715,000	$7,262,600	$9,077,600	$0	
	Beach Fill	$0	$363,200	$1,537,700	$1,900,900	$105,000	1500 cubic yards per year ÷ 800 linear feet beach = 1.9 CY/LF/YR
Hauula	Revetment *	$0	$995,200	$4,214,500	$5,209,700	$0	
	Highway Relocation	$13,500,000	$4,845,800	$20,522,100	$38,867,900	$0	
Punaluu	Revetment	$0	$983,800	$4,166,100	$5,149,900	$0	
	Highway Relocation	$4,000,000	$3,093,600	$13,101,100	$20,194,700	$0	
	Beach Fill *	$0	$1,017,000	$4,306,900	$5,323,900	$210,000	9000 cubic yards every 3 years ÷ 2400 linear feet beach = 1.25 CY/LF/YR
Kaaawa	Revetment *	$0	$1,988,000	$8,419,100	$10,407,100	$0	
Kaaawa-Kaolo Pt.	Revetment	$0	$2,373,800	$10,052,900	$12,426,700	$0	
	Revetment + Beach Fill *	$0	$2,538,000	$10,748,500	$13,286,500	$70,000	4100 cubic yards every 4 years ÷ 1100 linear feet beach = 1 CY/LF/YR
Mahie Pt - Kaolo Pt	Highway Relocation	$22,000,000	$5,368,600	$22,736,000	$50,104,600	$0	
Kualoa	Revetment	$0	$540,000	$2,286,800	$2,826,800	$0	
	Highway Relocation *	$700,000	$1,357,200	$5,747,500	$7,804,700	$0	
Makapuu Pier	Seawall with Upper Rock Slope *	$0	$722,800	$3,061,100	$3,783,900	$0	
	Highway Realignment	$0	$238,000	$1,007,800	$1,245,800	$0	
Makaha B.P.	Highway Relocation *	$2,000,000	$1,381,800	$5,851,900	$9,233,700	$0	
	Beach Fill with Grassed Dune	$0	$482,600	$2,043,900	$2,526,500	$273,000	3900 cubic yards per year ÷ 600 linear feet beach = 6.5 CY/LF/YR
	Revetted Dune	$0	$245,200	$1,038,700	$1,283,900	$0	
KAUAI							
Hanalei Bay	Revetment *	$0	$529,800	$2,243,400	$2,773,200	$0	
	Highway Realignment	$500,000	$2,348,200	$9,944,800	$12,793,000	$0	
MOLOKAI							
Niaupala Fishpond	Revetment *	$0	$325,600	$1,378,600	$1,704,200	$0	
	Beach Fill	$0	$609,600	$2,581,400	$3,191,000	$0	Beach protected by fishpond wall.
Waialua-Kumimi	Revetment	$0	$2,311,200	$9,788,200	$12,099,400	$0	
	Revetment + Highway Realignment	$2,500,000	$3,394,800	$14,377,000	$20,271,800	$0	
	Revetment + Beach Fill *	$0	$2,662,200	$11,274,100	$13,936,300	$0	Groins/breakwater will stabilize beach.
MAUI							
Kahului Bay	CRM Seawall	$0	$1,545,400	$6,544,500	$8,089,900	$0	
	CRM Seawall + Composite Slope *	$0	$944,600	$4,000,400	$4,945,000	$0	
Kealia Pond	Revetment	$0	$2,302,200	$9,750,000	$12,052,200	$0	
	Beach Fill *	$0	$1,249,800	$5,292,700	$6,542,500	$0	No significant nourishment for 25 years or more.
	Elevated Roadway	$150,000	$27,776,600	$117,633,800	$145,560,400	$0	
Ukumehame-Section 1	Revetment	$0	$809,400	$3,427,800	$4,237,200	$0	
Ukumehame-Section 2	Revetment	$0	$915,000	$3,875,000	$4,790,000	$0	
Ukumehame-Section 3	Revetment	$0	$1,244,800	$5,271,600	$6,516,400	$0	
Ukumehame-Section 3	Beach Fill	$0	$1,383,200	$5,857,800	$7,241,000	$0	Groins will stabilize beach.
Ukumehame-Section 1-3	Highway Relocation *	$10,000,000	$5,714,000	$24,199,000	$39,913,000	$0	
Olowalu	Revetment *	$0	$725,800	$3,073,900	$3,799,700	$0	
HAWAII							
Hilo Bayfront	Revetment	$0	$827,800	$3,506,000	$4,333,800	$0	
	Relocation Highway	$500,000	$1,473,400	$6,240,100	$8,213,500	$0	
	Beach Fill	$0	$2,461,200	$10,423,200	$12,884,400	$0	Groin field will stabilize beach.
	Groin Field Only *	$0	$488,000	$2,066,900	$2,554,900	$0	

Notes: First cost includes all costs through initial construction. Beach renourishment costs are not included.

Beach Nourishment cost is the estimated annualized (average annual) cost for periodic renourishment. Assume $70/CY in-place (planning, permitting, engineering/design completed as part of initial construction).

Some shoreline reaches have a combination of different alternatives. Refer to the plan sheets in Section 5.

Recommended Plans are indicated by asterisk (*). Section 2 summarizes the recommended alternatives.

2 - RECOMMENDATIONS

PRIORITY CRITERIA

During the inventory and assessment phase, shoreline areas were initially assigned a priority ranking based on the present condition of the shoreline and highway, and the susceptibility to future erosion and wave damage to the highway. The project funding limit necessitated the selection of high priority areas for which conceptual design alternatives would be developed to provide erosion protection or mitigation of wave damage. The analysis of shoreline changes using historical aerial photographs also provided a basis for evaluating the potential for future erosion damage. The shoreline areas that were selected for the development of conceptual alternative plans were chosen based on the following general criteria:

- Present evidence of shoreline erosion and imminent or actual highway damage due to wave attack, based on field observations.
- Long-term history of shoreline changes indicating significant erosionary trend.
- Potential for different types of approaches to dealing with the wave erosion problem.
- The selection of at least one shoreline site on each island.

RECOMMENDED ALTERNATIVES

A shoreline area is identified as a stretch of highway extending a few hundred feet along the shoreline, to as much as a few miles along the coast within a geographic location. For shoreline areas encompassing long stretches of highway, there may be multiple alternatives identified, or combinations of different alternatives to address the problem along the entire stretch of highway. For the sake of identifying and discussing the shoreline conditions and various alternative plans, shoreline segments were delineated as depicted on the plan sheets.

Conceptual alternative plans were developed cepending on the shoreline conditions and surrounding land uses. Note that the shoreline is a dynamic environment. At the time that a specific project site is budgeted for planning and design, the conditions may be very different. The socio-political environment could also be different. The preferred alternative identified in this study may not be the alternative of choice at the time of implementation. However, this report establishes a basis for budgeting for future work. Note also that the recommended alternative is not chosen based on only engineering and cost factors (i.e. cost-effectiveness), but takes into consideration the desires of the community and other stakeholders.

As a final note, we are an island state, and sooner or later, every mile of coastal highway will need to be dealt with either by protecting, relocating, or buffering with beach sand (provided we can find large enough sources for beach sand). It is the intent of this study to provide the groundwork for the future planning, design and construction of highway shore protection projects.

Section 5 provides plan sheets for all of the alternative plans. The recommended alternatives are summarized below for each shoreline area:

ISLAND OF OAHU:

KAWAILOA BEACH - **CRM Seawall** (Page 5-13): A seawall will protect the highway from seasonal high surf, while minimizing the "footprint" on the beach as compared to a revetment. This beach undergoes large seasonal fluctuations in beach profile, however, the emergent beachrock anchors the toe of the beach along this section. Therefore, the CRM seawall will protect the highway shoulder from erosion damage, without the need to commit to long-term or seasonal beach nourishment. The estimated first cost for 800 feet of seawall is $1,521,300. The cost of highway realignment ($9 million), while providing an opportunity for increased public accessibility, is hard to justify considering the other accessible beach areas along this north shore.

HAUULA - **Revetment** (Page 5-16): A revetment will protect the highway from seasonal high surf. Because there is little dry beach along this 2,300 feet stretch of shoreline, a revetment will replace the dumped boulders and concrete piles with a uniform rock slope. The estimated first cost for 2,250 feet of revetment is $5,209,700. A bypass highway is very expensive because of the level of residential development in this area and the large number of new bridges that would have to be built.

PUNALUU - **Beach Fill** (Page 5-20): Beach fill with an elevated dune is recommended to minimize wave overwash during seasonal high surf. The estimated first cost for beach fill along 2,100 feet of shoreline is $5,323,900, only slightly higher than the cost for a revetment. While beach nourishment is estimated at $210,000 annually, there is a possibility that nourishment may be less, depending on the seasonal wave climate. Restoring and maintaining a beach would greatly enhance the recreational capacity of this shoreline reach extending northward of Punaluu Beach Park.

KAAAWA - **Revetment** (Page 5-21): Revetments will protect two sections of highway from seasonal high surf. Because there is virtually no dry beach along this coastal reach, the revetments will replace the dumped rocks and concrete walls with a uniform rock slope. The estimated first cost for 4,400 feet of revetment is $10,407,100. A bypass highway, extending from Mahie Point to Kcolo Point, would guarantee that this 2-mile section of road would never again be closed or

affected by high winter surf events. However, this s a very scenic coastline and protecting the existing highway with a revetment would maintain the coastal views.

KAAAWA - KAOLO PT. - **Revetment + Beach Fill** (Page 5-25): A revetment is the recommended alternative for about 3,700 feet of highway south of Kalae Oio Beach Park (south of Kaaawa Bridge). Beach fill is recommended for about 1,100 feet of highway north of Kalae Oio Beach Park, extending to Kaaawa Beach Park. The estimated first cost for this revetment plus beach fill alternative is $13,286,500, only slightly higher than the cost for revetment only along this entire shoreline reach. While beach nourishment is estimated at $70,000 annually, there is a possibility that nourishment may be less, depending on the seasonal wave climate. Restoring and maintaining a beach would greatly enhance the recreational capacity of this shoreline reach extending between the two beach parks. As discussed above, a bypass highway extending from Mahie Point to Kaolo Point would guarantee that this 2-mile section of road would never again be closed or affected by high winter surf events. However, this is a very scenic coastline and protecting the existing highway with a revetment and beach would maintain and enhance the coastal views.

KUALOA - **Highway Relocation** (Page 5-27): The recommended alternative relocates 4,100 feet of highway inland about 250 feet, mauka of the sugar mill ruins. This section of coastal highway is frequently subject to wave overwash, and a revetment would need to be constructed with crest elevation higher than the roadway elevation to minimize wave overtopping. Such a shore protection measure would impact coastal views and access. Because this coastal reach is subject to long-term erosion, as evidenced by the erosion along the Kualoa Regional Park shoreline, relocating the highway inland is a prudent long-term solution. The estimated first cost for the relocated highway is $7,804,700. However, right-of-way acquisition costs could be minimized via a land exchange with Kualoa Ranch, because the relocated highway would facilitate Kualoa Ranch's access to the ocean at the locations where the existing highway sections are located directly adjacent to the ocean.

MAKAPUU PIER - **Retaining Wall** (Page 5-28): The recommended shore protection measure is a concrete retaining wall system at the base of the shoreline escarpment. Approximately 2,600 feet of highway will be protected by the concrete retaining wall, with top-of-wall elevation varying from 5 to 10 feet. The embankment slope above the wall will be faced with rock to minimize scouring of the slope from storm wave runup/overtopping of the wall and to prevent erosion from runoff. The estimated first cost is $3,783,900.

MAKAHA BEACH PARK - **Highway Relocation** (Page 5-30): About 600 feet of highway directly abuts Makaha Beach and is susceptible to wave overwash during storm events. The beach itself undergoes large seasonal fluctuations in beach profile and has suffered long-term erosion. Relocating the highway inland, around the mauka side of the City and County of Honolulu's comfort station facility, would provice a long-term solution and is consistent with the City's master plan for the beach park. The estimated first cos- is $9,233,700 for about 2,000 feet of new highway and one new bridge.

ISLAND OF KAUAI:

HANALEI BAY - **Revetment** (Page 5-34): A revetment will protect about 1,600 feet of highway on the extreme west side of Hanalei Bay. This shoreline reach is subject to seasonal wave attack and the beach width fluctuates from virtually no beach at Pohakuopo Point to a relatively wide beach near Waipa Stream mouth. The revetment would be partially buried within the beach, depending on the seasonal changes in beach profile. The estimated first cost is $2,773,200. The Department of Transportation, Kauai District, is planning to place approximately 3,000 cubic yards of sand along the worst section of highway as an emergency measure. The sand will be provided at no cost by the DLNR who is undertaking a wildlife habitat restoration project in Mana. Monitoring the condition of the shoreline after placement of the sand fill will provide data to determine the efficacy of beach nourishment as a shore protection measure for this section of the highway. The revetment option can be deferred until such time that it becomes necessary to implement.

ISLAND OF MOLOKAI:

NIAUPALA FISHPOND - **Revetment** (Page 5-37): A revetment will allow the highway shoulder to be reconstructed and protected. This 1,400 feet of highway forms the mauka shoreline of the fishpond. Estimated first cost for the revetment is $1,704,200. While beach fill could be placed along this shoreline, which would be protected from open ocean waves, a beach is not a natural feature of this shoreline reach and would likely become overgrown with vegetation over time.

WAIALUA - KUMIMI - **Revetment + Beach Fill** (Page 5-41): Revetment is recommended for 1,500 feet of highway at Waialua and 900 feet of highway at Kumimi. Beach fill is recommended for about 1,800 feet of highway at Palalupi, where there is an existing dry sand beach, but the beach berm is not high enough or wide enough to prevent wave erosion damage to the highway during storm wave attack. Because of the difficulty in providing periodic nourishment for this east Molokai area, groins are included to stabilize and contain the widened beach. The estimated first cost is $13,936,300.

ISLAND OF MAUI:

KAHULUI BAY - **CRM Seawall + Composite Slope** (Page 5-44): The ½ mile of shoreline on the west side of Kahului Bay has been artificially fixed by the highway and harbor basin structures. A CRM seawall is recommended for about 800 feet of highway outside the harbor. The seawall would be located within the highway right-of-way and would provide storm wave protection to the highway. A composite slope protection is recommended for about 2,600 feet of highway on the west side of the harbor basin. The existing shoreline consists of gravel and small rock on a relatively steep shoreline slope. The composite protection consists of a low profile concrete retaining wall along the MHHW line, with a rock slope above the wall to stabilize the upper shoreline embankment from storm wave overtopping and scouring. The concrete retaining wall at the waters edge would minimize the accumulation of seaweed on the shoreline. However, the low top-of-wall elevation would not prevent high surf from overtopping the wall and depositing seaweed on the backshore. Therefore, sufficient clear width is provided above the wall to enable access by heavy equipment to remove any accumulated seaweed. Total estimated first cost is $4,945,000.

KEALIA POND - **Beach Fill** (Page 5-46): Beach fill with an elevated dune is recommended to minimize wave overwash during seasonal high surf, although the beach would still be susceptible to wave overtopping during hurricane wave attack. The estimated first cost for beach fill along about 4,000 feet of highway is $6,542,500. There is not a large seasonal fluctuation in beach profile, although there has been long-term erosion. Based on the initial quantity of beach fill, it is expected that nourishment may not be required for about 25 years or so, or until erosion progresses into the dune section. If cost was not a factor, an elevated roadway would be the preferred alternative. The 1-mile long viaduct would be a permanent solution to the problem along this barrier beach shoreline fronting Kealia Pond, and would allow turtles and other wildlife to traverse the shoreline between the beach and the pond, unimpeded and not threatened by vehicular traffic. However, the $145 million cost for the viaduct would be difficult to justify.

UKUMEHAME - **Highway Relocation** (Page 5-49, 5-51, 5-53): The recommended alternative realigns about 3 miles of highway inland about 150 feet mauka of the existing highway. There are no homes affected by this realignment. Because of the primarily agricultural land use along this coast, right-of-way acquisition cost is relatively inexpensive compared to other coastal areas with residential land use. The estimated first cost for the realigned highway is $39,913,000, and although much more costly than protecting the five existing highway sections that are endangered by erosion, it is a permanent solution to the erosion problem along this entire coastal reach. For the approximate 2,000 feet of shoreline within Ukumehame Beach State Park, while beach fill could be implemented in lieu of realigning the highway, moving the highway would provide an opportunity to increase the beach park facilities. Removing the roadway pavement and allowing the shoreline to erode naturally may allow the beach to naturally restore itself. This recommendation is consistent with the community's desire as recommended by the West Maui Highway Action Committee, in their report *Recommendations for Traffic Improvements, West Maui Honoapiilani Highway Corridor, Maalaea-Kapalua,* dated January 2002.

OLOWALU - **Revetment** (Page 5-55): Revetment will protect the approximate 1,000 feet of highway on the west side of Hekili Point. Because the shoreline consists of cobbles and rocks (no dry beach sand), the revetment would be consistent with the existing shoreline condition. Emergency repairs have already been implemented along a short section where the highway pavement was undercut. The estimated first cost is $3,799,700.

ISLAND OF HAWAII:

HILO BAYFRONT - **Groin Field Only** (Page 5-59): The recommended alternative is a phased approach to the beach fill alternative. Only the groins would be constructed initially. From the sediment accumulation that occurred along the eastern half of the Bayfront shoreline subsequent to the construction of the groin adjacent to the Wailoa River mouth, it is expected that sand will similarly accumulate on the updrift side of the groins that are proposed for the western half of the Bayfront shoreline. If the rate of sand buildup on the updrift side of the groins is insufficient, then the beach can be supplemented by additional fill. Sand that has accumulated and already bypassed the Wailoa groin can be dredged and redeposited within the new groin field. The estimated first cost is $2,554,900 for the groins only (no initial beach fill).

3 - INVENTORY & ASSESSMENT

ISLAND OF OAHU

NORTH SHORE: (Page 3-5)

Kawailoa: There are two stretches of highway (700 feet and 200 feet) that are directly exposed to the ocean. The shoulder is narrow and erosion damage is evident from the undercutting of the boulder-protected escarpment.

Waimea Bay: With the realignment of the highway on the northeast side of the bay, the shoreline has been stabilized with revetment structure. The highway on the southwest side of the bay has a narrow shoulder that is showing signs of settlement. Temporary barriers have been placed to prevent parking along the shoulder. This is not considered a shoreline erosion problem.

Sunset Beach: There is a 1000 foot highway segment that is directly exposed to the ocean. There is a narrow shoulder for parking, fronted by a walkway/bikeway. The beach width varies seasonally, and can sustain wave runup and overwash of the highway during high storm surf conditions.

WINDWARD: (Page 3-6)

Hauula: Approximately 2300 feet of highway directly fronts the shoreline, and is subject to erosion damage and wave overwash. The US Army Corps of Engineers is the project sponsor for a proposed shoreline revetment project along about 1150 feet of this stretch of highway.

Punaluu: Approximately 2100 feet of highway north of Punaluu Beach Park directly fronts the shoreline, and is subject to erosion damage and wave overwash. About 630 feet is proposed to be protected by a shoreline revetment sponsored by the U.S. Army Corps of Engineers.

Kahana Bay: Two short 200-300 foot sections on the west side of the bay have narrow shoulders, and erosion damage is evident from the placement of large boulders.

Kaaawa - Kualoa: This entire 4 mile stretch of coastline is subject to chronic erosion. Approximately 3000 feet of highway from Mahie Point to Kaaawa Point has narrow shoulders and evidence of prior protective measures along certain sections of the shoreline. About 1500 feet of highway north of Kaaawa Beach Park has narrow shoulders and is protected by various types of shore protection structures, ranging from dumped rocks to concrete walls. About 1000 feet of highway north of Kalae Oio Beach Park has narrow shoulders and is protected by stacked concrete piles. About 4000 feet of highway from Kalae Oio Beach Park southward to Kaolo Point has narrow shoulders and various types of shore protection structures. The US Army Corps of Engineers is the project sponsor for a proposed shoreline revetment project along about 880 feet of this stretch of highway. Two highway segments north of Kualoa Beach Park are subject to erosion and wave overwash.

WINDWARD: (Page 3-7)

Kaiona Beach: Approximately 2000 feet of highway directly fronts Kaiona Beach. Seawalls protect a section of this highway. A relatively wide sandy beach fronts this area, but erosion is ongoing at the eastern end where boulders have been dumped in front of the seawall.

Makapuu Pier: Approximately 1000 feet of highway on the southeast side of the Makapuu Pier is in various stages of erosion damage. Erosion of the fronting beach and subsequent erosion of the base of the escarpment has resulted in collapse of sections of the highway shoulder, and there is no little or no buffer between the guardrail and the top edge of the escarpment. About 600-800 feet of highway on the northwest side of the pier and fronting the Oceanic Institute have narrow shoulders and steep shoreline embankment.

LEEWARD: (Page 3-8)

Nanakuli: The 2 mile stretch of highway from Nanakuli Beach Park northwestward to Maili Point follows the coastline and is set back from the abandoned railroad right-of-way. The beach dune backshore is at higher elevation than the highway, and there are low CRM walls on the mauka side of the dunes to provide some measure of protection from wave overwash of the beach and dune shoreline. The beach width likely varies seasonally, and there is a protective line of beachrock along the toe of the beach. Because there is sufficient buffer between the beach dune and the highway, this area is not considered an erosion problem for the highway.

Maili: The 1-1/2 mile stretch of highway from Ulehawa Beach Park northward to Mailiilii Stream (Lualualei Beach Park) is similar to the Nanakuli coastline. The highway is set back from the abandoned railroad right-of-way, and low walls on the mauka side of the beach berm provide some measure of protection from wave overwash of the beach. The beach and shoreline buffer zone (park area) is typically wider along this coastal reach than at Nanakuli. Because there is sufficient buffer between the beach and the highway, this area is not considered an erosion problem for the highway.

Mauna Lahilahi Beach Park: Approximately 2000 feet of highway fronts the beach between

Waianae High School and Lahilahi Point. Tiered walls separate the beach from the sidewalk and highway, and there is no shoreline buffer zone. The top of the tiered wall establishes the top elevation of the beach berm, and it is apparent that wave overwash of the beach is a problem. Although erosion damage to the highway is not a significant concern, this area is considered an area of concern because of the overwash problem.

Makaha Beach Park: Approximately 1000 feet of highway directly fronts Makaha Beach. There is no significant shoreline buffer between the beach and the highway shoulder that is used for parking. The beach is wide and erosion damage to the highway is not a significant concern, but there are problems with wave overwash of the beach and highway.

Keaau: Two short 200-foot sections of highway north of Keaau Beach Park are subject to potential storm wave damage.

Makua: The approximate 3000 foot stretch of highway along the cliff-side between Makua Beach and Kaena Point State Park is protected along certain segments by various seawalls and rock walls. Short unprotected segments have little or no shoulder, and undercutting of the embankment could lead to damage to the highway.

ISLAND OF KAUAI (Page 3-9)

Haena: There is a short 200 foot shoreline reach on the west side of the bay that sustains wave runup and overwash of the roadway during high surf conditions.There is no evidence that erosion is endangering the roadway.

Wainiha: There are problems with shoreline slope stability where the roadway is located at the edge of the cliff, on the east and west sides of the bay. An approximate +300 foot highway segment on the east side is in deteriorated condition, where the roadway pavement and low concrete barrier walls are cracking due to differential settlement. A project is already underway to address the problem. An approximate 400 foot highway segment on the west side shows no apparent signs of settling, but there is only a narrow shoulder, and erosion at the base of the cliff could lead to future problems.

Hanalei Bay: Approximately 1600 feet on the west side of the bay shows evidence of erosion problems. There is virtually no shoreline buffer zone between the beach and the roadway.

Kapaa: The highway in Kapaa has been relocated inland of the old coastal road along an approximate 1-1/4 mile stretch of coastline. While there are signs of erosion problems along the coastline, there is sufficient buffer between the old road and the existing highway. This area is not considered an area of concern.

Wailua: Approximately 2000 feet of highway directly fronts Wailua Beach. The beach is wide and shows no sign of chronic erosion, although there is likely seasonal changes in the beach width. There is evidence of shoreline protection (rocks) along the edge of the highway.

Kekaha: Approximately 2 miles of highway directly fronts the coastline from Oomano Point westward past Kekaha town. This entire stretch of coastline is protected with rock revetment. About 5800 feet of revetment fronting Kekaha Beach was built in the late 1970s by the U.S. Army Corps of Engineers after chronic erosion resulted in complete loss of the beach and closure of the highway due to undermining damage. The beach has since recovered and sections of the revetment are covered by the sand dunes that have naturally accreted. About 4000 feet of revetment around Oomano Point was constructed more recently by the State Highway District. Because this entire stretch of highway is now protected, future erosion will not endanger the highway, although storm wave overtopping may occur.

ISLAND OF MOLOKAI

SOUTHEAST: (Page 3-10)

Kamiloloa: There is a 700 foot stretch of highway near One Alii Homestead that is subject to erosion damage. The shoulder is narrow and rocks have been dumped along the shoreline.

Kawela: There is a 600 foot stretch of highway near the Kakahaia Wildlife Refuge that is subject to erosion damage. The shoulder is narrow and rocks have been dumped along the shoreline.

Pchiomu Fishpond - Kamahuehue Fishpond: There are short 200-300 foot sections of highway between the two fishponds that are subject to erosion damage. The shoulder is narrow and rocks have been dumped along the shoreline.

Niaupala Fishpond: Approximately 1200 feet of highway within the fishpond boundaries is in need of shoreline stabilization. The shoulders have eroded and collapsed, and the pavement is subject to undercutting.

EAST: (Page 3-11)

Kupeke Fishpond: A short 200 foot section of highway within the fishpond boundaries is in need of shoreline stabilization. The old rock walls are deteriorating and the shoulder is very narrow.

Pauwalu - Kalaekapu: This approximate 3 mile stretch of southeast-facing coastline is subject to erosion. There are four short 200 foot sections of the highway between Pauwalu and Waialua that have narrow eroding shoulders and rock or seawall structures in various stages of disrepair. About 1300 feet of highway northeastward of Waialua has narrow eroding shoulders. The next 1700 feet

of highway to Palalupi has narrow eroding shoulders, dumped rock and remnants of seawall structures. From Kumimi to Kalaekapu, the road winds along the edge of the cliffs, down into two embayments, and finally heads inland. An approximate 1000 foot reach from Kumimi Point into the first embayment has been stabilized by rock walls that are in various stages of deterioration. There is a void (cavity) extending about 10 feet mauka beneath the road at a location about midway into the embayment. A 600 foot reach on the northeast side of the embayment has narrow shoulder and steep embankment.

ISLAND OF MAUI

CENTRAL: (Page 3-12)

Kahului Bay: Approximately 3400 feet of highway within Kahului Bay is subject to erosion damage. About 1600 feet of cobble-strewn shoreline within the harbor is subject to wave runup that has eroded the shoreline embankment, and temporary barriers have been erected along the narrow shoulder. Another 1800 feet of shoreline, including areas outside the harbor, are susceptible to storm wave damage.

Kuau-Hookipa Park: The stretch of highway between Kuau and Hookipa Park follows along the edge of the cliff. There is only a narrow shoulder and erosion at the base of the cliff could lead to slope stability problems.

Kealia Pond: The 1-mile stretch of highway fronting Kealia Pond is vulnerable to erosion damage and wave overwash. There is little or no shoulder along much of this shoreline reach.

WEST MAUI: (Page 3-13)

Ukumehame: The 3 mile stretch of coastline from the Pali northwestward to Hekili Point is subject to erosion. The highway directly fronts the coastline along this entire reach. Erosion has resulted in undermining of the shoulder along sections of highway, and wave overwash of some sections on a regular basis.

Olowalu: Approximately 1 mile of highway directly fronts the coastline northwestward of Hekili Point. There is a short 200 foot segment of highway on the northwest side of Hekili Point that has suffered significant erosion damage, and has recently been repaired.

Launiupoko: The approximately 1-1/2 mile stretch of highway from Launiupoko Point to Lahaina town directly fronts the coastline and is subject to chronic erosion. Shore protection has been constructed to protect Launiupoko State Park lands, and DOT-Highways plans to construct shore protection for 1000 feet of highway north of the park under a U.S. Army Corps of Engineers' sponsored project.

Wahikuli: About 600 feet of highway on the south side of Wahikuli State Park directly fronts the coastline. This stretch is revetted but sustains wave overtopping. Because the shore protection provides adequate protection against erosion, the wave overtopping is considered a maintenance problem.

ISLAND OF HAWAII (Page 3-14)

Laupahoehoe: There are potential problems with slope stability where the highway is located very close to the top edge of the cliff. About 1000 feet of highway on the southeast side of Kuwaikahi Bridge has narrow shoulders and the vegetation near the top of the cliffside slope shows evidence that the embankment is sliding or collapsing.

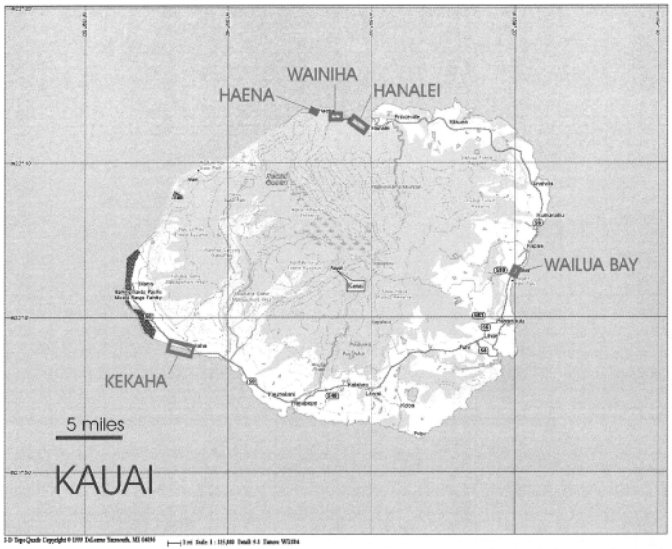
Umauma (north of Peleuli Point): About 1100 feet of highway southeast of Opea Bridge is located very close to the top edge of the cliff. There are existing problems with slope stability, where a section of the highway has settled and the shoulder pavement is cracking. State Highway engineers have measured 1/4 to 1/2 inch per month of lateral movement in a 10-month period since October 1999.

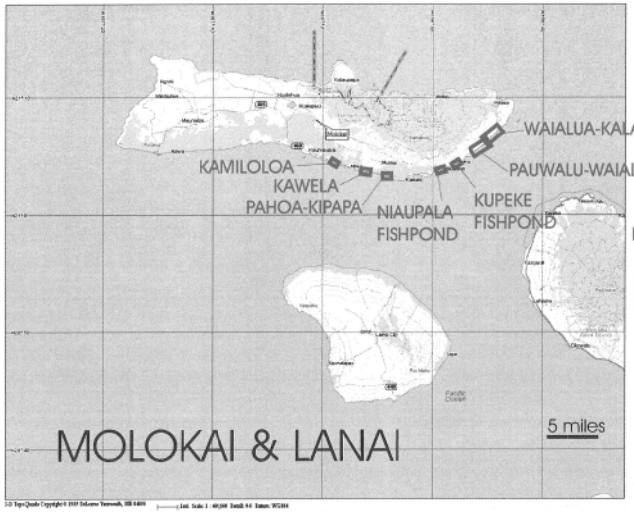
Hakalau Bridge: A site visit was made to assess the potential problems due to movement of sediments affecting the bridge footings. Apparently, sands and gravels can accrete at the mouth of the river, and effectively burying the abutments for the bridge footings, making it difficult to inspect. At the time of the site visit, the footings were not obstructed and there was little sediment blocking the stream mouth. This is not considered a shoreline erosion problem.

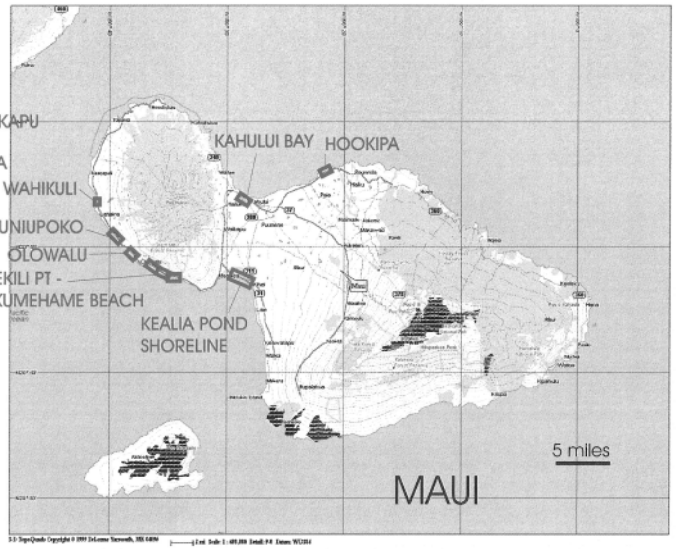
Wainaku: A short 200 foot section of highway on the south side of Alealea Point was recently stabilized by constructing a new concrete wall at the base of the cliff, and grading and filling the upper slope with rock. This is an example of how other cliffside areas can be stabilized.

Hilo Bayfront: Approximately 2500 feet of highway on the western half of the bayfront shoreline is subject to erosion damage and wave overwash. Shore protection along this coastal reach is in various stages of disrepair. The shore protection for about 400 feet of highway at the west end next to Cocoanut Point is in relatively good condition.

Naalehu: There is a 300 foot section of highway above Honuapo Bay that is close to the edge of the cliff. From a review of the aerial photograph and the geology of this coastal reach, this is not considered a shoreline erosion problem.

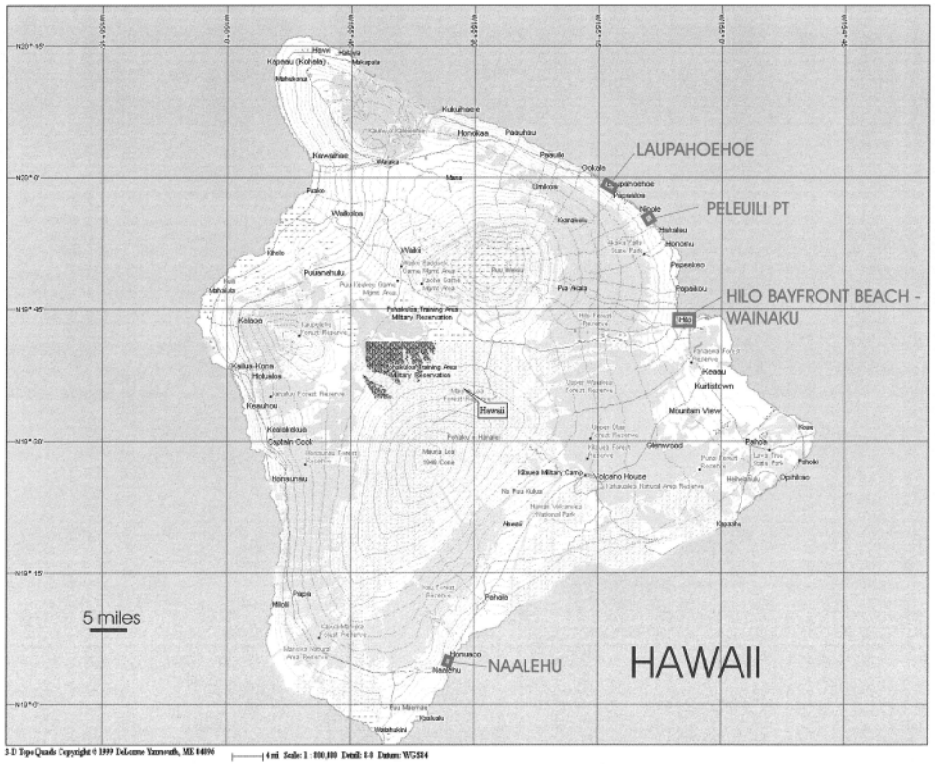


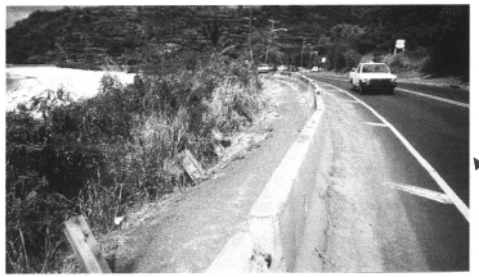




AERIAL PHOTO COVERAGE - AREAS OF CONCERN







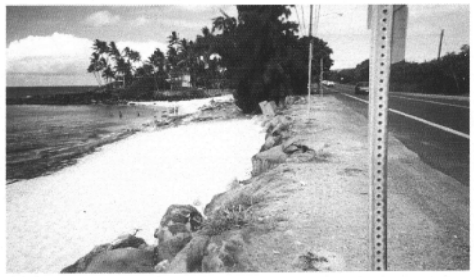
Waimea Bay. Narrow shoulder on southwest side of bay is settling. Temporary barriers prevent cars from parking. (9-13-00)



Waimea Bay. Revetment protecting realigned highway on northeast side of bay. (9-13-00)



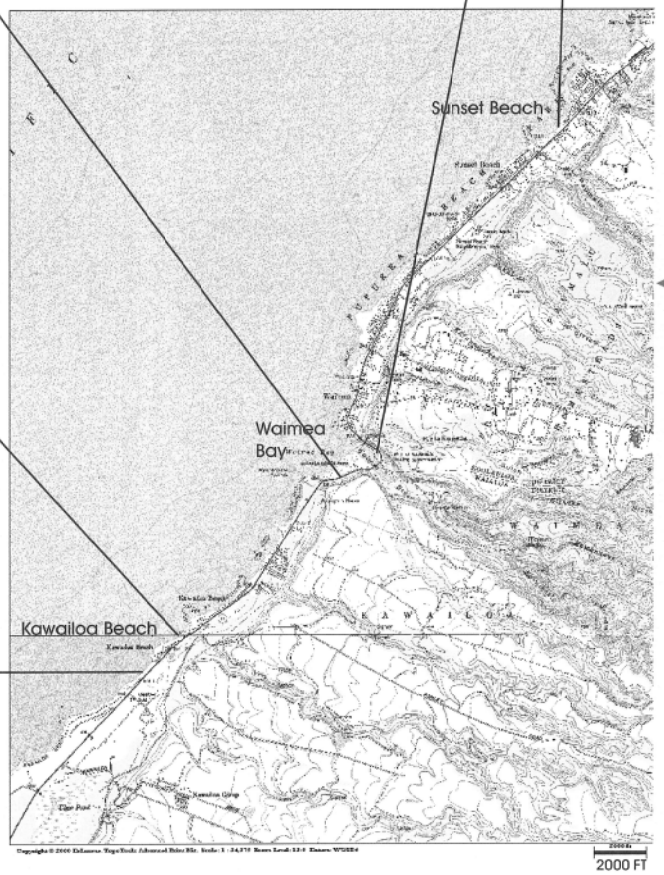
Sunset Beach. Bikeway/walkway separates beach from highway shoulder used for parking. Beach width varies seasonally and highway can sustain wave overwash during winter surf. (9-13-00, 2:30 pm, tide 2.0' MLLW)

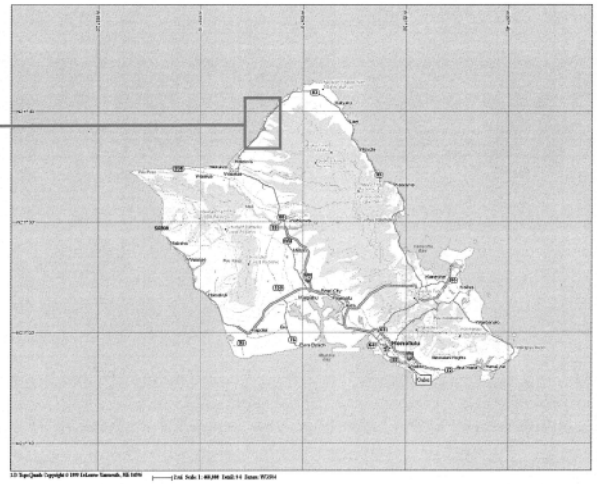


Kawailoa. Highway directly exposed to ocean, with narrow, eroding shoulder. (9-13-00, 3:30 pm, 2.0' MLLW)



Kawailoa. Highway directly exposed to ocean, with narrow, eroding shoulder. (9-13-00, 3:30 pm, tide 2.0' MLLW)





ISLAND OF OAHU
NORTH SHORE AREAS OF CONCERN

Statewide Highway Shoreline Protection
Project number HWY-08-98



Hauula. Existing seawall, constructed with concrete piles, provides minimal protection from wave overwash. (9-13-00, 2:00 pm, tide 2.0' MLLW)



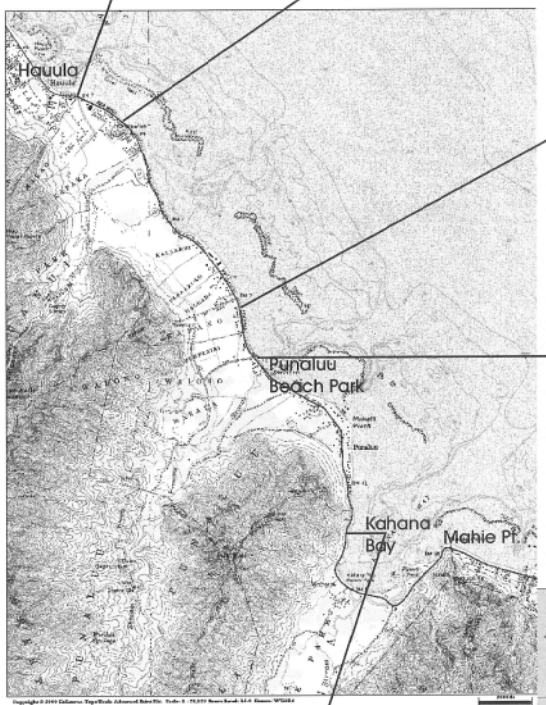
Hauula. Stretch of highway proposed to be protected with rock revetment by U.S. Army Corps of Engineers. (9-13-00, 1:55 pm, tide 2.0' MLLW)



Mahie Pt. - Kaaawa Pt. Highway has narrow shoulder and different types of protective structures. (9-13-00, 12:50 pm, tide 1.7' MLLW)



North of Kaaawa Beach Park. Highway has narrow shoulder protected by various types of structures. (9-13-00, 12:35 pm, tide 1.6' MLLW)





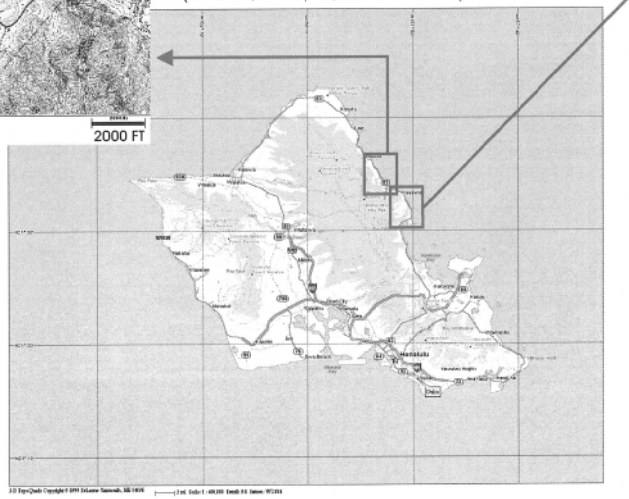
Punaluu. Stretch of highway proposed to be protected with rock revetment by U.S. Army Corps of Engineers. (9-13-00, 1:45 pm, tide 2.0' MLLW)

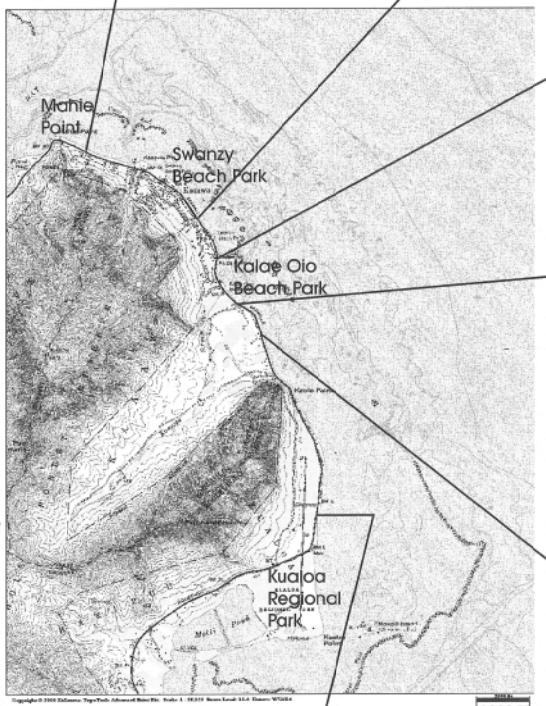


Punaluu. North side of Punaluu Beach Park. (9-13-00, 1:40 pm, tide 2.0' MLLW)



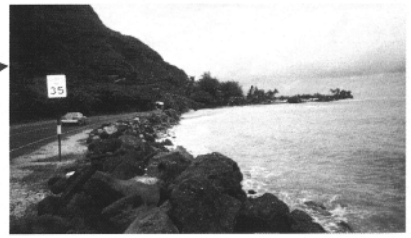
Kahana Bay. Short sections on west side of the bay have narrow, eroding shoulders. (9-13-00, 1:00 pm, tide 1.8' MLLW)







North of Kalae Oio Beach Park. Highway has narrow shoulder and is protected by stacked concrete piles. (9-13-00, 12:20 pm, tide 1.5' MLLW)



South of Kalae Oio Beach Park. Proposed for new rock revetment by U.S. Army Corps of Engineers. (9-13-00, 12:10 pm, tide 1.5' MLLW)



North of Kaolo Pt. Highway has narrow shoulder and various types of shore protection. (9-13-00, 12:00 pm, tide 1.4' MLLW)



North of Kualoa Beach Park. Exposed segments of highway subject to erosion and wave overwash. (9-13-00, 11:50 pm, tide 1.4' MLLW)

ISLAND OF OAHU
WINDWARD AREAS OF CONCERN

Statewide Highway Shoreline Protection
Project number HWY-08-98



Kaiona Beach. Seawalls protect a section of the highway. This section of beach has been relatively stable in recent times.
(9-13-00, 10:30 am, tide 0.8' MLLW)



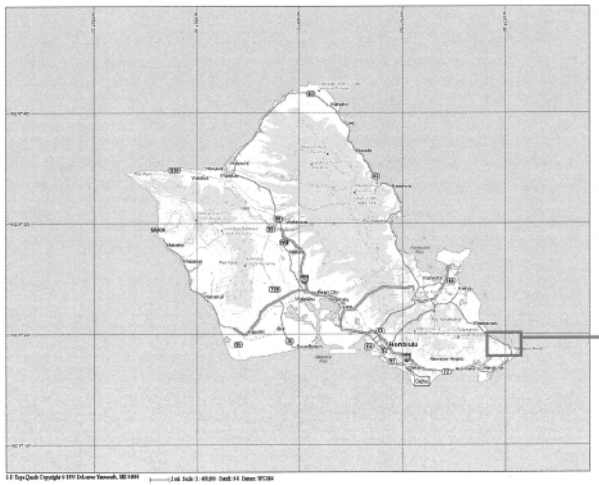
Kaiona Beach. Boulders have been dumped in front of the seawall along this eroding section at the eastern end. (9-13-00, 10:30 am, tide 0.8' MLLW)

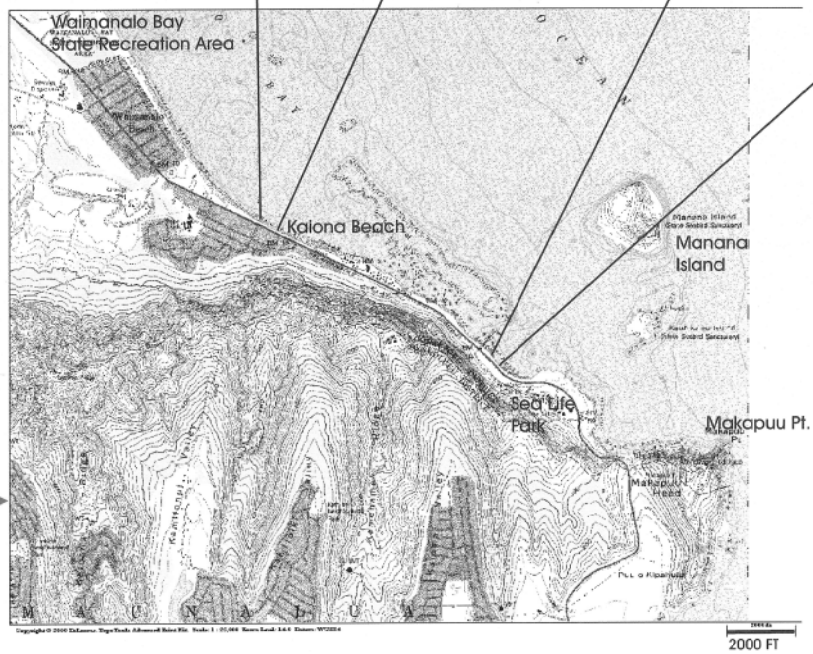


Near Makapuu Pier. Erosion of the fronting beach and base of the escarpment has resulted in collapse of a section of the highway shoulder on the east side of Makapuu Pier. (9-13-00, 9:40 am, tide 0.5' MLLW)



East of Makapuu Pier. Along another section of highway towards Sea Life Park, erosion has resulted in little or no buffer between the guardrail and the top edge of the escarpment. Concrete piles have been stacked against the escarpment to help stabilize the slope.
(9-13-00, 9:40 am, tide 0.5' MLLW)





ISLAND OF OAHU
WINDWARD AREAS OF CONCERN

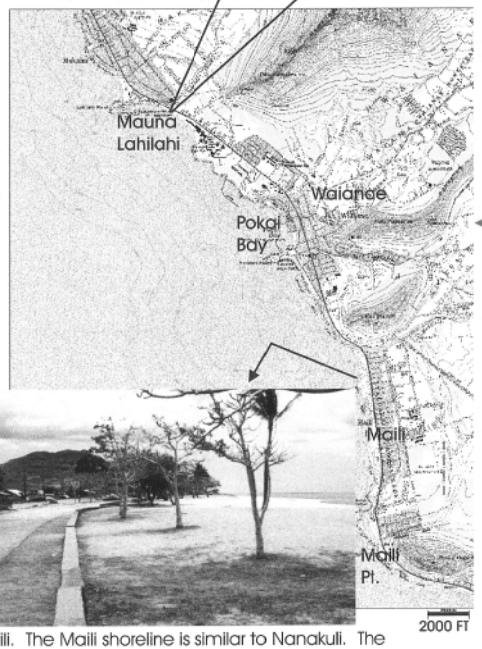
Statewide Highway Shoreline Protection
Project number HWY-08-98



Mauna Lahilahi. The top of the tiered wall establishes the top elevation of the beach berm. Wave overwash is a problem. (9-14-00, 11:50 am, tide 0.6' MLLW)



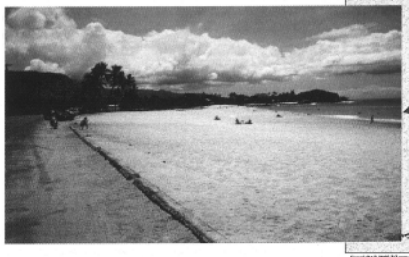
Mauna Lahilahi. Tiered walls separate the beach from the sidewalk and highway. There is no shoreline buffer zone. (9-14-00)



Maili. The Maili shoreline is similar to Nanakuli. The highway is set back from the beach and there are low CRM walls on the mauka side of the beach. (9-14-00)



Keaau. Two short sections of highway north of Keaau Beach Park are subject to storm wave erosion damage near bridges. (9-14-00, 11:20 am, tide 0.5' MLLW)



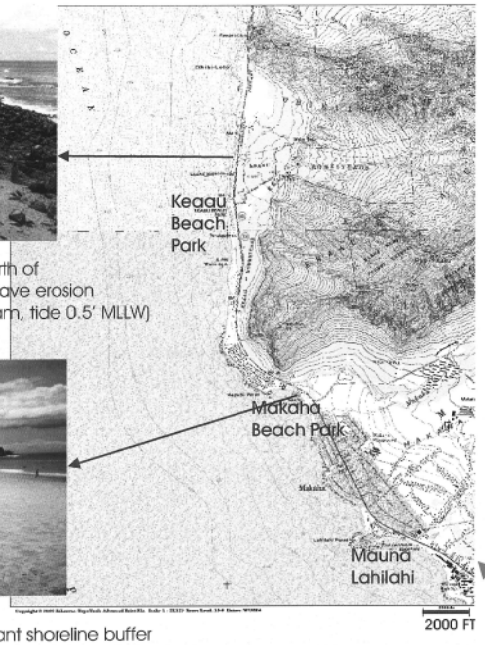
Makaha Beach Park. There is no significant shoreline buffer between the beach and the highway shoulder that is used for parking. The beach is wide, but there are problems with wave overwash of the highway during storm surf conditions. (9-14-00, 11:40 am, tide 0.5' MLLW)



Nanakuli. The beach width varies seasonally, and there is a protective line of beachrock along the toe of the beach. (9-14-00, 12:20 pm, tide 0.7' MLLW)

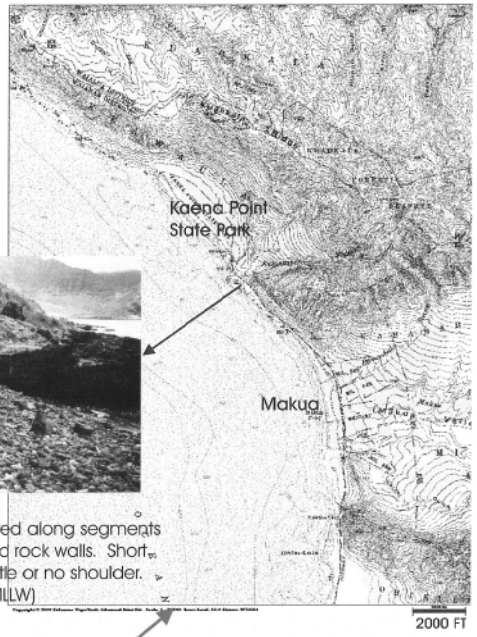


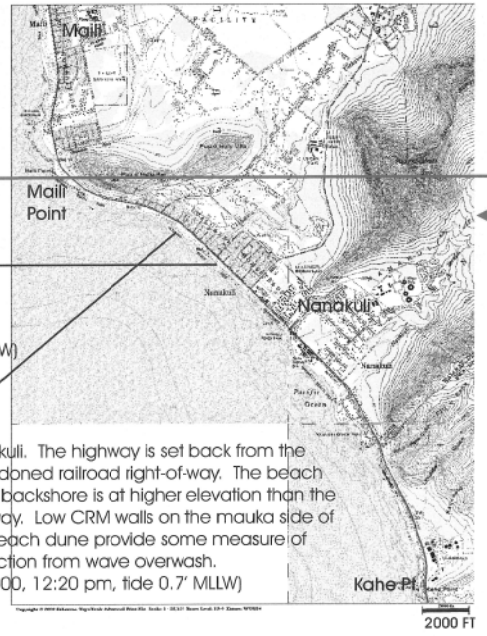
Nanakuli. The highway is set back from the abandoned railroad right-of-way. The beach dune backshore is at higher elevation than the highway. Low CRM walls on the mauka side of the beach dune provide some measure of protection from wave overwash. (9-14-00, 12:20 pm, tide 0.7' MLLW)

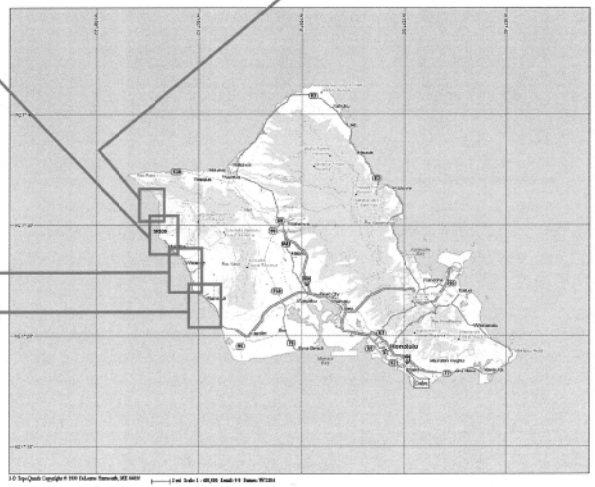




Makua. The highway is protected along segments by various types of seawalls and rock walls. Short unprotected segments have little or no shoulder. (9-14-00, 11:00 am, tide 0.4' MLLW)







ISLAND OF OAHU
LEEWARD AREAS OF CONCERN

Statewide Highway Shoreline Protection
Project number HWY-08-98



Wainiha Bay. Short stretch of highway on east side of bay shows signs of differential settlement due to possible erosion at base of the cliff. (8-24-00)



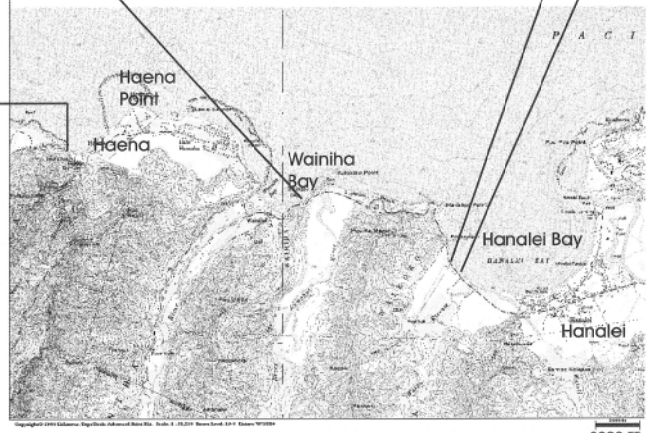
Hanalei Bay. Collapsed bridge on west side of bay has not been rebuilt. Erosion of shoreline continues to endanger integrity of road and bridge. (8-24-00)

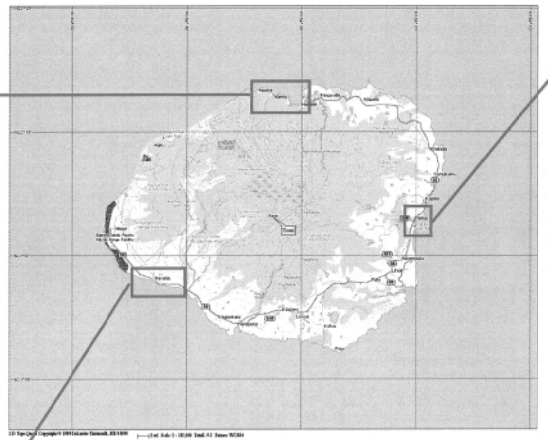


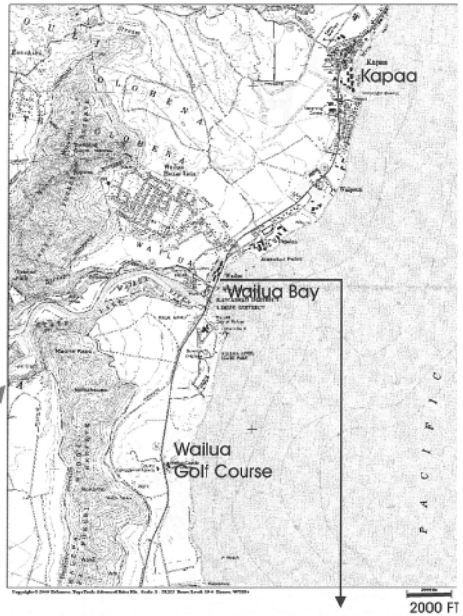
Hanalei Bay. West side of bay shows evidence of shoreline erosion. Vegetated shoulder of highway is eroded and narrow. (8-24-00, 4:00 pm, tide 0.8' MLLW)



Haena Bay. Short stretch of highway on west side of bay sustains wave overwash during high surf conditions. (8-24-00)





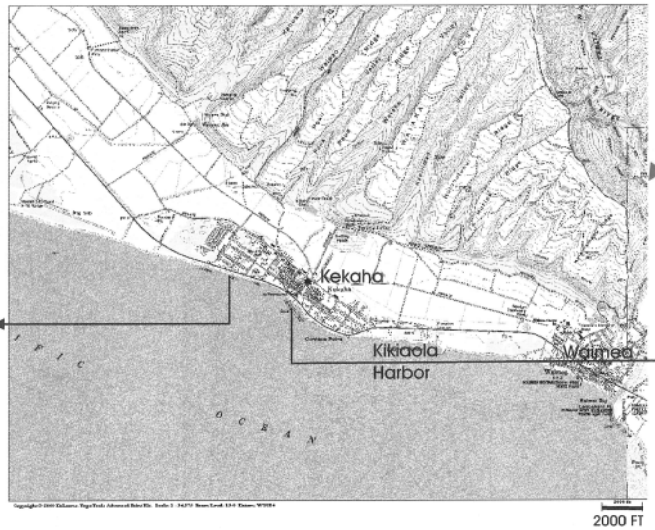




Wailua Bay. Beach is wide, but likely undergoes seasonal changes. No evidence of chronic erosion. (8-24-00, 12:00 pm, tide 2.2' MLLW)



Kekaha. Over 1 mile of shoreline was revetted by the U.S. Army Corps of Engineers in late 1970s when chronic erosion undermined the highway. This entire reach has since accreted and dunes bury the revetment. (8-24-00, 10:30 am, tide 2.0' MLLW)

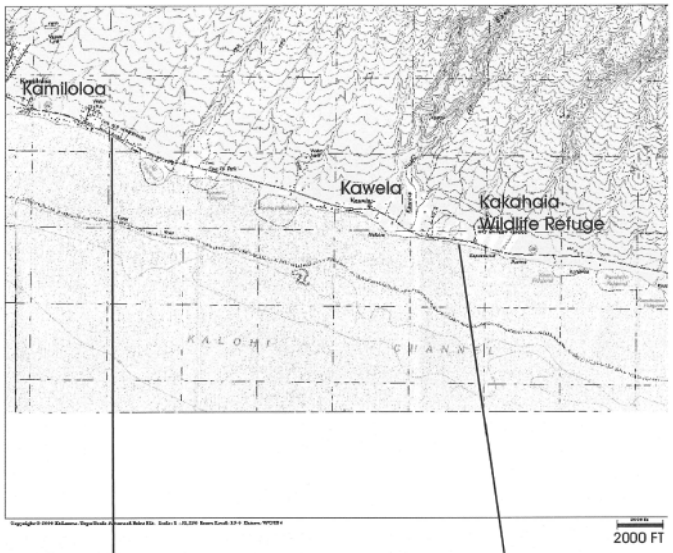


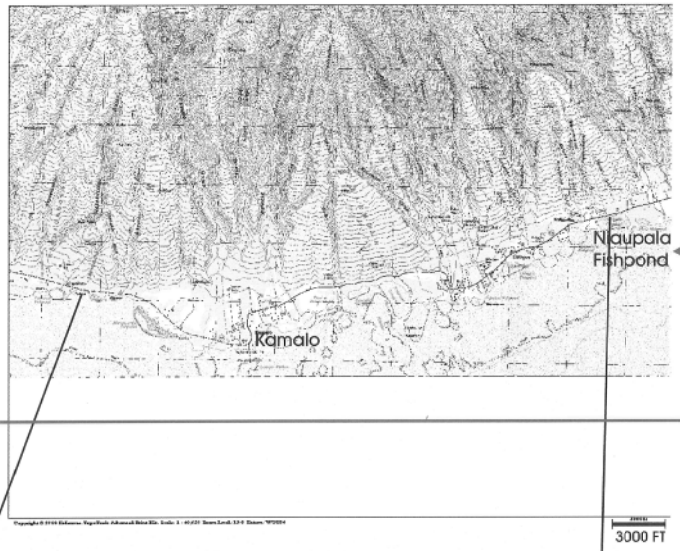


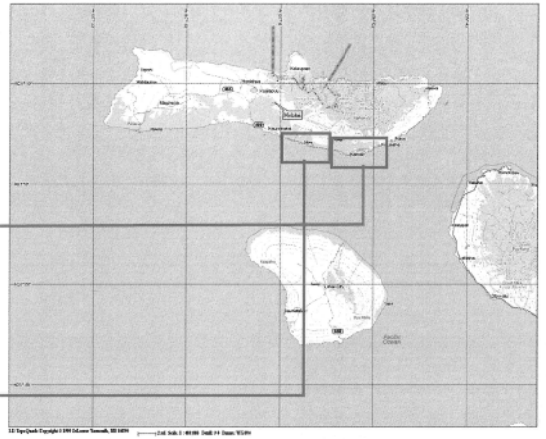
Kekaha. Revetment was extended more recently around Oomano Point to protect the highway. (8-24-00, 10:00 am, tide 1.8' MLLW)

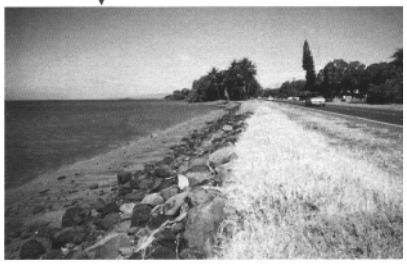
ISLAND OF KAUAI
AREAS OF CONCERN

Statewide Highway Shoreline Protection
Project number HWY-08-98









Kamiloloa. Highway fronting One Alii Homestead is subject to erosion damage. Rocks have been dumped and shoulder is narrow. (8-31-00, 9:40 am, tide 0.5' MLLW)



Pahiomu-Kamahuehue Fishponds. Short sections of highway between the two fishponds are subject to erosion damage. (8-31-00, 10:15 am, tide 0.4' MLLW)



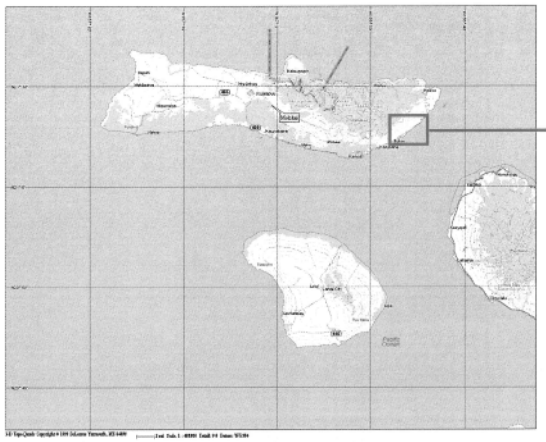
Kawela. Highway fronting Kakahaia Wildlife Refuge is subject to erosion damage. Rocks have been dumped and shoulder in narrow. (8-31-00, 10:00 am, tide 0.4' MLLW)

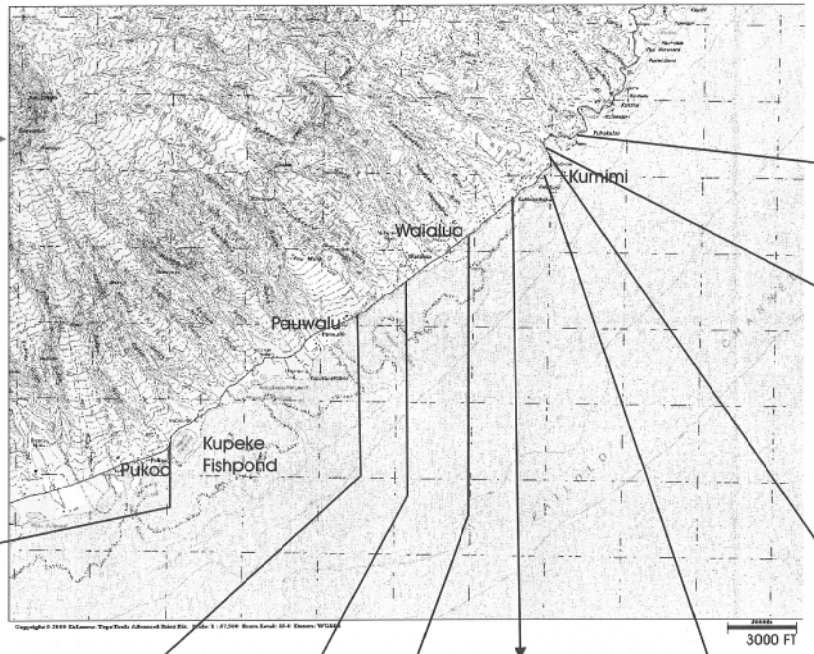


Niaupala Fishpond. Highway bordering the fishpond is in need of shoreline stabilization. (8-31-00, 10:30 am, tide 0.4' MLLW)

ISLAND OF MOLOKAI
AREAS OF CONCERN

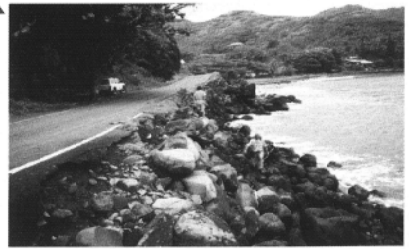
Statewide Highway Shoreline Protection
Project number HWY-08-98







Stretch of highway on northeast side of Kumimi embayment. (8-31-00)



Kumimi. The road shoulder on the southwest side of the Kumimi embayment is in deteriorated condition. (8-31-00, 11:50 am, tide 0.6' MLLW)



Kupeke Fishpond. Short section of highway bordering the fishpond is in need of shoreline stabilization. (8-31-00, 10:40 am, tide 0.4' MLLW)



Pauwalu. Section of highway between Pauwalu and Waialua has narrow eroding shoulder and dumped rock. (8-31-00, 11:15 am, tide 0.4' MLLW)



Palalupi. Highway near Palalupi has narrow eroding shoulder. (8-31-00, 11:40 am, tide 0.5' MLLW)



Kumimi. From Kumimi Pt. Into the embayment, the road follows the cliff. Rock walls are in deteriorated condition. (8-31-00, 11:45 am, tide 0.5' MLLW)



Pauwalu. Section of highway between Pauwalu and Waialua has narrow eroding shoulder and dumped rock. (8-31-00, 11:00 am, tide 0.4' MLLW)



Waialua. Highway from Waialua to Palalupi has narrow eroding shoulder and dumped rocks. (8-31-00, 11:35 am, tide 0.5' MLLW)



Palalupi. Highway near Palalupi has eroded shoulder that is undercut because of erosion of fronting beach. (8-31-00, 11:40 am, tide 0.5' MLLW)

ISLAND OF MOLOKAI
AREAS OF CONCERN

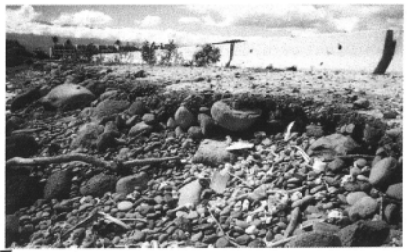
Statewide Highway Shoreline Protection
Project number HWY-08-98



Kahului Bay. Shoreline reach on northwest side of harbor is subject to erosion damage. Concrete barriers protect highway from wave overwash. (8-14-00, 9:40 am, tide 0.6' MLLW)



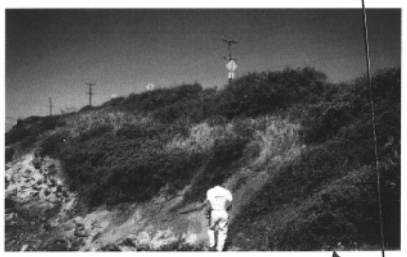
Kahului Bay. Eroded shoreline within the harbor has required fill, and temporary concrete barriers are placed along the narrow shoulder. (8-14-00, 9:30 am, tide 0.6' MLLW)



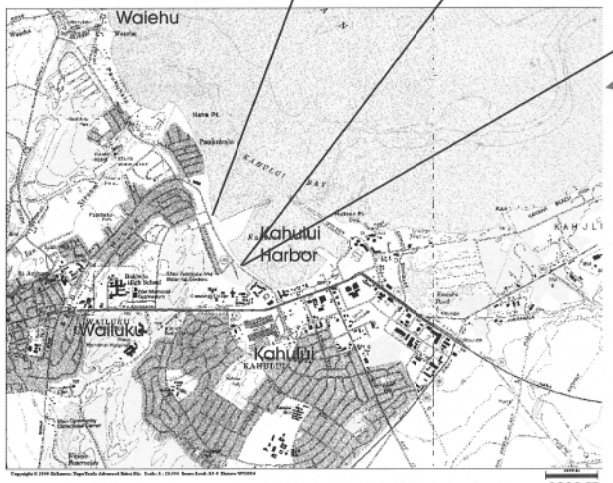
Kahului Bay. Erosion has damaged the shoreline embankment along the highway shoulder within the harbor. (8-14-00)

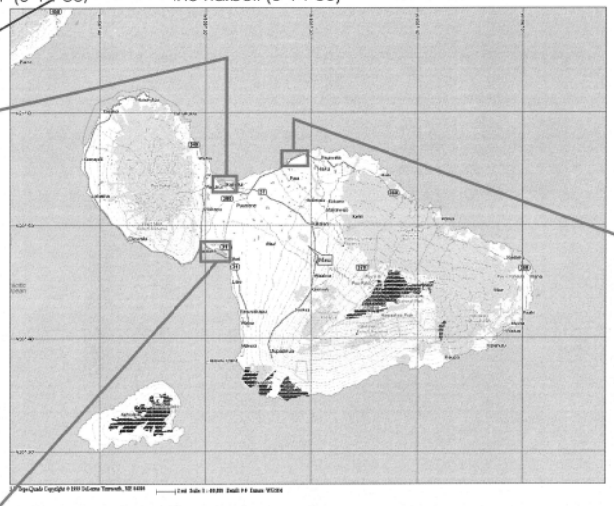


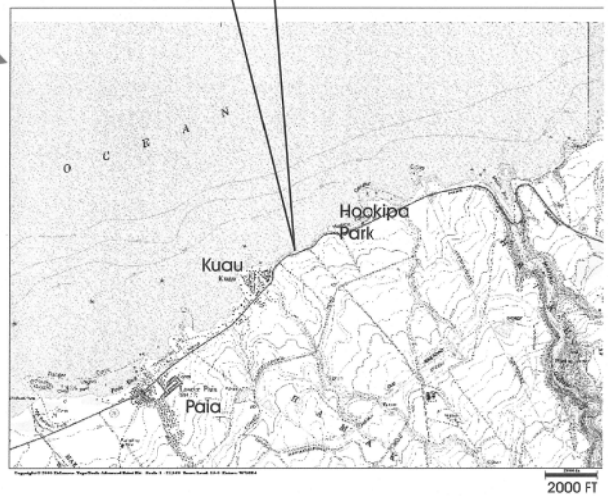
Kuau-Hookipa Park. The highway follows along the top edge of the cliff. The highway shoulder is narrow. (8-14-00, 3:20 pm, tide 2.2' MLLW)

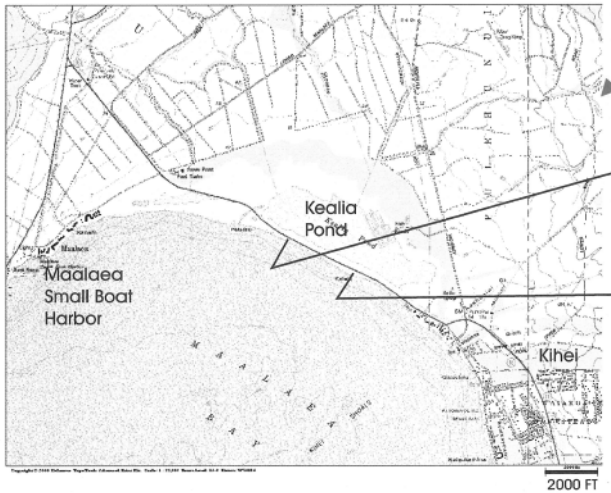


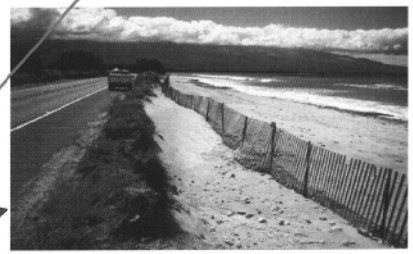
Kuau-Hookipa Park. The shoreline is rocky, but large waves can reach the base of the cliff and cause slope stability problems. (8-14-00, 3:20 pm, tide 2.2' MLLW)











Kealia Pond. Highway fronting Kealia Pond is vulnerable to erosion damage and wave overwash. The pavement is subject to undermining in some areas. The wooden fence has been erected to prevent nesting turtles from crossing the highway. (8-14-00, 10:20 am, tide 0.3' MLLW)



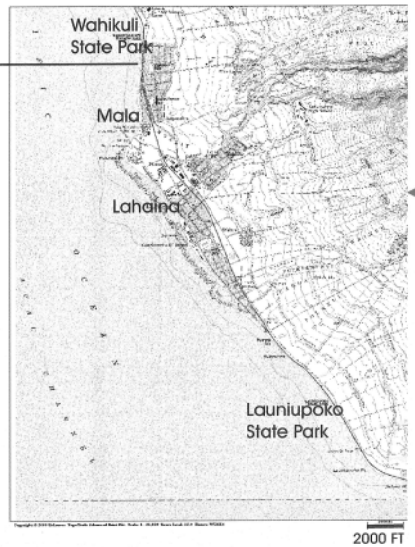
Kealia Pond. Beach fronting the central portion of Kealia Pond is wider than on the east and west end. Erosion is still a problem. (8-14-00, 10:30 am, tide 0.3' MLLW)

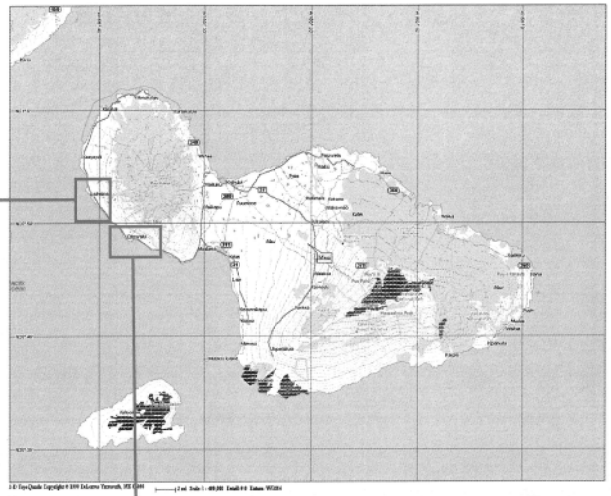
ISLAND OF MAUI
CENTRAL MAUI AREAS OF CONCERN

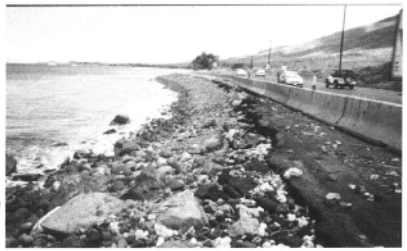
Statewide Highway Shoreline Protection
Project number HWY-08-98



Wahikuli. The stretch of highway south of Wahikuli State Park is revetted, but sustains wave overwash during storm conditions. (8-14-00, 1:15 pm, tide 1.7' MLLW)





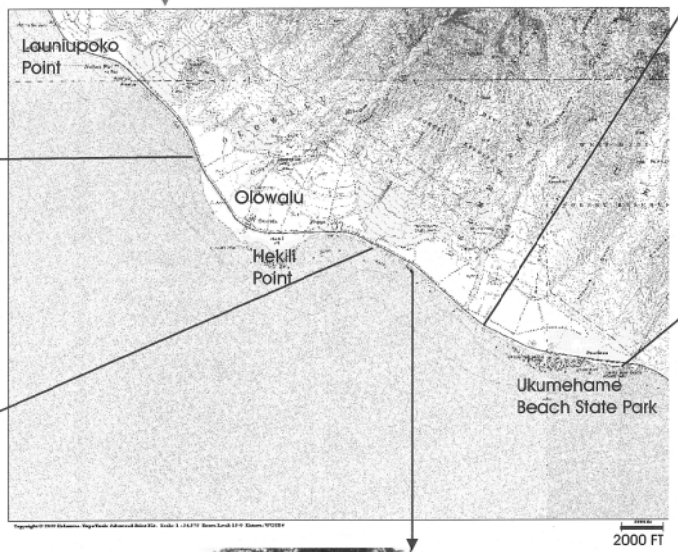


Ukumehame. Erosion has resulted in undermining this section of highway shoulder northwest of Ukumehame Beach Park. (8-14-00, 11:00 am, tide 0.7' MLLW)





Olowalu. Short section of highway on northwest side of Hekili Pt. Is suffering erosion damage. The highway shoulder is undercut to beneath the temporary barriers. (8-14-00, 11:50 am, tide 1.1' MLLW)





Ukumehame. Erosion has resulted in undermining this section of highway shoulder between the Pali and Ukumehame Beach Park. (8-14-00, 10:45 am, tide 0.6' MLLW)



Ukumehame. Wave overwash of this section of highway east of Hekili Pt. Occurs on a regular basis. (8-14-00, 11:20 am, tide 1.0' MLLW)

Ukumehame. Wave overwash of this section of highway east of Hekili Pt. occurs on a regular basis. Erosion has resulted in loss of mature trees. (8-14-00, 11:15 am, tide 1.0' MLLW)

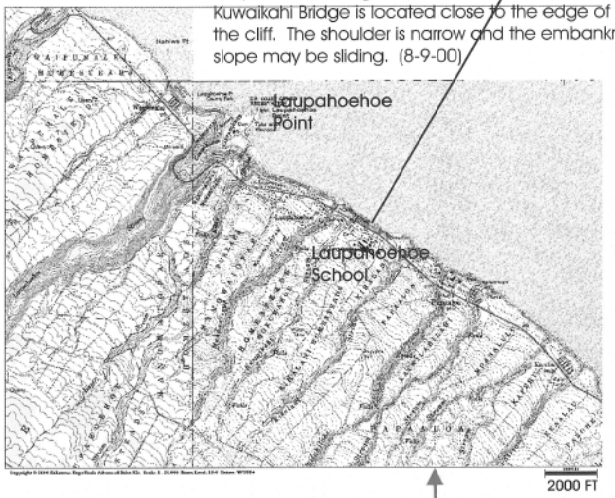


ISLAND OF MAUI
WEST MAUI AREAS OF CONCERN

Statewide Highway Shoreline Protection
Project number HWY-08-98



Laupahoehoe. Highway on southeast side of Kuwaikahi Bridge is located close to the edge of the cliff. The shoulder is narrow and the embankment slope may be sliding. (8-9-00)

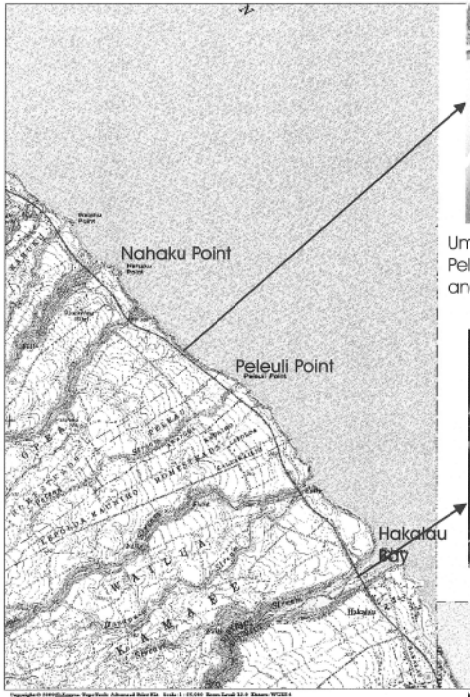




Wainaku. A short section of highway north of Hilo has been stabilized by constructing a new concrete wall at the base of the embankment. (8-9-00, 11:00 am, tide 1.8' MLLW)



Wainaku. The upper portion of the slope was filled and graded with rock. (8-9-00, 11:00 am, tide 1.8' MLLW)

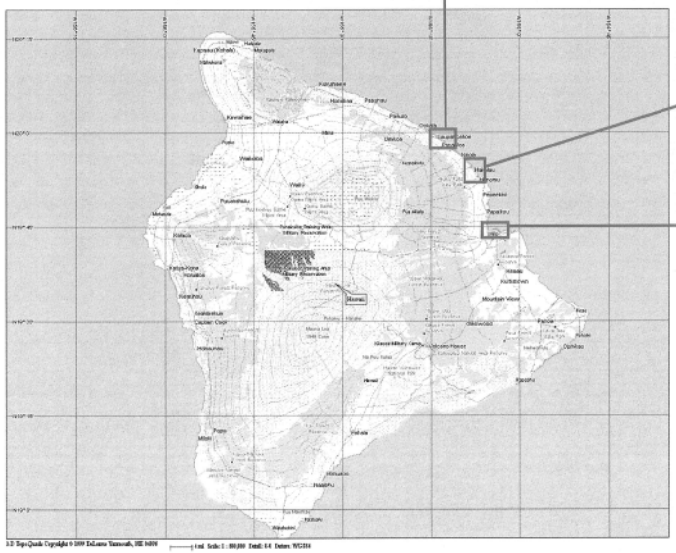


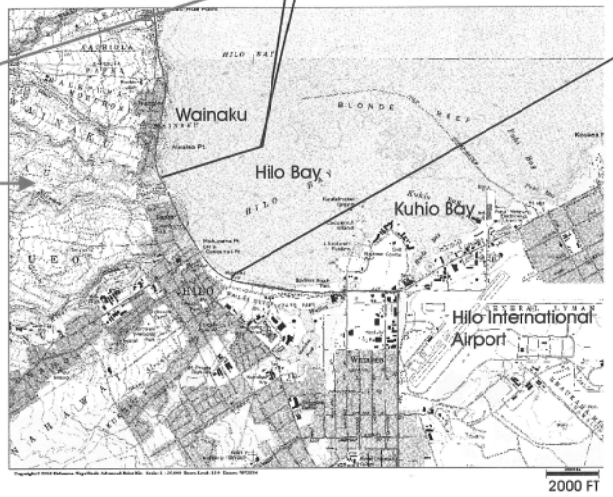


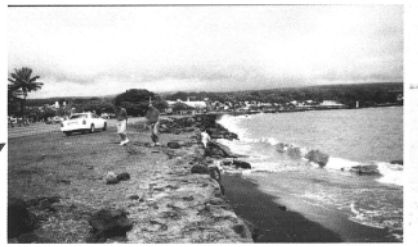
Umauma. Highway between Opea Bridge and Peliuli Pt. Is damaged from settlement of pavement and shoulder. The embankment slope is sliding. (8-9-00)



Hakalau Bridge. Although not obstructed at this time, accretion of sands and gravels can bury the footings of the bridge, making inspection difficult. This is not considered a shoreline erosion problem. (8-9-00, 12:30 pm, tide 2.0' MLLW)









Hilo Bayfront. Shore protection along the west half of the bayfront shoreline is in disrepair. Wave overtopping damage occurs periodically. [Note that the east half of the bayfront shoreline has accreted subsequent to construction of the groin adjacent to the Wailoa River.] (8-9-00, 10:30 am, tide 1.7' MLLW)

ISLAND OF HAWAII
EAST HAWAII AREAS OF CONCERN

Statewide Highway Shoreline Protection
Project number HWY-08-98

4 - AERIAL PHOTO ANALYSIS OF SHORELINE CHANGES

ISLAND OF OAHU

Kawailoa: Aerial photos spanning the 47-year period 1949-1996 indicate that there has been little change to the vegetation line (average gain +0.2 ft/yr) while there has been net beach accretion of about 45 feet (average rate +0.7 ft/yr) along a shoreline reach of about 1700 feet. The shoreline appears to have been artificially stabilized over this time period.

Sunset Beach: Aerial photos spanning the 48-year period 1952-2000 indicate that there has been little change to the vegetation line and beach (average loss -0.2 ft/yr). Net beach loss was only 7 feet along a shoreline reach of about 2300 feet. Along a 1000-foot stretch, the shoreline has been artificially fixed over this time period by the location of the highway.

Hauula: Aerial photos spanning the 51-year period 1949-2000 indicate that there has been little change to the vegetation line and beach. Net beach loss was only 7 feet (average rate -0.2 ft/yr) along a shoreline reach of about 3100 feet. The shoreline has been artificially fixed over this period of time by the location of the highway.

Punaluu: Aerial photos spanning the 41-year period 1959-2000 indicate that both the vegetation line and beach have accreted. Along a 3000 foot shoreline reach north of Punaluu Beach Park, there has been a net gain of 22 feet (average rate +0.6 ft/yr) for the vegetation line, and net gain of 41 feet (rate +1.3 ft/yr) for the beach. The northern section of this reach appears to have been artificially stabilized over this time period. The 2000 foot shoreline reach south of Punaluu Beach Park has also accreted over this time period.

Kahana Bay: Aerial photos spanning the 51-year period 1959-2000 indicate that both the vegetation line and beach have accreted within the bay. Along a 2500 foot shoreline reach inside the bay, there has been a net gain of 95 feet (average rate +1.8 ft/yr) for the vegetation line and a net gain of 40 feet (rate of +0.2 ft/yr) for the beach. The northern shoreline of the bay has been artificially stabilized over this time period and has not changed.

Kaaawa - Kualoa: Aerial photos span the 47-year period 1949-1996. Section 1 is a 3200 foot shoreline reach from Mahie Point to Kaaawa Point. There has been a net gain in the vegetation line of 12 feet (average rate +0.4 ft/yr), and the beach has fluctuated (average rate +0.1 ft/yr). Section 2 is a 2700 foot shoreline reach from east of Swanzy Beach Park to Kaaawa Beach Park. The vegetation line has been stable (practically this entire reach has been artificially stabilized), and the beach has exhibited net erosion (average rate -0.5 ft/yr). Section 3 is a 2500 foot shoreline reach from Kaaawa Beach Park to south of Kalae Oio Beach Park. Both the vegetation line and beach have shown no net change, although the beach has fluctuated over this time period. Section 4 is a 3600 foot shoreline reach from south of Kalae Oio Beach Park to Kaolo Point. This section has a net loss of 10 feet (average rate -0.4 ft/yr) for the vegetation line and a net loss of 32 feet (rate -0.8 ft/yr) for the beach. Section 5 is a 3100 foot shoreline reach north of Kualoa Regional Park. There has been net gain of 14 feet (rate of +0.2 ft/yr) for the vegetation line and also gain in the beach (rate of +0.5 ft/yr). The shoreline has been artificially fixed by the location of the highway along 2 short stretches.

Kaiona Beach: Aerial photos spanning the 47-year period 1949-1996 indicate that there has been no net change in the vegetation line, although there was a cycle of erosion and recovery. The beach has gained a net 51 feet (average rate +1.2 ft/yr) along a shoreline reach of about 3200 feet over this time period.

Makapuu Pier: Aerial photos span the 25-year period 1971-1996. Section 1 is a 1400 foot shoreline reach north of the pier, and Section 2 is a 1800 foot reach south of the pier. There has been net increase in the vegetation line for both sections on the order of about 16 feet (rate +0.2 ft/yr). There has been net beach gain for Section 1 but slight net beach loss for Section 2.

Mauna Lahilahi Beach Park: Aerial photos spanning the 47-year period 1949-1996 indicate that both the vegetation line and beach have eroded. Along a 1800 foot shoreline reach within the embayment, there has been a net loss in the vegetation line of 17 feet (average rate -0.1 ft/yr), and a net loss of 52 feet (rate -0.9 ft/yr) for the beach. The shoreline has been artificially fixed over this period of time by the location of the highway.

Makaha Beach Park: Aerial photos spanning the 50-year period 1949-1999 indicate that both the vegetation line and beach have eroded. Along a 2200 foot shoreline reach within the embayment, there has been a net loss in the vegetation line of 12 feet (average rate -0.5 ft/yr), and a net loss of 30 feet (rate -0.5 ft/yr) for the beach.

ISLAND OF KAUAI

Wainiha Bay: Aerial photos spanning the 45-year period 1950-1995 indicate that both the vegetation line and beach within the bay have eroded. Along a 1500 foot shoreline reach inside the bay, there has been a net loss of 60-70 feet over this period of time. There have been large fluctuations, but since 1963, net change to the shoreline and beach have been negligible. The southern shoreline leading into the bay is steep and vegetated, and it is difficult to determine beach and shoreline changes from the aerial photos.

Hanalei Bay: Aerial photos spanning the 45-year period 1950-1995 indicate that there has been little change to the vegetation line, and the beach has accreted. Net beach gain was 57 feet (average rate 1.7 ft/yr) along a shoreline reach of about 2000 feet. The shoreline has been artificially fixed by the location of the highway.

Wailua: Aerial photos spanning the 42-year period 1950-1992 indicate that there has been little change to the vegetation line (average gain +0.2 ft/yr), and that the beach has acreted over this time period. Along a 2300 foot shoreline reach, there has been a net beach gain of 27 feet (average rate +2.2 ft/yr). There was substantial accretion from 1975 to 1988 of over 100 feet, followed by a period of erosion such that the beach position in 1992 was substantially the same as in 1975. The shoreline has been artificially fixed by the location of the highway.

ISLAND OF MOLOKAI

Kamiloloa: Aerial photos spanning the 51-year period 1949-2000 indicate that there has been erosion of the vegetation line, but little net change to the beach. Along a 1500 foot shoreline reach, there has been net loss of 16 feet (average rate -0.3 ft/yr) for the vegetation line, and a net change of only 5 feet for the beach, although the beach has fluctuated over this period of time. The shoreline appears to have been artificially stabilized over this time period.

Kawela: Aerial photos spanning the 51-year period 1949-2000 indicate that both the vegetation line and beach have eroded. Net erosion was 20 feet (average rate -0.4 ft/yr) for the vegetation line and 10 feet (average rate -0.2 ft/yr) for the beach along a shoreline reach of about 2500 feet.

Niaupala Fishpond: Aerial photos spanning the 51-year period 1949-2000 indicate that there has been accretion along the 1600 foot interior shoreline reach within the fishpond. There has been a net gain of 39 feet (average rate +0.7 ft/yr) for the vegetation line. There is no beach along this shoreline adjacent to the highway.

Kupeke Fishpond: Aerial photos spanning the 51-year period 1949-2000 indicate that there has been little net change along the 500 foot interior shoreline reach within the fishpond where the road is directly adjacent the pond waters.

Pauwalu - Kalaekapu: Aerial photos span the 51-year period 1949-2000. Section 1 is a 4300 foot shoreline reach from Pauwalu to Waialua. There has been little change to the vegetation line, and very little dry beach along this shoreline reach. Section 2 is a 4900 foot shoreline reach from Waialua to Kumimi. There has been little net change to the vegetation line, and except for a short stretch near Kumimi, there has been little dry beach along this shoreline reach. Sections of the shoreline appear to have been artificially stabilized over this time period.

ISLAND OF MAUI

Kahului Bay: Aerial photos span the 46-year period 1953-1999. Section 1 is a 2300 foot shoreline reach along the western shoreline within the harbor. There has been net gain in the vegetation line of 21 feet (average rate +0.5 ft/yr), and there has been little dry beach along this shoreline reach. This shoreline appears to have been artificially extended seaward of the highway. Section 2 is a 2400 foot shoreline reach along the southern shoreline within the harbor. There has been a net gain in the vegetation line of 30 feet (average rate +0.8 ft/yr), and a relatively stable beach (average gain 0.2 ft/yr).

Kealia Pond: Aerial photos spanning the 49-year period 1949-1998 indicate that both the vegetation line and beach have eroded. Section 1 is a 3900 foot shoreline reach fronting the northern half of Kealia Pond, and Section 2 is a 3300 foot shoreline reach fronting the southern half of the pond. There has been greater erosion of the vegetation line in Section 1 (net loss 21 feet, average rate -0.4 ft/yr) than in Section 2 (net loss 6 feet, average rate -0.2 ft/yr). Beach erosion has been the same for both sections (net loss 24 feet, average rate -0.5 ft/yr).

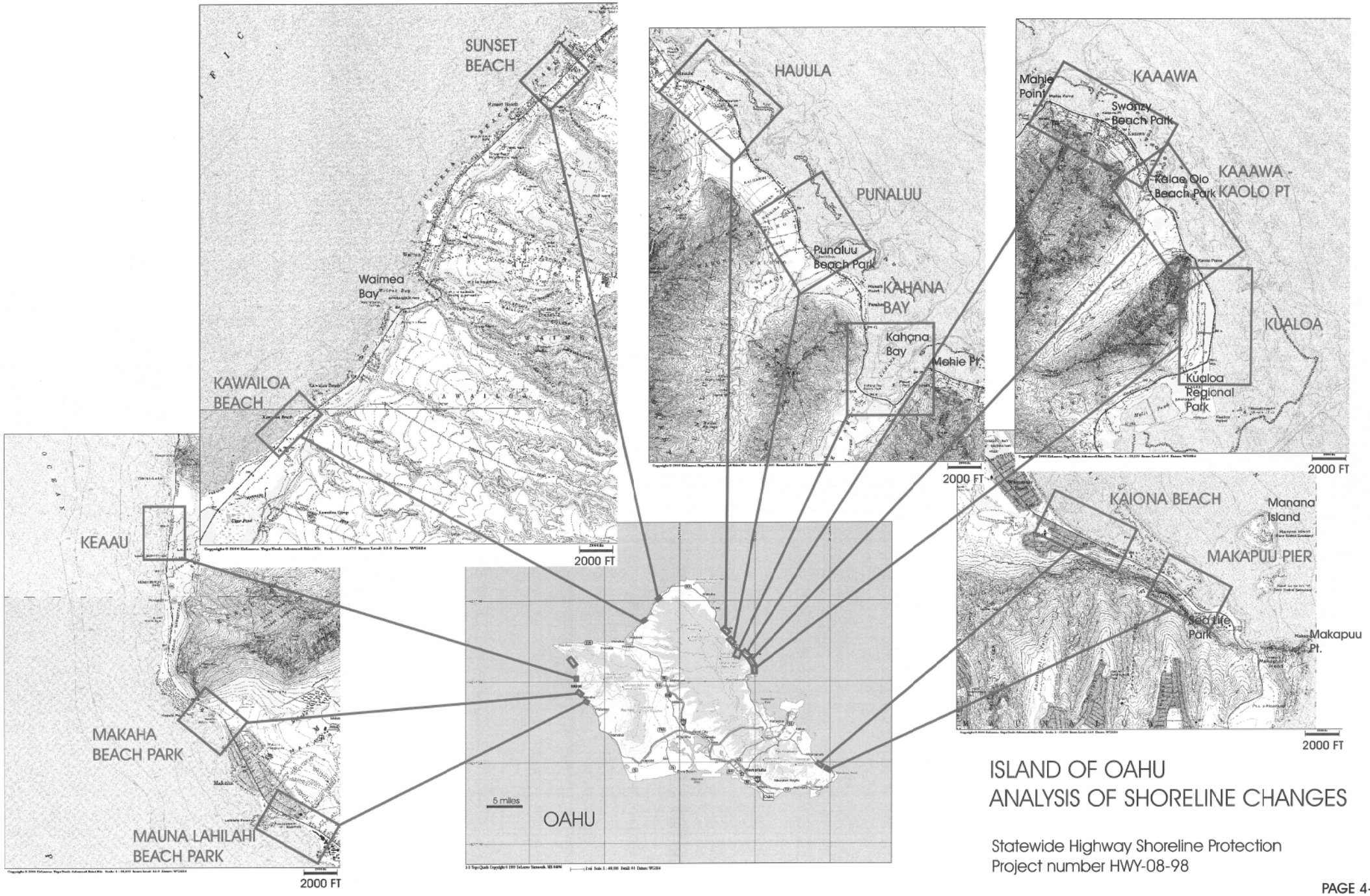
Ukumehame: Aerial photos span the 48-year period 1949-1997. Section 1 is a 4200 foot shoreline reach extending east of Hekili Point. There has been little change to the shoreline, and virtually no dry beach over this period of time. Section 2 is a 4600 foot shoreline reach extending southward of Section 1 to Ukumehame Beach State Park. There has been net loss to the vegetation line of 28 feet (average rate -0.3 ft/yr), and very little dry beach except near the beach park. Section 3 is a 6300 foot shoreline reach from Ukumehame Beach State Park to the Pali. There has been net loss to the vegetation line of 24 feet (average rate of -0.7 ft/yr), and loss of what little dry beach fronted this shoreline reach.

Olowalu: Aerial photos spanning the 28-year period 1971-1999 indicate that there has been little net change along the 3900 foot shoreline reach north of Hekili Point. However, there has been erosion on the south end of this reach, and accretion on the north end over this period of time.

Launiupoko: Aerial photos spanning the 50-year period 1949-1999 indicate that there has been significant erosion over this period of time. Section 1 is a 3800 foot shoreline reach extending from Puamana Park southward, and Section 2 is a 3100 foot shoreline reach extending southward past Launiupoko State Park. Erosion of the vegetation line was about the same for both sections (net loss 46 feet for Section 1 and 40 feet for Section 2, average rate about 1 ft/yr). There was little dry beach along this shoreline except at the northern end of Section 1. This 1000 foot shoreline reach near Puamana Park lost a net 31 feet of beach (average rate -0.6 ft/yr) over this period of time.

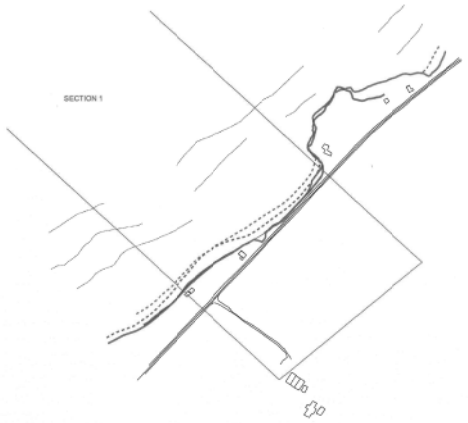
ISLAND OF HAWAII

Hilo Bayfront: Aerial photos span the 49-year period 1949-1998. Section 1 is a 2900 foot shoreline reach extending eastward from Cocoanut Point along the west half of the Bayfront shore, and Section 2 is a 2600 foot shoreline reach extending eastward to Wailoa River (east half of the Bayfront shore). There has been accretion to the shoreline in Section 2 of over 100 feet (average rate +2.7 ft/yr), while Section 1 has lost a net 36 feet (average rate -0.9 ft/yr). Because of the dark color of the sand, and the difficulty in differentiating the vegetation line from the beach line, the upper swash zone was considered the vegetation line or shoreline.



ISLAND OF OAHU
ANALYSIS OF SHORELINE CHANGES

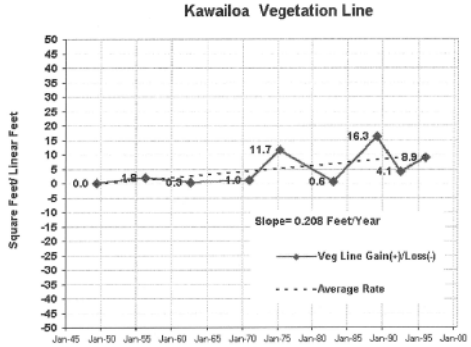
Statewide Highway Shoreline Protection
Project number HWY-08-98



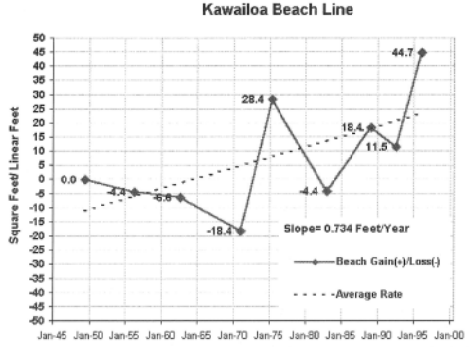
KAWAILOA, OAHU

0 500 1000
GRAPHIC SCALE IN FEET

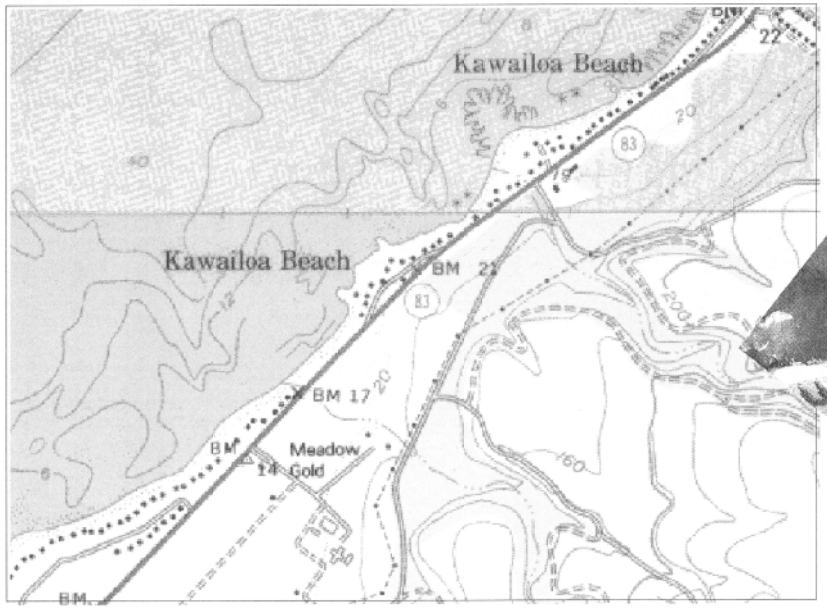
1949 VEGETATION LINE
1949 BEACH LINE
1996 VEGETATION LINE
1996 BEACH LINE



	5/8/49	4/12/56	8/24/62	1/23/71	4/11/75	12/5/82	2/16/89	7/27/92	1/13/96
Veg Line Gain(+)/Loss(-)	0.0	1.8	0.3	1.0	11.7	0.6	16.3	4.1	8.9
Shoreline Length (Feet)	1727	1727	1727	1727	1727	1727	1727	1727	1727



	5/8/49	4/12/56	8/24/62	1/23/71	4/11/75	12/5/82	2/16/89	7/27/92	1/13/96
Beach Gain(+)/Loss(-)	0.0	-4.4	-5.6	-18.4	28.4	-4.4	18.4	11.5	44.7
Beach Length (Feet)	1731	1731	1731	1731	1731	1731	1731	1731	1731



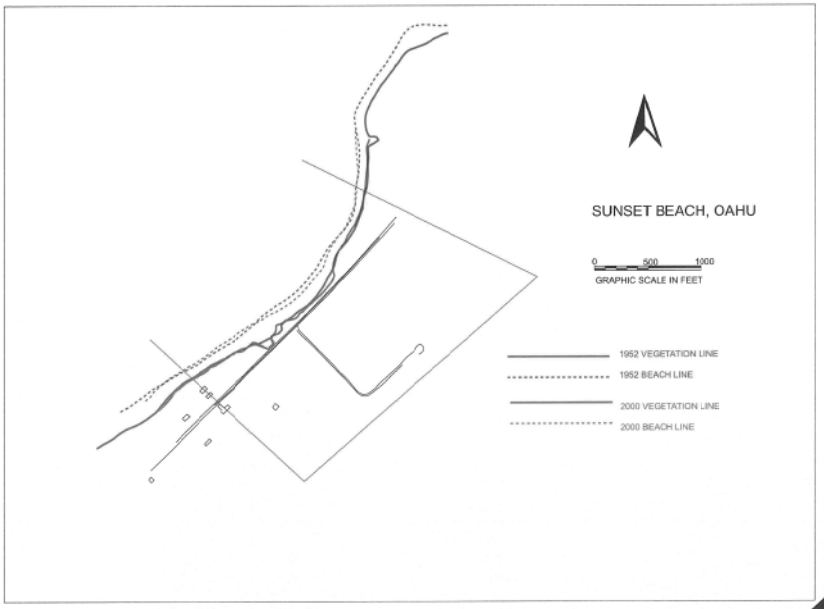


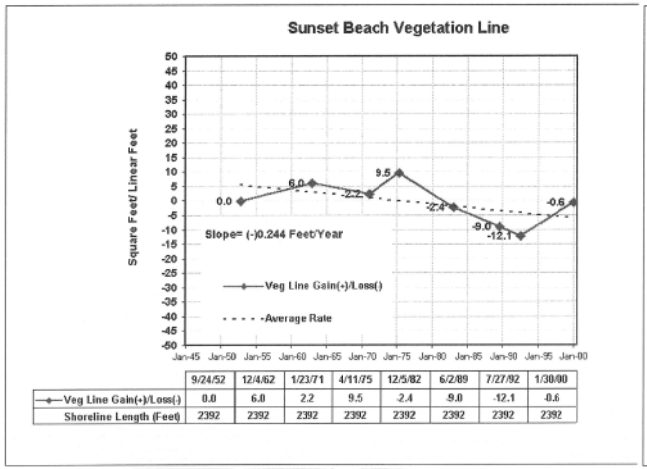
5-8-49

7-27-92

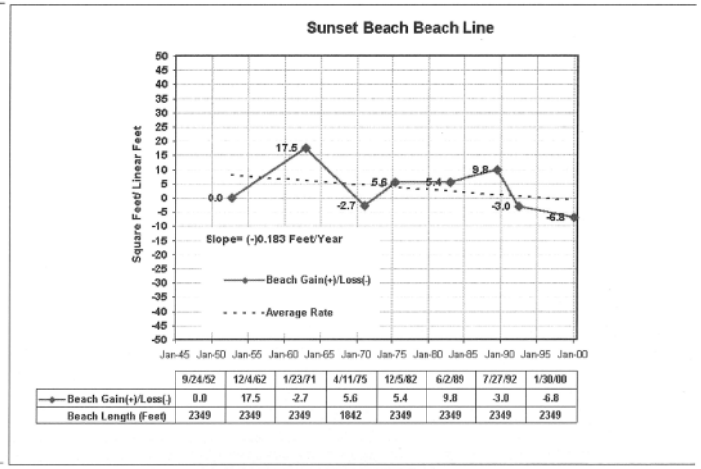
AERIAL PHOTOGRAPHIC ANALYSIS
KAWAILOA BEACH, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

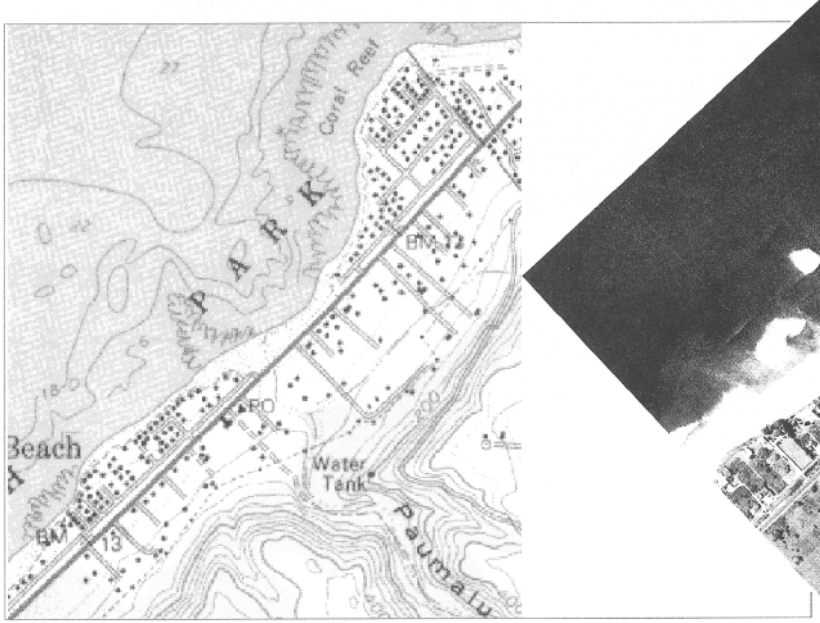


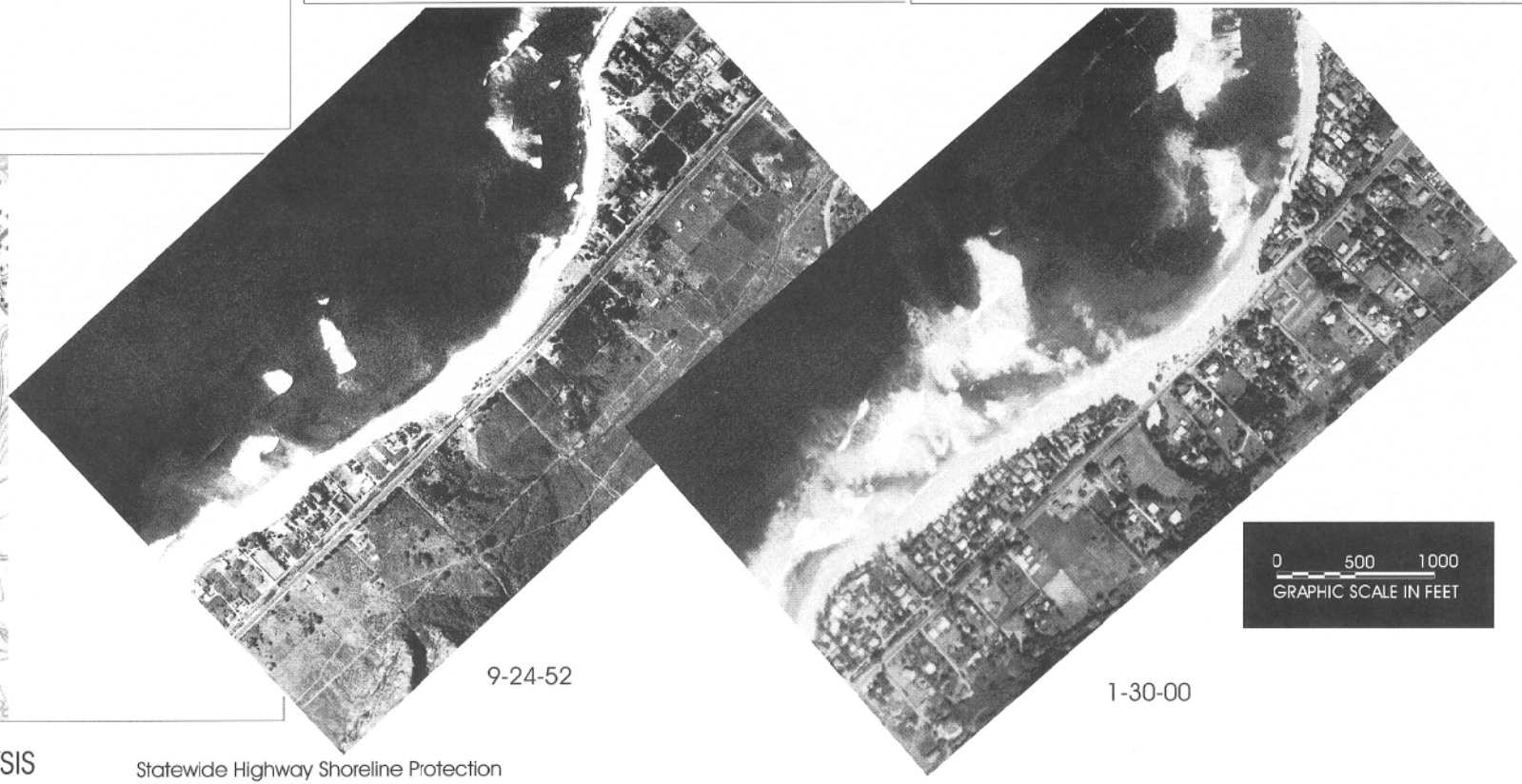


	9/24/52	12/4/62	1/23/71	4/11/75	12/5/82	6/2/89	7/27/92	1/30/00
Veg Line Gain(+)/Loss(-)	0.0	6.0	2.2	9.5	-2.4	-9.0	-12.1	-0.6
Shoreline Length (Feet)	2392	2392	2392	2392	2392	2392	2392	2392



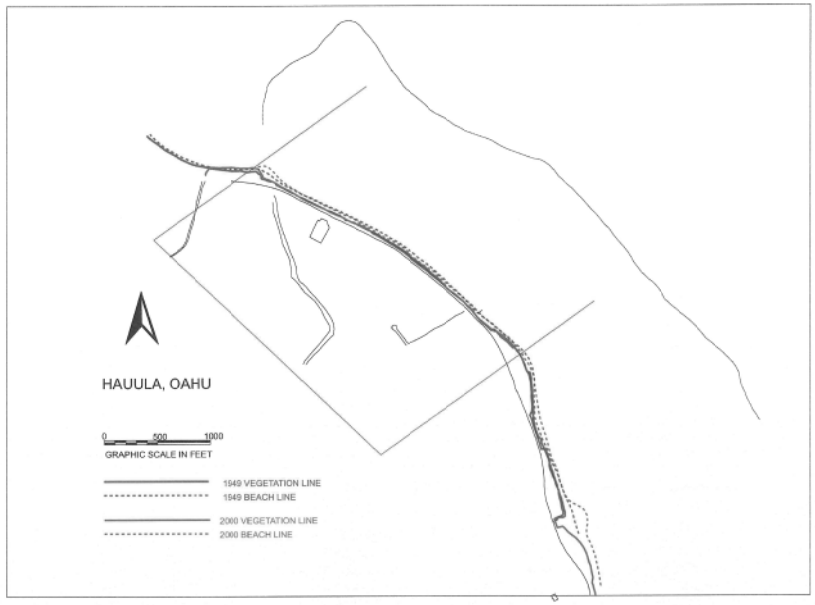
	9/24/52	12/4/62	1/23/71	4/11/75	12/5/82	6/2/89	7/27/92	1/30/00
Beach Gain(+)/Loss(-)	0.0	17.5	-2.7	5.6	5.4	9.8	-3.0	-6.8
Beach Length (Feet)	2349	2349	2349	1842	2349	2349	2349	2349

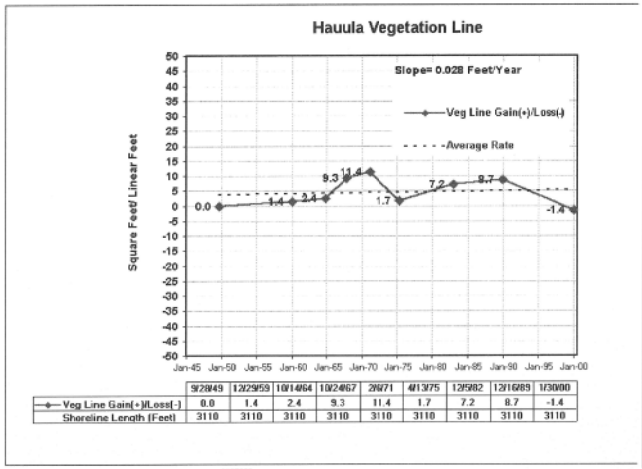




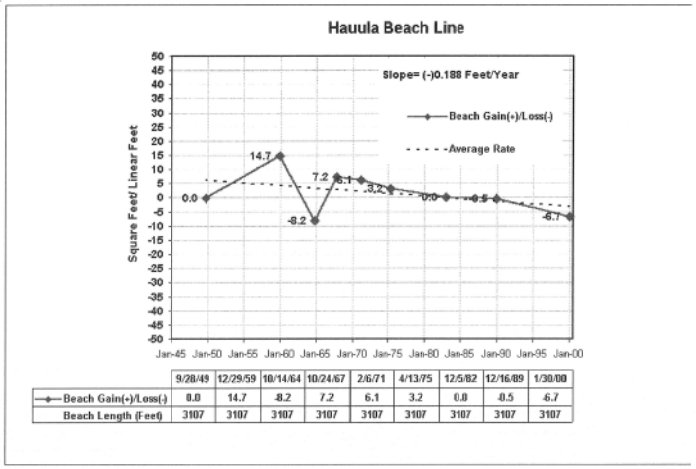
AERIAL PHOTOGRAPHIC ANALYSIS
SUNSET BEACH, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

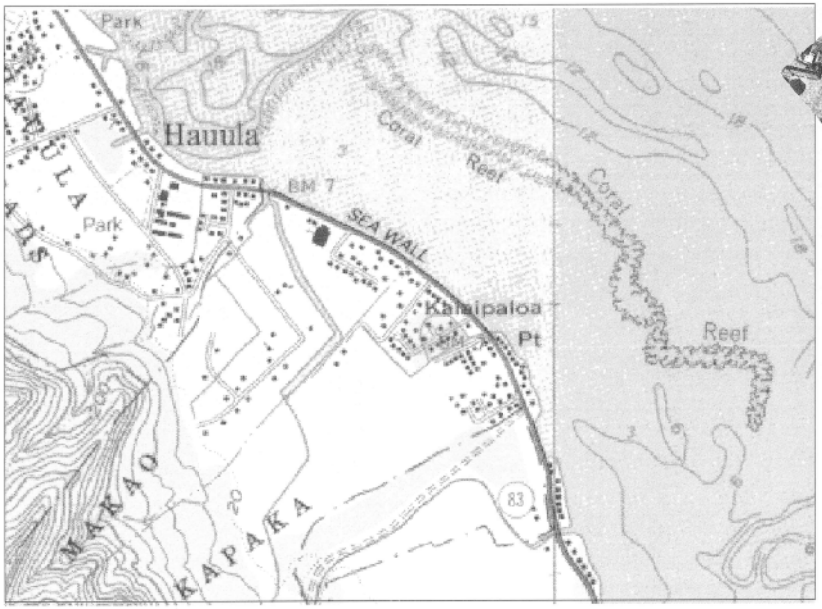




	9/28/49	12/29/59	10/14/64	10/24/67	2/6/71	4/13/75	12/5/82	12/16/89	1/30/00
Veg Line Gain(+)/Loss(-)	0.0	1.4	2.4	9.3	11.4	1.7	7.2	8.7	-1.4
Shoreline Length (Feet)	3110	3110	3110	3110	3110	3110	3110	3110	3110



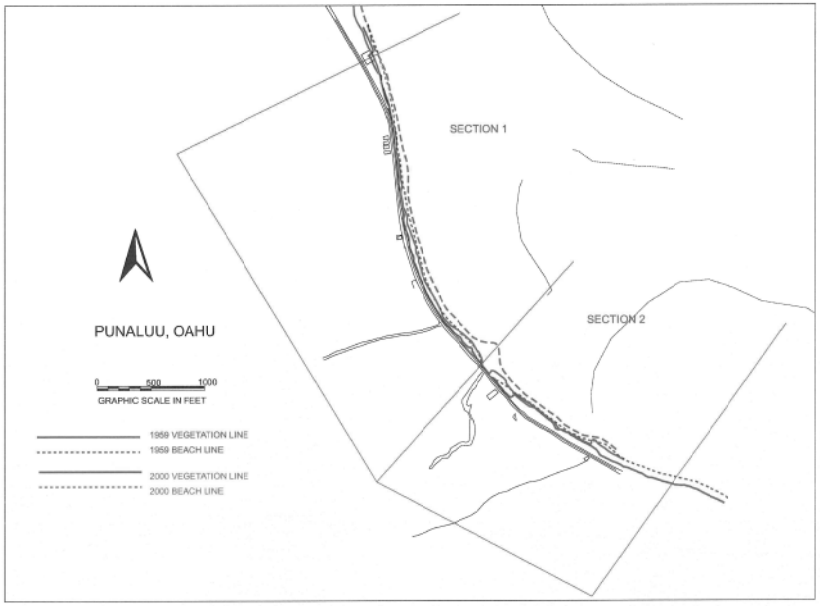
	9/28/49	12/29/59	10/14/64	10/24/67	2/6/71	4/13/75	12/5/82	12/16/89	1/30/00
Beach Gain(+)/Loss(-)	0.0	14.7	-8.2	7.2	6.1	3.2	0.0	-0.5	-6.7
Beach Length (Feet)	3107	3107	3107	3107	3107	3107	3107	3107	3107

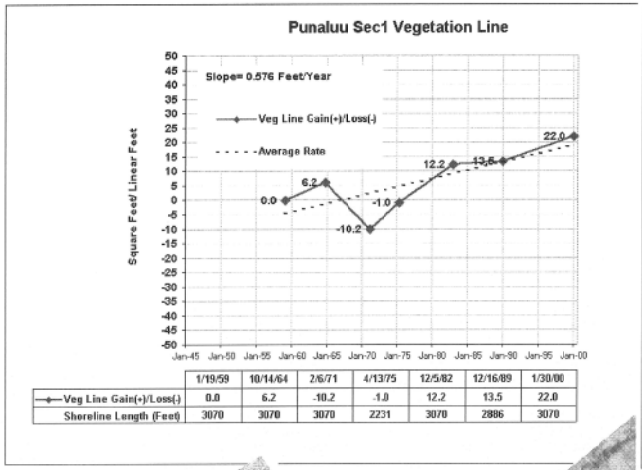




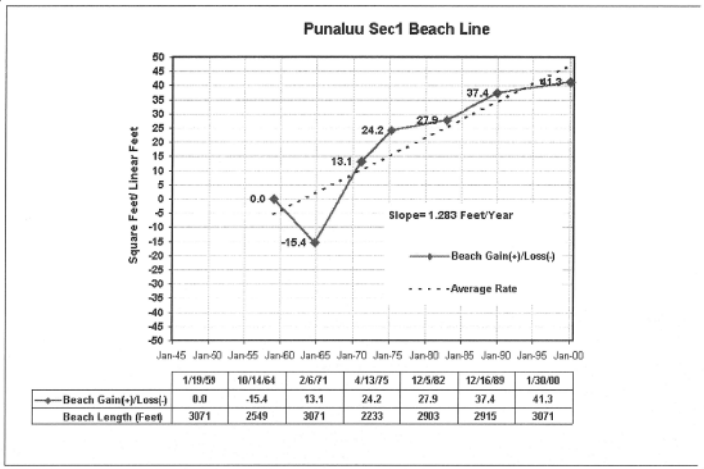
AERIAL PHOTOGRAPHIC ANALYSIS
HAUULA, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98





	1/19/59	10/14/64	2/6/71	4/13/75	12/5/82	12/16/89	1/30/00
Veg Line Gain(+)/Loss(-)	0.0	6.2	-10.2	-1.0	12.2	13.5	22.0
Shoreline Length (Feet)	3070	3070	3070	2231	3070	2886	3070



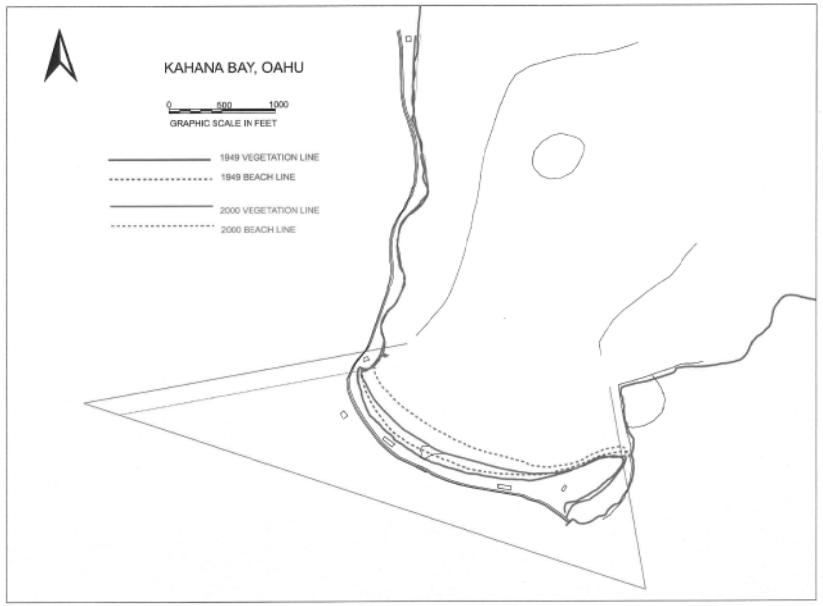
	1/19/59	10/14/64	2/6/71	4/13/75	12/5/82	12/16/89	1/30/00
Beach Gain(+)/Loss(-)	0.0	-15.4	13.1	24.2	27.9	37.4	41.3
Beach Length (Feet)	3071	2549	3071	2233	2903	2915	3071

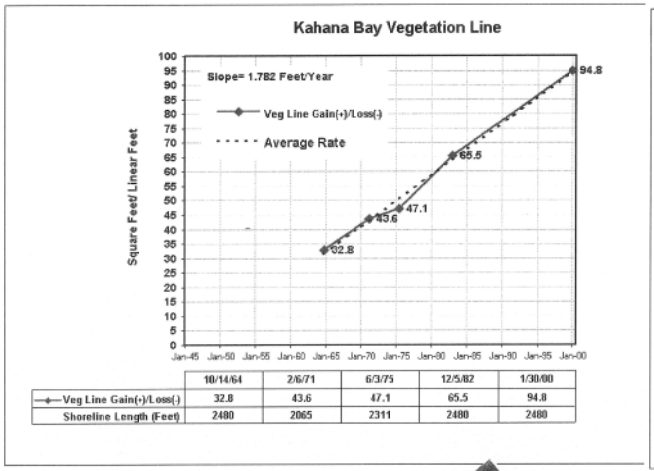




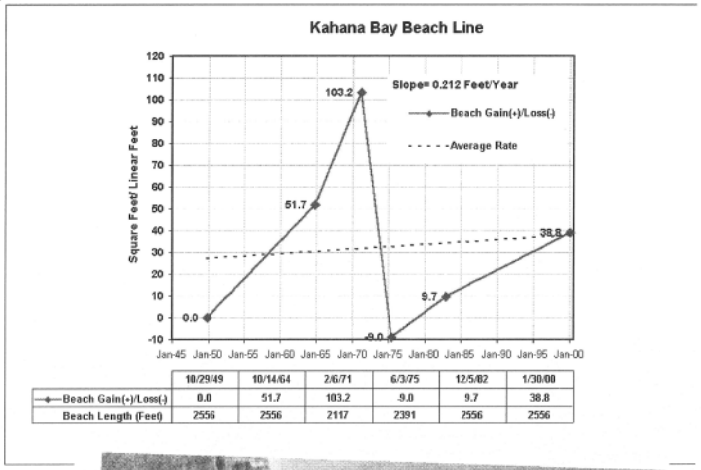
AERIAL PHOTOGRAPHIC ANALYSIS
PUNALUU, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

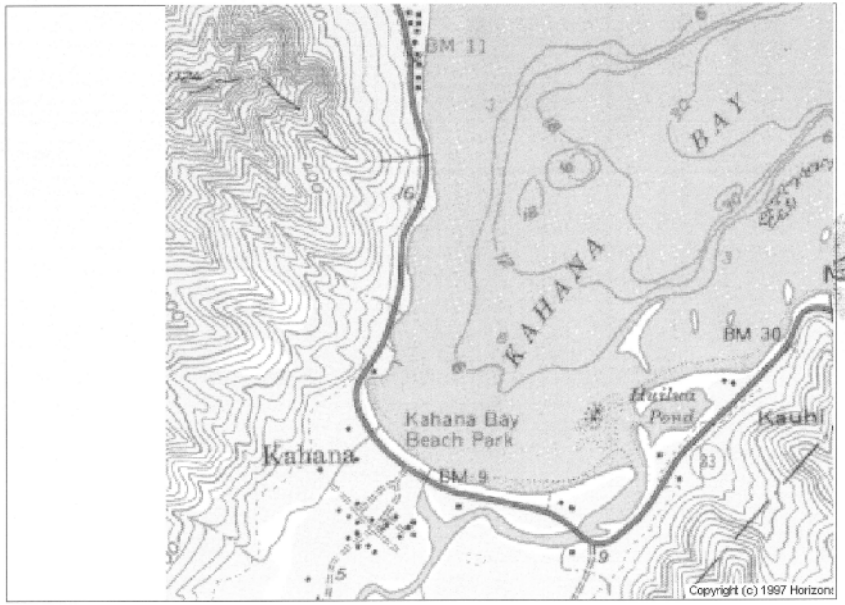


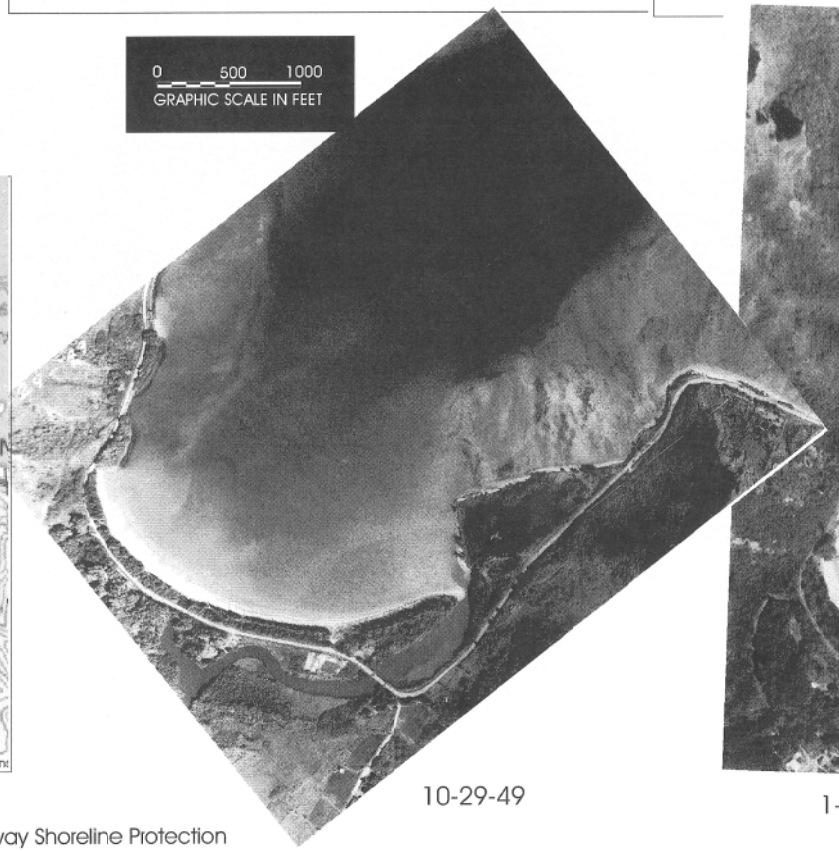


	10/14/64	2/6/71	6/3/75	12/5/82	1/30/00
Veg Line Gain(+)/Loss(-)	32.8	43.6	47.1	65.5	94.8
Shoreline Length (Feet)	2480	2065	2311	2480	2480



	10/29/49	10/14/64	2/6/71	6/3/75	12/5/82	1/30/00
Beach Gain(+)/Loss(-)	0.0	51.7	103.2	-9.0	9.7	38.8
Beach Length (Feet)	2556	2556	2117	2391	2556	2556





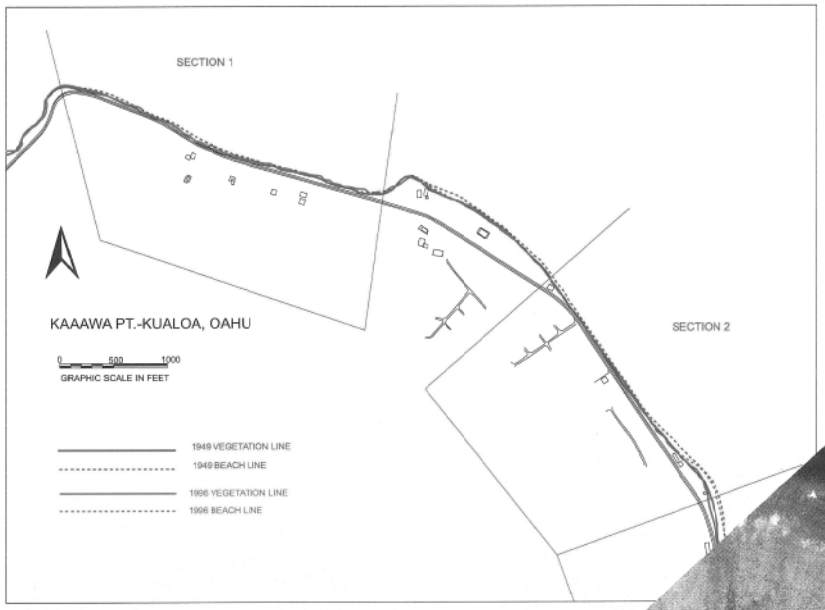
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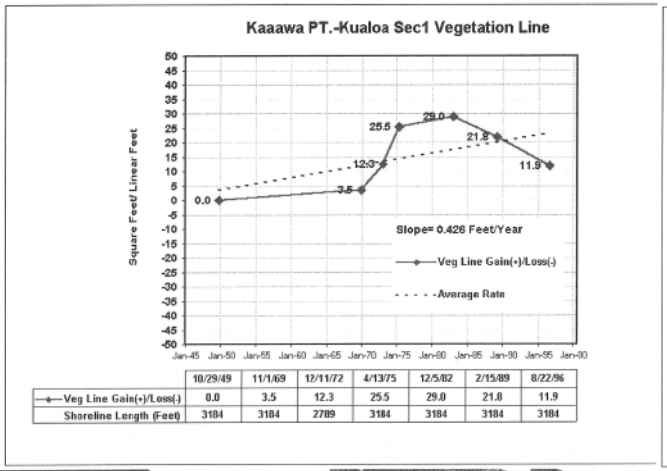


1-30-00

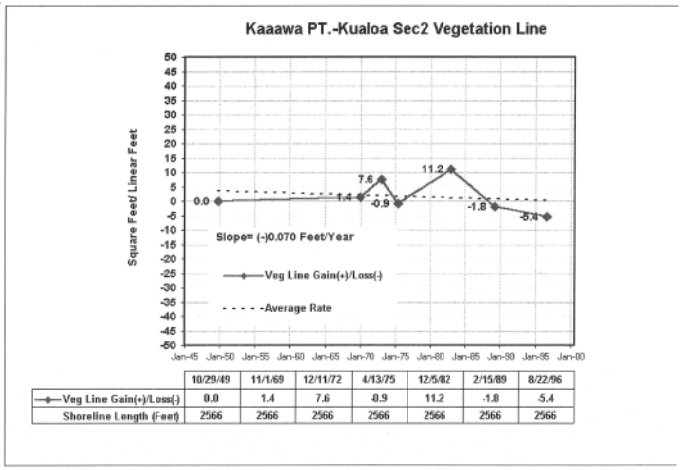
AERIAL PHOTOGRAPHIC ANALYSIS
KAHANA BAY, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

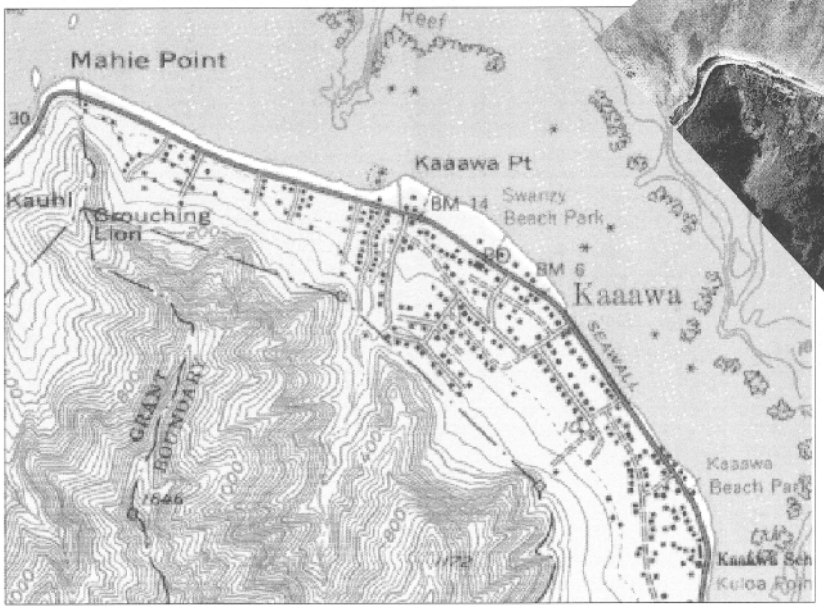


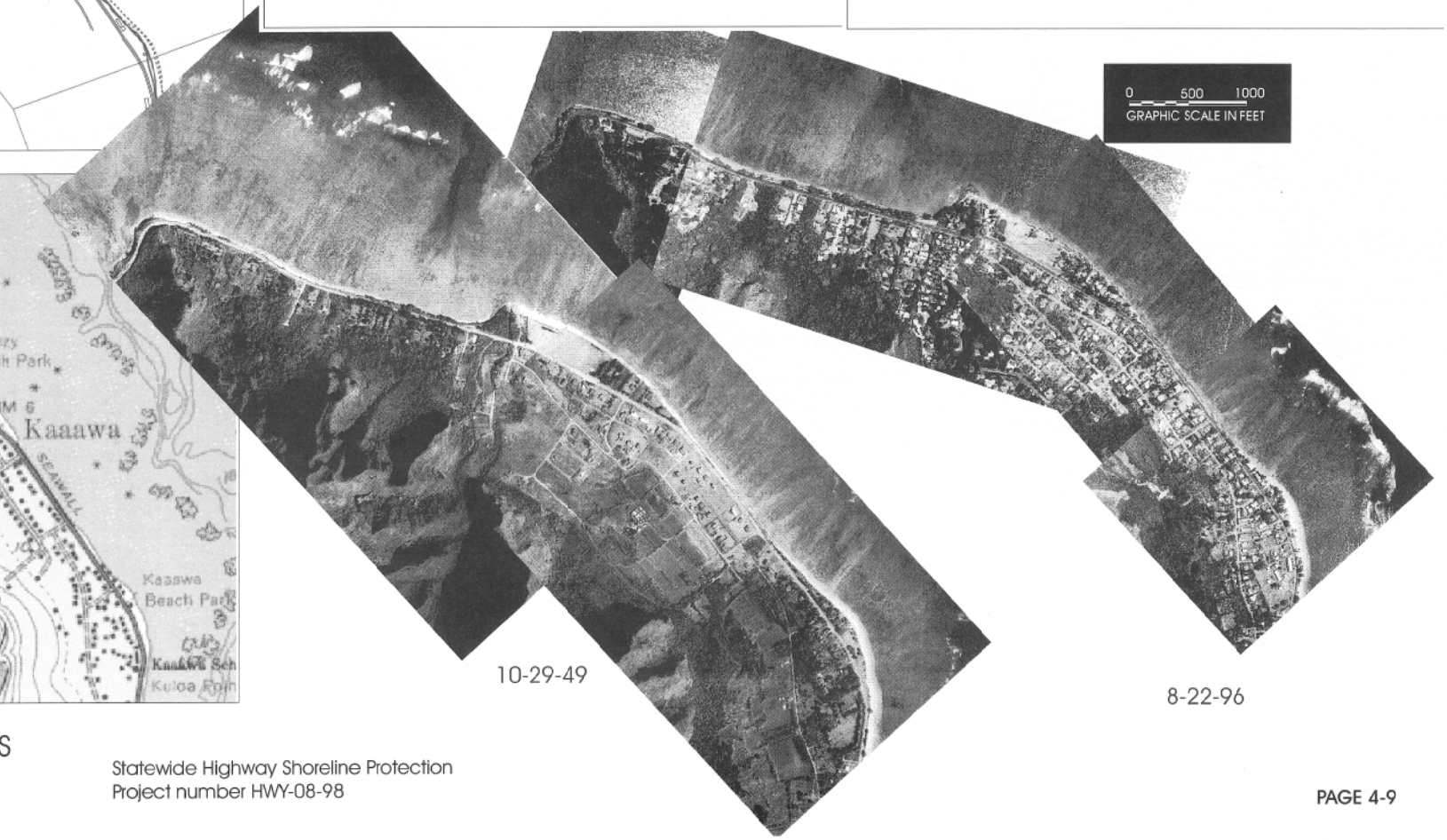


	10/29/49	11/1/69	12/11/72	4/13/75	12/5/82	2/15/89	8/22/96
Veg Line Gain(+)/Loss(-)	0.0	3.5	12.3	25.5	29.0	21.8	11.9
Shoreline Length (Feet)	3184	3184	2789	3184	3184	3184	3184



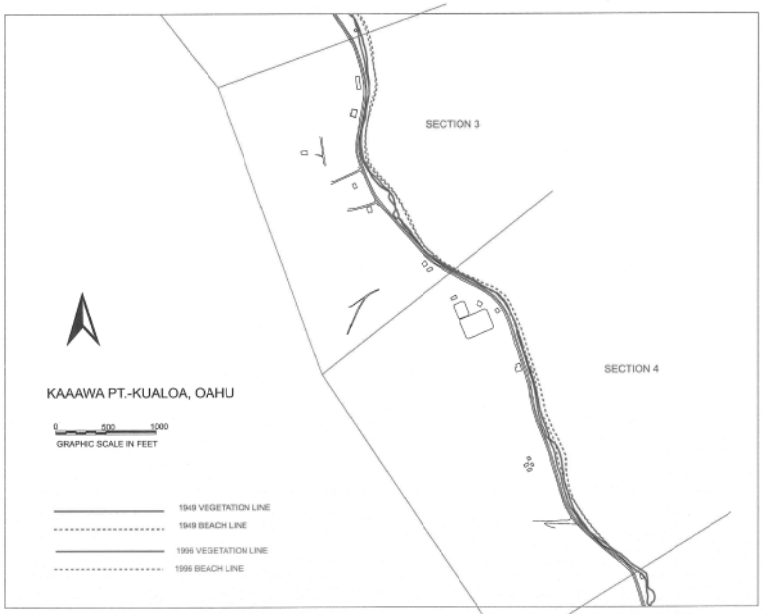
	10/29/49	11/1/69	12/11/72	4/13/75	12/5/82	2/15/89	8/22/96
Veg Line Gain(+)/Loss(-)	0.0	1.4	7.6	-0.9	11.2	-1.8	-5.4
Shoreline Length (Feet)	2566	2566	2566	2566	2566	2566	2566

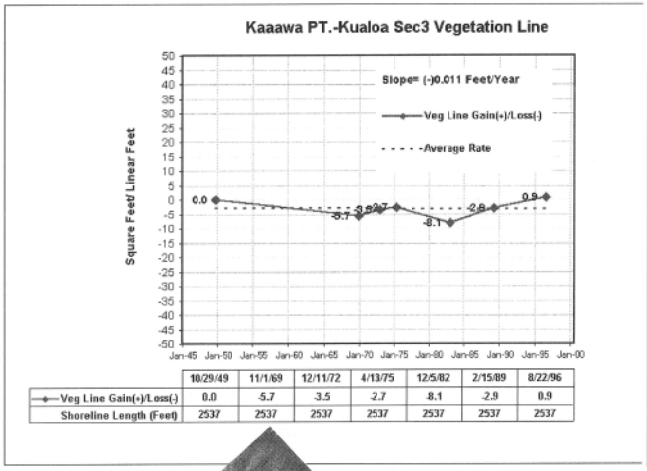




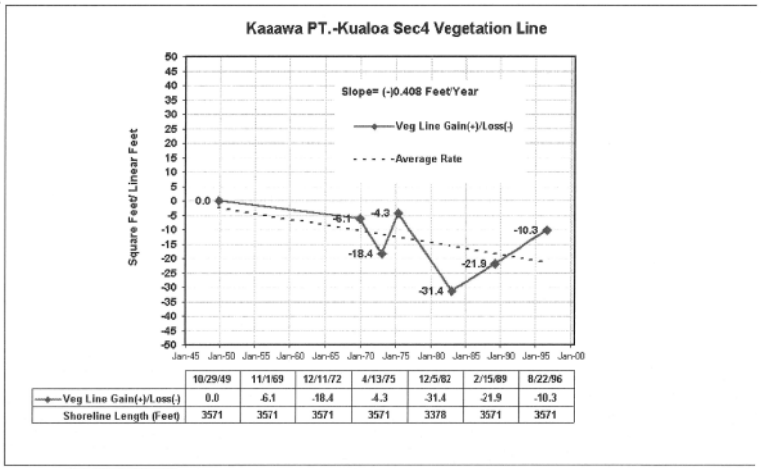
AERIAL PHOTOGRAPHIC ANALYSIS
KAAAWA, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

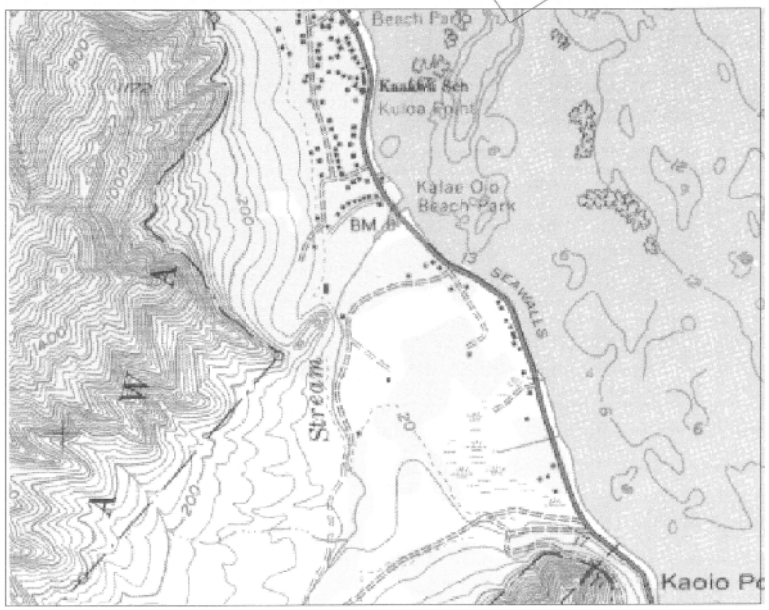




	10/29/49	11/1/69	12/11/72	4/13/75	12/5/82	2/15/89	8/22/96
Veg Line Gain(+)/Loss(-)	0.0	-5.7	-3.5	-2.7	-8.1	-2.9	0.9
Shoreline Length (Feet)	2537	2537	2537	2537	2537	2537	2537



	10/29/49	11/1/69	12/11/72	4/13/75	12/5/82	2/15/89	8/22/96
Veg Line Gain(+)/Loss(-)	0.0	-6.1	-18.4	-4.3	-31.4	-21.9	-10.3
Shoreline Length (Feet)	3571	3571	3571	3571	3378	3571	3571



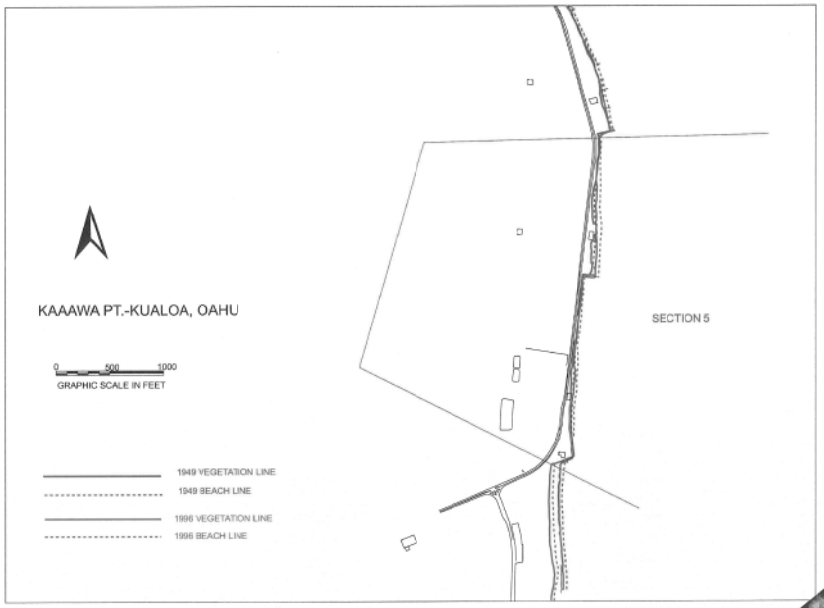


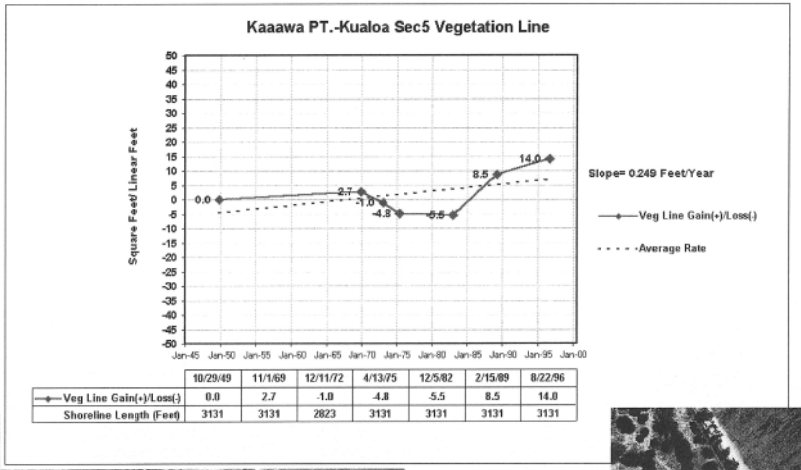
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8-22-96

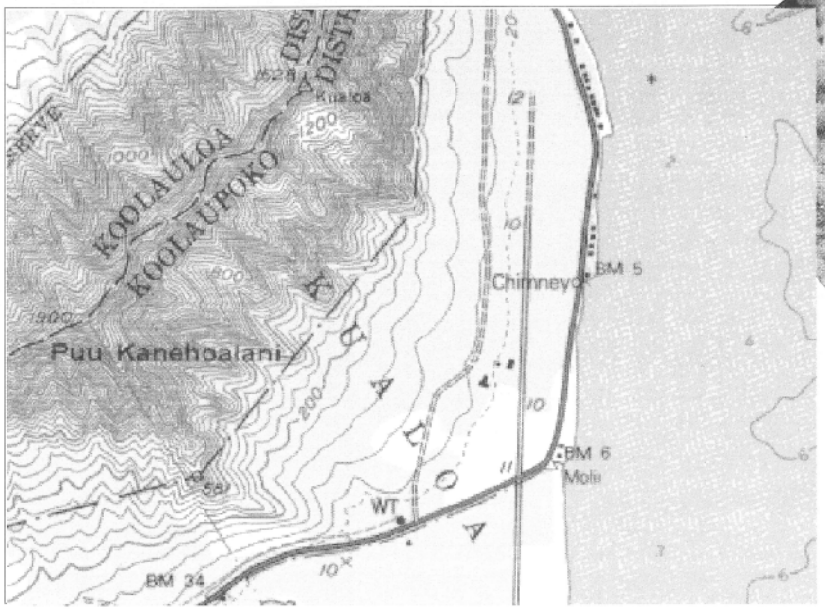
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KAAAWA-KAOLO PT., OAHU

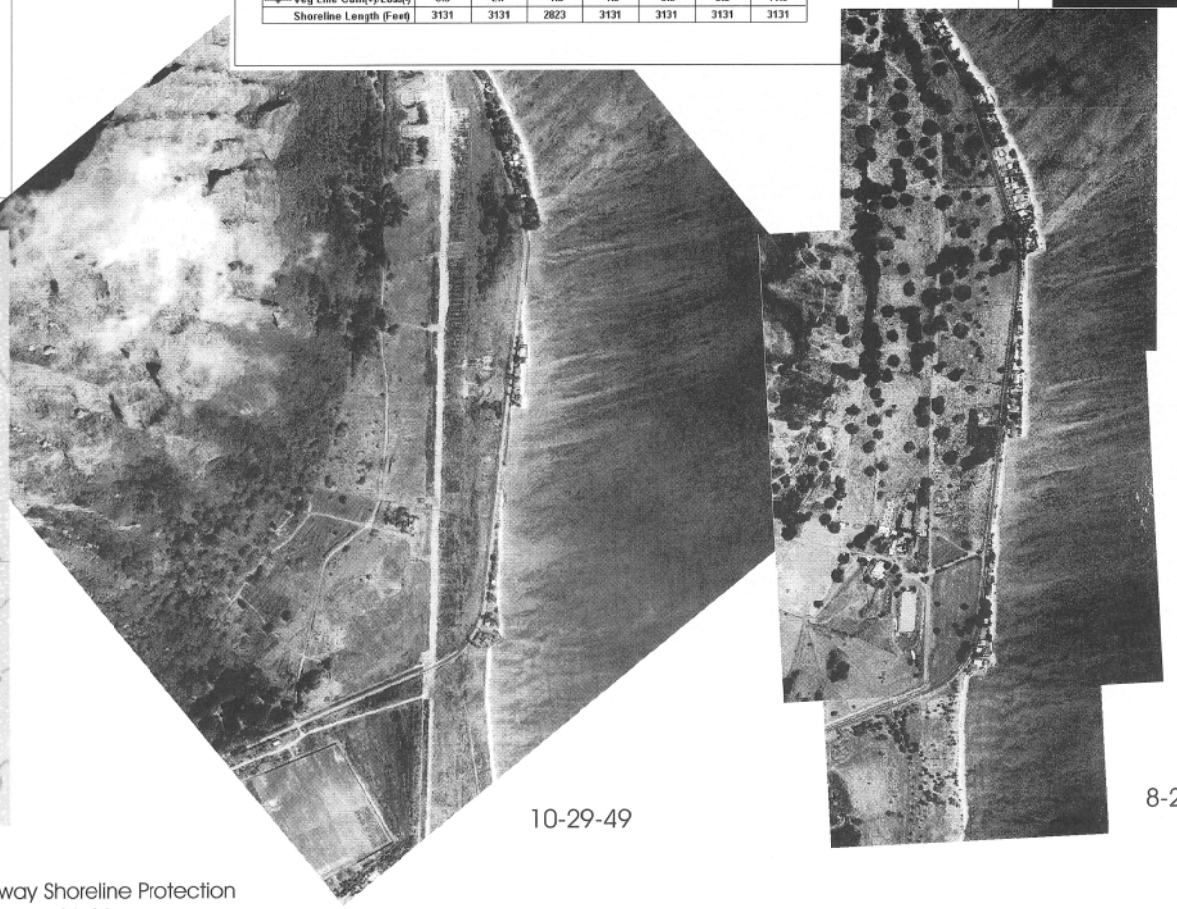
Statewide Highway Shoreline Protection
Project number HWY-08-98





	10/29/49	11/1/69	12/11/72	4/13/75	12/5/82	2/15/89	8/22/96
Veg Line Gain(+)/Loss(-)	0.0	2.7	-1.0	-4.8	-5.5	8.5	14.0
Shoreline Length (Feet)	3131	3131	2823	3131	3131	3131	3131



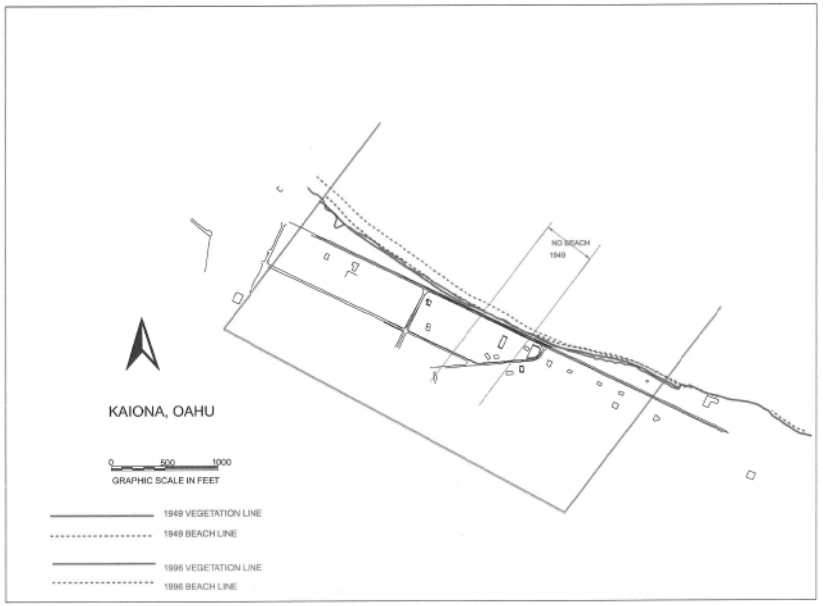


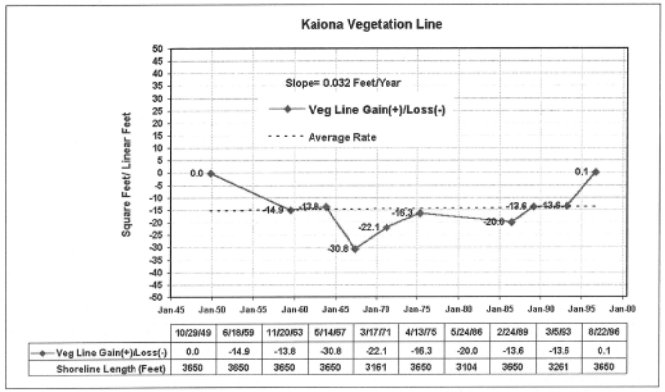
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8-22-96

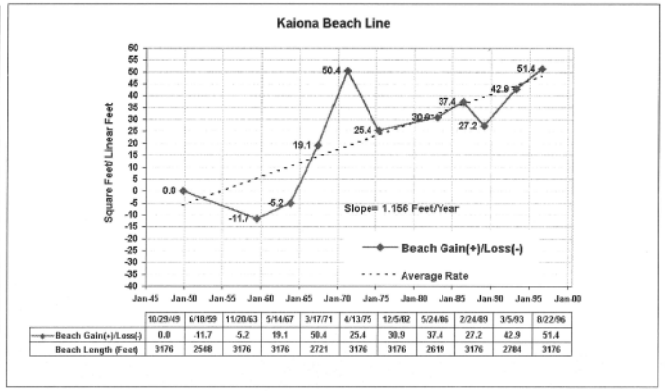
AERIAL PHOTOGRAPHIC ANALYSIS
KUALOA, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

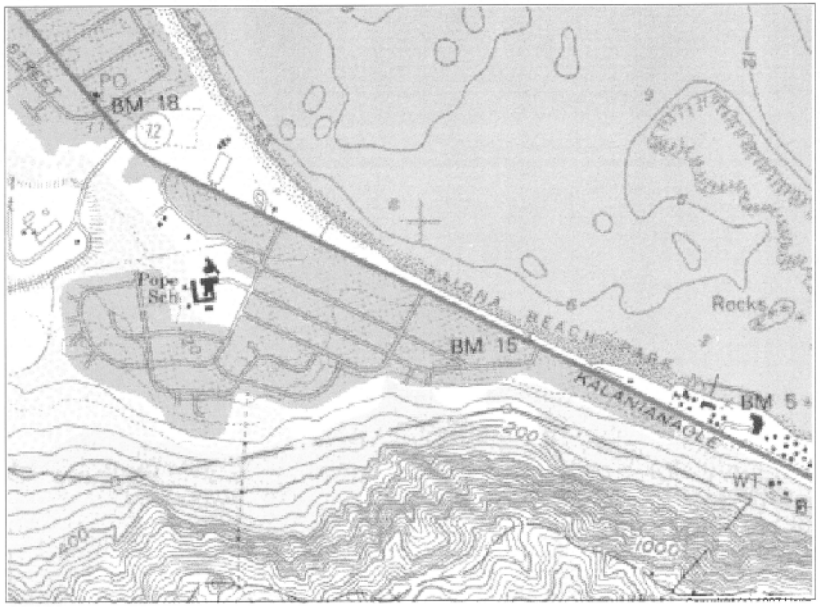




	10/29/49	6/18/59	11/20/63	5/14/67	3/17/71	4/13/75	5/24/86	2/24/89	3/5/93	8/22/96
Veg Line Gain(+)/Loss(-)	0.0	-14.9	-13.8	-30.8	-22.1	-16.3	-20.0	-13.6	-13.5	0.1
Shoreline Length (Feet)	3650	3650	3650	3650	3161	3650	3104	3650	3261	3650



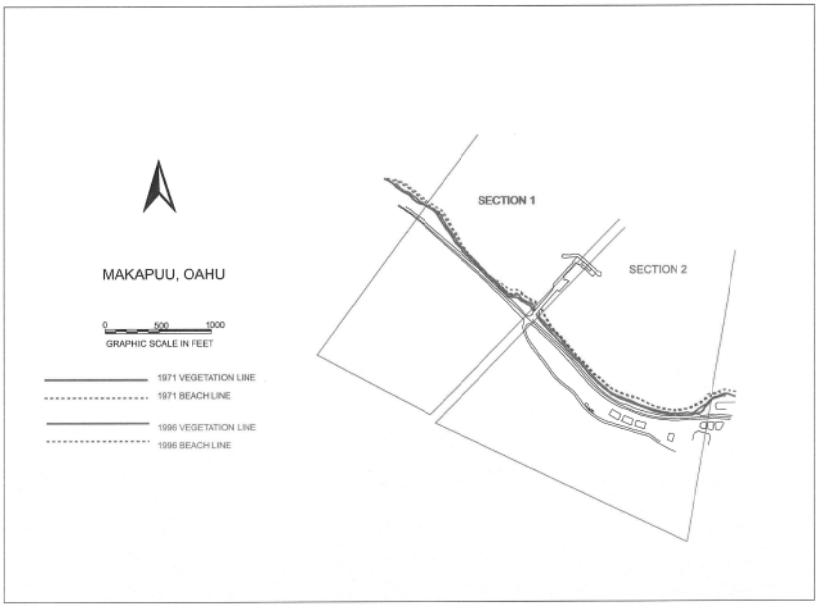
	10/29/49	6/18/59	11/20/63	5/14/67	3/17/71	4/13/75	12/5/82	5/24/86	2/24/89	3/5/93	8/22/96
Beach Gain(+)/Loss(-)	0.0	-11.7	-5.2	19.1	50.4	25.4	30.9	37.4	27.2	42.9	51.4
Beach Length (Feet)	3176	2548	3176	3176	2721	3176	3176	2619	3176	2784	3176

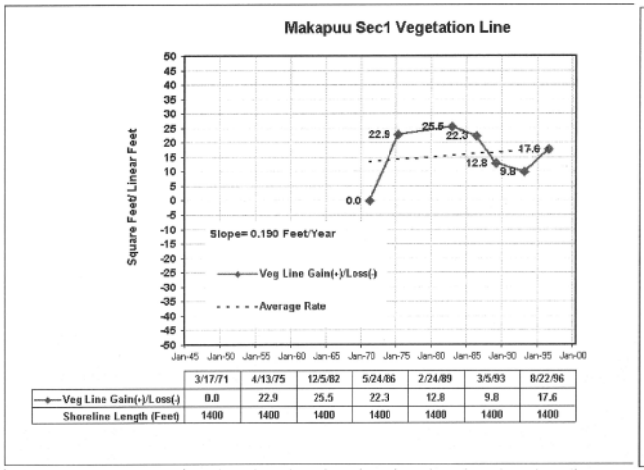




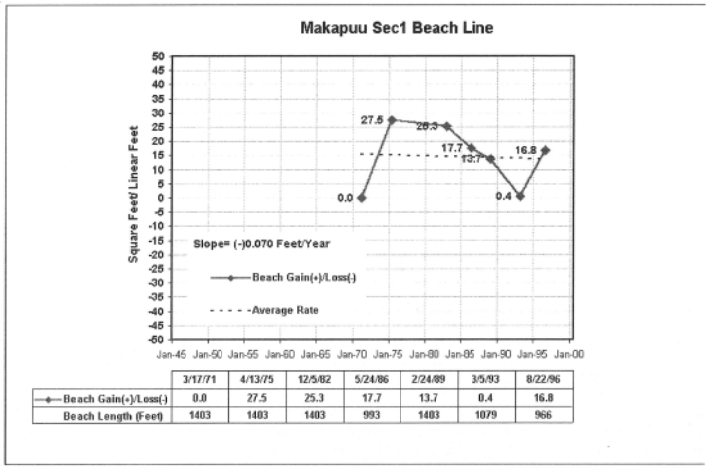
AERIAL PHOTOGRAPHIC ANALYSIS
KAIONA BEACH, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

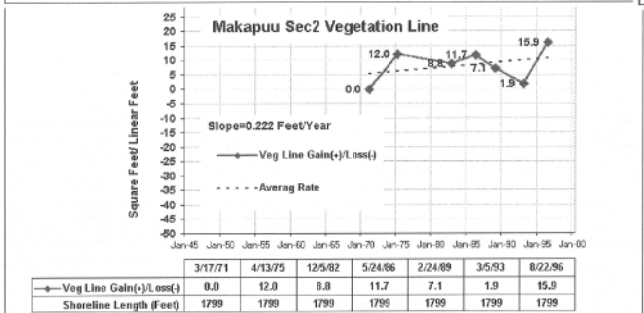




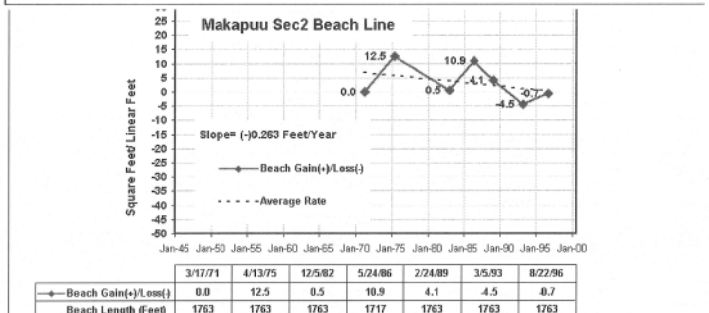
	3/17/71	4/13/75	12/5/82	5/24/86	2/24/89	3/5/93	8/22/96
Veg Line Gain(+)/Loss(-)	0.0	22.9	25.5	22.3	12.8	9.8	17.6
Shoreline Length (Feet)	1400	1400	1400	1400	1400	1400	1400



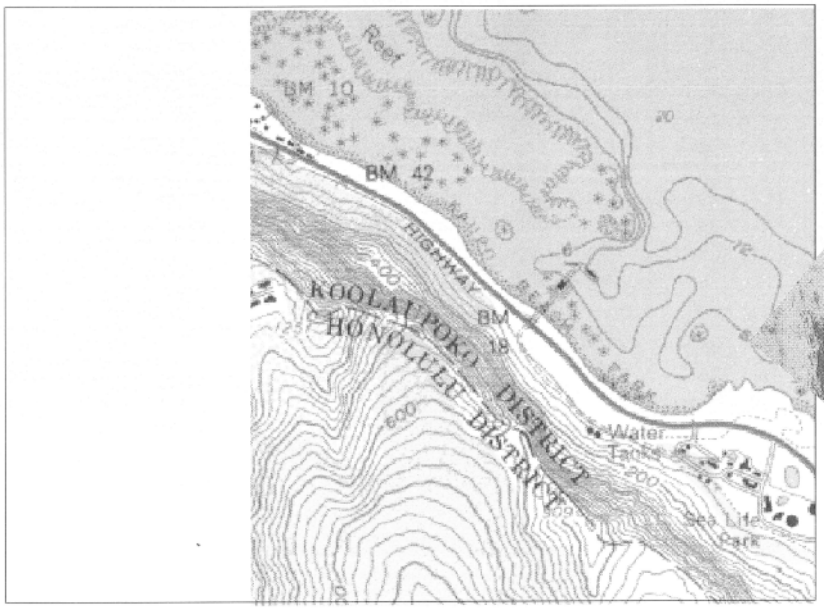
	3/17/71	4/13/75	12/5/82	5/24/86	2/24/89	3/5/93	8/22/96
Beach Gain(+)/Loss(-)	0.0	27.5	25.3	17.7	13.7	0.4	16.8
Beach Length (Feet)	1403	1403	1403	993	1403	1079	966



	3/17/71	4/13/75	12/5/82	5/24/86	2/24/89	3/5/93	8/22/96
Veg Line Gain(+)/Loss(-)	0.0	12.0	8.8	11.7	7.1	1.9	15.9
Shoreline Length (Feet)	1799	1799	1799	1799	1799	1799	1799

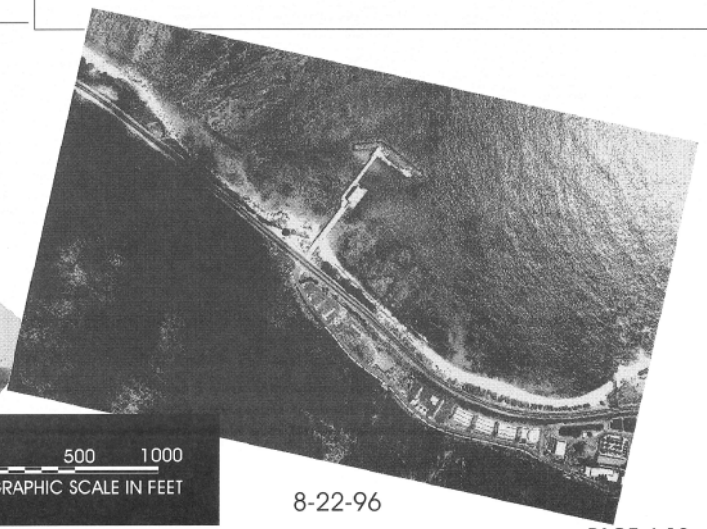


	3/17/71	4/13/75	12/5/82	5/24/86	2/24/89	3/5/93	8/22/96
Beach Gain(+)/Loss(-)	0.0	12.5	0.5	10.9	4.1	4.5	0.7
Beach Length (Feet)	1763	1763	1763	1717	1763	1763	1763





3-17-71

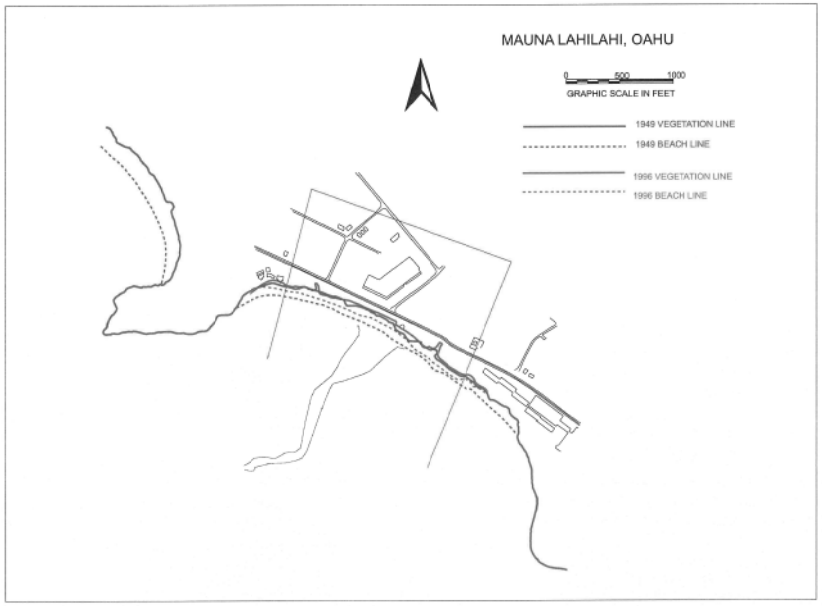


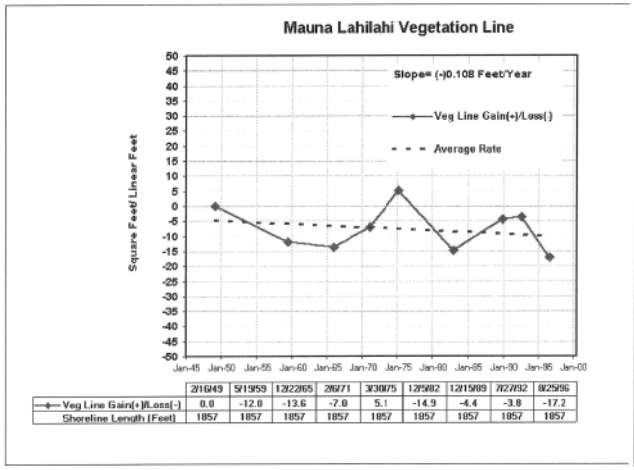
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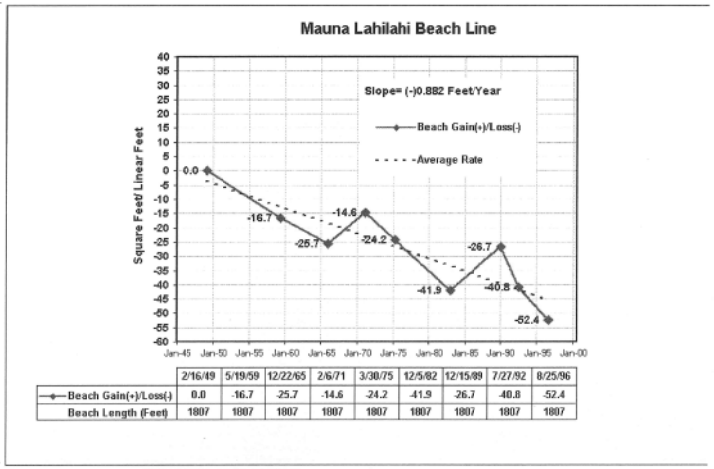
AERIAL PHOTOGRAPHIC ANALYSIS
MAKAPUU PIER, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

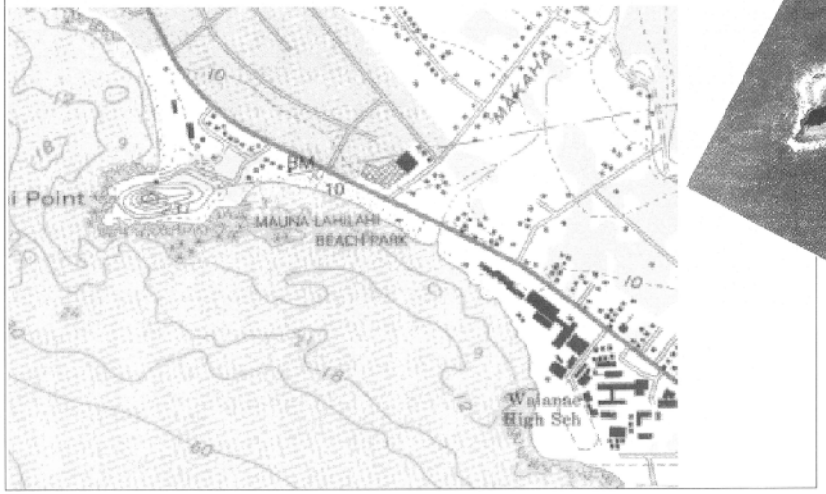




	2/16/49	5/19/59	12/22/65	2/6/71	3/30/75	12/5/82	12/15/89	7/27/92	8/25/96
Veg Line Gain(+)/Loss(-)	0.0	-12.0	-13.6	-7.0	5.1	-14.9	-4.4	-3.8	-17.2
Shoreline Length (Feet)	1857	1857	1857	1857	1857	1857	1857	1857	1857



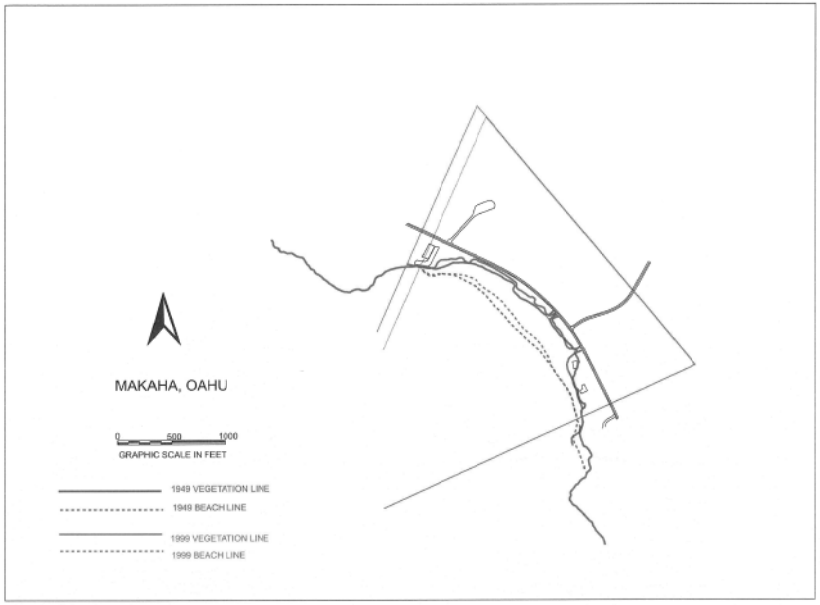
	2/16/49	5/19/59	12/22/65	2/6/71	3/30/75	12/5/82	12/15/89	7/27/92	8/25/96
Beach Gain(+)/Loss(-)	0.0	-16.7	-25.7	-14.6	-24.2	-41.9	-26.7	-40.8	-52.4
Beach Length (Feet)	1807	1807	1807	1807	1807	1807	1807	1807	1807

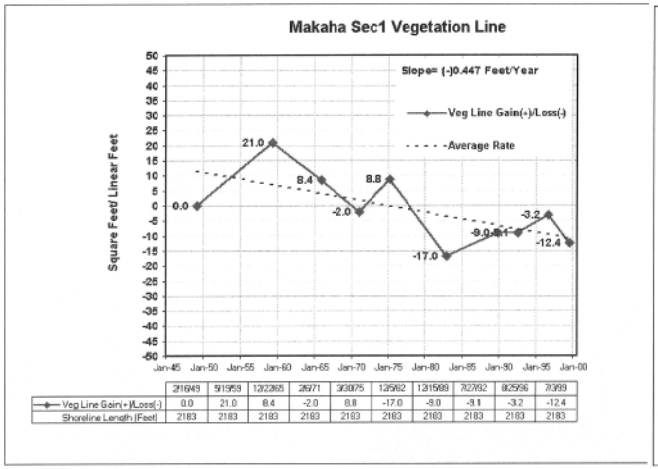




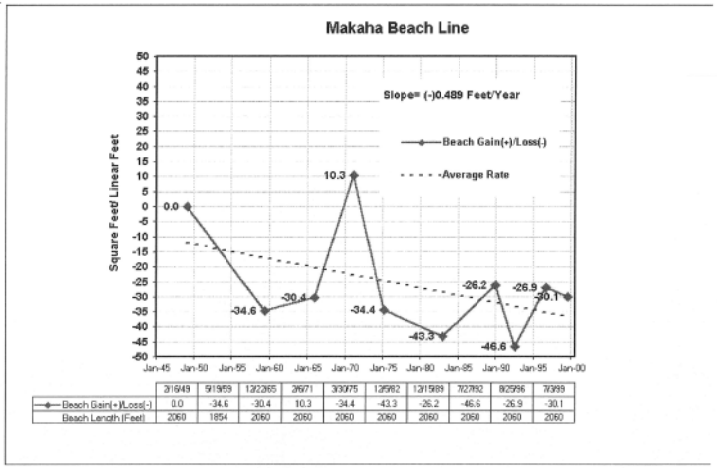
AERIAL PHOTOGRAPHIC ANALYSIS
MAUNA LAHILAHI, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

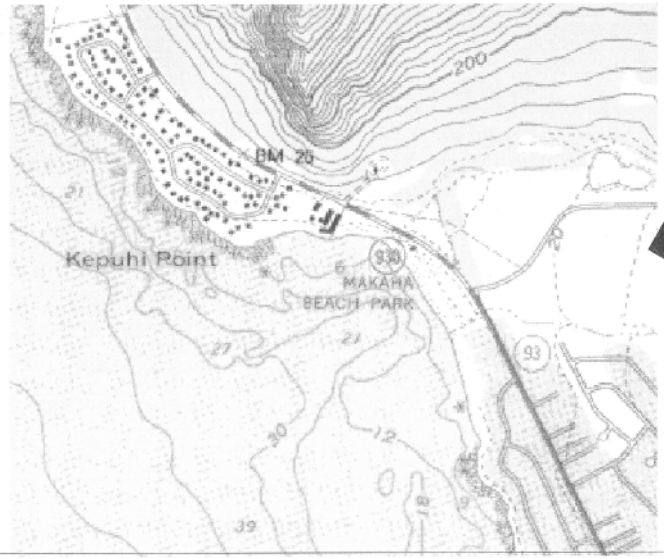


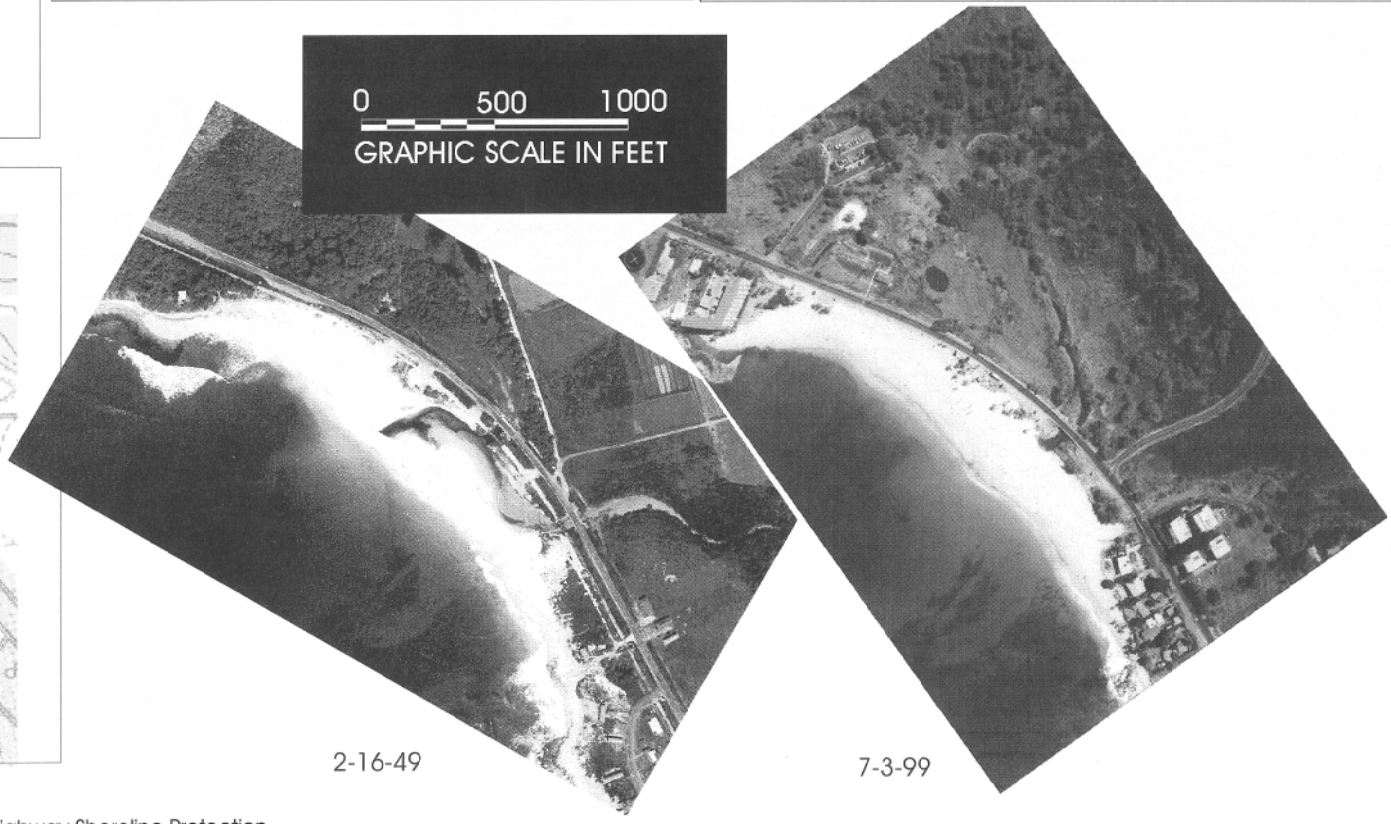


	216949	519959	1222365	26971	330075	125982	1215989	702792	825996	70999
Veg Line Gain(+)/Loss(-)	0.0	21.0	8.4	-2.0	8.8	-17.0	-9.0	-9.1	-3.2	-12.4
Shoreline Length (Feet)	2183	2183	2183	2183	2183	2183	2183	2183	2183	2183



	216949	519959	1222365	26971	330075	125982	1215989	702792	825996	70999
Beach Gain(+)/Loss(-)	0.0	-34.6	-30.4	10.3	-34.4	-43.3	-26.2	-46.6	-26.9	-30.1
Beach Length (Feet)	2060	1854	2060	2060	2060	2060	2060	2058	2060	2060



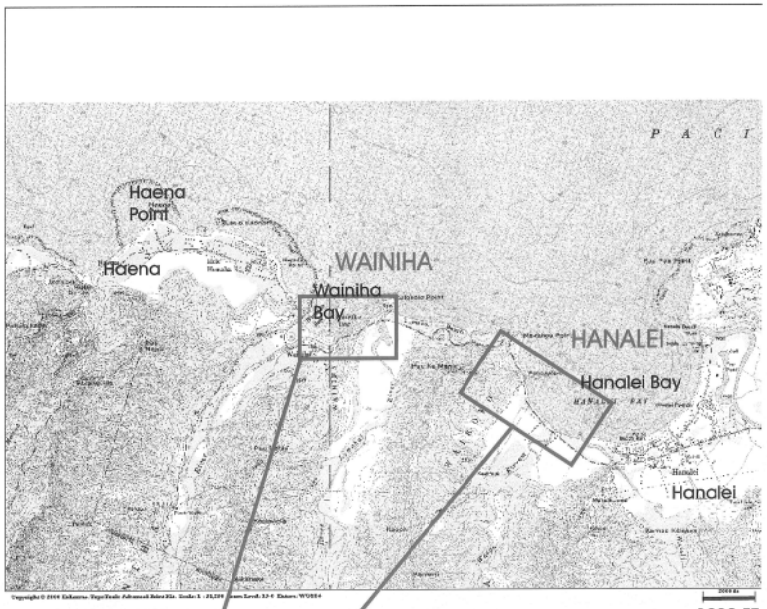


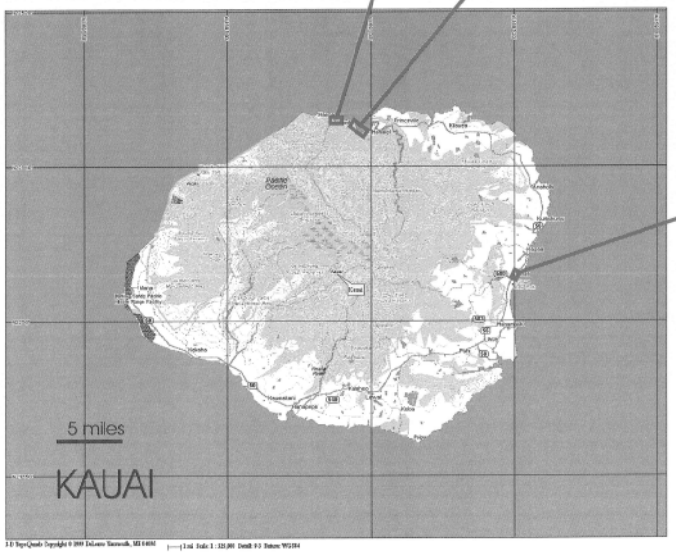
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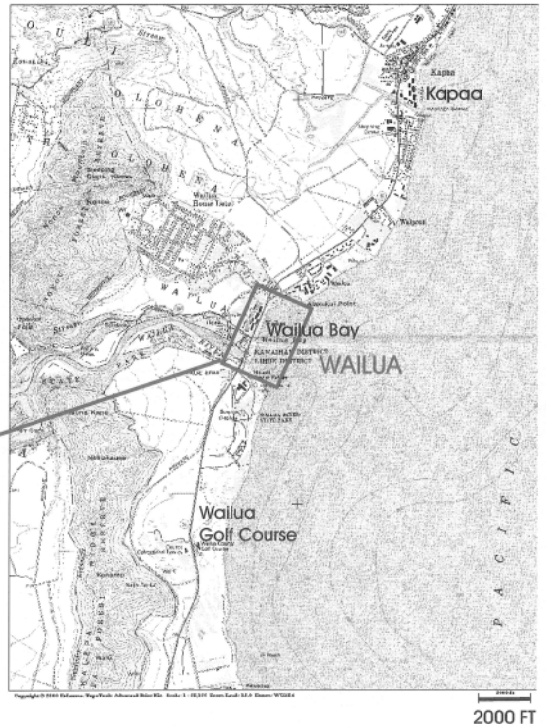
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AERIAL PHOTOGRAPHIC ANALYSIS
MAKAHA, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

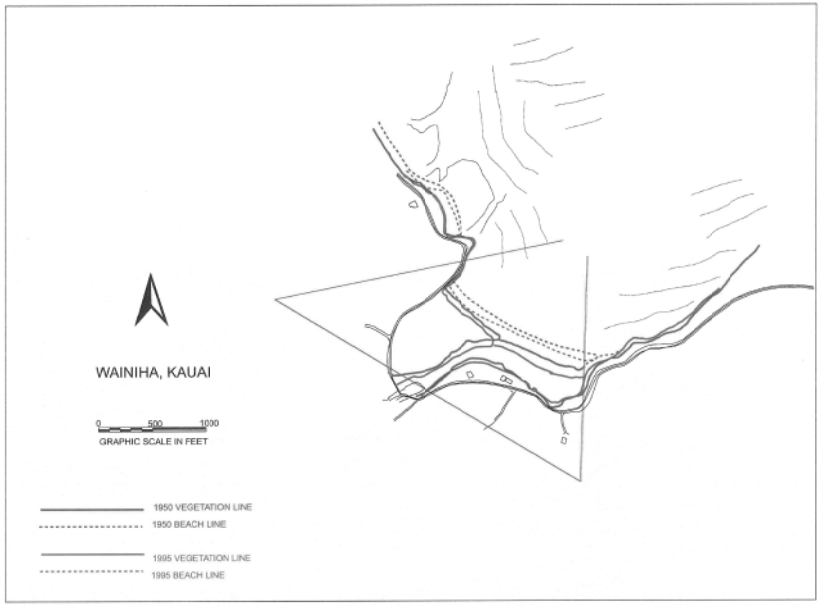


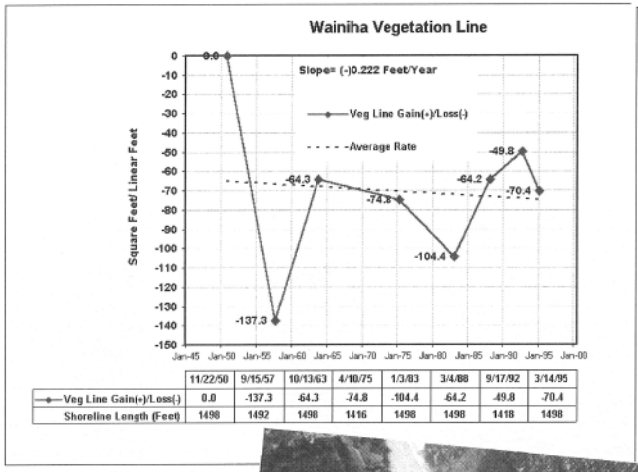




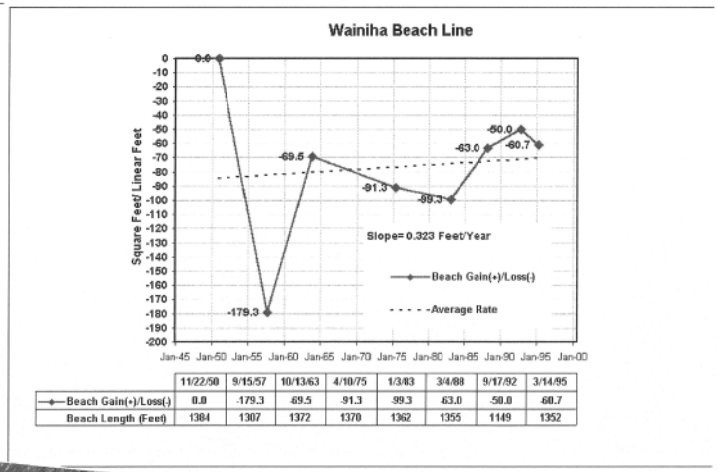
ISLAND OF KAUAI
ANALYSIS OF SHORELINE CHANGES

Statewide Highway Shoreline Protection
Project number HWY-08-98

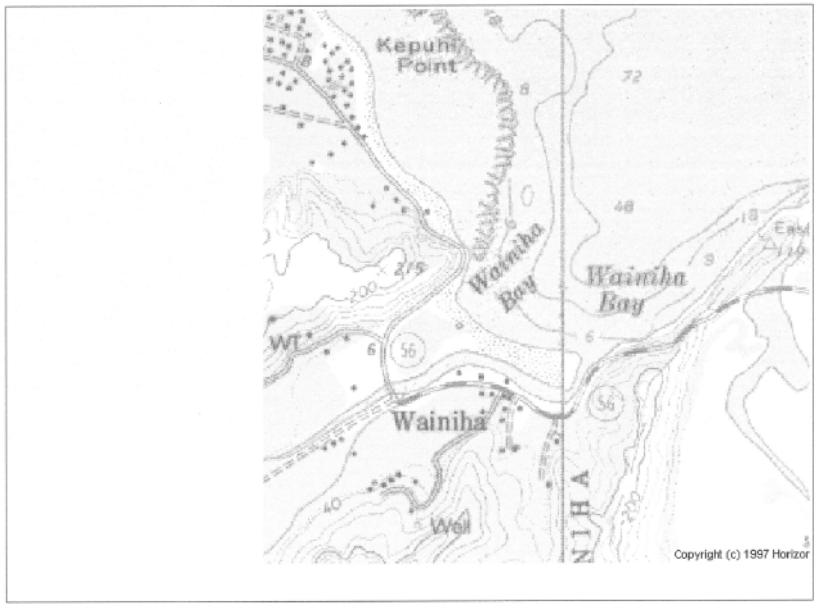




	11/22/50	9/15/57	10/13/63	4/10/75	1/3/83	3/4/88	9/17/92	3/14/95
Veg Line Gain(+)/Loss(-)	0.0	-137.3	-64.3	-74.8	-104.4	-64.2	-49.8	-70.4
Shoreline Length (Feet)	1498	1492	1498	1416	1498	1498	1418	1498

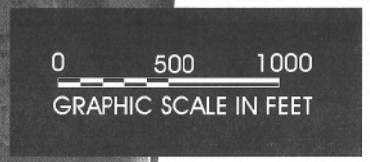


	11/22/50	9/15/57	10/13/63	4/10/75	1/3/83	3/4/88	9/17/92	3/14/95
Beach Gain(+)/Loss(-)	0.0	-179.3	-69.5	-91.3	-99.3	-63.0	-50.0	-60.7
Beach Length (Feet)	1384	1307	1372	1370	1362	1355	1149	1352



3-14-95



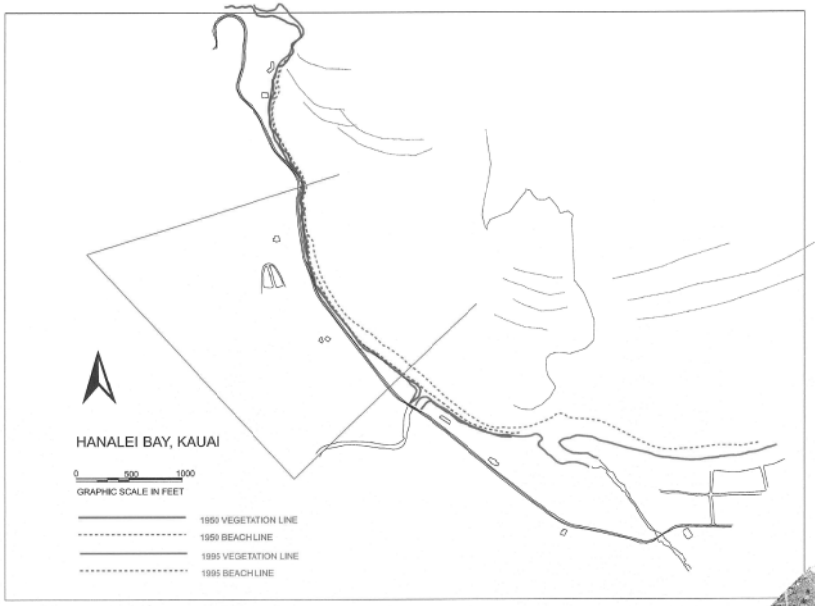


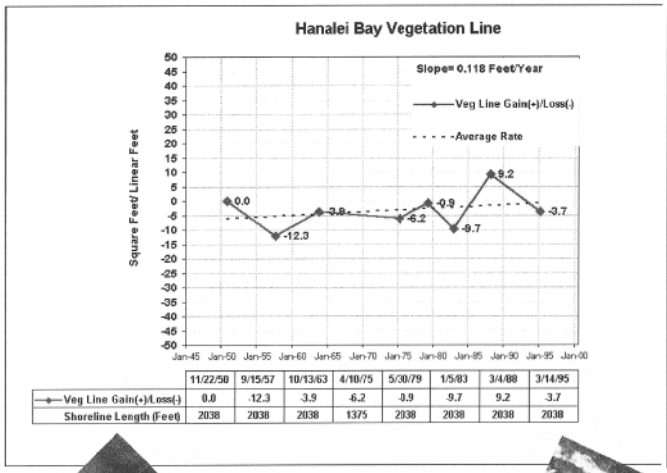
11-22-50



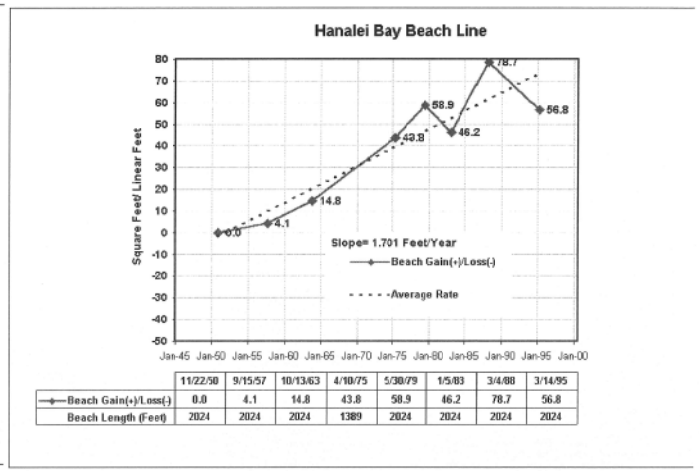
AERIAL PHOTOGRAPHIC ANALYSIS
WAINIHA BAY, KAUAI

Statewide Highway Shoreline Protection
Project number HWY-08-98

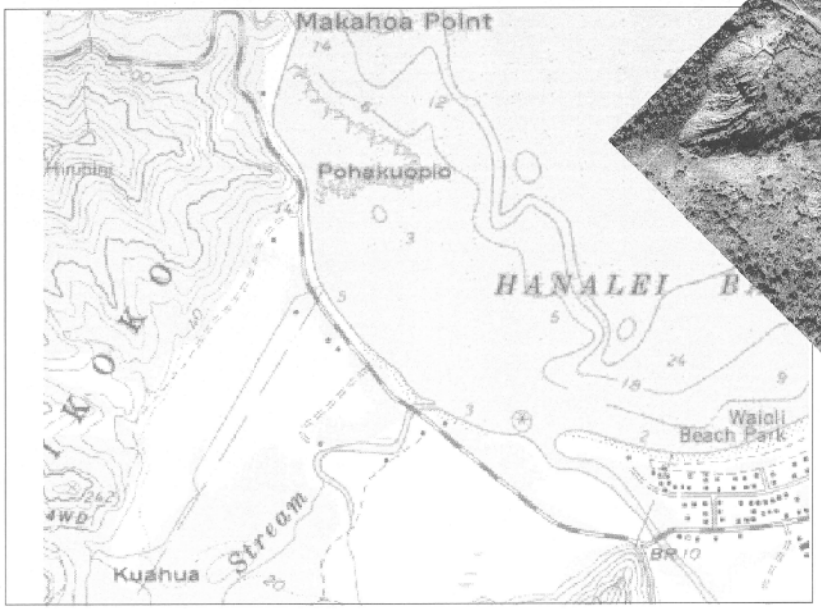




	11/22/50	9/15/57	10/13/63	4/10/75	5/30/79	1/5/83	3/4/88	3/14/95
Veg Line Gain(+)/Loss(-)	0.0	-12.3	-3.9	-6.2	-0.9	-9.7	9.2	-3.7
Shoreline Length (Feet)	2038	2038	2038	1375	2038	2038	2038	2038



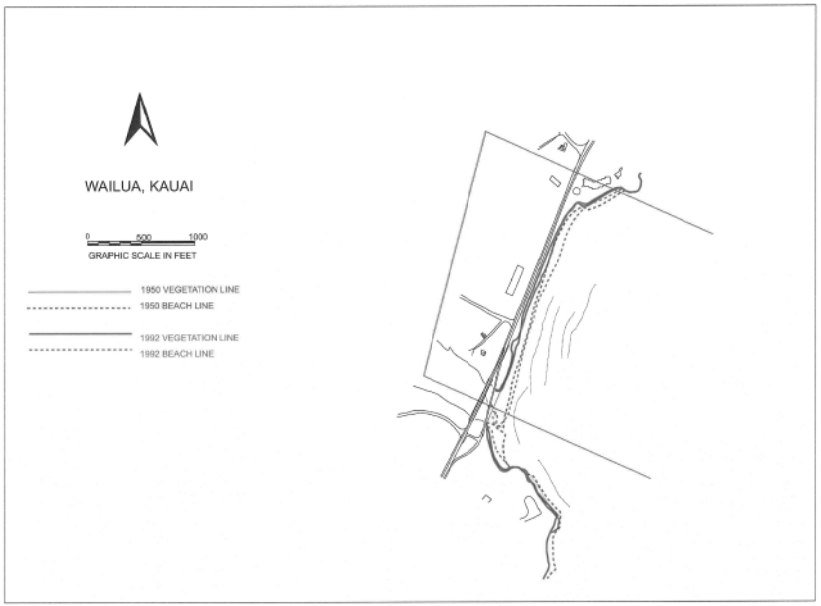
	11/22/50	9/15/57	10/13/63	4/10/75	5/30/79	1/5/83	3/4/88	3/14/95
Beach Gain(+)/Loss(-)	0.0	4.1	14.8	43.8	58.9	46.2	78.7	56.8
Beach Length (Feet)	2024	2024	2024	1389	2024	2024	2024	2024

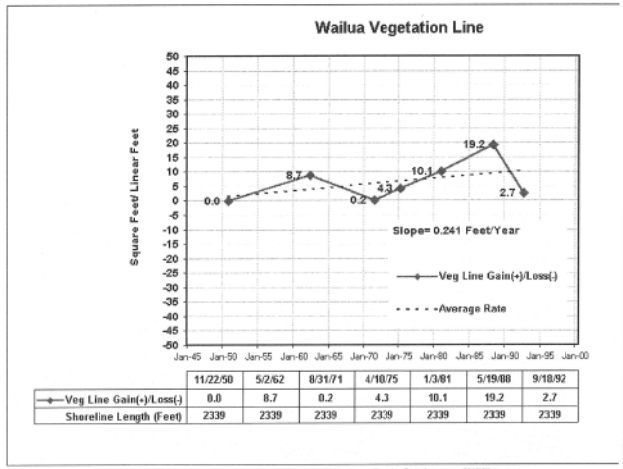




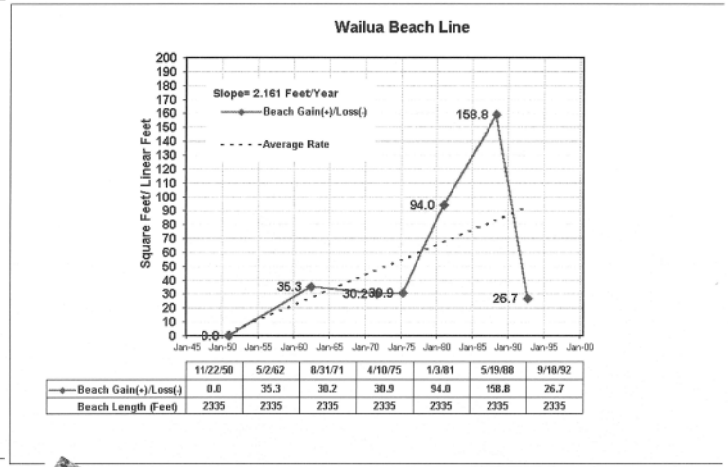
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HANALEI BAY, KAUAI

Statewide Highway Shoreline Protection
Project number HWY-08-98

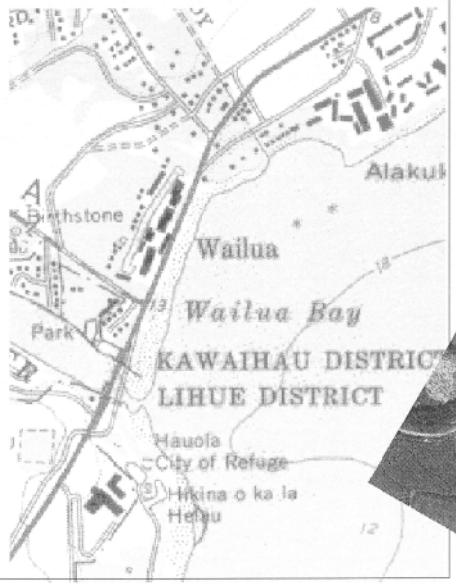




	11/22/50	5/2/62	8/31/71	4/10/75	1/3/81	5/19/88	9/18/92
Veg Line Gain(+)/Loss(-)	0.0	8.7	0.2	4.3	10.1	19.2	2.7
Shoreline Length (Feet)	2339	2339	2339	2339	2339	2339	2339



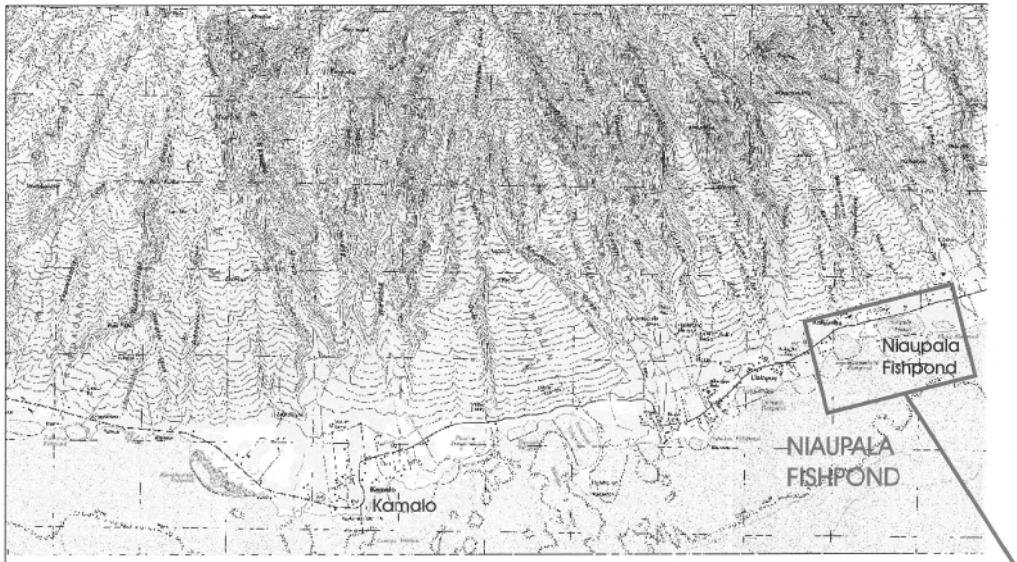
	11/22/50	5/2/62	8/31/71	4/10/75	1/3/81	5/19/88	9/18/92
Beach Gain(+)/Loss(-)	0.0	35.3	30.2	30.9	94.0	158.8	26.7
Beach Length (Feet)	2335	2335	2335	2335	2335	2335	2335

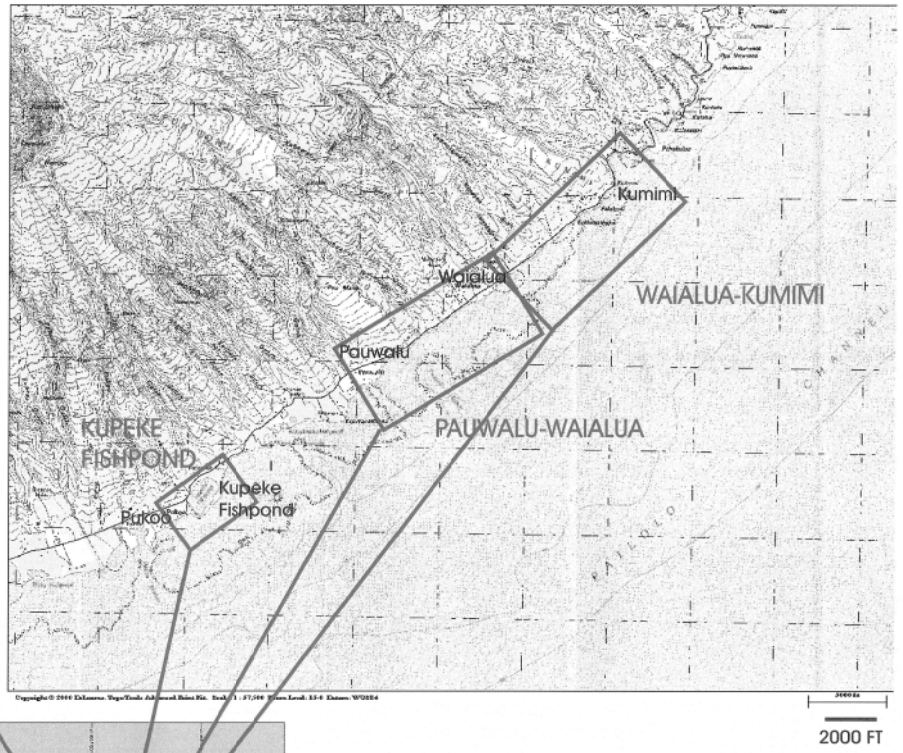


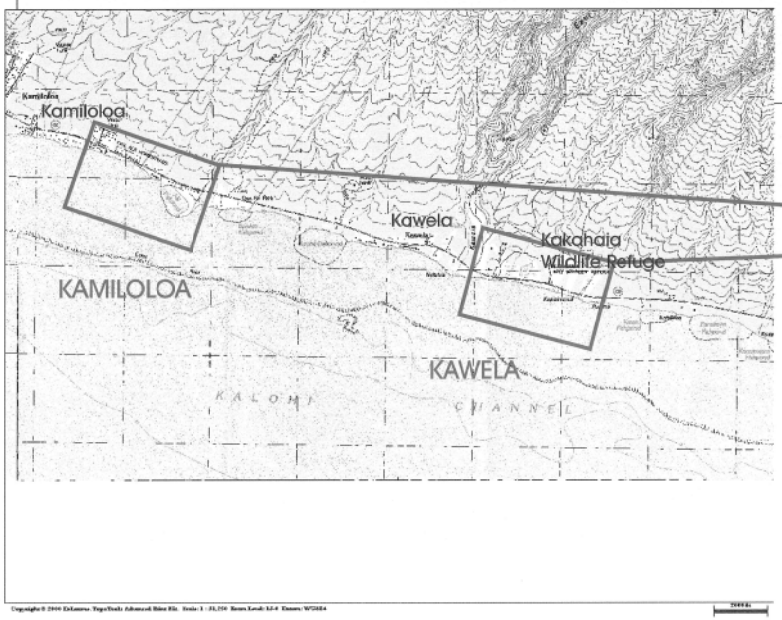


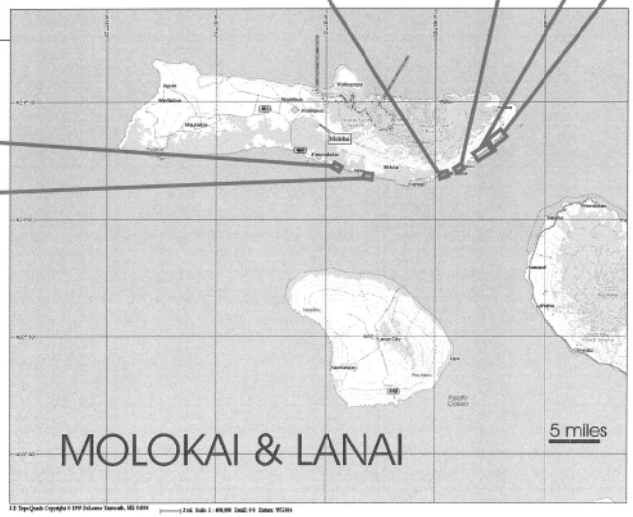
AERIAL PHOTOGRAPHIC ANALYSIS
WAILUA BAY, KAUAI

Statewide Highway Shoreline Protection
Project number HWY-08-98



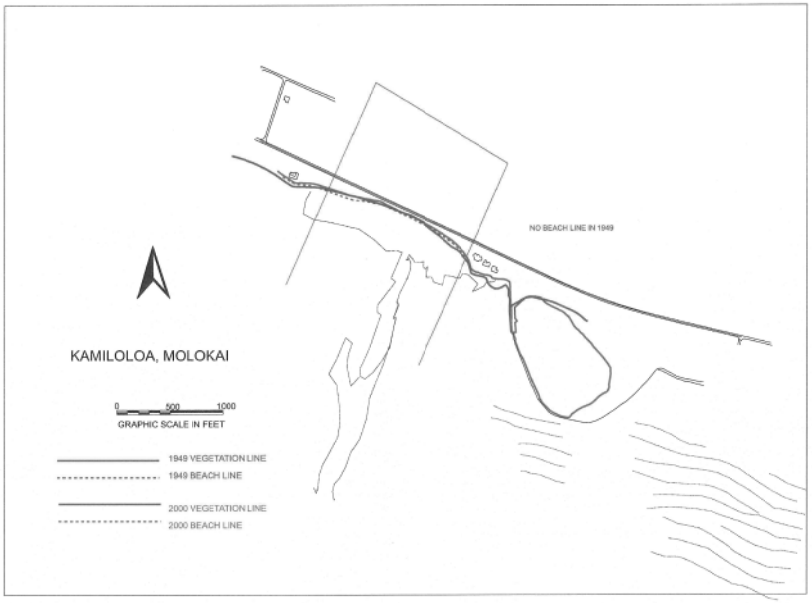


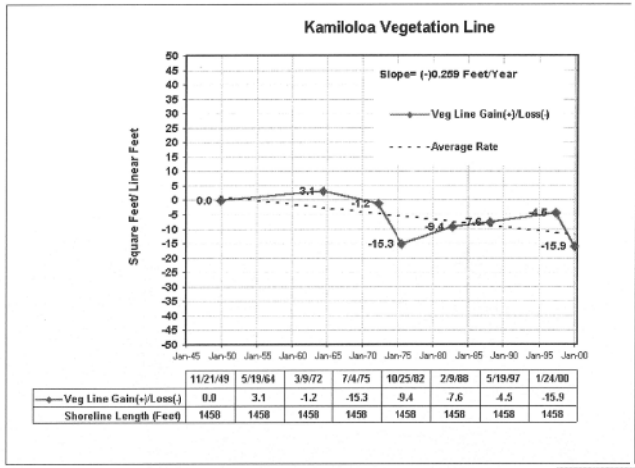




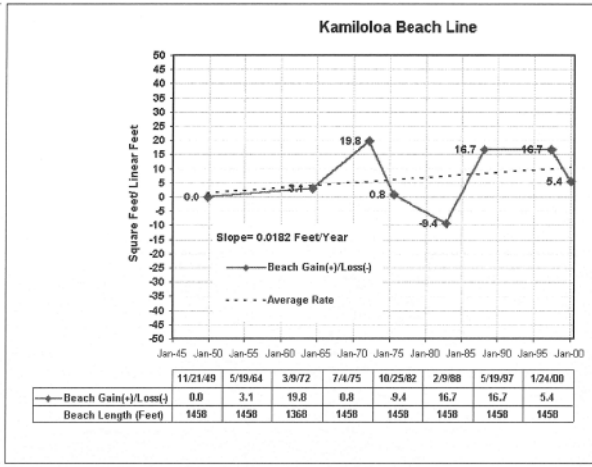
ISLAND OF MOLOKAI
ANALYSIS OF SHORELINE CHANGES

Statewide Highway Shoreline Protection
Project number HWY-08-98

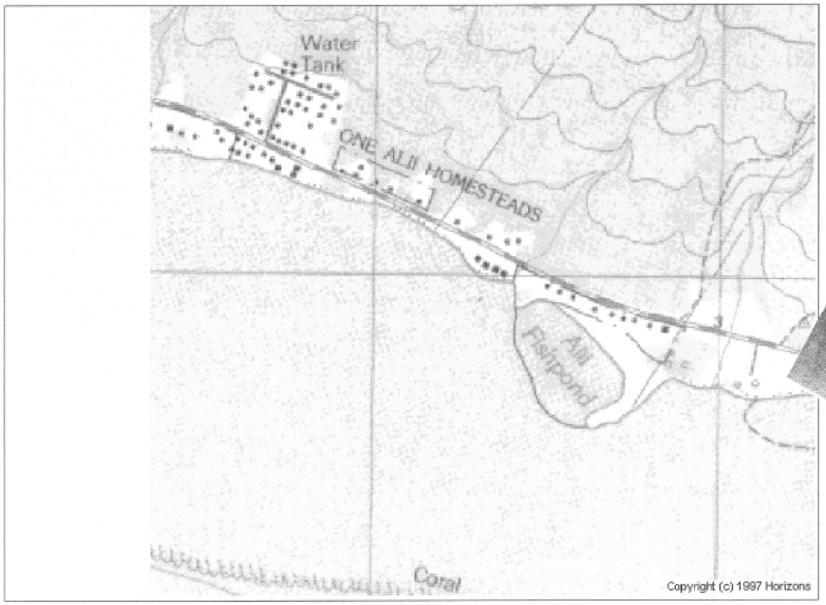


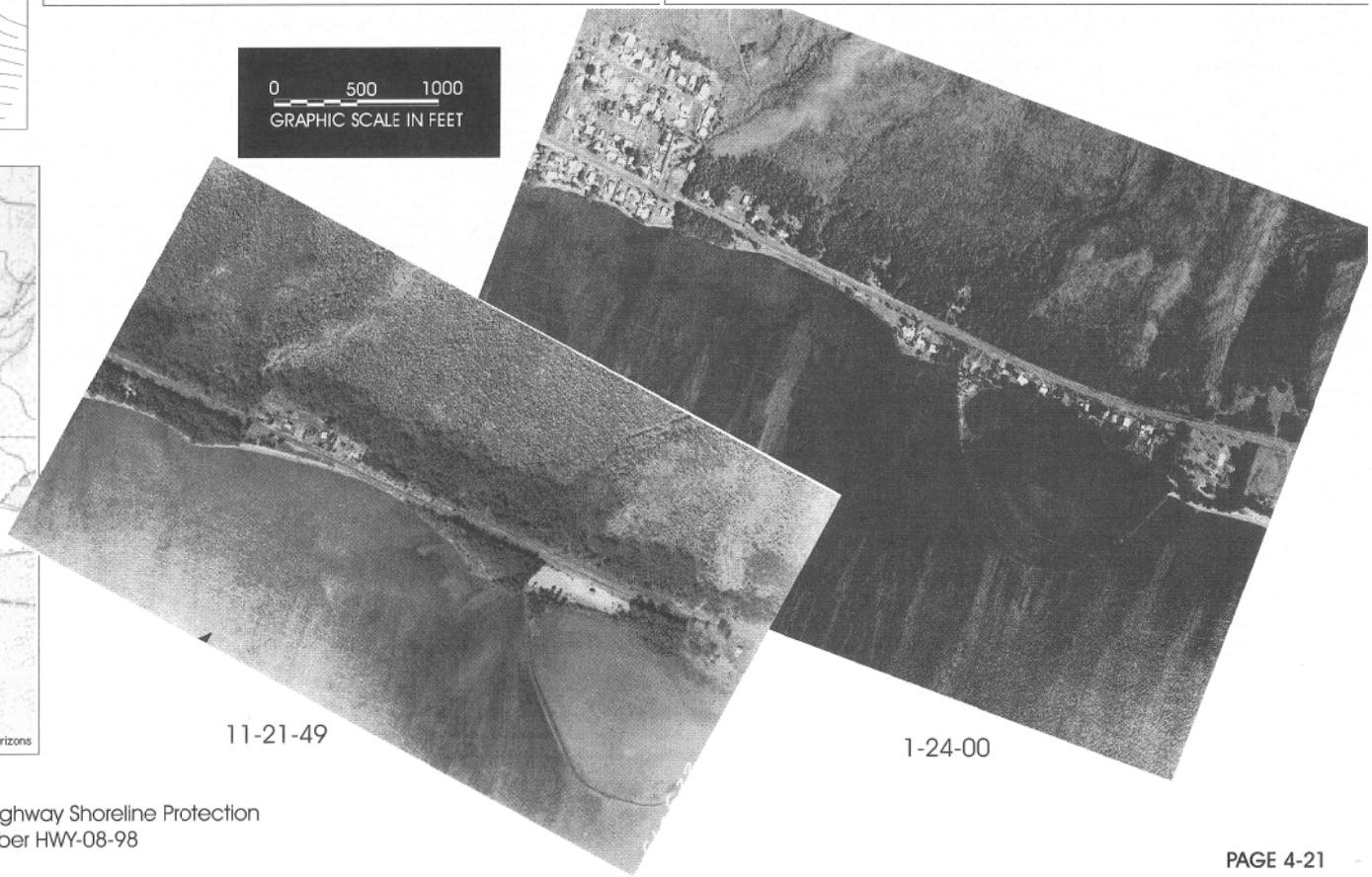


	11/21/49	5/19/64	3/9/72	7/4/75	10/25/82	2/9/88	5/19/97	1/24/00
Veg Line Gain(+)/Loss(-)	0.0	3.1	-1.2	-15.3	-9.4	-7.6	-4.5	-15.9
Shoreline Length (Feet)	1458	1458	1458	1458	1458	1458	1458	1458



	11/21/49	5/19/64	3/9/72	7/4/75	10/25/82	2/9/88	5/19/97	1/24/00
Beach Gain(+)/Loss(-)	0.0	3.1	19.8	0.8	-9.4	16.7	16.7	5.4
Beach Length (Feet)	1458	1458	1368	1458	1458	1458	1458	1458



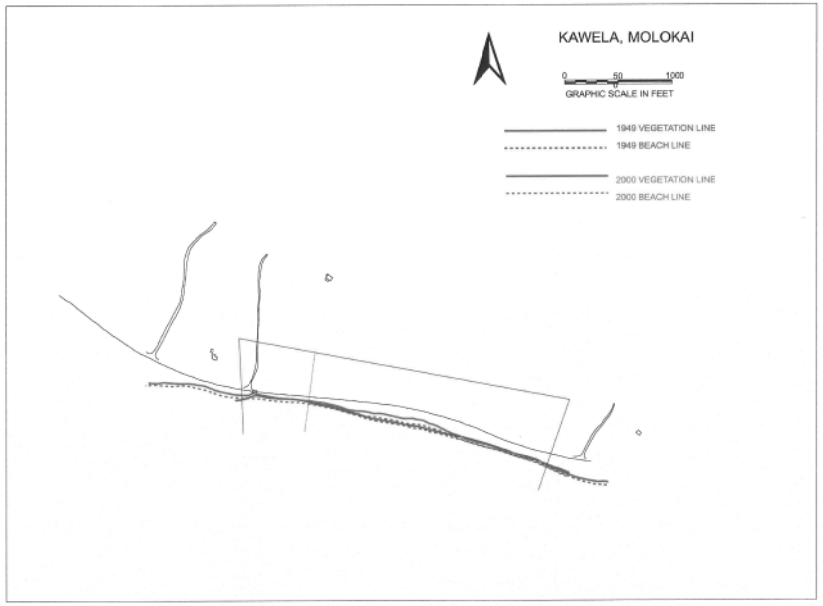


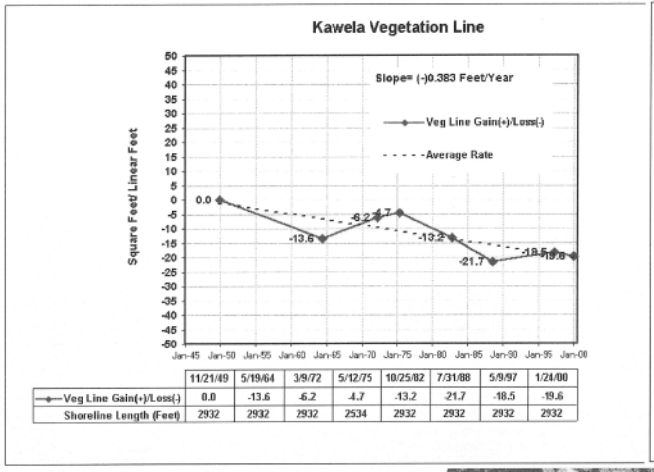
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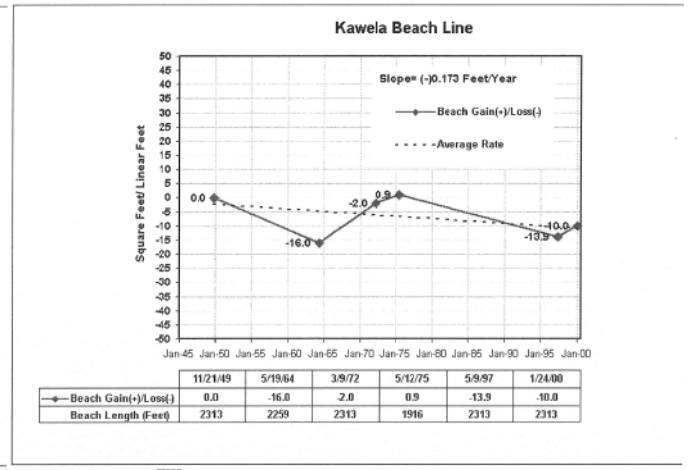
AERIAL PHOTOGRAPHIC ANALYSIS
KAMILOLOA, MOLOKAI

Statewide Highway Shoreline Protection
Project number HWY-08-98

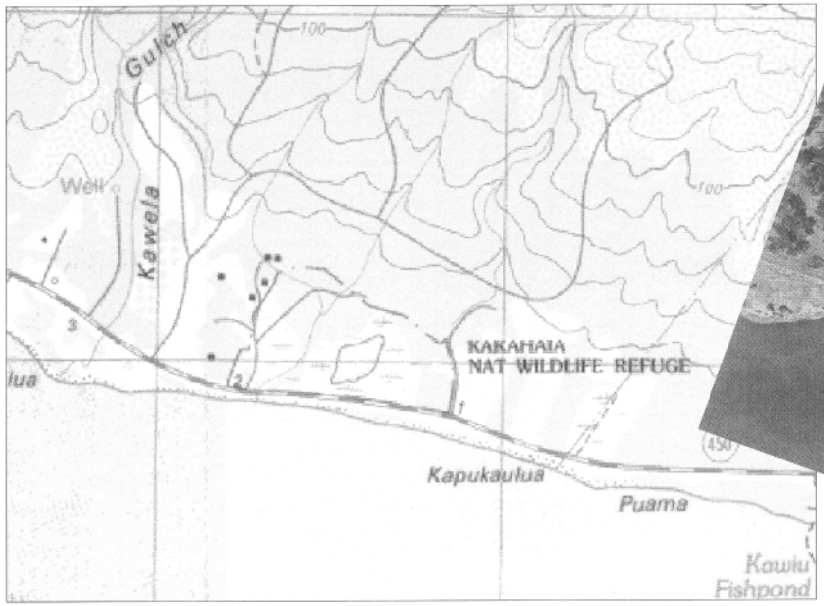




	11/21/49	5/19/64	3/9/72	5/12/75	10/25/82	7/31/88	5/9/97	1/24/00
Veg Line Gain(+)/Loss(-)	0.0	-13.6	-6.2	-4.7	-13.2	-21.7	-18.5	-19.6
Shoreline Length (Feet)	2932	2932	2932	2534	2932	2932	2932	2932



	11/21/49	5/19/64	3/9/72	5/12/75	5/9/97	1/24/00
Beach Gain(+)/Loss(-)	0.0	-16.0	-2.0	0.9	-13.9	-10.0
Beach Length (Feet)	2313	2259	2313	1916	2313	2313



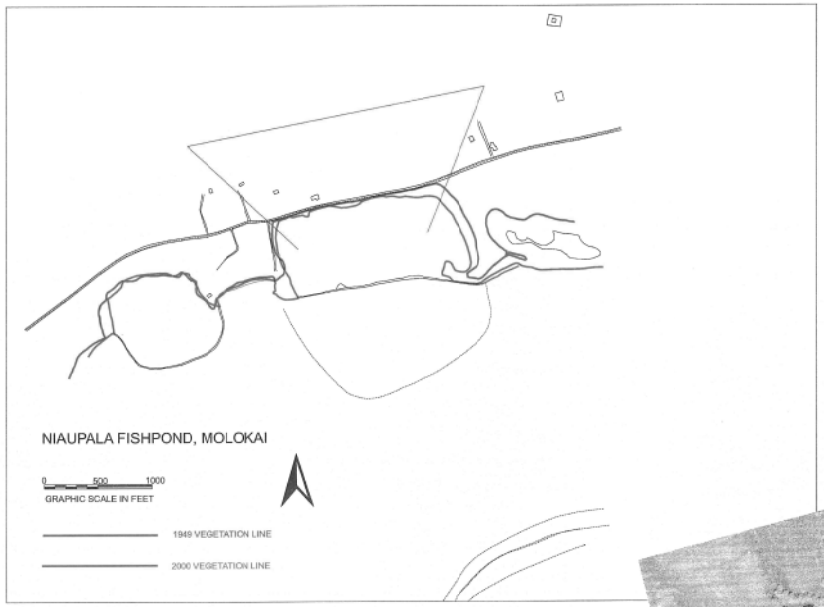


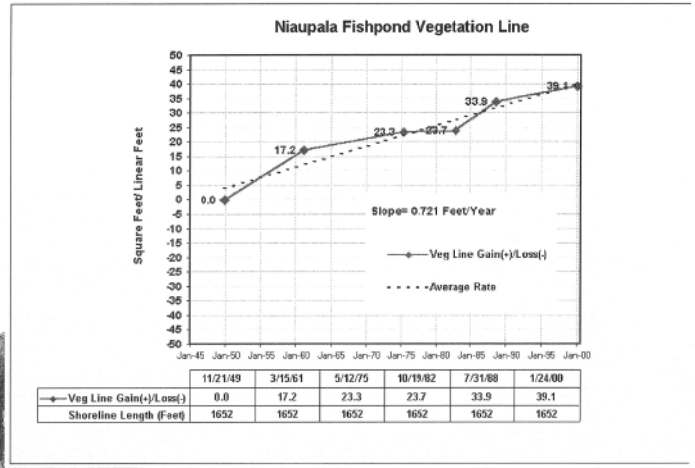
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AERIAL PHOTOGRAPHIC ANALYSIS
KAWELA, MOLOKAI

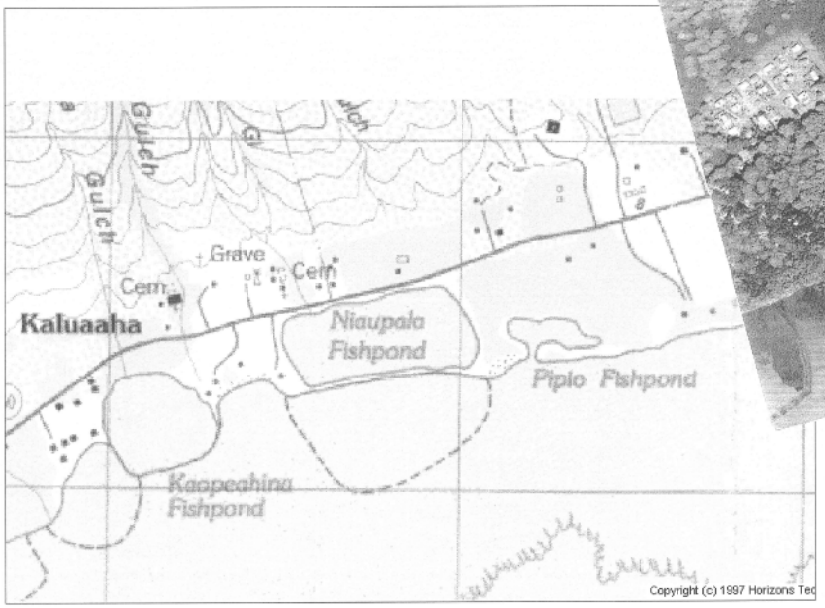
Statewide Highway Shoreline Protection
Project number HWY-08-98





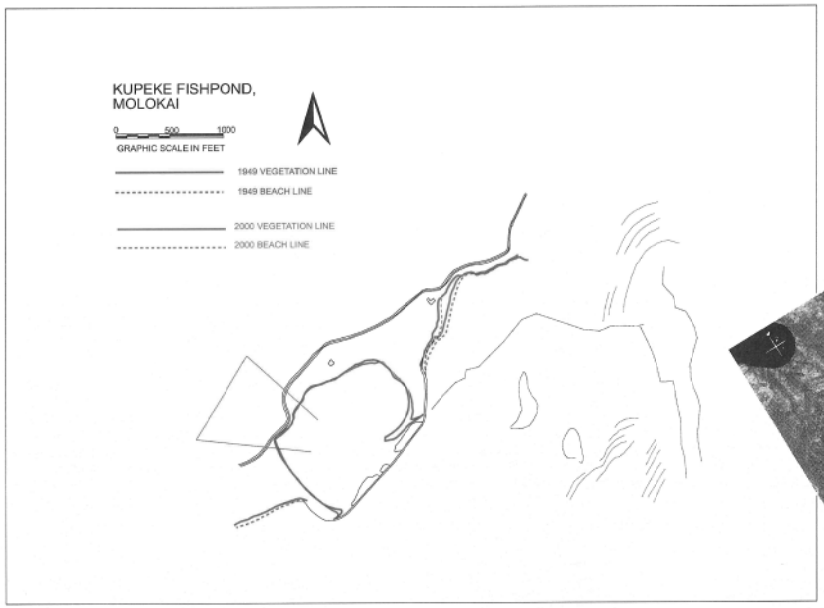
	11/21/49	3/15/61	5/12/75	10/19/82	7/31/88	1/24/00
Veg Line Gain(+)/Loss(-)	0.0	17.2	23.3	23.7	33.9	39.1
Shoreline Length (Feet)	1652	1652	1652	1652	1652	1652

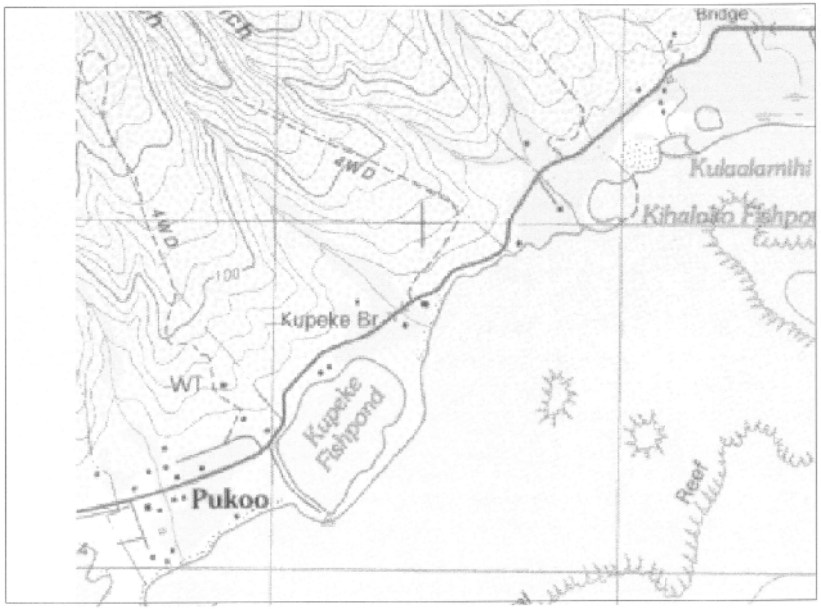


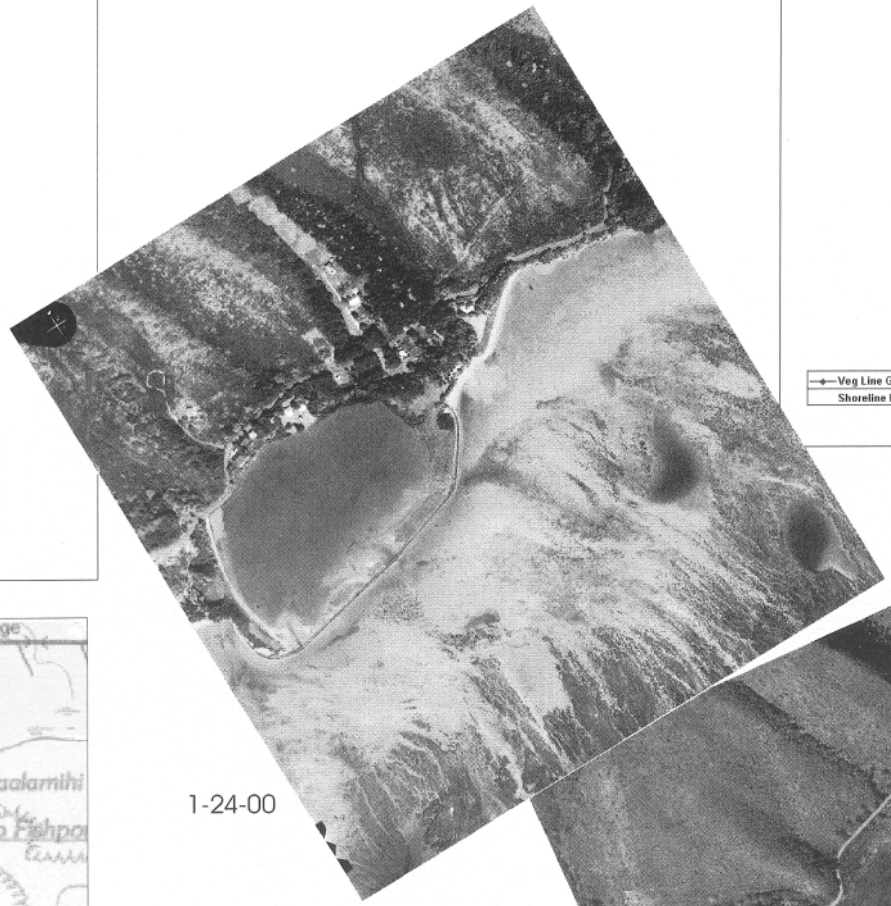


AERIAL PHOTOGRAPHIC ANALYSIS
NIAUPALA FISHPOND, MOLOKAI

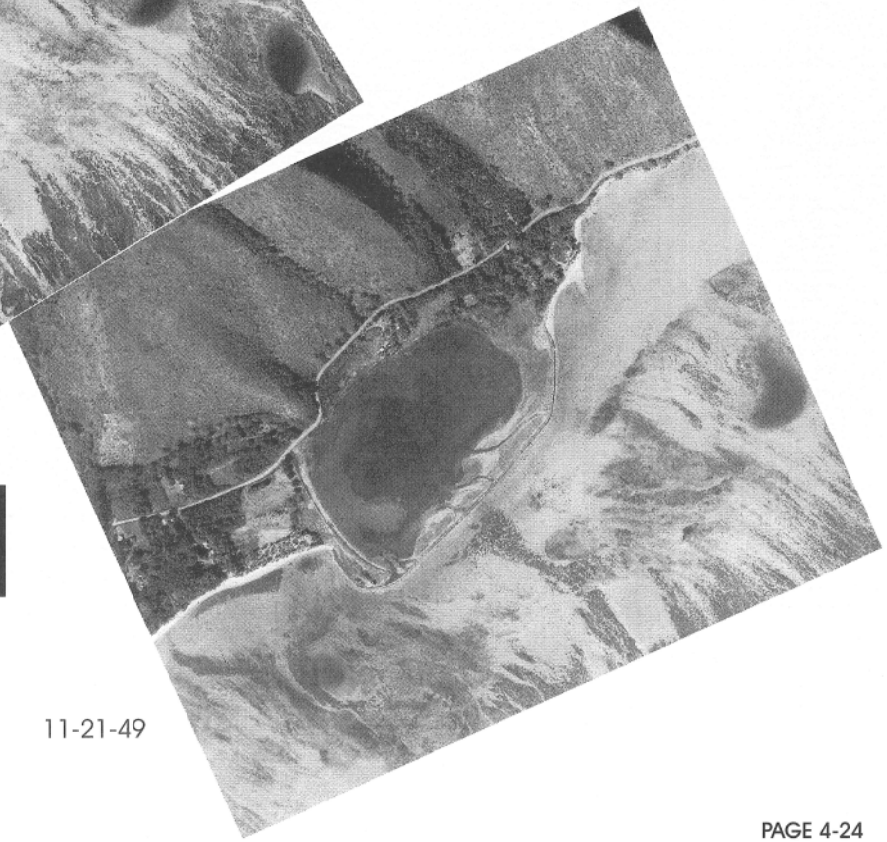
Statewide Highway Shoreline Protection
Project number HWY-08-98





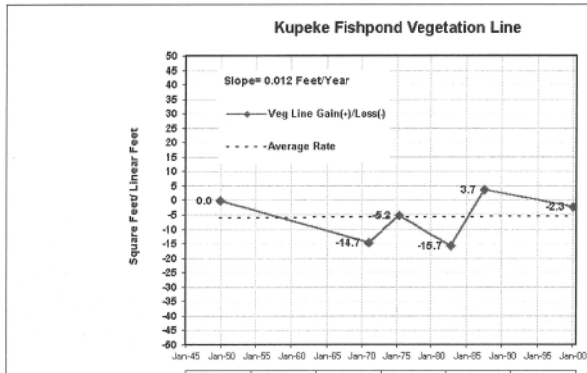


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11-21-49

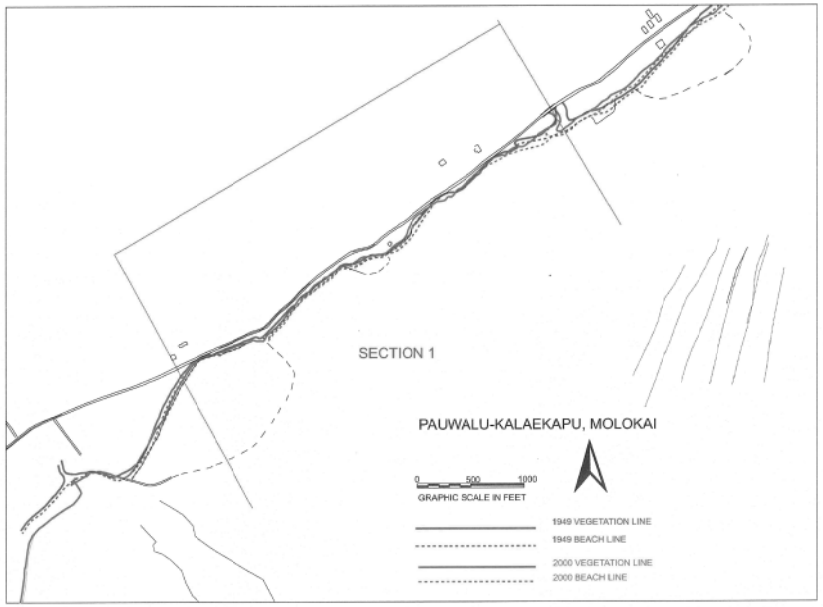
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GRAPHIC SCALE IN FEET

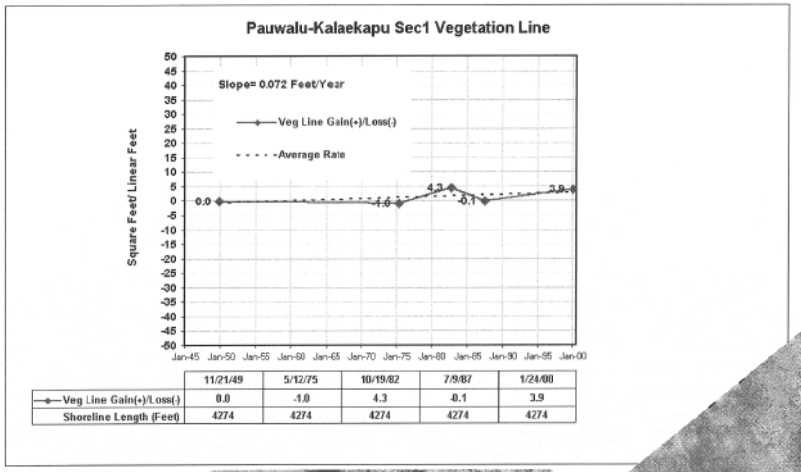


	11/21/49	1/26/71	5/12/75	10/19/82	7/9/87	1/24/00
Veg Line Gain(+)/Loss(-)	0.0	-14.7	-5.2	-15.7	3.7	-2.3
Shoreline Length (Feet)	471	471	471	471	471	471

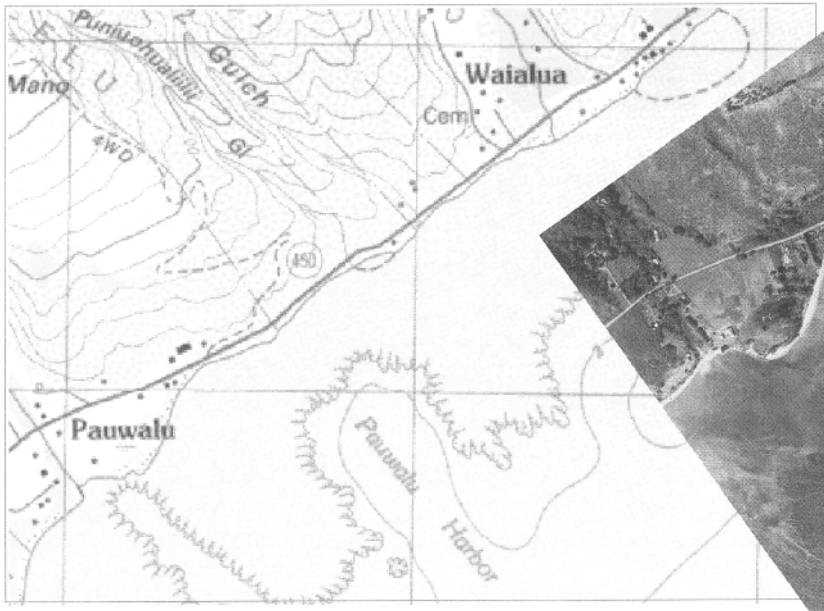
AERIAL PHOTOGRAPHIC ANALYSIS
KUPEKE FISHPOND, MOLOKAI

Statewide Highway Shoreline Protection
Project number HWY-08-98





	11/21/49	5/12/75	10/19/82	7/9/87	1/24/00
Veg Line Gain(+)/Loss(-)	0.0	-1.0	4.3	-0.1	3.9
Shoreline Length (Feet)	4274	4274	4274	4274	4274



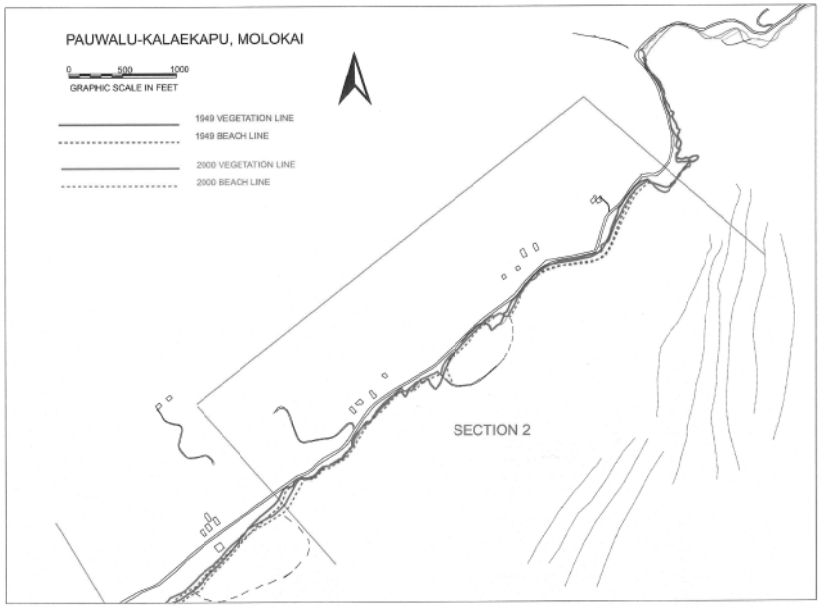


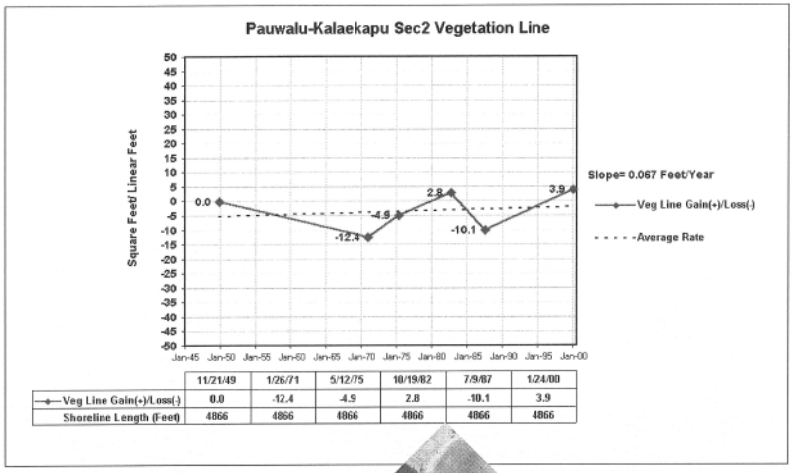
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1-24-00

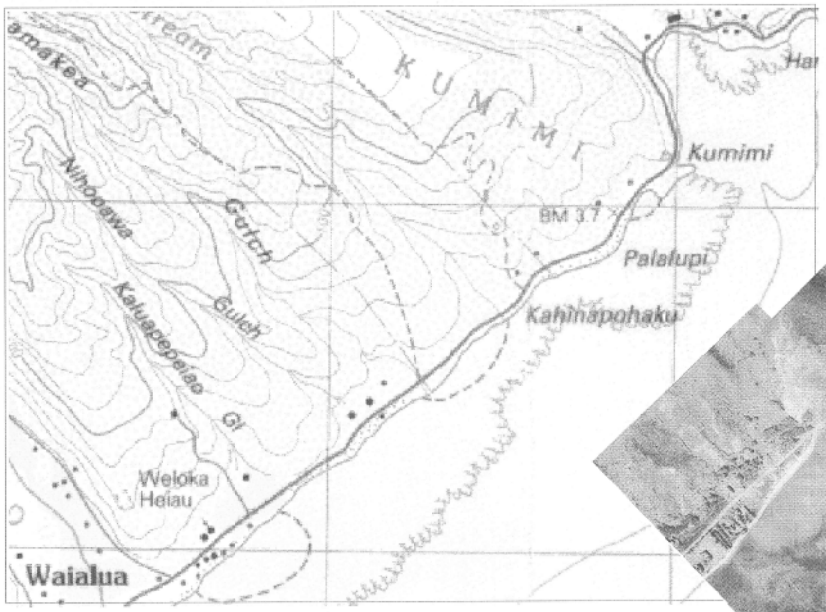
AERIAL PHOTOGRAPHIC ANALYSIS
PAUWALU - WAIALUA, MOLOKAI

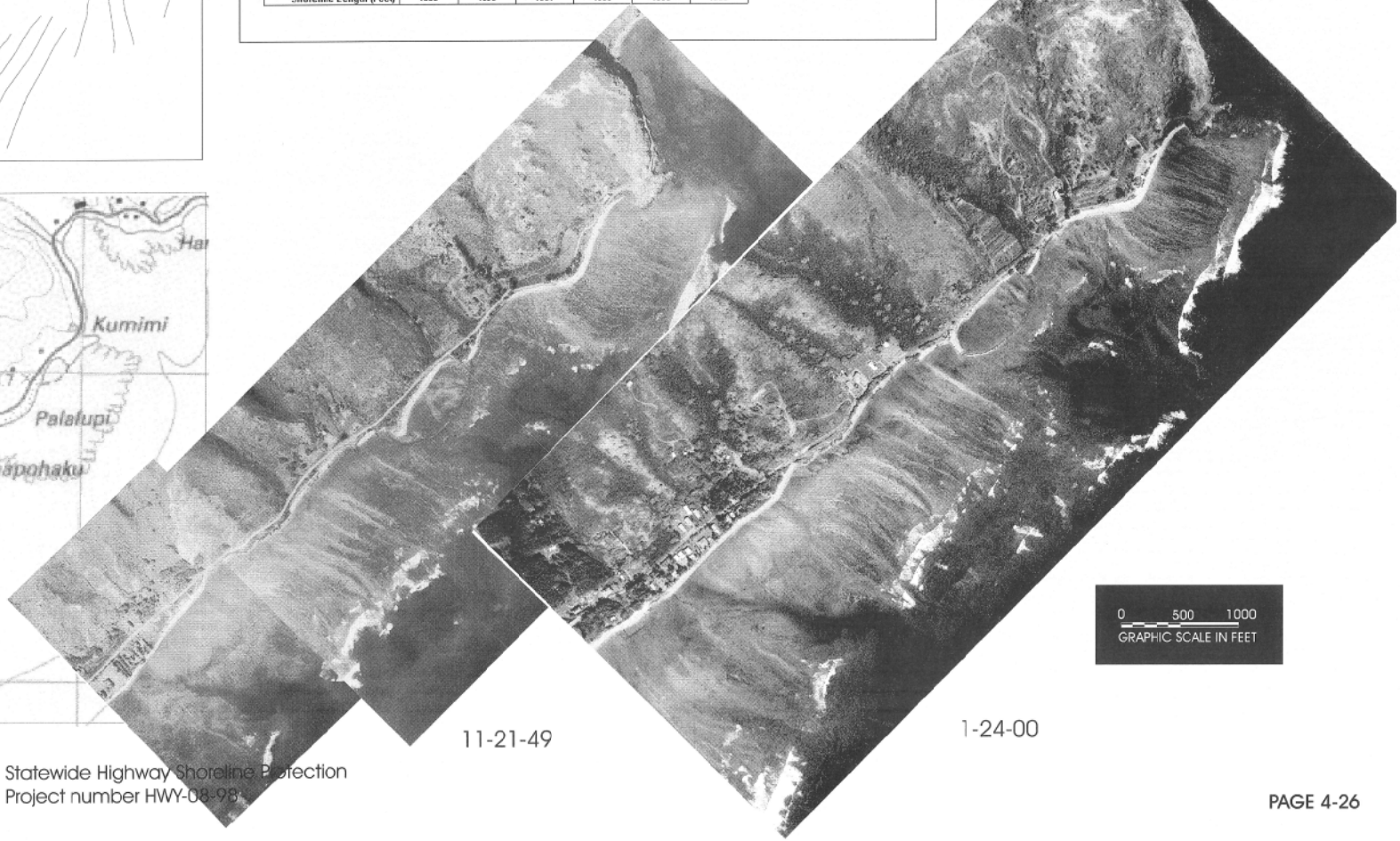
Statewide Highway Shoreline Protection
Project number HWY-08-98





	11/21/49	1/26/71	5/12/75	10/19/82	7/9/87	1/24/00
Veg Line Gain(+)/Loss(-)	0.0	-12.4	-4.9	2.8	-10.1	3.9
Shoreline Length (Feet)	4866	4866	4866	4866	4866	4866



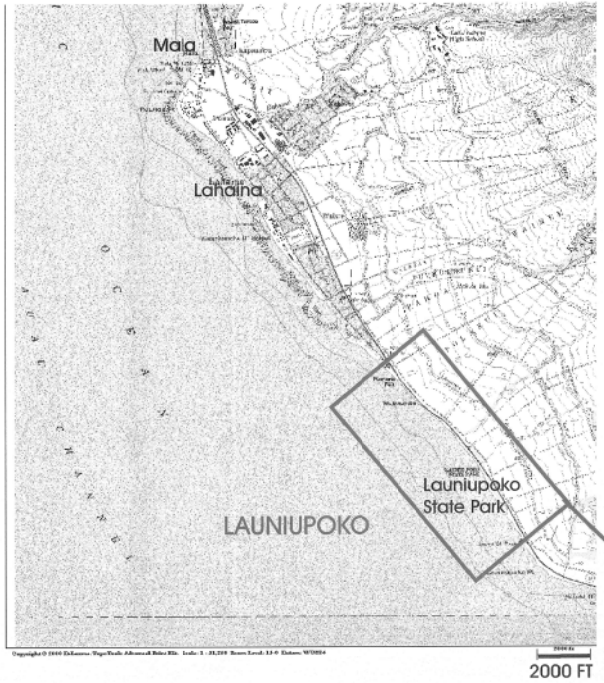


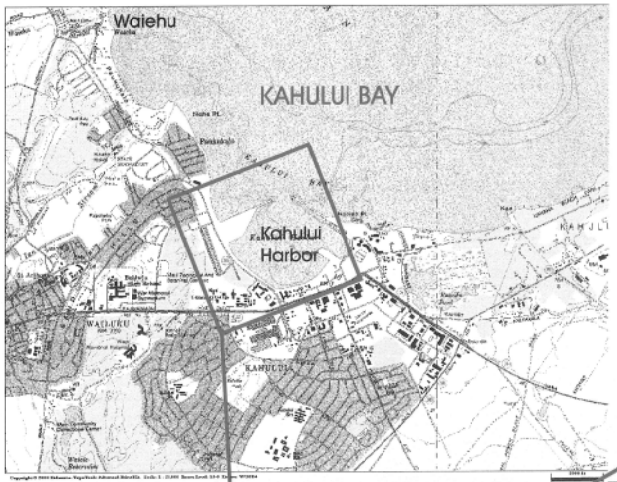
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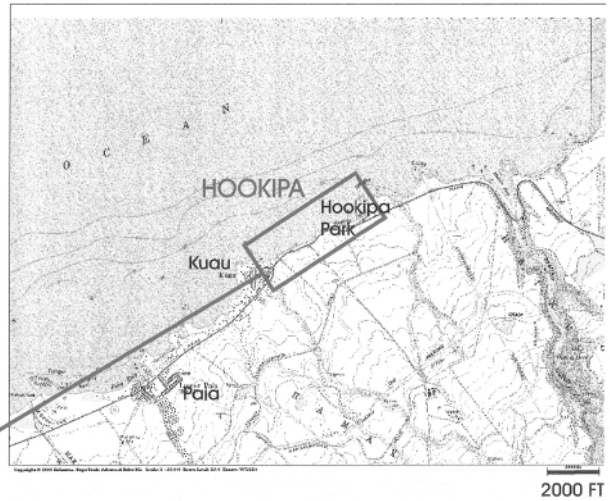
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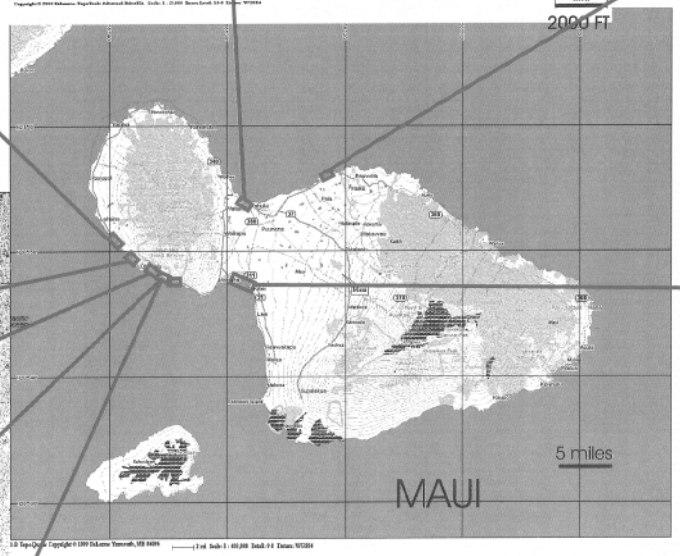
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WAIALUA - KUMIMI, MOLOKAI

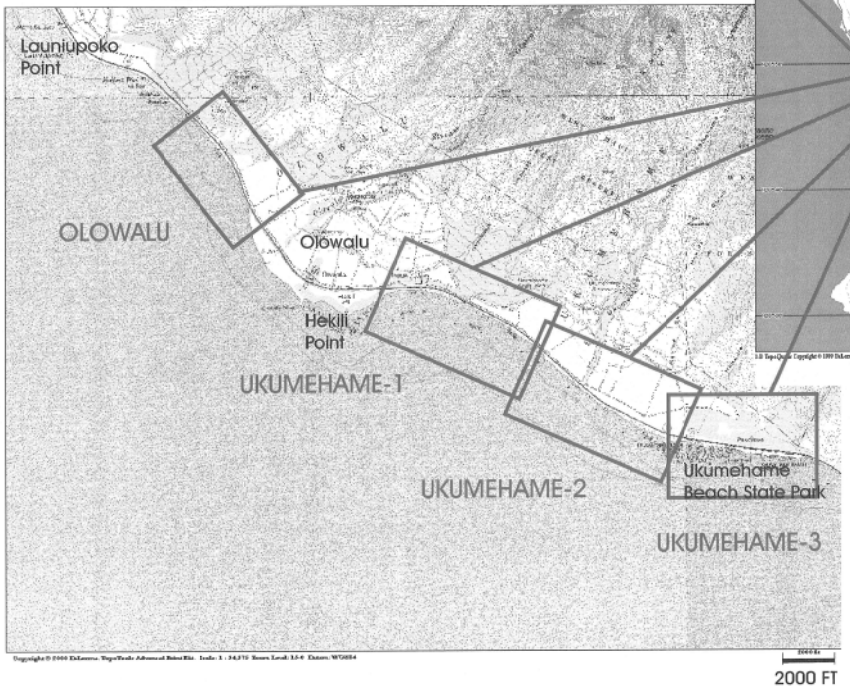
Statewide Highway Shoreline Protection
Project number HWY-08-98

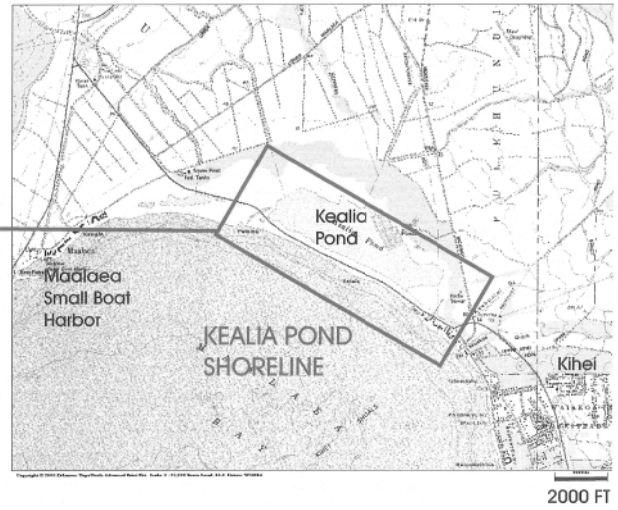






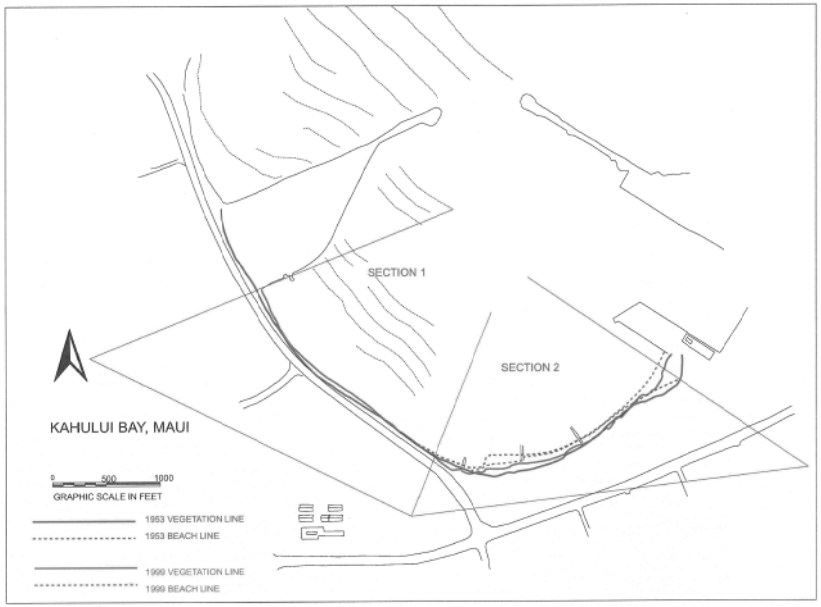


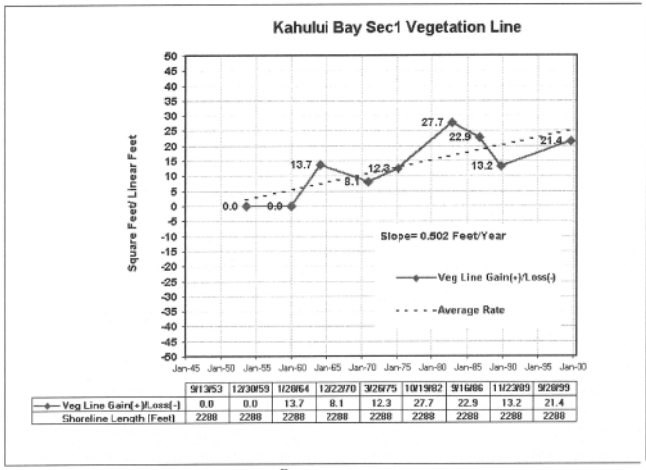




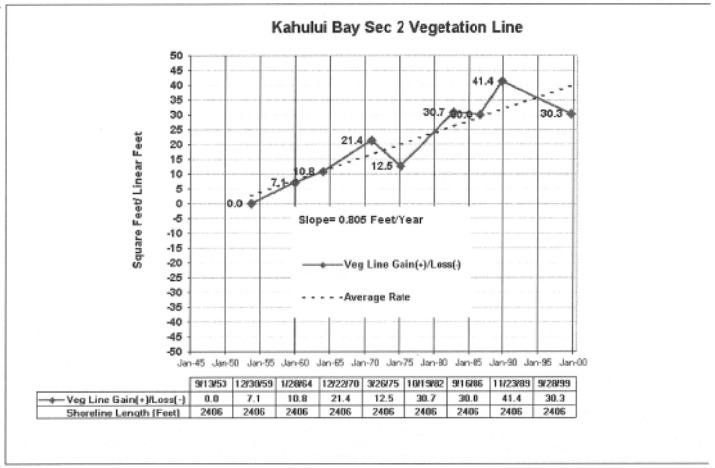
ISLAND OF MAUI
ANALYSIS OF SHORELINE CHANGES

Statewide Highway Shoreline Protection
Project number HWY-08-98

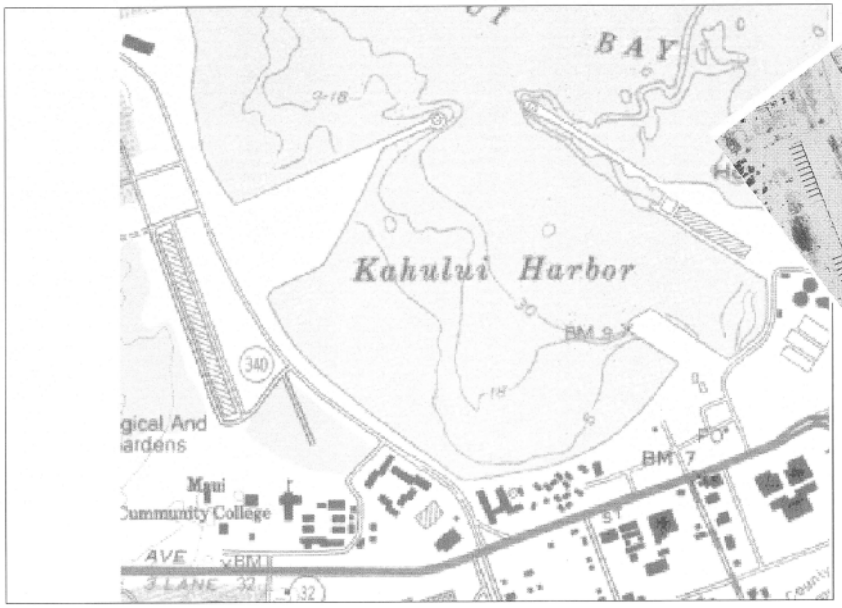


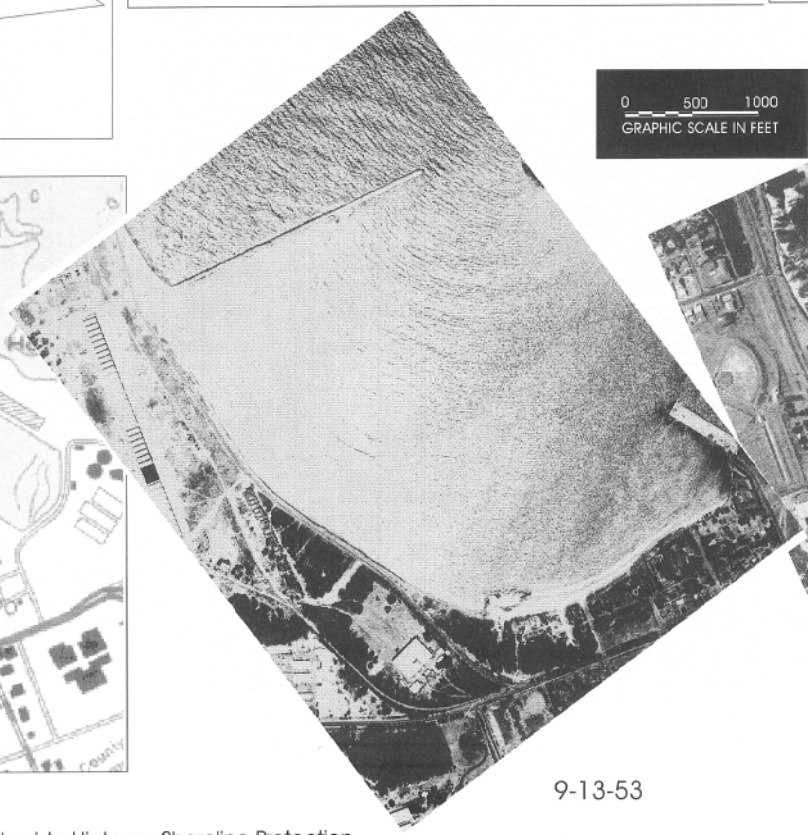


	9/13/53	12/30/59	1/28/64	12/22/70	3/26/75	10/1/82	9/16/86	11/23/89	9/28/99
Veg Line Gain(+)/Loss(-)	0.0	0.0	13.7	8.1	12.3	27.7	22.9	13.2	21.4
Shoreline Length (Feet)	2288	2288	2288	2288	2288	2288	2288	2288	2288



	9/13/53	12/30/59	1/28/64	12/22/70	3/26/75	10/1/82	9/16/86	11/23/89	9/28/99
Veg Line Gain(+)/Loss(-)	0.0	7.1	10.8	21.4	12.5	30.7	30.0	41.4	30.3
Shoreline Length (Feet)	2406	2406	2406	2406	2406	2406	2406	2406	2406





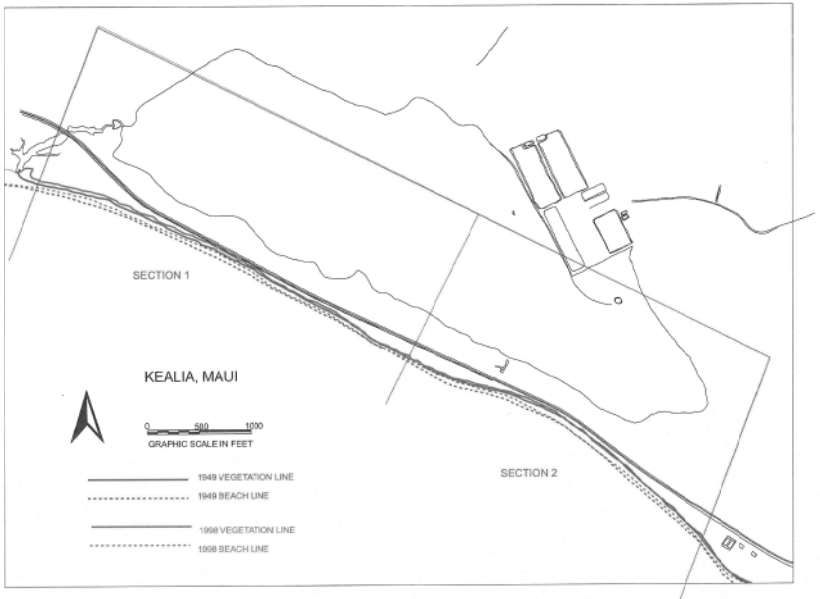


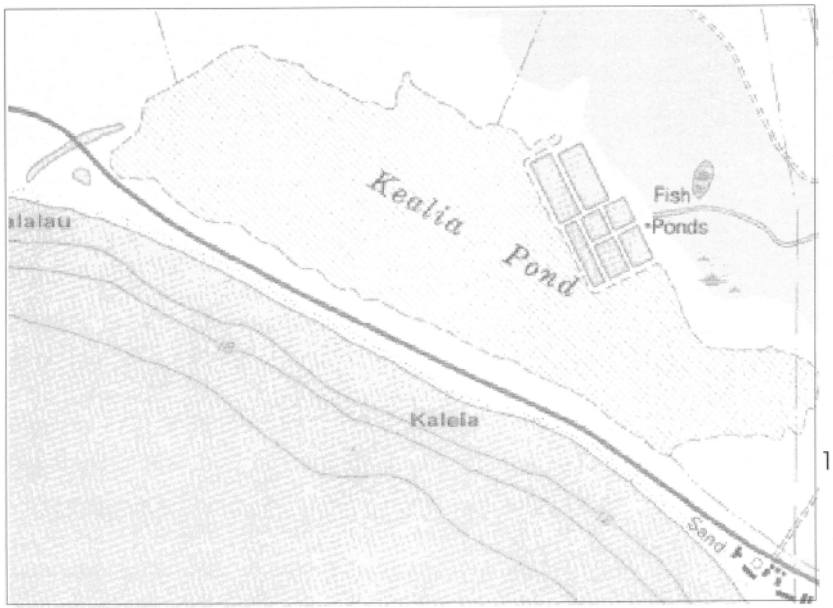
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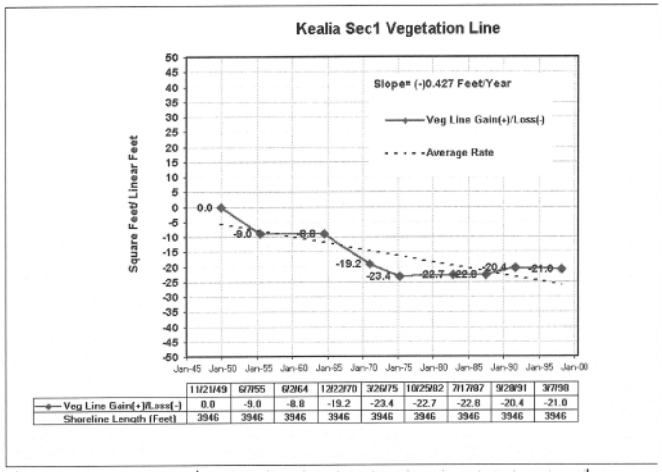
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AERIAL PHOTOGRAPHIC ANALYSIS
KAHULUI BAY, MAUI

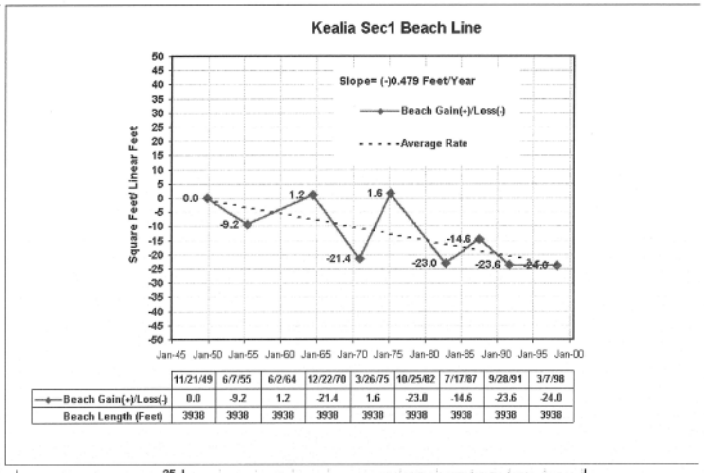
Statewide Highway Shoreline Protection
Project number HWY-08-98



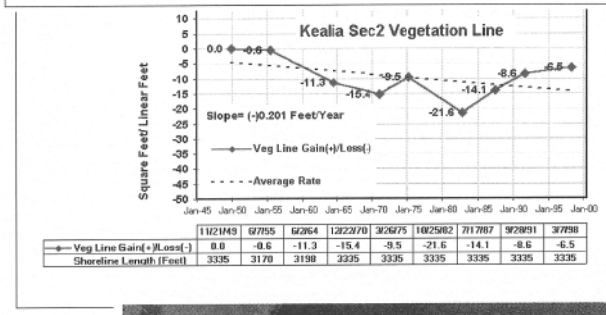




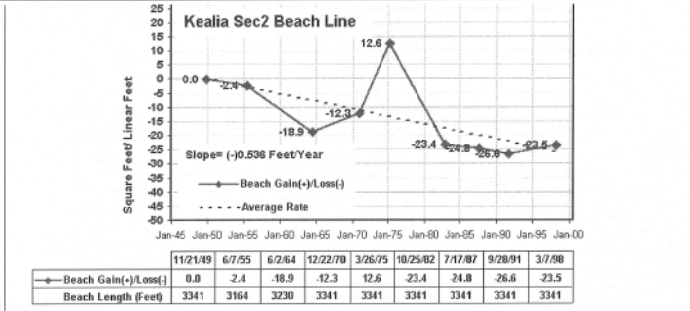
	11/21/49	6/7/55	6/2/64	12/22/70	3/26/75	10/25/82	7/17/87	9/28/91	3/7/98
Veg Line Gain(+)/Loss(-)	0.0	-9.0	-8.8	-19.2	-23.4	-22.7	-22.8	-20.4	-21.0
Shoreline Length (Feet)	3946	3946	3946	3946	3946	3946	3946	3946	3946



	11/21/49	6/7/55	6/2/64	12/22/70	3/26/75	10/25/82	7/17/87	9/28/91	3/7/98
Beach Gain(+)/Loss(-)	0.0	-9.2	1.2	-21.4	1.6	-23.0	-14.6	-23.6	-24.0
Beach Length (Feet)	3938	3938	3938	3938	3938	3938	3938	3938	3938

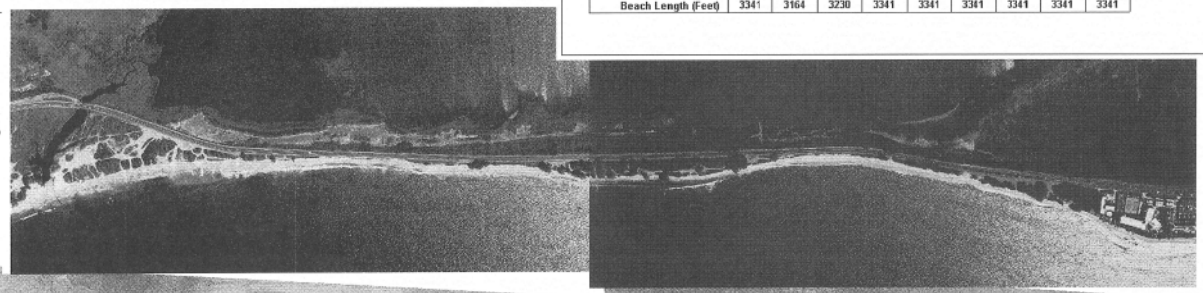


	11/21/49	6/7/55	6/2/64	12/22/70	3/26/75	10/25/82	7/17/87	9/28/91	3/7/98
Veg Line Gain(+)/Loss(-)	0.0	-0.6	-11.3	-15.4	-9.5	-21.6	-14.1	-8.6	-6.5
Shoreline Length (Feet)	3335	3170	3198	3335	3335	3335	3335	3335	3335

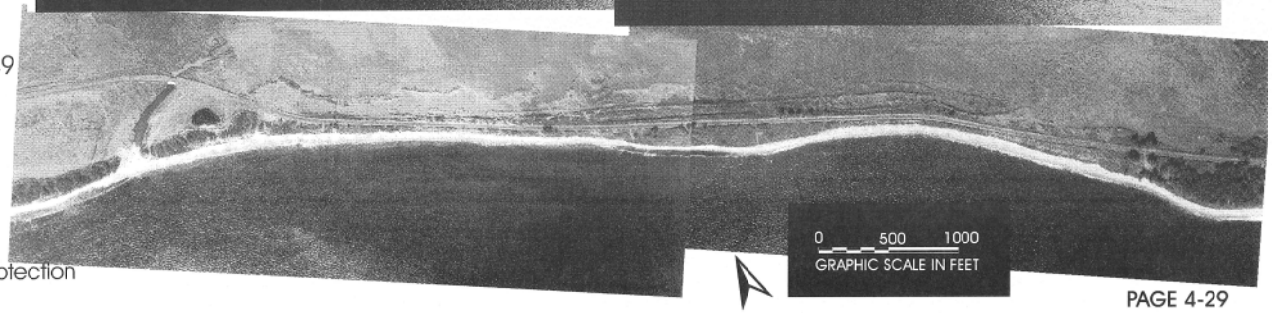


	11/21/49	6/7/55	6/2/64	12/22/70	3/26/75	10/25/82	7/17/87	9/28/91	3/7/98
Beach Gain(+)/Loss(-)	0.0	-2.4	-18.9	-12.3	12.6	-23.4	-24.8	-26.6	-23.5
Beach Length (Feet)	3341	3164	3230	3341	3341	3341	3341	3341	3341

3-7-98

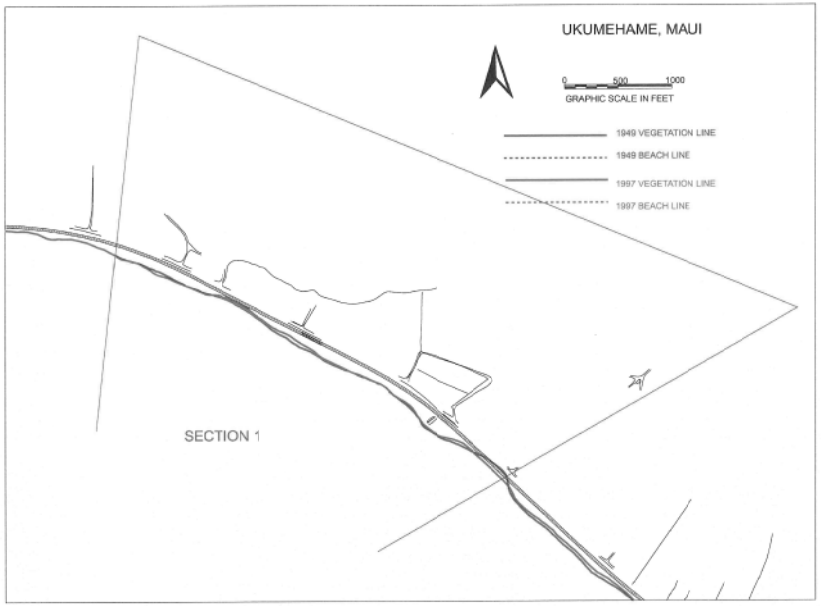


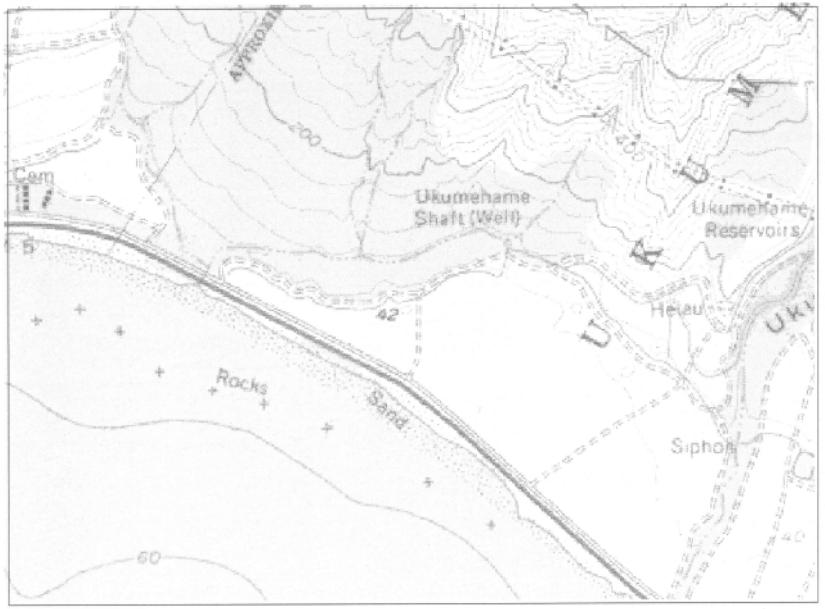
11-21-49

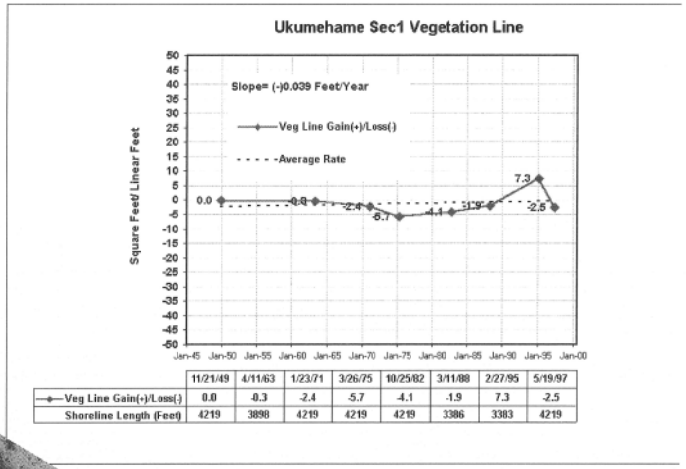


AERIAL PHOTOGRAPHIC ANALYSIS
KEALIA POND, MAUI

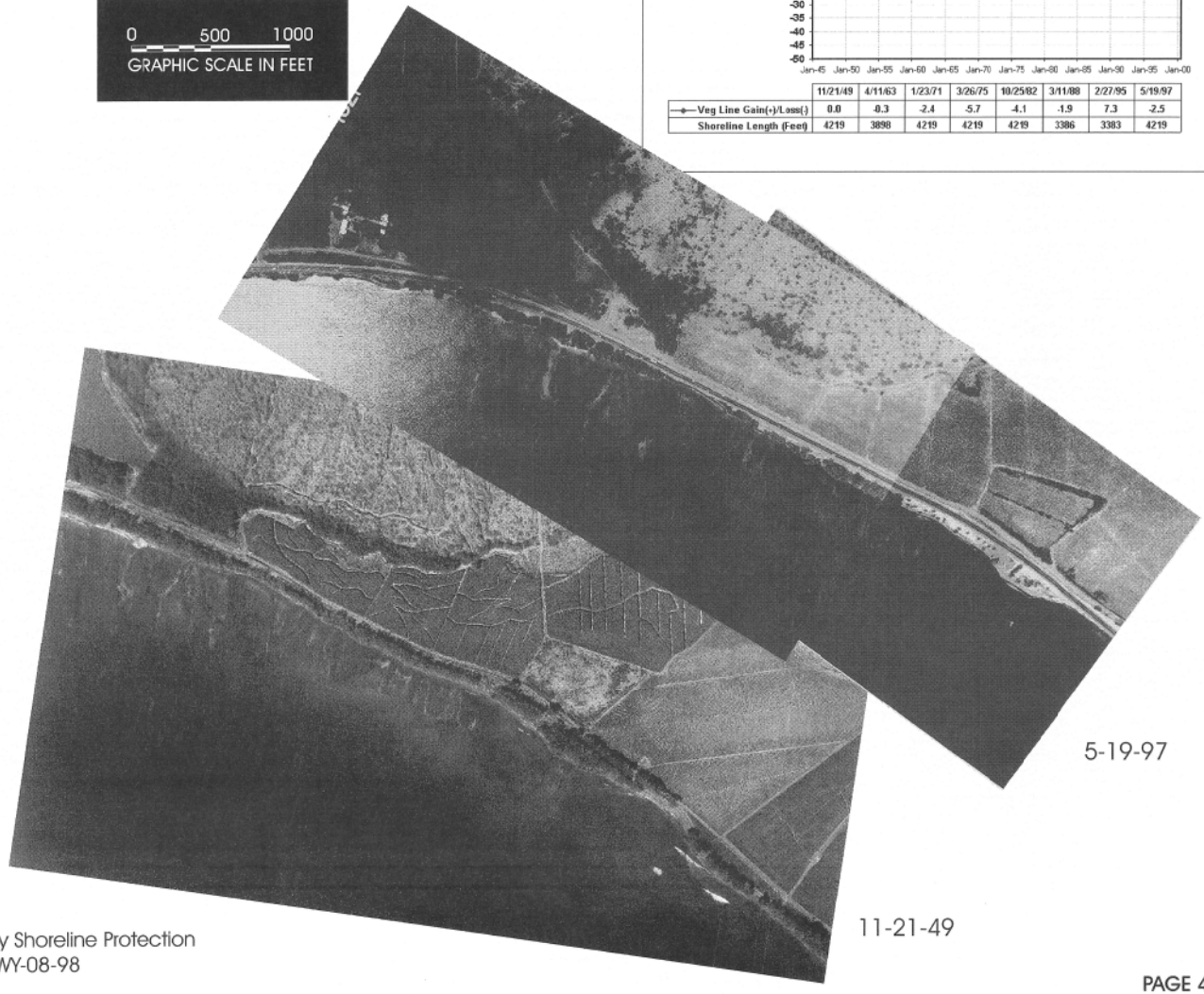
Statewide Highway Shoreline Protection
Project number HWY-08-98







	11/21/49	4/11/63	1/23/71	3/26/75	10/25/82	3/11/88	2/27/95	5/19/97
Veg Line Gain(+)/Loss(-)	0.0	-0.3	-2.4	-5.7	-4.1	-1.9	7.3	-2.5
Shoreline Length (Feet)	4219	3898	4219	4219	4219	3386	3383	4219

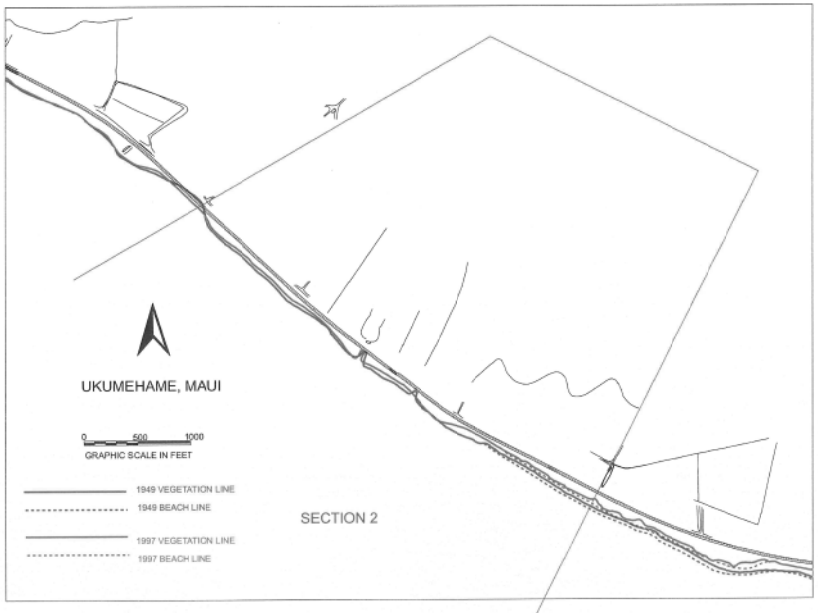


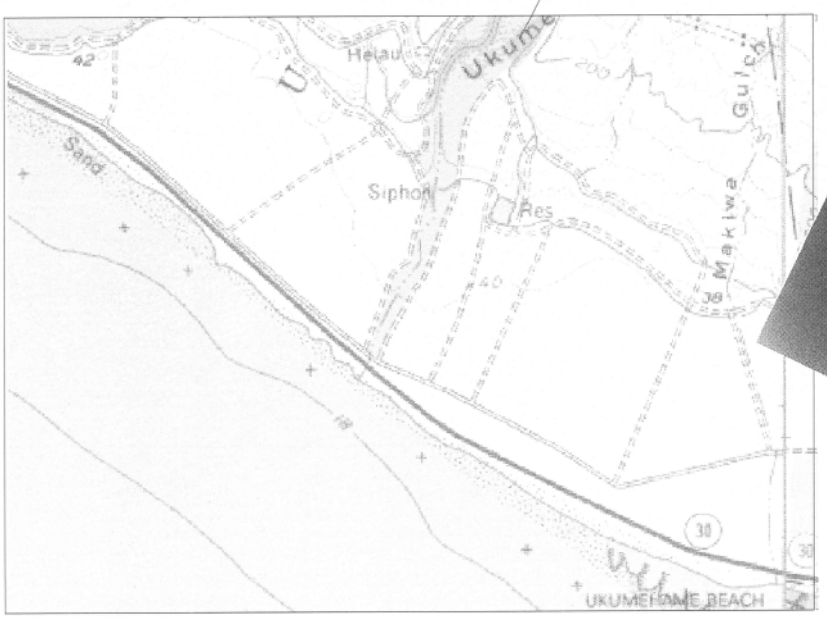
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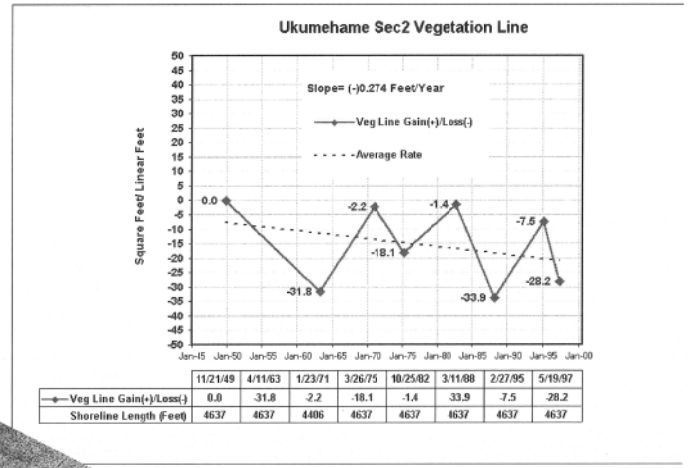
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AERIAL PHOTOGRAPHIC ANALYSIS
UKUMEHAME-1, MAUI

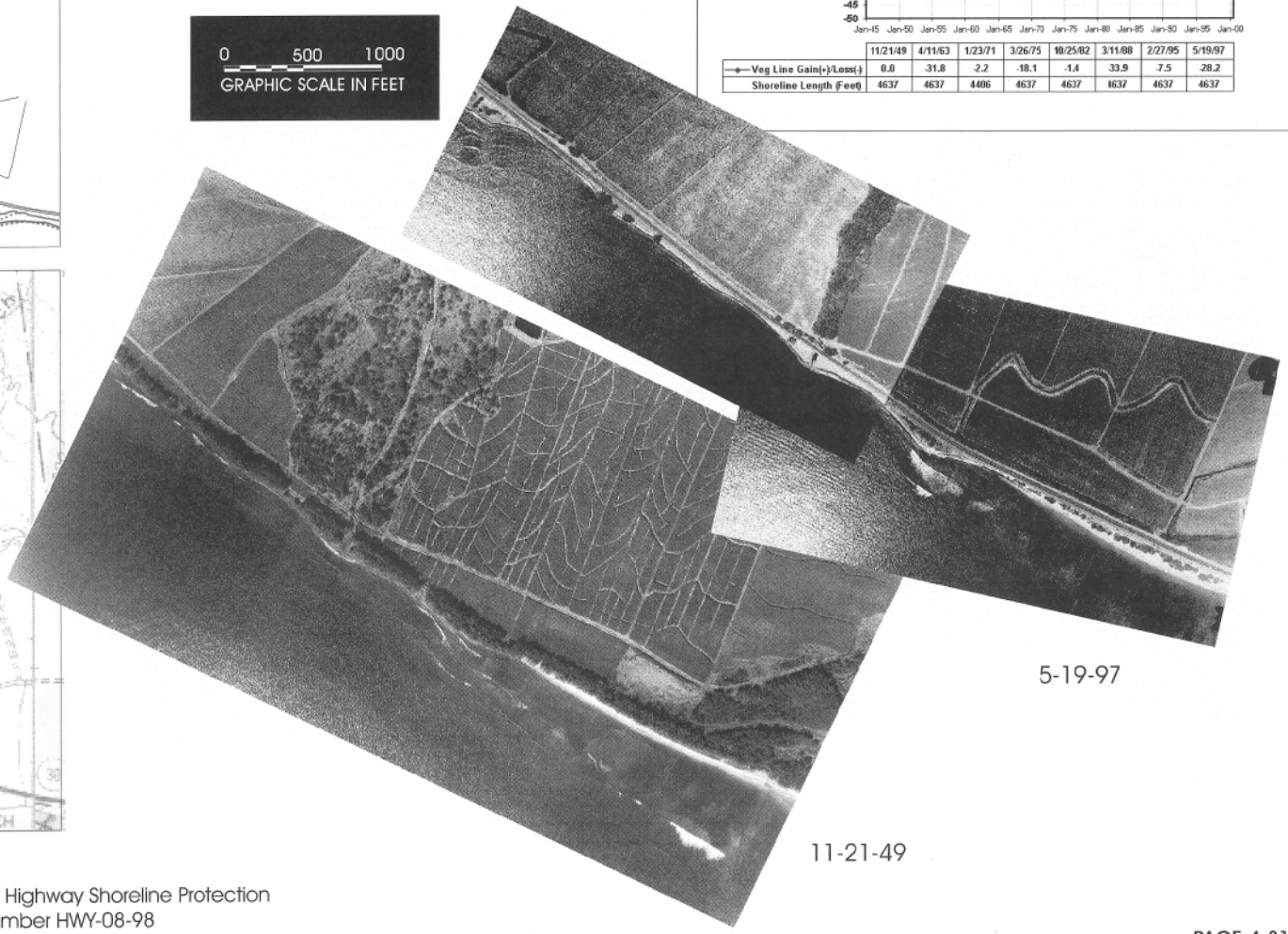
Statewide Highway Shoreline Protection
Project number HWY-08-98







	11/21/49	4/11/63	1/23/71	3/26/75	10/25/82	3/11/88	2/27/95	5/19/97
Veg Line Gain(+)/Loss(-)	0.0	-31.8	-2.2	-18.1	-1.4	-33.9	-7.5	-28.2
Shoreline Length (Feet)	4637	4637	4486	4637	4637	4637	4637	4637

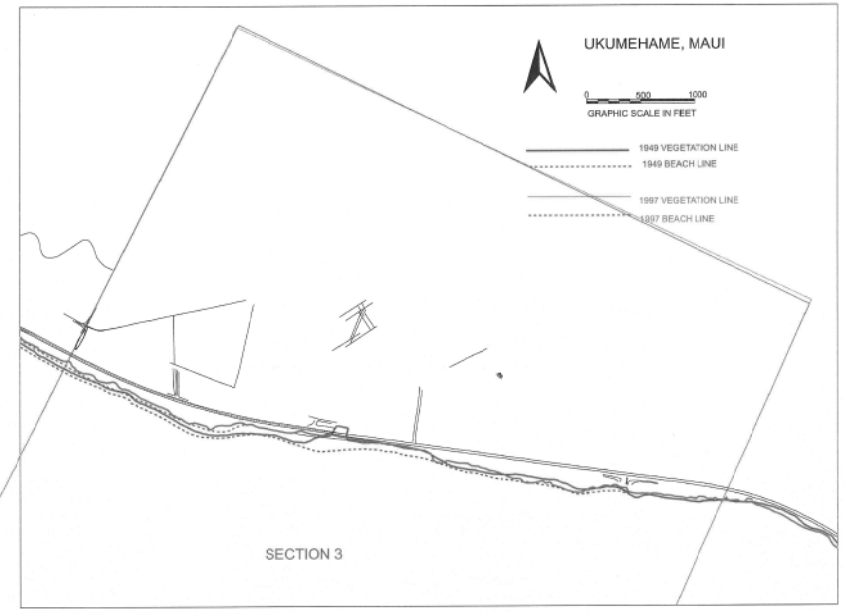


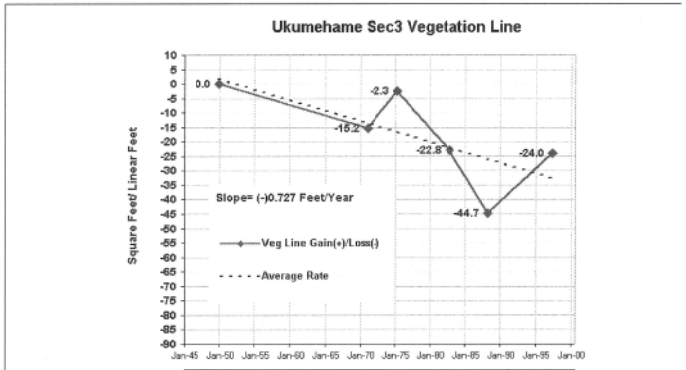
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11-21-49

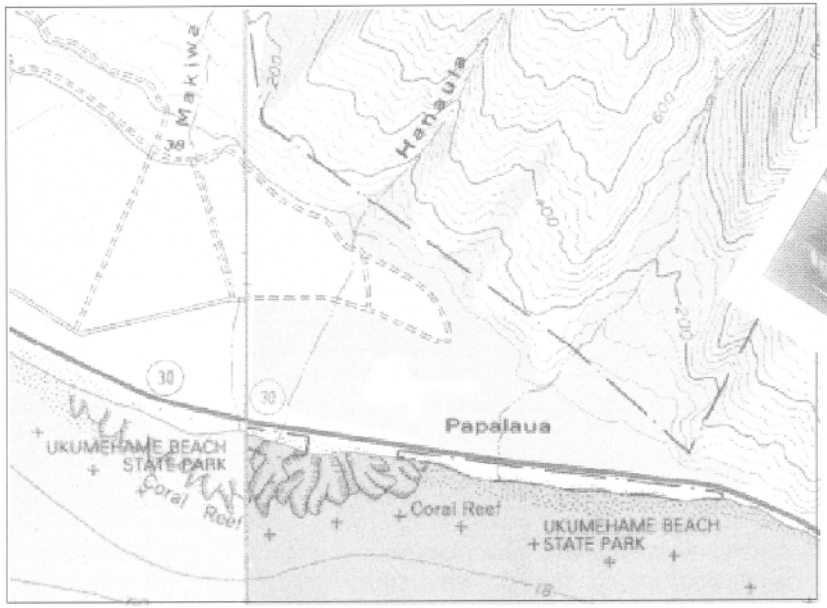
AERIAL PHOTOGRAPHIC ANALYSIS
UKUMEHAME-2, MAUI

Statewide Highway Shoreline Protection
Project number HWY-08-98





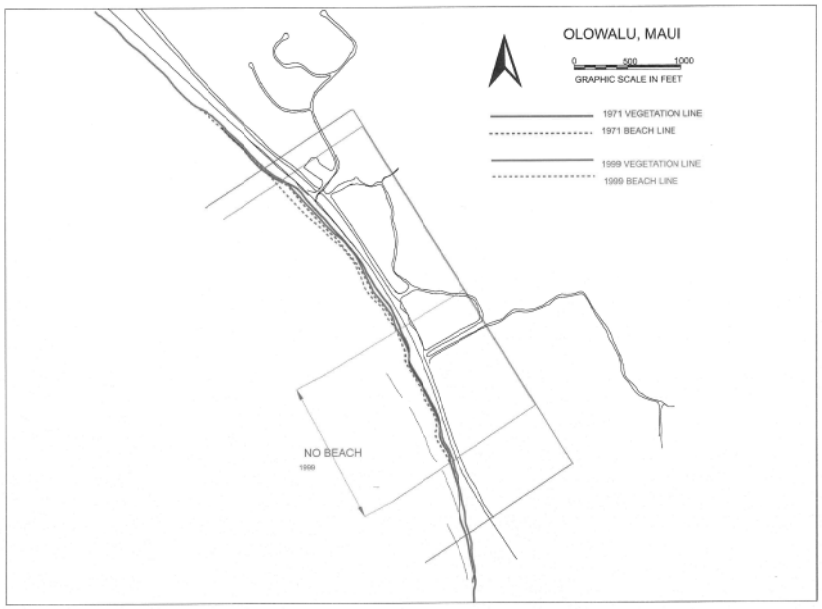
	11/21/49	1/23/71	3/26/75	10/25/82	3/11/88	5/19/97
Veg Line Gain(+)/Loss(-)	0.0	-15.2	-2.3	-22.8	-44.7	-24.0
Shoreline Length (Feet)	6263	3754	5157	6263	5560	6263

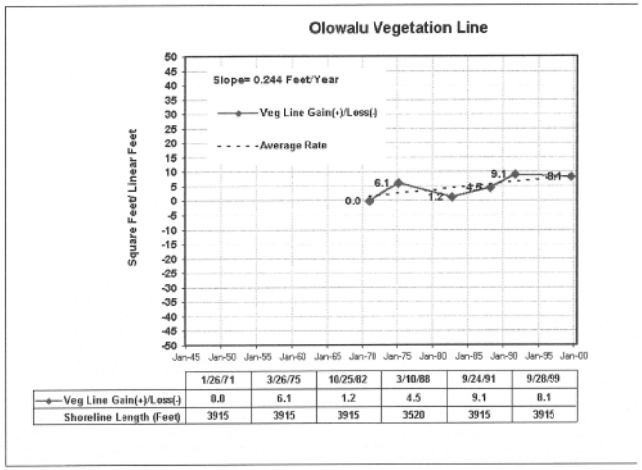




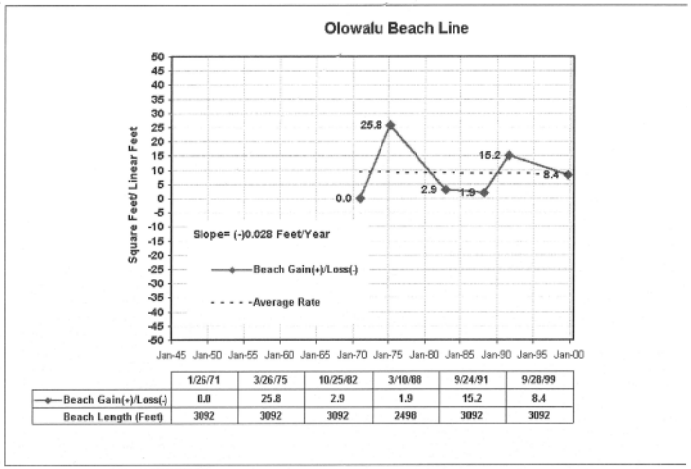
AERIAL PHOTOGRAPHIC ANALYSIS
UKUMEHAME-3, MAUI

Statewide Highway Shoreline Protection
Project number HWY-08-98





	1/26/71	3/26/75	10/25/82	3/10/88	9/24/91	9/28/99
Veg Line Gain(+)/Loss(-)	0.0	6.1	1.2	4.5	9.1	8.1
Shoreline Length (Feet)	3915	3915	3915	3520	3915	3915



	1/26/71	3/26/75	10/25/82	3/10/88	9/24/91	9/28/99
Beach Gain(+)/Loss(-)	0.0	25.8	2.9	1.9	15.2	8.4
Beach Length (Feet)	3092	3092	3092	2498	3092	3092

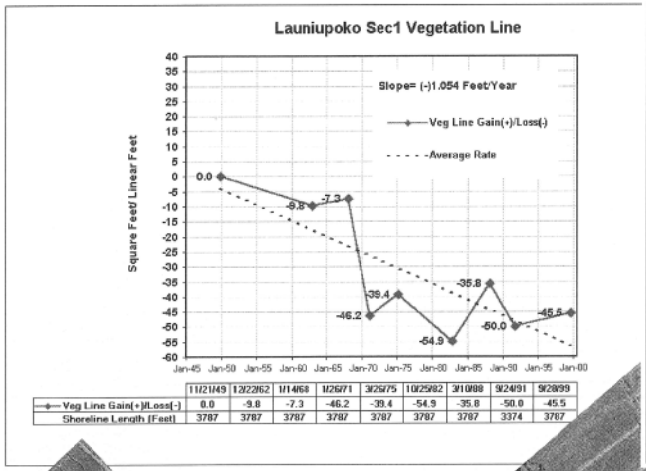




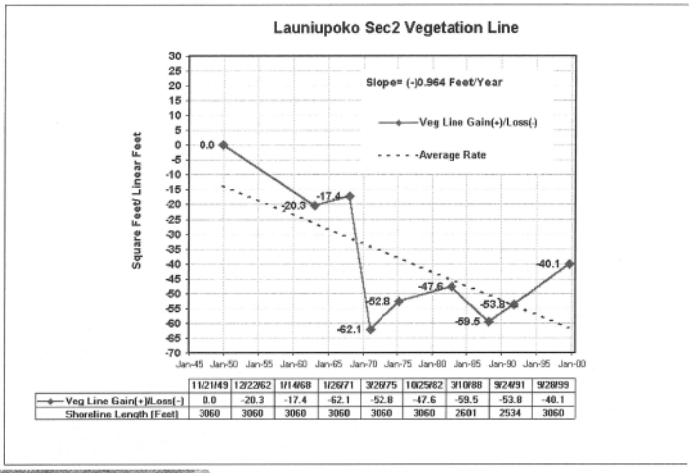
AERIAL PHOTOGRAPHIC ANALYSIS
OLOWALU, MAUI

Statewide Highway Shoreline Protection
Project number HWY-08-98

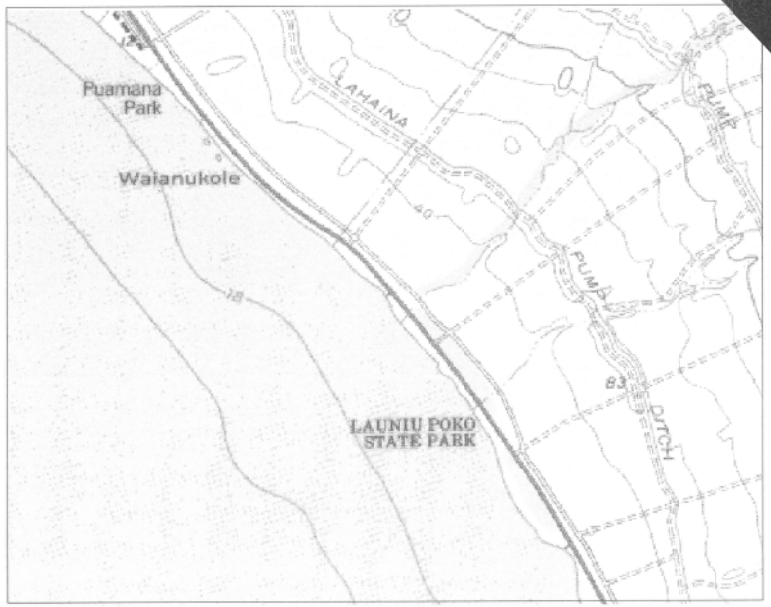




	11/21/49	12/22/62	1/14/68	1/26/71	3/26/75	10/25/82	3/10/88	9/24/91	9/28/99
Veg Line Gain(+)/Loss(-)	0.0	-9.8	-7.3	-46.2	-39.4	-54.9	-35.8	-50.0	-45.5
Shoreline Length (Feet)	3787	3787	3787	3787	3787	3787	3787	3374	3787



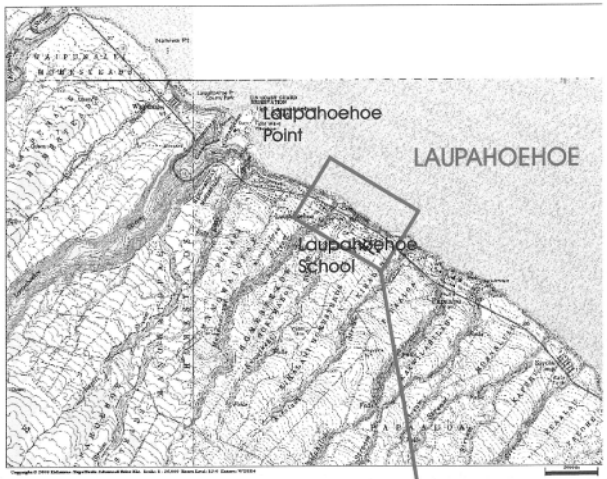
	11/21/49	12/22/62	1/14/68	1/26/71	3/26/75	10/25/82	3/10/88	9/24/91	9/28/99
Veg Line Gain(+)/Loss(-)	0.0	-20.3	-17.4	-62.1	-52.8	-47.6	-59.5	-53.8	-40.1
Shoreline Length (Feet)	3060	3060	3060	3060	3060	3060	2601	2534	3060

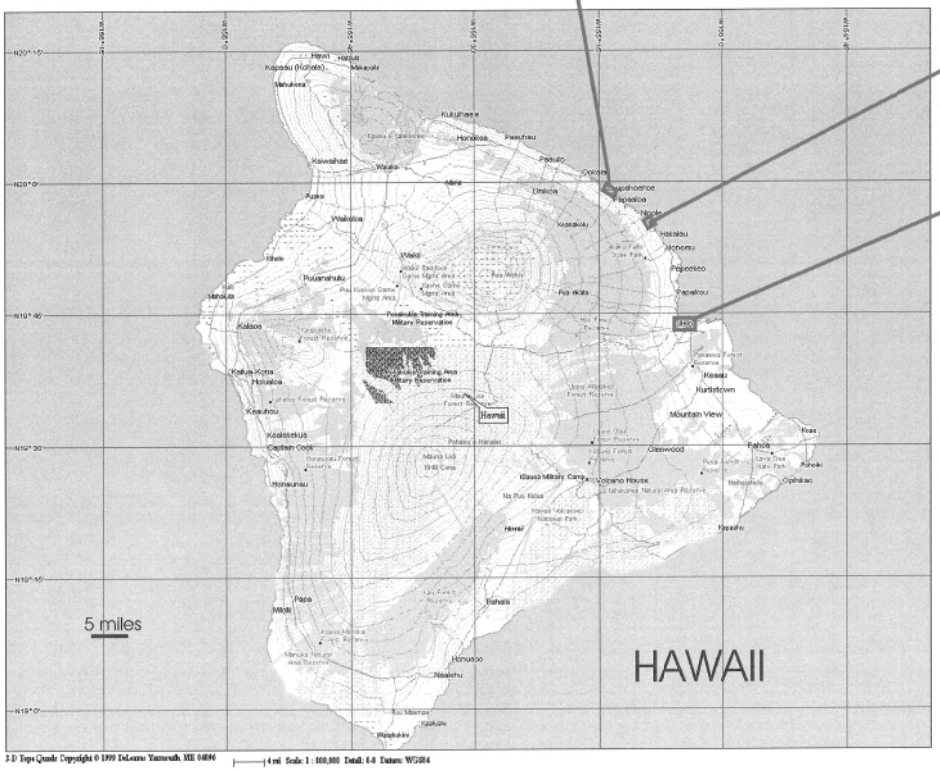


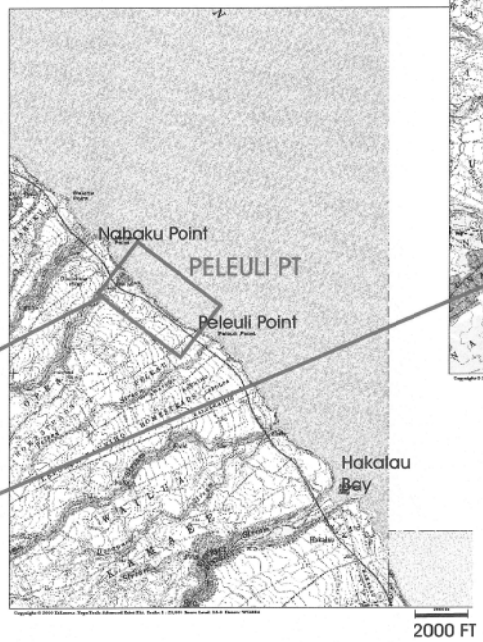


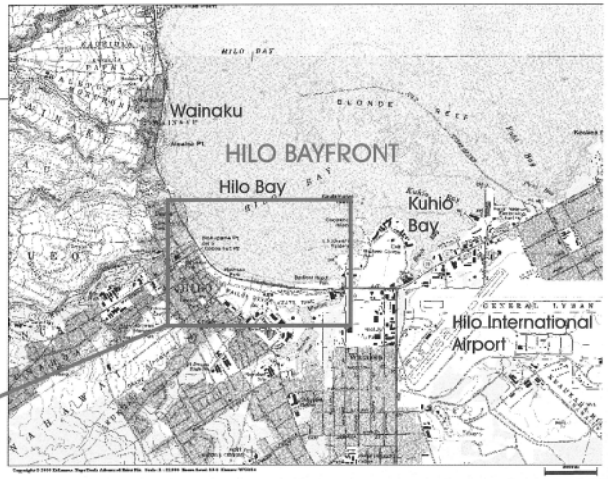
AERIAL PHOTOGRAPHIC ANALYSIS
LAUNIUPOKO, MAUI

Statewide Highway Shoreline Protection
Project number HWY-08-98



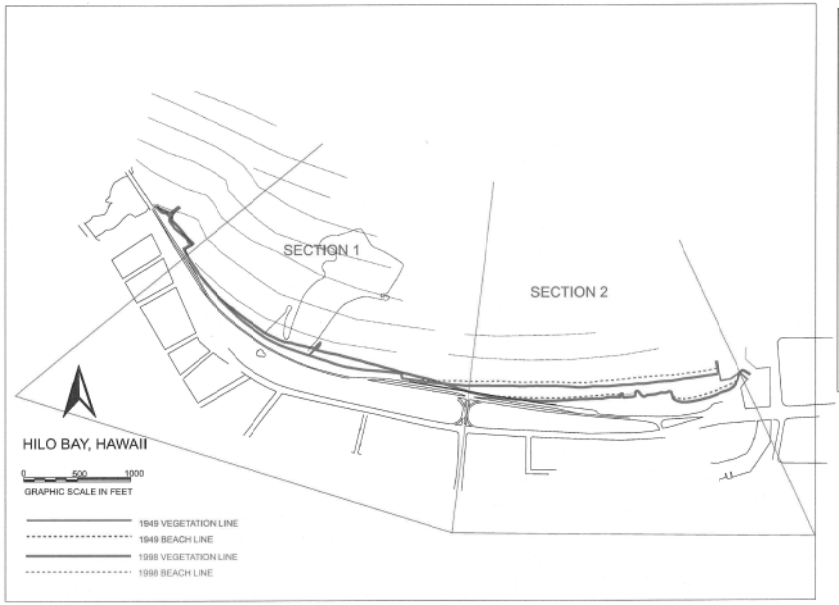


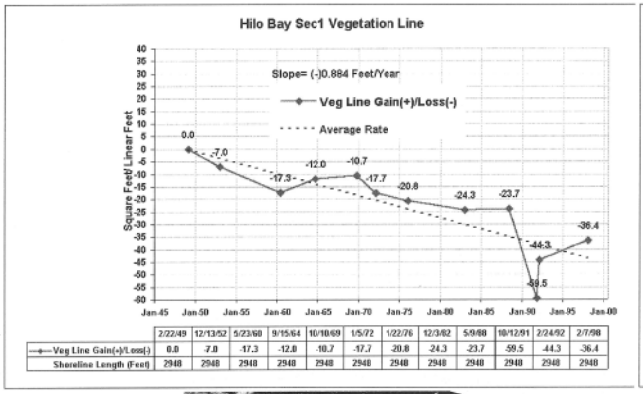




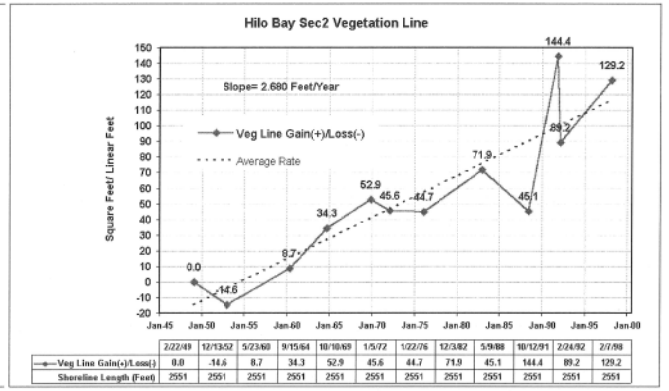
ISLAND OF HAWAII
ANALYSIS OF SHORELINE CHANGES

Statewide Highway Shoreline Protection
Project number HWY-08-98

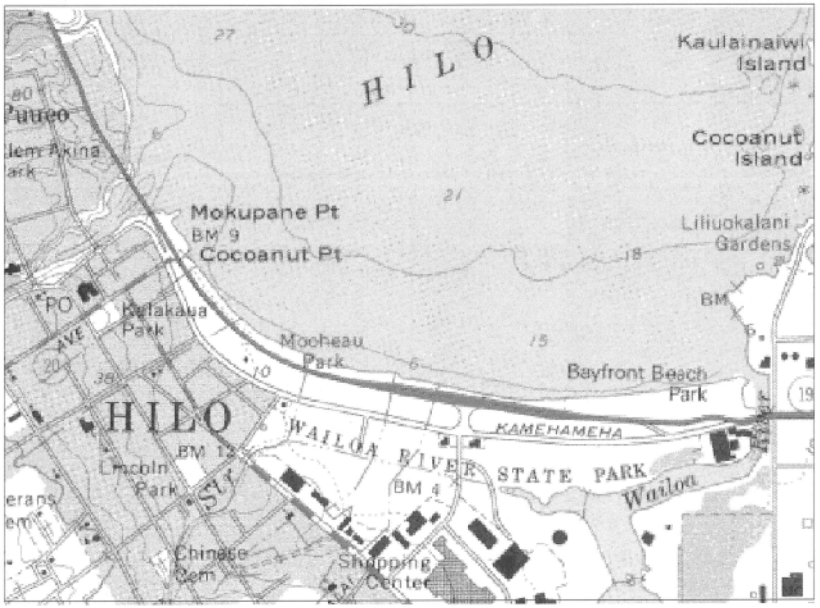


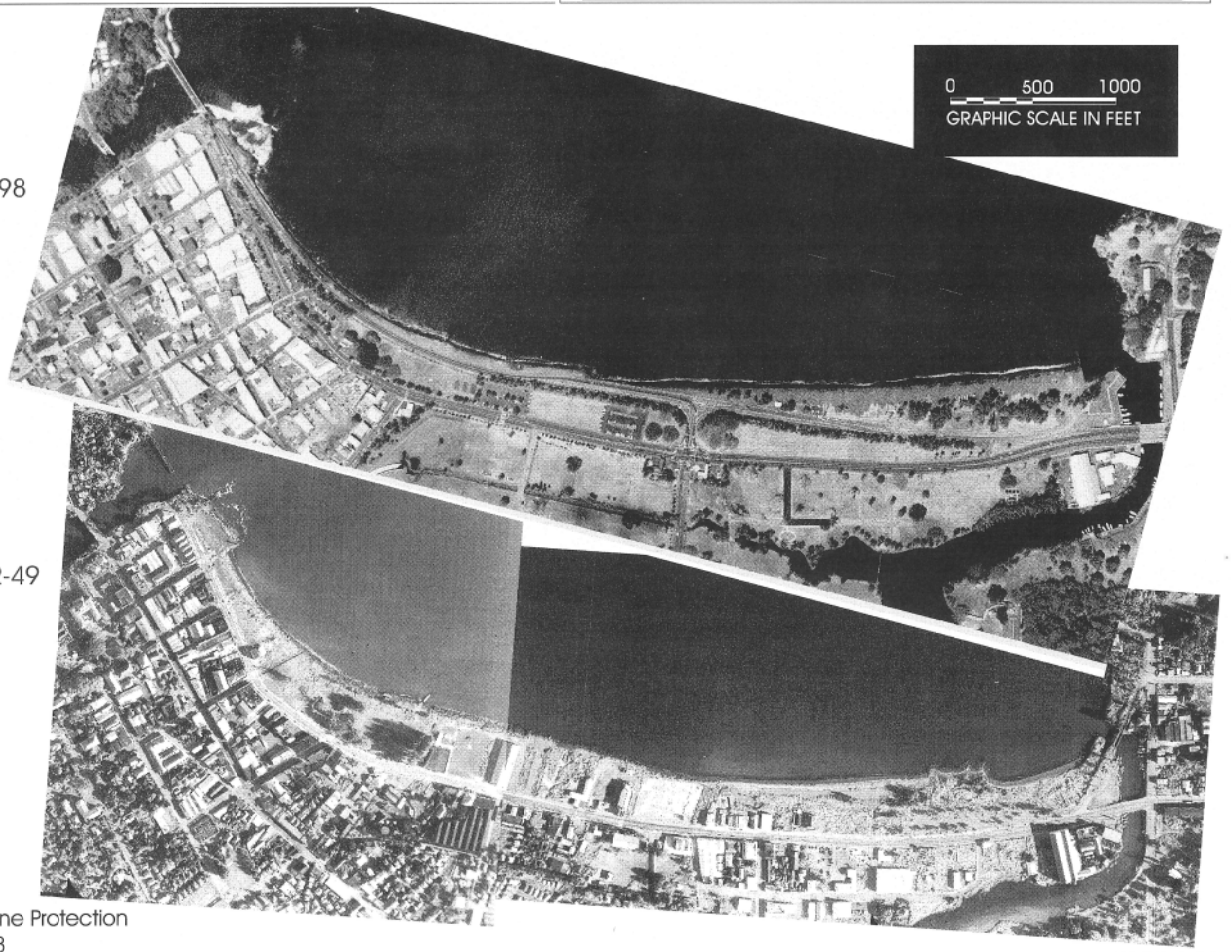


	2/22/49	12/13/52	5/23/60	9/15/64	10/10/69	1/5/72	1/22/76	12/3/82	5/9/88	10/12/91	2/24/92	2/7/98
Veg Line Gain(+)/Loss(-)	0.0	-7.0	-17.3	-12.8	-10.7	-17.7	-20.8	-24.3	-23.7	-59.5	-44.3	-36.4
Shoreline Length (Feet)	2948	2948	2948	2948	2948	2948	2948	2948	2948	2948	2948	2948



	2/22/49	12/13/52	5/23/60	9/15/64	10/10/69	1/5/72	1/22/76	12/3/82	5/9/88	10/12/91	2/24/92	2/7/98
Veg Line Gain(+)/Loss(-)	0.0	-14.6	8.7	34.3	52.9	45.6	44.7	71.9	45.1	144.4	89.2	129.2
Shoreline Length (Feet)	2551	2551	2551	2551	2551	2551	2551	2551	2551	2551	2551	2551





AERIAL PHOTOGRAPHIC ANALYSIS
HILO BAY, HAWAII

Statewide Highway Shoreline Protection
Project number HWY-08-98

5 - CONCEPTUAL ALTERNATIVE PLANS

DESIGN CRITERIA

Conceptual alternative plans were developed depending on the shoreline conditions and surrounding land uses. Coastal engineering analysis of storm wave exposure established the design wave parameters and design stillwater levels for the development of shore protection and beach fill alternatives. Shoreline surveys were accomplished for most of the priority sites to provide typical profile sections and to establish "baseline" shoreline conditions. Highway relocation or realignment alternatives were developed based on consideration for minimizing impacts to existing structures and homes and to: utilize existing public right-of-ways; minimize excess roadway curvature; minimize vertical curvature; avoid existing large structures; maintain access to existing communities; and minimize the division of existing parcels. For areas encompassing long stretches of highway on the windward coast of Oahu, bypass alternatives were proposed because of the relatively developed condition of the mauka areas directly adjacent to the coastal highway.

The maximum design wave at the shoreline is dependent on the deepwater wave characteristics, nearshore bottom slope and contours, and the water depth fronting the shoreline. For the shoreline sites, the design wave (i.e. the maximum breaking wave on the shoreline or protective structure) is depth-limited. As such, the deeper the water depth fronting the shoreline or protective structure, the larger the breaking wave height at the shoreline. Storms can cause a rise in the nearshore stillwater level (SWL) due to storm surge and wave setup. In general, the larger the deepwater wave height, the farther offshore it initiates breaking (i.e. the wider the surf zone), and the higher the rise in water level at the shore due to wave setup. The deepwater design wave height affecting the north and windward coast sites of the islands was estimated to be a winter North Pacific storm with a return period of 10 years, having significant wave height Hs = 22 feet, and significant wave period Ts = 12 seconds. For the south and west shore sites, the deepwater design wave was estimated based on Hurricane Iniki, having significant wave height Hs = 40 feet, and significant wave period Ts = 14 seconds.

Along the Atlantic and Gulf of Mexico coasts, the primary mechanism of coastal flooding by hurricanes is the elevation of the water surface by the shoreward component of wind stress - the so-called *hurricane surge*. In Hawaii, by contrast, surge is of minor importance owing to the great nearshore water depths and the absence of any significant continental shelf, which are required for the generation of surge. For Hawaii, the primary contribution to the elevated mean water level is the phenomenon of wave setup. As a wave approaches shore, it first increases in amplitude owing to the effect of wave shoaling. As the wave height increases, there is a small *set-down* of the mean water level. At some point the wave becomes sufficiently large (as the depth becomes steadily shallower) that it breaks. Thereafter, as the wave continues toward shore, its height decreases as its energy is consumed by turbulence, and the shoreward flux of momentum decreases as well. This change of momentum is balanced by an excess hydrostatic pressure associated with a steady rise, or *setup*, of the mean water level. A singular finite-difference numerical model, which considers the local bathymetry as it influences wave transformation and breaking, was applied to estimate the wave setup component due to potential storm waves affecting the sites. The typical bathymetric profile at each site was established based on USGS topographic maps. Computed wave setup varied from almost 3 feet for the north and windward sites to over 4 feet for the south and west sites.

The design SWL includes the tide level, which establishes the elevation datum upon which the other factors contributing to the total rise in water level are added. A mean high water level of 1.5 feet above MLLW was used for the north and windward sites, while a mean sea level of 1.0 feet above MLLW was used for the south and west sites. Table 5 summarizes the design SWL for each site.

When waves break on the beach or on a shore protection structure, the vertical height above the SWL to which the waves rush up the slope is called the runup height. The non-overtopping elevation is the SWL elevation plus the wave runup height. The wave runup is dependent on many parameters, including the beach or structure slope both shoreward and seaward of the SWL shoreline, the breaking wave characteristics, and the roughness of the structure slope. Breaking wave height on the structure is a function of the depth at the toe of the structure, the bottom slope, and the wave period. The wave runup height and non-overtopping elevation were estimated for each site, for a range of water depths at the toe of the structure, based on the U.S. Army Corps of Engineers, Coastal Engineering Research Center computer application *"Automated Coastal Engineering System (ACES), Version 1.07a"*. Table 5 (page 5-2) summarizes the wave runup and non-overtopping elevation for structures with rock slope of 1V:1.5H and for vertical walls. For sites with beach fill alternatives, the wave runup and non-overtopping beach berm elevation were estimated based on the site-specific beach characteristics.

For most sites, a typical hardening alternative is a rock revetment. The revetment armor stones were sized based on the design breaking wave height at the structure, using methodology from the U.S. Army Corps of Engineers, Coastal Engineering Research Center publication *"Shore Protection Manual, 4th ed. 1984"*. The revetment typical section is comprised of a standard two-stone thick armor layer, with two-stone thick underlayer of smaller stones, and geotextile fabric to prevent leaching of backfill material through the stone layers. For shorelines fronted by hard limestone reef, it is assumed that the revetment toe would be excavated and placed on the hard foundation material.

For shorelines where the limestone is at relatively deep elevation or where there is undetermined thickness of sand covering the nearshore reef, an extended toe is provided to prevent scouring at the base of the revetment slope. For sites where vertical structures are an alternative, the structure is either a CRM seawall or a pre-cast concrete wall. For sites where beach fill is an alternative (typically locations associated with beach parks or recreation areas), beach stabilization structures that may be associated with the beach fill are rock structures. While there are a wide variety of building materials and different types of construction options for shore protection structures, there was no attempt to identify or incorporate specific manufactured products into the alternative plans. Most manufactured products are considered lower cost alternatives to the traditional rock revetment or concrete seawall, but are generally less durable and therefore have higher maintenance requirements. It is generally recognized that, for public works projects, maintenance is difficult to budget for and accomplish on a regular basis. Therefore, it is preferable to construct reasonably durable structures that require minimal maintenance.

Design criteria for the relocated/realigned highway was largely based on the design of the existing roadway and DOT and FHWA manuals. These criteria were extracted from the DOT-Highways *"Designated Way and Travel Way Routes"* inventories, the Department of Transportation guidance publication *"Highways Division Statewide Uniform Design Manual for Streets and Highways"*, and the 2001 edition of the AASHTO publication *"A Policy on Geometric Design of Highways and Streets"*. Criteria from the DOT-Highway inventories included pavement type and thickness, shoulder and right of way width, as well as posted speed limits. As the proposed relocated roadway will become the main thoroughfare, the proposed alignment has a smooth transition to the existing roadway. The locations and sizing for stream crossings and drainage facilities were from the DOT-Highways inventory maps, USGS maps and the Tax Map Keys.

Almost all highway sections considered for realignment are two-lane rural arterials with one lane of traffic in either direction, varying moderate posted speed limits and variable width shoulder conditions, in flat terrain. A typical section for each roadway was designed, primarily based on the existing roadway, and to comply with the *"Highways Division Statewide Uniform Design Manual for Streets and Highways"*, and the *"A Policy on Geometric Design of Highways and Streets, 2001 Edition"*.

In most cases, the relocated highway will have larger curve radii than the existing road with no requirement for superelevation of the curves. Existing interior roads, or new roadways, will serve as collector roads to provide access to the existing communities. The location of the collector roadways was based on considerations for sight and stopping distance along the new alignment. Also, access to the new roadways were limited to minimize congestion and to promote traffic safety.

TABLE 5: DESIGN CRITERIA FOR SHORE PROTECTION

ISLAND				1V:1.5H Rock Slope		Vertical Wall	
SHORELINE LOCATION	Design SWL (+ft MLLW)	Depth @ Toe (MLLW)	Hb (ft)	Wave Runup (ft)	Non-overtopping elev. (+ft MLLW)	Wave Runup (ft)	Non-overtopping elev. (+ft MLLW)
OAHU							
Kawailoa Beach (bottom slope m = 0.01)	4.2	1	3.2	4.8	9.0	6.4	10.6
Hauula (bottom slope m = 0.01)		0	4.2	6.1	10.3	8.8	13.0
Punaluu (bottom slope m = 0.01)		-1	5.2	7.3	11.5	11.6	15.8
Kaaawa (bottom slope m = 0.01)		-2	6.2	8.6	12.8	14.4	18.6
Kualoa (bottom slope m = 0.01)	4.3	0	4.3	6.1	10.4	9.2	13.5
		-1	5.3	7.4	11.7	12.0	16.3
		-2	6.3	8.7	13.0	14.8	19.1
Makaha Beach (bottom slope m = 0.05)	5.6	1	6.3	6.8	12.4	9.2	14.8
		0	7.6	8.2	13.8	12.0	17.6
		-1	8.9	9.5	15.1	14.8	20.4
KAUAI							
Hanalei Bay (bottom slope m = 0.01)	4.0	1	3	4.5	8.5	6.0	10.0
		0	4	5.8	9.8	8.4	12.4
		-1	5	7.0	11.0	10.8	14.8
MOLOKAI							
Palalupi (bottom slope m = 0.01)	5.6	0	5.6	8.2	13.8	12.0	17.6
		-1	6.6	9.5	15.1	14.8	20.4
		-2	7.6	10.6	16.2	17.2	22.8
Kumimi (bottom slope m = 0.02)	5.7	0	5.7	8.3	14.0	12.4	18.1
		-1	6.7	9.5	15.2	14.8	20.5
		-2	7.7	10.7	16.4	17.6	23.3
MAUI							
Kahului Bay - Inside Harbor (m = 0.02)	3.0	0	3	4.5	7.5	6.0	9.0
		-1	4	5.8	8.8	8.4	11.4
Kahului Bay - Outside Harbor (m = 0.02)	4.2	0	4.2	6.1	10.3	8.8	13.0
		-1	5.2	7.3	11.5	11.6	15.8
Kealia Pond (bottom slope m = 0.025)	6.8	1	5.8	8.5	15.3	12.4	19.2
		0	6.8	9.6	16.4	13.6	20.4
		-1	7.8	10.9	17.7	18.0	24.8
Ukumehame (bottom slope m = 0.02)	5.7	0	5.7	8.3	14.0	12.4	18.1
		-1	6.7	9.5	15.2	14.8	20.5
		-2	7.7	10.7	16.4	17.6	23.3
Olowalu (bottom slope m = 0.03)	5.6	0	6.2	8.2	13.8	12.0	17.6
		-1	7.3	9.5	15.1	14.8	20.4
		-2	8.4	10.6	16.2	17.2	22.8
HAWAII							
Hilo Bayfront (bottom slope m = 0.02)	3.0	0	3	4.5	7.5	6.0	9.0
		-1	4	5.8	8.8	8.4	11.4
		-2	5	7.0	10.0	10.8	13.8

ISLAND OF OAHU (Page 5-11)

KAWAILOA BEACH: Approximately 800 feet of highway on the northeast side of Lauhulu Bridge is directly adjacent to the beach. The shoreline escarpment adjacent to the highway is subject to seasonal winter wave attack, and dumped boulders provide insufficient protection to the shoreline. The top of the shoreline escarpment (edge of road pavement) is 17 feet above MLLW and the toe of the escarpment (top of the beach berm is about 11 feet above MLLW). Emergent beach rock protects the toe of the beach, and the beach has gained in width between 1949 and 1996. The conceptual alternatives include protecting the shoreline, realigning the highway, and providing beach fill.

Revetment: (Page 5-12) The revetment would provide protection to the highway from seasonal high surf and winter storms. Because the existing beachrock anchors the toe of the "perched" beach, the revetment toe is only buried to elevation +4 feet MLLW within the beach berm, with an extended underlayer beneath the toe. The revetment crest is slightly lower than the road elevation.

CRM Seawall: (Page 5-13) An alternative shore protection option is a seawall, which has a much smaller "footprint" than a sloping revetment, and therefore takes up much less space on the beach. Because the seawall is located about 40 feet mauka of the water's edge, the CRM seawall will be subject to wave attack less frequently than the revetment. The toe of the wall would be excavated and placed at least 2 feet below existing beach grade. The top of the wall is at elevation +17 feet MLLW (the same elevation as the road) to minimize wave overwash. Stairs could be incorporated within the wall to allow access to the beach.

Highway Realignment: (Page 5-14) This alternative provides for realigning about 3,200 feet of highway up to about 100 feet mauka of the existing highway. There are no homes affected by this realignment. Lauhulu Bridge would be replaced by a new bridge. The existing highway pavement along the shoreline would be removed and the shoreline will achieve a crescent-shaped alignment (similar to the beach alignment) if allowed to erode. Public parking could be accommodated on the mauka side of Pohakuloa Road.

Beach Fill: (Page 5-15) Because this is a popular recreational area, beach fill as a shore protection alternative is proposed as an option. The beach fill would need to have a wide enough berm at high enough elevation to provide protection to the shoreline from wave runup. Therefore, a groin is proposed adjacent to the Lauhulu Bridge to provide "containment" of the beach fill. The groin would stabilize a beach extending an average of 40-50 feet seaward of the present beach. A short wall should still be provided to stabilize the shoreline-beach interface from runoff erosion, people-traffic, and occasional storm waves.

Beach Nourishment: Beach nourishment is estimated based on beach profile data from the *Hawaii Beach Monitoring Program*, U.S. Geological Survey Open-File Report 01-308, dated 2001. Average sand loss was about 50 square feet per year between the first profile in August 1994 and the last profile in July 1999. For 800 linear feet of shoreline, this results in an annual rate of about 1,500 cubic yards per year. Seasonal changes in the beach profile were on the order of about 200-400 square feet, which is about the same order of magnitude as the initial beach fill quantity of about 10,000 cubic yards for the 800 linear feet of shoreline.

HAUULA: Approximately 2,300 feet of highway between Maheiwi Bridge and Waimanana Bridge is directly adjacent to the ocean. This entire shoreline reach has been artificially fixed by the highway and the various methods of shore protection for the highway (e.g. dumped rocks, stacked concrete piles). The shoreline and highway are subject to seasonal winter wave attack, and are suffering from erosion damage and wave overwash. The beach has always been narrow, but the continued gradual loss from 1949 to present has resulted in virtually no dry beach along much of this reach. The conceptual alternatives include protecting the shoreline and relocating the highway.

Revetment: (Page 5-16) The revetment would provide protection to the highway from seasonal high surf and winter storms. Because there is little dry beach fronting this shoreline, the revetment would replace the remnant beach, dumped boulders and concrete piles with a uniform rock slope. A moderate amount of fill will be required to provide sufficient shoreline width alongside the paved road because of safety and constructability concerns. The revetment crest would be at elevation +11 feet MLLW to minimize wave overwash, resulting in a line of boulders extending about 2-3 feet above the road elevation. The revetment toe would be at elevation -1 feet MLLW, with an extended underlayer beneath the toe. Alternatively, the revetment toe could be excavated and placed directly on the hard limestone reef.

Highway Relocation: (Page 5-17) This alternative is a 1-mile long bypass highway that extends from the north side of Waipuhi Bridge, mauka of Pokiwai Place, and reconnecting south of Kcluanui Bridge. This relocated highway would minimize impacts to the residential dwellings and other existing uses located directly mauka of the existing highway. The existing highway along the shoreline would be subject to continued erosion damage, and would eventually become unsafe for vehicular travel. This roadway could be converted to a pedestrian walkway and bicycle path.

PUNALUU: Approximately 2,100 feet of highway north of South Punaluu Bridge (north of Punaluu Beach Park) is directly adjacent to the beach. Both the vegetation line and beach have accreted between 1959 and 2000. However, the northern end of this reach is experiencing erosion damage and wave overwash from seasonal high surf. Dumped rocks and remnant shore protection structures provide insufficient protection to the shoreline. Tree canopies are likely

responsible for the apparent gain in the vegetation line along the southern end of this reach. On the ground, it is apparent that seasonal high surf can overwash the highway. The conceptual alternatives include protecting the shoreline, relocating the highway, and providing beach fill.

Revetment: (Page 5-18) The revetment would provide protection to the highway from seasonal high surf and winter storms. There is dry beach along the shoreline, therefore the revetment would be partially "buried" within the beach, seaward of the tree line. Beach sand within the limits of the excavation for the revetment would be replaced on the beach in front of the completed structure. The revetment crest would be at elevation +11 feet MLLW to minimize wave overwash, resulting in a line of boulders extending about 2-3 feet above the road elevation. The revetment toe would be at elevation -1 feet MLLW, with an extended underlayer beneath the toe. Alternatively, the revetment toe could be excavated and placed directly on the hard limestone reef.

Highway Relocation: (Page 5-19) This alternative is a bypass highway that extends from the north side of Hale Aha Road, mauka of the residential dwellings (about 300-400 feet mauka of the shoreline), and reconnecting in the vicinity of Punaluu Beach Park. The almost 1-mile long relocated highway would minimize impacts to the residential dwellings and other existing uses located directly mauka of the existing highway. The existing shoreline would be subject to continued erosion and wave overwash damage, and the highway could eventually become unsafe for vehicular travel. This roadway could be converted to a pedestrian walkway and bicycle path.

Beach Fill: (Page 5-20) Because this is a popular recreational beach area and located adjacent to an existing beach park, beach fill as a shore protection alternative is proposed as an option. The beach fill would need to have a wide enough berm at high enough elevation to provide protection to the highway from wave overwash. A grassed "dune" at elevation +11 feet MLLW is provided above the beach berm The proposed beach fill extends about 70 feet seaward of the present beach. Groins (jettys) or culverts extending through the new beach will probably be necessary at North Punaluu Bridge to convey the stream flows to the ocean.

Beach Nourishment: The beach profile data from the *Hawaii Beach Monitoring Program*, U.S. Geological Survey Open-File Report 01-308, datec 2001, indicates no net loss between August 1994 and July 1999. However, there is seasonal change in the profiles on the order of about 100 square feet, or about 9,000 cubic yards for 2,400 linear feet of shoreline. The aerial photographic analysis performed under the present study indicates a net gain in the beach and shoreline. (Shoreline recession has been constrained by the maintenance of the existing highway.) The initial quantity of beach fill is 52,500 cubic yards, which would last about 6 years if the beach lost up to 100 square feet per linear feet seasonally. Because the long-term change has not been significant, it is assumed that nourishment on the order of about 9,000 cubic yards may be required every three years, or an average of 3,000 cubic yards per year for the entire 2,400 linear feet of shoreline.

KAAAWA: There is an approximately 3,000 feet stretch of highway from Mahie Point (near the Crouching Lion Inn) to Kaaawa Point that is directly adjacent to the ocean. The vegetation line has moved seaward between 1949 and 1996, however, tree canopies are likely responsible for the apparent gain. Another 1,600 feet stretch of highway between Swanzy Beach Park and Kaaawa Beach Park is also directly exposed to seasonal winter wave attack and wave overwash. Remnants of various types of shore protection that have been built to protect the highway, such as dumped rocks and concrete walls, are in various stages of disrepair. The beach has always been narrow, but the continued gradual loss over the past 50 years has resulted in virtually no dry beach along this stretch of shoreline. The conceptual alternatives include protecting the shoreline and relocating the highway.

Revetment: (Page 5-21) The revetment would provide protection to the highway from seasonal high surf and winter storms. Because there is virtually no dry beach fronting this shoreline area, the revetment would replace any remnant beach, dumped rocks and concrete seawalls with a uniform rock slope. A moderate amount of fill will be required to provide sufficient shoreline width alongside the paved road because of safety and constructability concerns. The revetment crest would be at elevation +11 feet MLLW to minimize wave overwash, resulting in a line of boulders extending about 2-3 feet above the road elevation. The revetment toe would be at elevation -1 feet MLLW, with an extended underlayer beneath the toe. Alternatively, the revetment toe could be excavated and placed directly on the hard limestone reef.

Highway Relocation: (Page 5-22 & 5-24) This alternative is a 2-mile long bypass highway that extends from Mahie Point (near the Crouching Lion Inn), past Kaaawa to Kaolo Point. The highway alignment minimizes impacts to the residential dwellings and other existing uses located directly mauka of the existing highway. Sections of the existing highway that are exposed to the ocean would be subject to continued erosion and wave overwash damage, and the highway could eventually become unsafe for vehicular travel. This roadway could be converted to a pedestrian walkway and bicycle path.

KAAAWA - KAOLO POINT: Nearly the entire 1-mile stretch of highway from Kaaawa Beach Park to Kaolo Point is directly adjacent to the ocean. This entire shoreline reach has been artificially fixed by the highway and the various methods of shore protection for the highway (dumped rocks, stacked concrete piles, seawalls). The existing shore protection structures are in various stages of disrepair, and provide insufficient protection to the shoreline and highway from erosion damage and wave overwash. The beach has always been narrow along this coastal reach, and some areas have virtually no fronting dry beach. The conceptual alternatives include protecting the shoreline, relocating the highway, and providing beach fill.

Revetment: (Page 5-23) The revetment would provide protection to the highway from seasonal high surf and winter storms. For those areas where there is little or no dry beach fronting the shoreline, the revetment would replace any remnant beach, dumped rocks and concrete walls

with a uniform rock slope. Minor filling may be required to provide sufficient shoreline width alongside the paved road because of safety and constructability concerns. For those areas where there is dry beach along the shoreline, the revetment would be partially buried within the beach, and any sand within the limits of excavation would be replaced on the beach in front of the completed structure. The revetment crest would be at elevation +11 feet MLLW to minimize wave overwash. The elevction of the shoreline varies such that the top of the revetment would range from 0 to 3 feet above the road elevation. The revetment toe would be at elevation -1 feet MLLW, with an extended underlayer beneath the toe. Alternatively, the revetment toe could be excavated and placed directly on the hard limestone reef.

Highway Relocation: (Page 5-22 & 5-24) As described above for Kaaawa, this alternative is a bypass highway that extends from Mahie Point to Kaolo Point. The highway alignment minimizes impacts to the residential dwellings and other existing uses located directly mauka of the existing highway. Sections of the existing highway that are exposed to the ocean would be subject to continued erosion and wave overwash damage, and the highway could eventually become unsafe for vehicular travel. This roadway could be converted to a pedestrian walkway and bicycle path.

Beach Fill: (Page 5-25) Beach fill is proposed as an option for an approximate 1,100 foot shoreline reach north of Kalae Oio Beach Park to Kaaawa Beach Park. The beach fill would need to have a wide enough berm at high enough elevation to provide protection to the highway from wave overwash. A grassed "dune" at elevation +11 feet MLLW is provided above the beach berm. The proposed beach fill extends about 70 feet seaward of the present beach, and provides a continuous dry beach extending between Kaaawa Beach Park and Kalae Oio Beach Park. One culvert would need to be extended through the new beach to convey the drainage to the ocean.

Beach Nourishment: There is no profile data from the *Hawaii Beach Monitoring Program*, U.S. Geological Survey Open-File Report 01-308, dated 2001. The aerial photographic analysis performed under the present study indicates no significant shoreline change. It is assumed that the seasonal change in the beach profile is similar to Punaluu, on the order of about 100 square feet, or about 4,100 cubic yards for 1,100 linear feet of shoreline. The initial quantity of beach fill is 34,800 cubic yards, which would last about 8 years if the beach lost up to about 100 square feet per linear feet seasonally. Because the long-term change has not been significant, it is assumed that nourishment on the order of about 4,100 cubic yards may be required every 4 years, or an average of 1,000 cubic yards per year for the entire 1,100 linear feet of shoreline.

KUALOA: There are two stretches of highway north of Kualoa Regional Park (about 500 feet and 900 feet long) that are directly adjacent to the ocean. Dumped rocks provide insufficient protection to the shoreline and highway from erosion damage and wave overwash. The beach has always been narrow along this coastal reach. The conceptual alternatives include protecting the shoreline and relocating the highway.

Revetment: (Page 5-26) The revetment would provide protection to the highway from seasonal high surf and winter storms. Because there is virtually no dry beach fronting this shoreline area, the revetment would replace any remnant beach and dumped rocks, with a uniform rock slope. The revetment crest would be at elevation +10 feet MLLW resulting in a line of boulders extending about 3 feet above the road elevation. The revetment will sustain minor wave overtopping during extreme winter storms. The revetment toe would be at elevation -1 feet MLLW, with an extended underlayer beneath the toe. Alternatively, the revetment toe could be excavated and placed directly on the hard limestone reef.

Highway Relocation: (Page 5-27) This alternative relocates a 4,100 foot stretch of highway inland about 250 feet, mauka of the sugar mill ruins. The relocated highway would reconnect at the entrance to Kualoa Regional Park. There are no homes affected by this realignment. The homes on the makai side of the highway are protected from erosion damage, but the two exposed highway sections will be subject to continued erosion and wave damage, and would eventually become unsafe for vehicular travel. These sections could be part of a land exchange with Kualoa Ranch for the new highway right-of-way, which would facilitate the Ranch's access to the ocean.

MAKAPUU PIER: Approximately 2,500 feet of highway fronting the Oceanic Institute in the vicinity of the Makapuu Pier is directly adjacent to the ocean. Erosion at the base of the shoreline escarpment has resulted in collapse of the highway shoulder along a section southeast of the pier. Concrete piles have been stacked in attempt to stabilize the base of the escarpment. Beach rock lines the shoreline and is exposed where the erosion is the worst. This shoreline area is generally protected from open ocean waves by the offshore islands of Manana and Kcohikaipu. However, the channel that was dredged through the reef to allow vessel access to Makapuu Pier allows more wave energy than normal to reach the shoreline on the southeast side of the pier. Therefore, storm waves attack the base of the high shoreline escarpment more aggressively along this section of shoreline compared to areas on the northwest side of the pier and farther eastward towards Sea Life Park. The conceptual alternatives include protecting the shoreline and relocating the highway.

Seawall with upper rock slope: (Page 5-28) Because of the relatively high elevation of the highway above the beach, the narrow beach, and the dredged areas near the shoreline, the proposed shore protection alternative is a concrete retaining wall system at the base of the shoreline escarpment. The upper slope of the embankment would be faced with smaller rock. This concept is similar to the shoreline stabilization performed by the Hawaii District DOT along a section of highway at Wainaku, just north of the Wailuku River in Hilo. This design concept minimizes the footprint of the shore protection measure, thereby minimizing impacts to the existing beach area. Along a 1200 feet section where erosion is most severe, the seawall crest

elevation is +10 feet MLLW. The crest elevation along the other less exposed reaches is +5 feet MLLW. The lower portion of the embankment slope (above the seawall) is protected by multiple layers of graded rock to minimize scouring of the slope from storm wave runup/overtopping of the wall. The toe or base of the seawall would be excavated and keyed into the beach rock.

Highway Relocation: (Page 5-29) The roadway realignment alternative was provided by the DOT-Highway Division. This alignment shifts the roadway inland by about a lane width and is constrained by the terrain and existing development on the mauka side. This is considered an interim rather than a long-term measure, because continued storm wave attack will cause further undercutting and collapse of the shoreline embankment. Slope areas that have recently collapsed are also more vulnerable to rainfall runoff erosion because of the lack of vegetated cover.

MAKAHA BEACH PARK: Approximately 1,000 feet of highway fronts Makaha Beach. The beach width varies seasonally, but has generally suffered net erosion at an average rate of about 0.5 feet/year between 1949 and 1999. Along about 600 feet of shoreline, there is no vegetative buffer zone between the beach and highway, and this is the section that is most susceptible to wave overwash during storm wave events. The existing beach berm elevation is about +10 to +13 feet MLLW, which is a couple feet lower than the makai edge of pavement for the road. The conceptual alternatives include relocating the highway and providing beach fill.

Highway Relocation: (Page 5-30) This alternative provides for moving the highway up to about 400 feet mauka of the existing highway. The highway must be routed around the mauka side of the City and County of Honolulu's comfort station facility and the adjacent wetland area on the mauka side of Farrington Highway. This alignment is consistent with the City's Master Plan for Makaha Beach Park (May 1999). There are no homes affected by this realignment.

Beach Fill with Grassed Dune: (Page 5-31) The beach fill would need to have a wide enough berm at high enough elevation to provide protection to the highway from wave overwash. A grassed "dune" at elevation +16 feet MLLW is provided above the beach berm. The proposed beach fill extends an average of about 50 feet seaward of the existing beach, but because of the seasonal variability in the beach slope and configuration, the more important criteria is to provide the dune to minimize wave overwash during storm wave attack.

Beach Nourishment: Beach nourishment is estimated based on beach profile data from the *Hawaii Beach Monitoring Program*, U.S. Geological Survey Open-File Report 01-308, dated 2001. Average sand loss was about 176 square feet per year between the first profile in August 1994 and the last profile in July 1999. (The aerial photographic analysis performed under the present study indicates an average shoreline recession of 0.5 feet per year between 1949 and 1999.) For 600 linear feet of shoreline, this results in an annual rate of about 3,900 cubic yards per year. Seasonal changes in the beach profile were on the order of about 800 square feet, or about 18,000 cubic yards for 600 linear feet of shoreline, which is about the same order of magnitude as the initial beach fill quantity of about 27,000 cubic yards.

Revetted Dune: (Page 5-32) Although subject to wave overwash, the highway is not threatened by erosion damage because of a sufficiently wide beach. To address the wave overwash problem, a wall could be built alongside the highway. However, a more aesthetic option is to build a dune on the mauka side of the existing beach berm. If no additional beach fill is provided, the new "dune" could potentially be scoured by storm wave attack. A revetment on the seaward face of the dune would stabilize the slope. Beach morning glory or similar groundcover could be planted to conceal the rock slope.

ISLAND OF KAUAI (Page 5-33)

HANALEI BAY: There is a 1,600 feet stretch of highway on the west side of Hanalei Bay that is directly adjacent to the ocean. There has been little change to the shoreline since 1950, although the beach has gained in width between 1950 and 1995 (an average of 1.7 feet/year). The shoreline is subject to seasonal winter wave attack. Although Highways Division has no records or construction plans of Kuhio Highway in this area, it is apparent that the highway was elevated and the embankment stabilized (revetted) with boulders. This section of shoreline transitions from low-lying wetlands (the Waikoko Stream and Waipa Stream drainage basins) to the rocky promontory forming the west end of Hanalei Bay. The highway along this section of shoreline was necessarily raised to elevate it above the flood elevation, with the provision of bridges to drain the riverine areas. Erosion of the fronting beach has exposed the boulders along the highway embankment. The conceptual alternatives include protecting the shoreline and relocating the highway.

Revetment: (Page 5-34) The revetment, which would involve reconstructing the highway embankment to provide a properly designed shore protection structure, would provide protection to the highway from seasonal high surf and winter storms. The revetment would be partially buried within the beach alongside the highway. Beach sand within the limits of the excavation for the revetment would be replaced on the beach in front of the completed structure. The revetment crest would be at elevation +10 feet MLLW, which is at or lower than the elevation of the road. The revetment toe would be buried to elevation 0 feet MLLW, with an extended underlayer beneath the toe.

Highway Relocation: (Page 5-35) This alternative realigns a 1,800 feet stretch of highway at least 50 feet mauka of the existing highway. There are no homes affected by this realignment. Waikoko Bridge would be replaced by a new bridge. The existing highway pavement would be removed to facilitate vegetative growth which would help to stabilize the shoreline.

ISLAND OF MOLOKAI (Page 5-36)

NIAUPALA FISHPOND: Approximately 1,400 feet of the roadway was constructed along the top of the fishpond wall on the mauka side of the pond. The old wall is deteriorating and the shoreline is eroding, subjecting the pavement to undercutting and collapse. There is no shoulder along this entire reach. Although there is no wave activity during normal tradewind conditions because of the outer fishpond wall, storm waves can result in high water levels and larger waves which overtop the makai wall. The conceptual alternatives include protecting the shoreline and providing beach fill.

Revetment: (Page 5-37) The revetment would allow for reconstruction of the shoulder of the highway and stabilization of the shoreline. No topographic surveying was performed - the site conditions were estimated from the site reconnaissance and USGS map. The design wave criteria for the revetment is a transmitted wave height of 2.8 feet over the outer pond wall. The revetment crest elevation of +6 feet MLLW is estimated to be adequate to minimize wave overwash during typical high surf, but will likely sustain significant overwash during design storm conditions.

Beach Fill: (Page 5-38) There is very little dry beach along this southeast coast of Molokai. This very large fishpond offers an opportunity to build a recreational beach that would be protected from open ocean waves. The proposed beach fill provides a 50 feet wide berm at the approximate elevation of the roadway. No significant beach nourishment will be required because the shoreline is protected by the fishpond wall.

WAIALUA - KUMIMI: Nearly the entire 1-mile stretch of highway from Waialua to the embayment at Kumimi is directly adjacent to the ocean. This entire shoreline reach has been artificially fixed by the highway and the various methods of shore protection for the highway (dumped rocks, seawalls, etc.). The existing shore protection structures are in various stages of disrepair, and provide insufficient protection to the shoreline and highway from erosion damage and wave overwash. The beach has always been narrow along this coastal reach, and most areas have virtually no fronting dry beach. The conceptual alternatives include protecting the shoreline, relocating the highway, and providing beach fill.

Revetment: (Page 5-39) The revetment would provide protection to the highway from seasonal high surf and the infrequent swell waves from passing hurricanes. For those areas where there is little or no dry beach fronting the shoreline, the revetment would replace any remnant beach, dumped rocks and concrete walls with a uniform rock slope. A moderate amount of fill will be required to provide sufficient shoreline width alongside the paved road because of safety and constructability concerns. For the area near Palalupi where there is a dry beach along the shoreline, the revetment would be partially buried within the beach, and any sand within the limits of excavation would be replaced on the beach in front of the completed structure. No topographic surveying was performed - the site conditions were estimated from the site reconnaissance and USGS map. The revetment crest would be at elevation +10 to +12 feet MLLW (about 2 feet above the existing road elevation) along the south-facing shoreline that is fronted by shallow reef. At Kumimi, the revetment on the south side of the embayment would replace the deteriorated condition of the existing shore protection. Because this shoreline reach is not fronted by shallow reef flat, the estimated wave conditions are larger and the revetment crest elevation would be higher. The elevation of the road decreases as it enters the embayment.

Highway Relocation: (Page 5-40) This alternative realigns about 1 mile of the road at least 25 feet mauka of the existing highway. There are no homes directly impacted by this realignment. The existing highway pavement would be removed to facilitate vegetative growth which would help to stabilize the shoreline. The section of road leading into the Kumimi embayment is cut directly along the edge of the steep cliff, and therefore realignment is not an option for this reach.

Beach Fill: (Page 5-41) Beach fill is proposed as an option for an approximate 1800 foot shoreline reach at Palalupi. This reach has a fronting dry sand beach, although the beach berm is not wide enough or high enough to prevent wave erosion damage to the highway during storm wave attack. Groins are provided to contain the beach fill at the extreme northeast end (at the rocky headland) and southwest end (near the remnant wall of Kaapohaku Fishpond), and a T-groin is provided in the middle to compartmentalize the beach into two segments for further stability. The proposed beach fill extends about 50-70 feet seaward of the existing beach with berm elevation of about +7 feet MLLW, which is the approximate elevation of the road. It is expected that no significant nourishment will be required on a regular basis because of the structures that are proposed to stabilize and contain the widened beach.

ISLAND OF MAUI (Page 5-42)

KAHULUI BAY: The approximately 2,600 feet stretch of shoreline along the west side of Kahului Harbor has been artificially fixed by the highway, and the shoreline has been alternately stabilized and reconstructed as the highway has been widened and improved over the past 50 years. The present shoreline is in need of protection as the embankment is being undercut by erosion, and temporary concrete barriers have been placed along the highway shoulder to minimize wave overwash. About 800 feet of highway outside of the harbor (north of the west breakwater) is exposed to the ocean and also subject to erosion damage and wave overwash. The "beach" along the west shoreline consists of gravel and small rock on a relatively steep shoreline slope. In contrast, a narrow sandy beach fronts the south shoreline within the harbor. Within the harbor, seaweed that is broken loose from the ocean bottom by wave action accumulates in thick algal mats along the west shoreline, presumably driven there by the prevailing tradewinds. The seaweed is removed from the shoreline by mechanical means, which also results in the removal

of sediment that is scraped up along with the algal mat. The conceptual alternatives provide for protecting the shoreline, while also addressing the seaweed problem.

CRM Seawall: (Page 5-43) Within the harbor, the CRM seawall is located at the MHHW line to prevent the accumulation of seaweed on the shoreline. The top of wall elevation of +11 feet MLLW will minimize wave overwash. The shoreline mauka of the wall will be filled to provide a wide clear space alongside the highway. This will provide a much more aesthetic and functional shoreline treatment than currently exists. Outside the harbor, the CRM seawall is located within the highway right-of-way, and will provide storm wave protection for the highway with minimal impacts to the existing shoreline.

Composite Slope Protection: (Page 5-44) Within the harbor, an alternative shore protection option is to provide a low profile concrete retaining wall at the MHHW line, with a rock slope above the wall. The concrete wall would serve the purpose of minimizing seaweed accumulation on the shoreline. However, the low profile would not prevent storm wave runup/overtopping and erosion of the backshore. Therefore, the backshore slope would be faced with rock to prevent scouring and erosion from overtopping waves. The shoreline character would be more similar to the existing condition than the CRM seawall alternative. However, this alternative will not eliminate the seaweed problem, as high waves can still deposit the seaweed above the concrete wall. Therefore, there must be sufficient clear width above the concrete wall to enable heavy equipment to access and remove any accumulated seaweed.

KEALIA POND: Nearly the entire 1-mile stretch of highway fronting Kealia Pond is directly adjacent to the ocean. Both the vegetation line and beach have eroded between 1949 and 1998 (average rate of beach loss was 0.5 feet/year). Except for an approximate 1300 feet length in the middle of this stretch, the highway is directly exposed to the ocean with little or no vegetative buffer between the road and the beach. The highway is subject to erosion damage and wave overwash. Relatively high vegetated dunes have formerly provided much protection for this coastal area. However, breaching of this dune system, from both natural and man-made causes, have contributed to the present condition. Wooden fences have been erected along this entire coastal reach to prevent nesting turtles from crossing the highway. The conceptual alternatives include protecting the shoreline, providing beach fill, and elevating the highway above the influence of wave attack.

Revetment: (Page 5-45) The revetment would provide protection to the two exposed sections of highway from seasonal high surf and the infrequent swell waves from passing hurricanes. The revetment would be partially buried within the beach alongside the highway. Beach sand within the limits of the excavation for the revetment would be replaced on the beach in front of the completed structure. The revetment crest would be at elevation +12 feet MLLW to minimize wave overwash during seasonal high surf, resulting in a line of boulders extending about 5 feet above the road elevation. This crest elevation is about the same as the shoreline and dune elevation along this coastal area. This revetment is susceptible to wave overwash during the design hurricane wave condition, however, this would be an infrequent event. The revetment toe would be buried to elevation 0 feet MLLW, with an extended underlayer beneath the toe. Alternatively, the revetment toe could be placed directly on the existing beach rock, if found within the limits of excavation.

Beach Fill: (Page 5-46) Because this is a popular recreational area with significant wildlife resources, beach fill is proposed as an option. The beach fill would need to have a wide enough berm at high enough elevation to provide protection to the highway from wave erosion damage and overwash. A grassed dune at elevation +11 feet MLLW is provided above the beach berm. The proposed beach fill extends an average of less than 50 feet seaward of the existing beach, but the higher beach berm elevation with dune provides the protective buffer to minimize wave overwash during seasonal high surf. The dune would be susceptible to wave overwash during the design hurricane wave condition, however, this would be an infrequent event.

Beach Nourishment: The beach profile data from the *Hawaii Beach Monitoring Program*, U.S. Geological Survey Open-File Report 01-308, dated 2001, indicates net gain between the first profile in September 1995 and the last profile in June 1999. The aerial photographic analysis performed under the present study indicates average beach recession of about 0.5 feet per year between 1949 and 1998. Assuming a profile change of 10 square feet per year, for 3,900 linear feet of shoreline, this results in about 1,400 cubic yards per year. The initial quantity of beach fill is 67,900 cubic yards, which would last about 48 years assuming an annual loss of 1,400 cubic yards. Therefore, nourishment may not be required for about 25 years or so, or until the erosion progresses into the protective dune section.

Elevated Roadway: (Page 5-47) Because the existing highway is located on a narrow coastal strand fronting Kealia Pond, realigning the highway farther inland would necessarily involve filling within the limits of the pond. This elevated roadway alternative is a 1-mile long viaduct that is located directly mauka of the existing highway, that would be unaffected by wave erosion and wave overwash of the present shoreline. The elevated roadway would also allow turtles to traverse the shoreline beneath the viaduct, unimpeded and not threatened by vehicular traffic. The roadway elevation is about +16 feet MLLW, supported on girders (bottom elevation about +11 feet MLLW), which is about 5 feet above the existing pavement elevation. The girders are supported on pile caps, on a foundation of drilled shafts, with about 100 feet between bents. The bottom of the pile caps are about the same elevation as the existing road, therefore, little excavation will be necessary to construct the caps. The existing highway pavement would be removed after completion of the viaduct to facilitate vegetative growth, which would help to stabilize the shoreline.

UKUMEHAME: This nearly 3-mile stretch of highway, from east of Hekili Point and extending westward to the Pali, is located adjacent to the ocean with little or no vegetated buffer between

the highway and the ocean. This ertire shoreline reach has been artificially fixed by the highway and some sections have already required shore protection, while additional sections are presently endangered by erosion and wave overwash. The shoreline on the south-facing shore, encompassing Ukumehame Beach State Park, has suffered the most erosion, losing an average of 0.7 feet/year between 1949 and 1997. The beach has always been narrow along this coastal reach, and much of this shoreline is now fronted by a cobble and rock beach rather than a sandy beach. The conceptual alternatives include protecting the shoreline, relocating the highway, and providing beach fill.

Revetment: (Page 5-48, 5-50, 5-52) There are five stretches of highway that are proposed for revetment protection. These sections range from about 500 feet in length to 1,900 feet, and would provide protection to the highway from seasonal high surf and the infrequent swell waves from passing hurricanes. Because these are highway sections that are already endangered by erosion, a moderate amount of fill will be required to provide sufficient shoreline width alongside the paved road because of safety and constructability concerns. The revetment crest would be at elevation +12 feet MLLW to minimize wave overwash during seasonal high surf, resulting in a line of boulders extending about 4-5 feet above the road elevation. This revetment is susceptible to wave overwash during the design hurricane wave condition, however, this would be an infrequent event. The revetment toe would be placed directly on the hard limestone reef.

Highway Relocation: (Page 5-49, 5-51, 5-53) This alternative realigns about 3 miles of the road about 150 feet mauka of the existing highway. There are no homes affected by this realignment. The existing highway would be subject to continued erosion and wave damage, and the highway would eventually become unsafe for vehicular travel. This roadway could be converted to a pedestrian walkway and bicycle path.

Beach Fill: (Page 5-54) Beach fill is proposed as an option for the south-facing shoreline reach encompassing Ukumehame Beach State Park (Section 3). There is a narrow beach fronting the park facilities on the east and west end of this reach, but almost 2,000 feet of shoreline is devoid of sand and the highway pavement is becoming undermined from the erosion damage. Two T-groins are provided to compartmentalize the beach into three 600-foot segments for increased stability. The proposed beach berm is 50 feet wide with berm elevation of +6 to +7 feet MLLW, which is the approximate elevation of the road. The beach will minimize wave overwash during seasonal high surf, but may sustain significant overwash during the design hurricane wave event. Because structures are proposed to stabilize and contain the widened beach, it is expected that no significant nourishment will be required on a regular basis, unless infrequent storm waves cause significant damage to the beach.

OLOWALU: North of Hekili Point, a short section of highway was being undermined from erosion damage, and was in imminent danger of collapsing. Emergency shore protection has recently been constructed to repair the shoreline and highway damage. However, at least about 1,000 feet of highway continuing northward of this location is located adjacent to the ocean with little or no vegetated buffer between the highway and the ocean. Within a 4,000 feet coastal reach from Hekili Point northward to Awalua, while erosion has been occurring at the south end, the north end has been accreting, with little net change to the shoreline between 1971 and 1999. Therefore, it is expected that continued transport northward will result in progressive potential erosion damage to the highway at the southern end.

Revetment: (Page 5-55) The revetment would provide protection to the highway from seasonal high surf and the infrequent swell waves from passing hurricanes. There is little or no dry beach fronting the shoreline, and therefore the revetment would replace any remnant beach and cobble shoreline with a uniform rock slope. Minor filling may be required to provide sufficient shoreline width alongside the paved road because of safety and constructability concerns. The revetment crest would be at elevation +15 feet MLLW, which is the approximate elevation of the road. The revetment toe would be placed directly on the hard limestone reef.

ISLAND OF HAWAII (Page 5-56)

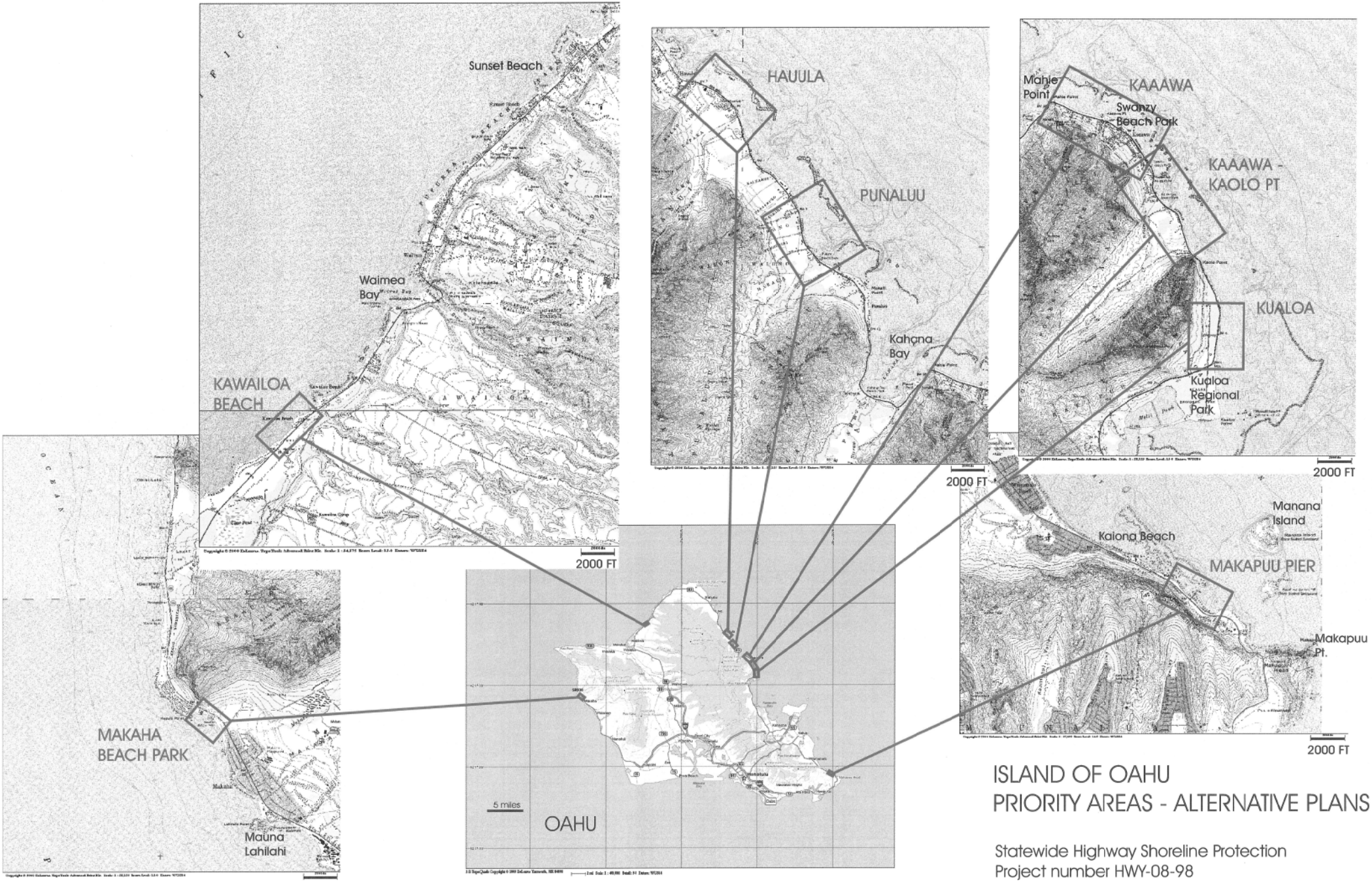
HILO BAYFRONT: The construction in the 1920s of the 2-mile long breakwater extending across Hilo Bay has altered the littoral processes along the Bayfront shoreline. Prior to the construction of the breakwater, the shoreline and offshore contours were indicative of a stable crescent shoreline exposed to the northeast tradewinds. With the construction of the breakwater, only diffracted tradewind waves and northerly waves can enter the bay. By blocking the direct approach of northeast tradewind waves, the breakwater modified the littoral transport at the shoreline to a predominantly one-way longshore transport to the east. Between 1949 and 1998, the shoreline on the east half of the Bayfront, from Pauahi Street eastward to Wailoa River, had accreted an average of 2.7 feet/year, while the west half of the shoreline to Coconut Point had eroded an average of 0.9 feet/year. The accretion on the eastern segment is limited by the length of the groin that was constructed alongside the entrance to the Wailoa Basin to prevent shoaling within the entrance channel. The 175-foot long groin was designed to provide "storage" of sediments for a nominal 5-year period, after which time the County would have to redistribute the sand that had accumulated on the updrift side of the groin to the opposite end of the Bayfront shoreline. The periodic removal of accreted beach material is required to prevent bypassing of the groin once the storage capacity is reached. Because maintenance sand removal has not been performed since the groin was constructed in the late 1980s, sand has continued to bypass the groin and accumulate at the entrance to Wailoa River. The erosion on the western half of the Bayfront shoreline is limited by the shore protection measures that have been implemented over the years. Much of the shore protection is in disrepair, and provide insufficient protection to the shoreline and highway from erosion damage and wave overwash. The conceptual alternatives include protecting the shoreline, relocating the highway, and providing beach fill.

Revetment: (Page 5-57) The revetment would provide protection to an approximate 2,500 feet shoreline reach on the west half of the Bayfront shoreline. The revetment crest would be about 2 feet above the existing shoreline grade to minimize wave overwash. The revetment toe would be at elevation -1 feet MLLW , with an underlayer extending at least 5 feet beyond the toe. A single layer of armor stones would be placed at the extended toe of the revetment to provide additional protection against scouring.

Highway Relocation: (Page 5-58) This alternative involves closing the stretch of Bayfront Highway to through-traffic, from Pauahi Street to Coconut Point near the Wailuku River Bridge. About 2,100 feet of new 4-lane highway would extend from Waianuenue Avenue to merge with the existing 4-lane Kamehameha Avenue just southeast of Ponahawai Street.

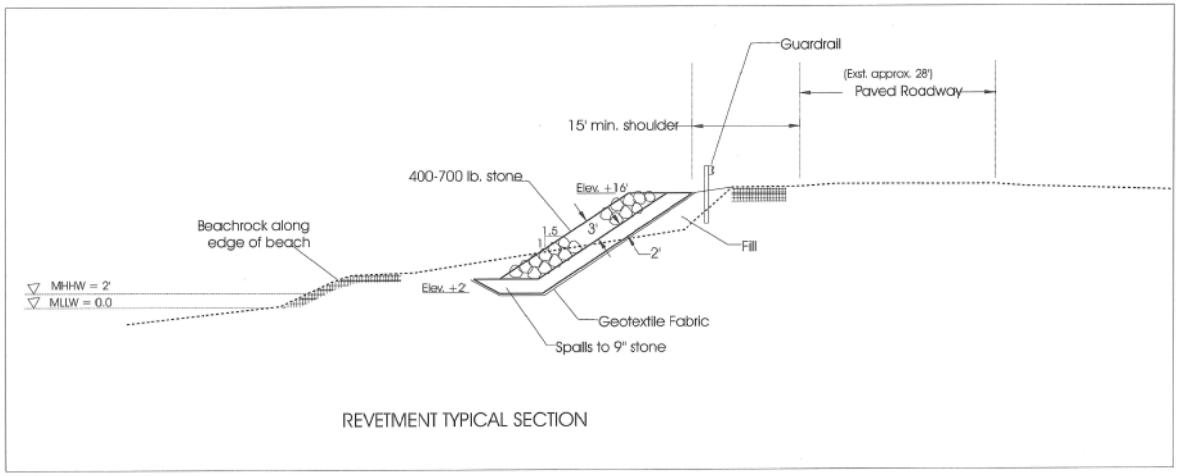
Beach Fill: (Page 5-59) The Bayfront shoreline makai of Kamehameha Avenue is a designated recreational area owned by the County and the State. This entire shoreline area was set aside for park use to prevent redevelopment subsequent to the devastating 1946 tsunami. A plan for shoreline improvements was developed by the U.S. Army Corps of Engineers (USACE) in the early 1980s as part of their "Hilo Area Comprehensive Study". The primary benefits of their plan were the enhancement of recreational opportunities, including stabilization of the beach on the west half of the Bayfront shore. Because their plan lacked Federal interest, implementation rested solely with the local government. To date, the groin adjacent to the Wailoa River mouth has been constructed, and shoreline protection has been constructed along the western portions of the Bayfront shoreline. However, the beach fill has not been implemented. The present beach fill option incorporates a groin field similar to the USACE plan, however, fewer groins are proposed based on the present configuration of the shoreline (subsequent to the construction of the groin adjacent to the Wailoa River mouth). Three 200-foot long groins are expected to stabilize a beach extending about 50-100 feet seaward of the existing shoreline. Because longshore transport is predominantly eastward, the groin field will stabilize and contain the beach. It is expected that no significant nourishment will be required on a regular basis.

Groin Field: This option is a phased approach to the beach fill alternative, which provides for the construction of the groins only. From the sediment accumulation that occurred along the eastern half of the Bayfront shoreline subsequent to the construction of the groin adjacent to the Wailoa River mouth, it can be expected that sand will similarly accumulate on the updrift side of the groins that are proposed for the western half of the Bayfront shoreline. As long as the Wailuku River discharges sediments, and the incoming wave energy moves this sediment towards shore, together with the existing sediment that has accumulated within the bay over the 80 years since the breakwater was constructed, then there will be a source for rebuilding the Bayfront Beach. If the rate of sand buildup on the updrift side of the groins is insufficient, then the beach can be supplemented by additional fill.



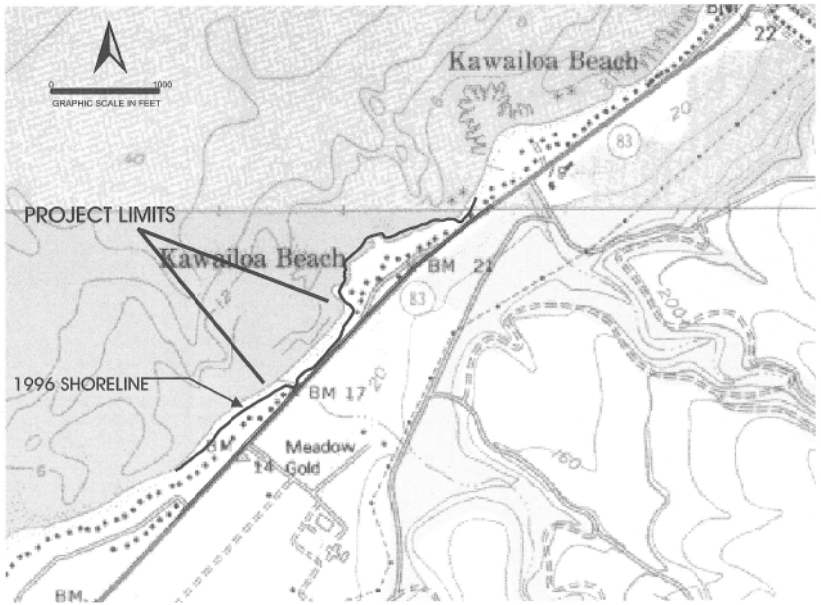
ISLAND OF OAHU
PRIORITY AREAS - ALTERNATIVE PLANS

Statewide Highway Shoreline Protection
Project number HWY-08-98



REVETMENT TYPICAL SECTION

REAL ESTATE (R/W ACQUISITION):	$ N/A
PLANNING & PERMITTING:	$ 123,900
ENGINEERING & DESIGN:	$ 123,900
CONSTRUCTION COST:	$1,049,200
TOTAL COST FOR ALTERNATIVE:	$1,297,000

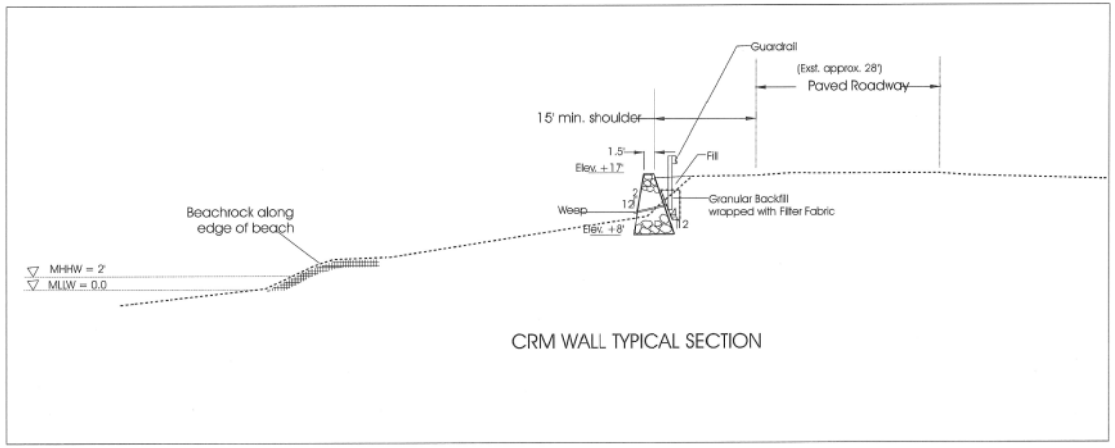




ALTERNATE PLAN - REVETMENT
KAWAILOA BEACH, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

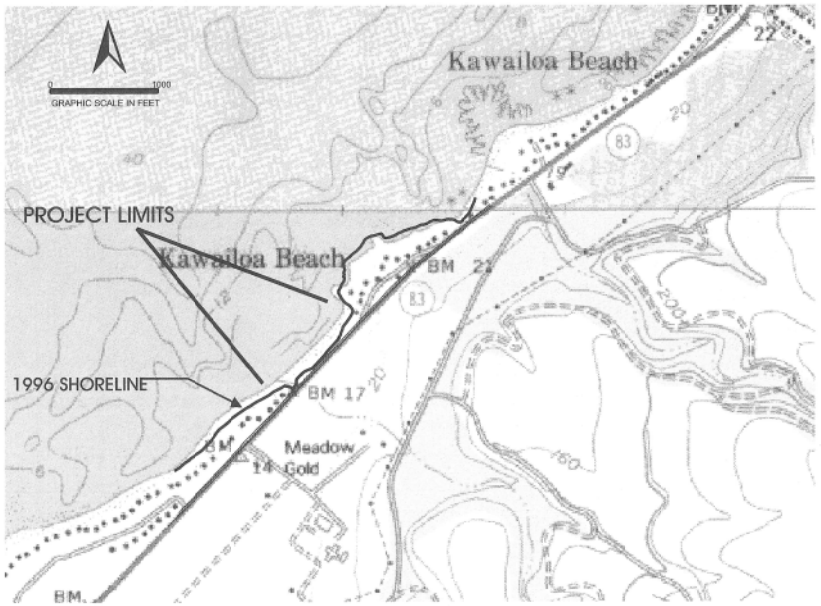
7-27-92



CRM WALL TYPICAL SECTION

REAL ESTATE (R/W ACQUISITION): $ N/A
PLANNING & PERMITTING: $ 145,300
ENGINEERING & DESIGN: $ 145,300
CONSTRUCTION COST: $1,230,700

TOTAL COST FOR ALTERNATIVE: $1,521,300

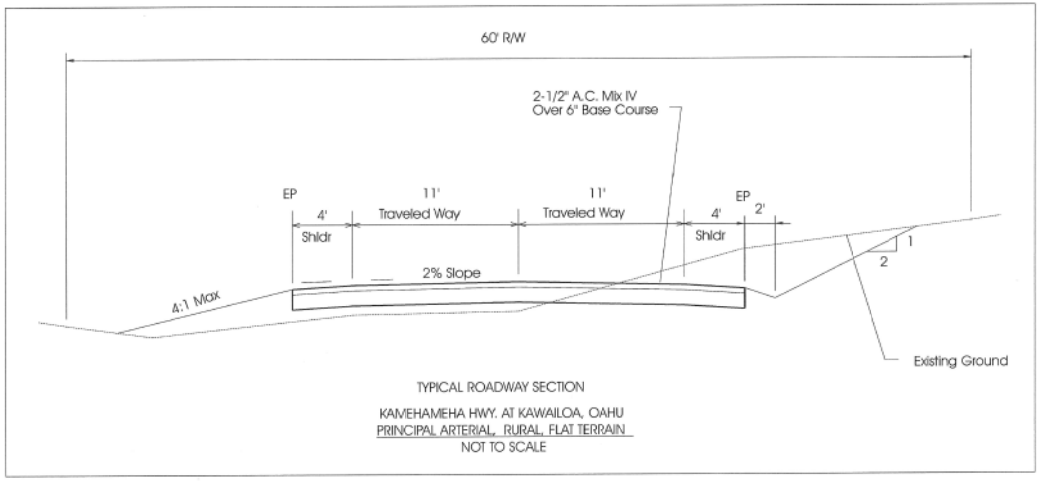




ALTERNATE PLAN - CRM WALL
KAWAILOA BEACH, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

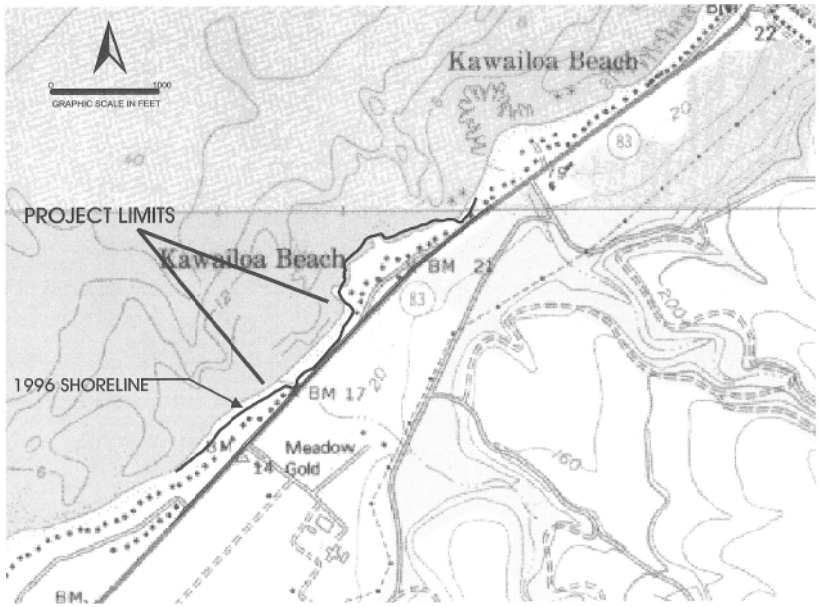
7-27-92

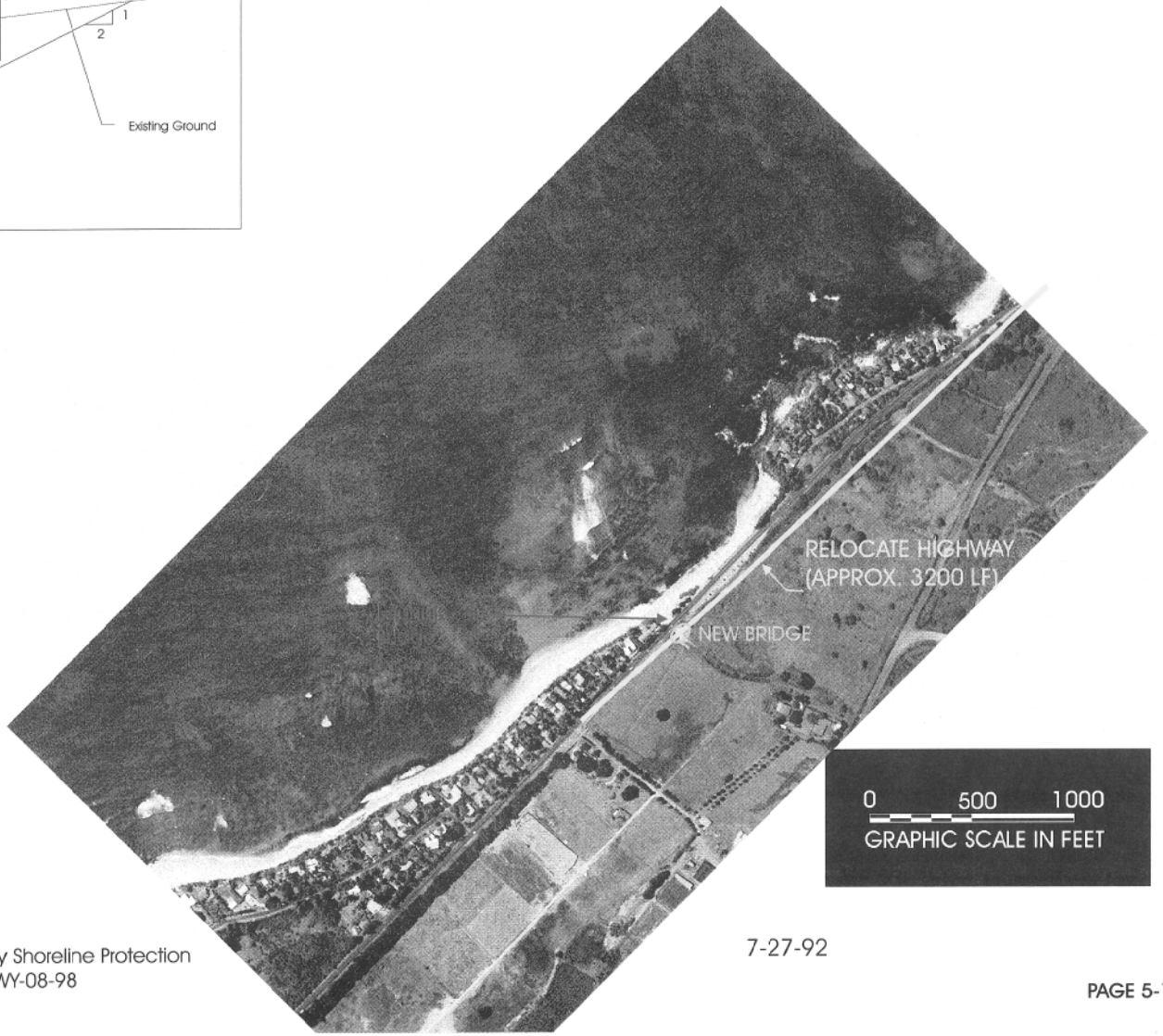


TYPICAL ROADWAY SECTION

KAMEHAMEHA HWY. AT KAWAILOA, OAHU
PRINCIPAL ARTERIAL, RURAL, FLAT TERRAIN
NOT TO SCALE

REAL ESTATE (R/W ACQUISITION):	$ 100,000
PLANNING & PERMITTING:	$ 857,500
ENGINEERING & DESIGN:	$ 857,500
CONSTRUCTION COST:	$7,262,600
TOTAL COST FOR ALTERNATIVE:	$9,077,600

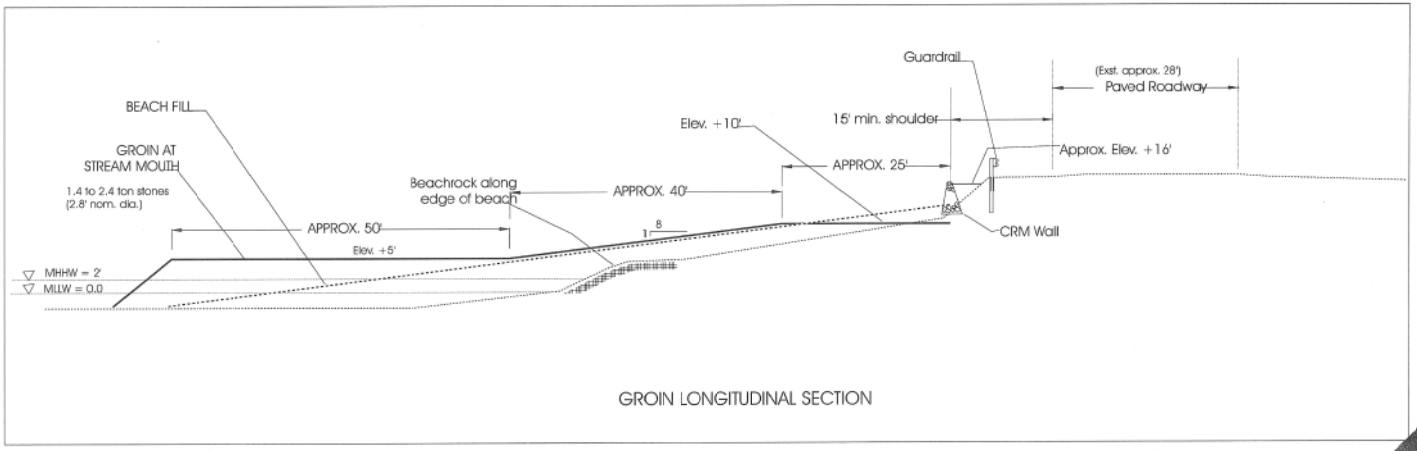




ALTERNATE PLAN - RELOCATE HIGHWAY
KAWAILOA BEACH, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

7-27-92

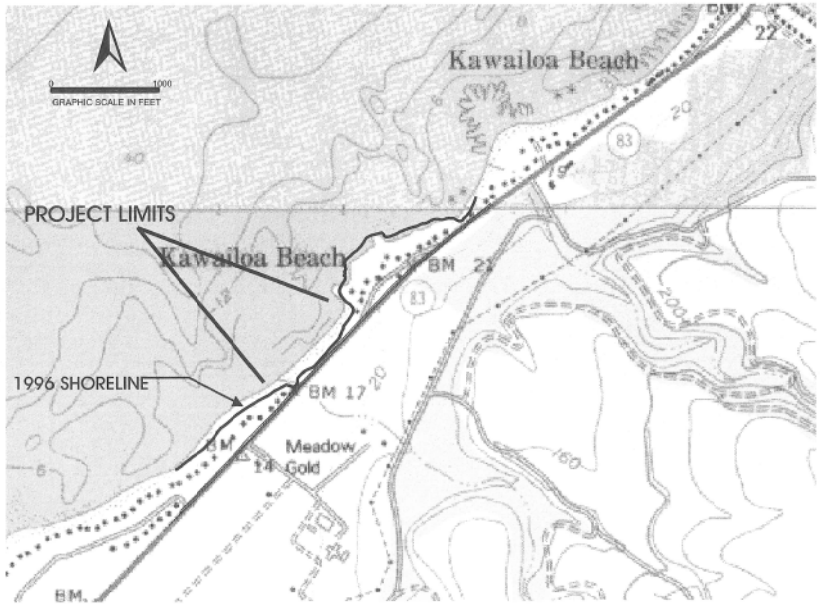


GROIN LONGITUDINAL SECTION

REAL ESTATE (R/W ACQUISITION): $ N/A
PLANNING & PERMITTING: $ 181,600
ENGINEERING & DESIGN: $ 181,600
CONSTRUCTION COST: $1,537,700

TOTAL COST FOR ALTERNATIVE: $1,900,900

BEACH NOURISHMENT: $ 105,000 / YR

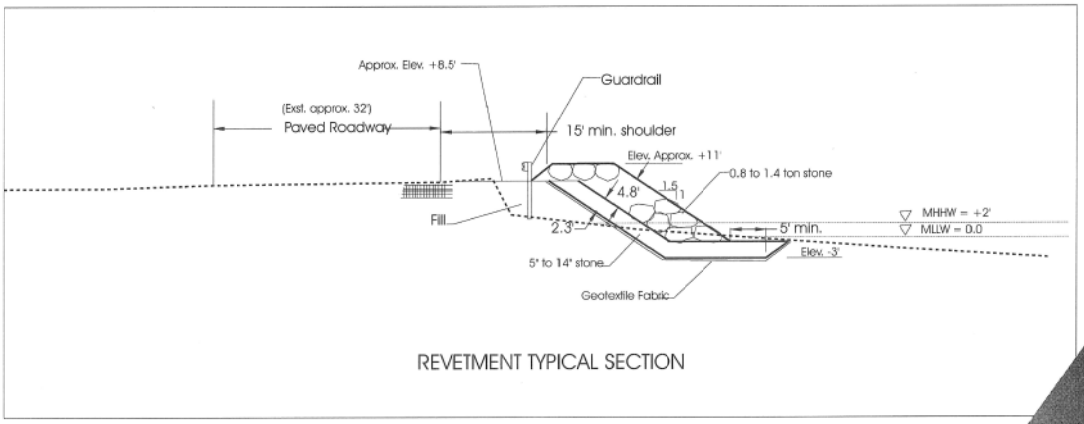




ALTERNATE PLAN - BEACH FILL
KAWAILOA BEACH, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

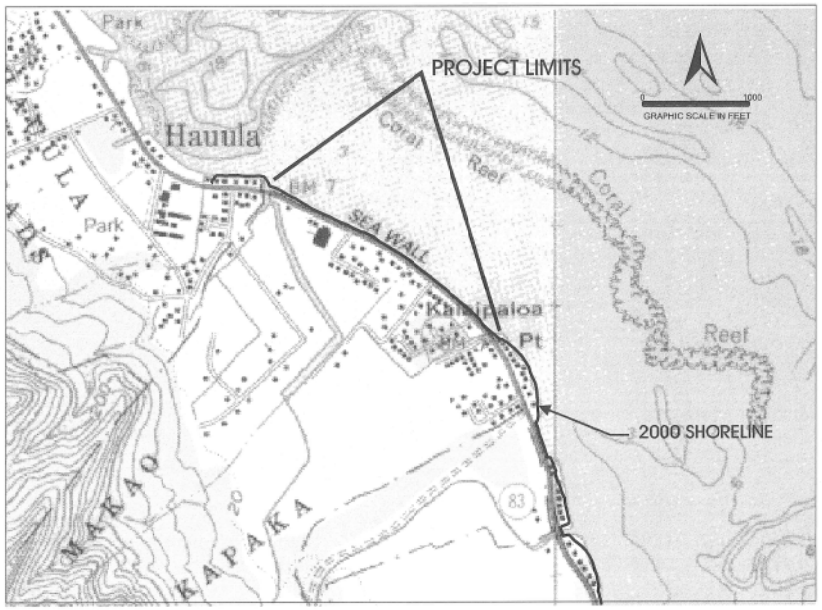
7-27-92



REVETMENT TYPICAL SECTION

REAL ESTATE (R/W ACQUISITION): $ N/A
PLANNING & PERMITTING: $ 497,600
ENGINEERING & DESIGN: $ 497,600
CONSTRUCTION COST: $4,214,500

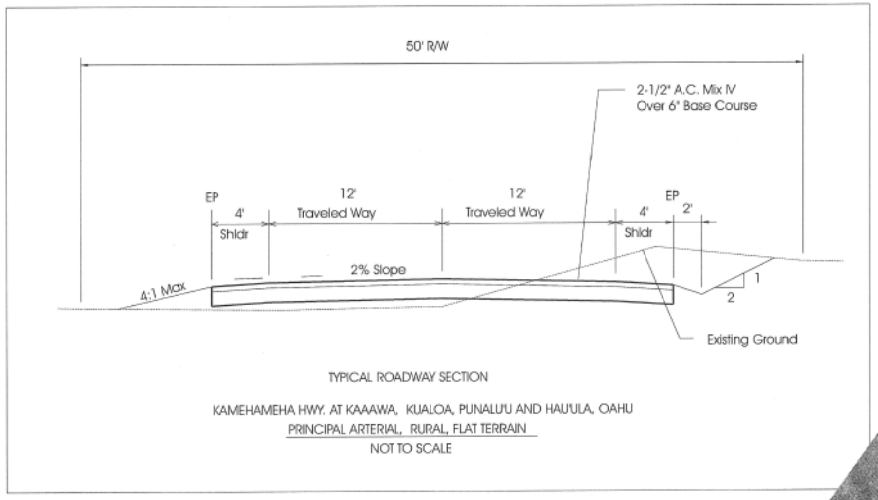
TOTAL COST FOR ALTERNATIVE: $5,209,700





ALTERNATE PLAN - REVETMENT
HAUULA, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

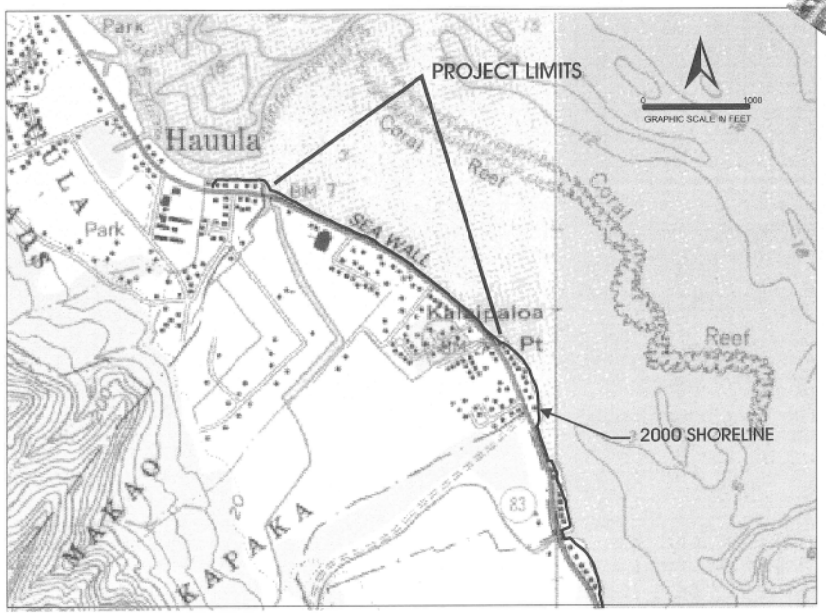


TYPICAL ROADWAY SECTION

KAMEHAMEHA HWY. AT KAAAWA, KUALOA, PUNALU'U AND HAU'ULA, OAHU
PRINCIPAL ARTERIAL, RURAL, FLAT TERRAIN
NOT TO SCALE

REAL ESTATE (R/W ACQUISITION): $13,500,000
PLANNING & PERMITTING: $ 2,422,900
ENGINEERING & DESIGN: $ 2,422,900
CONSTRUCTION COST: $20,522,100

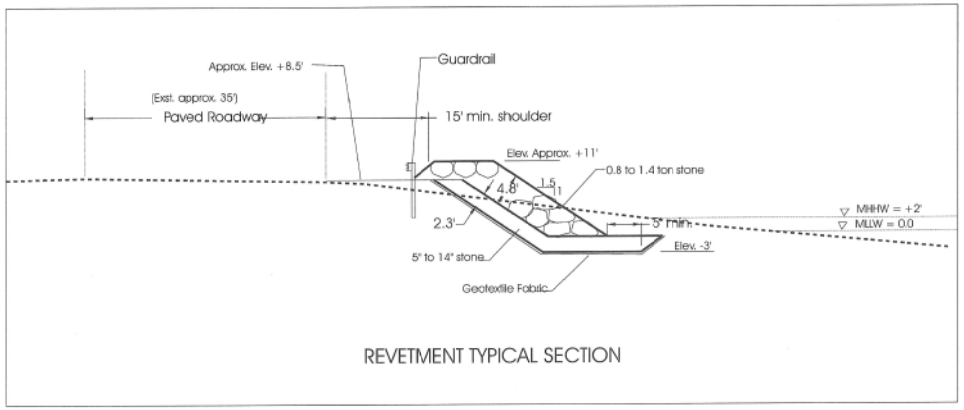
TOTAL COST FOR ALTERNATIVE: $38,867,900





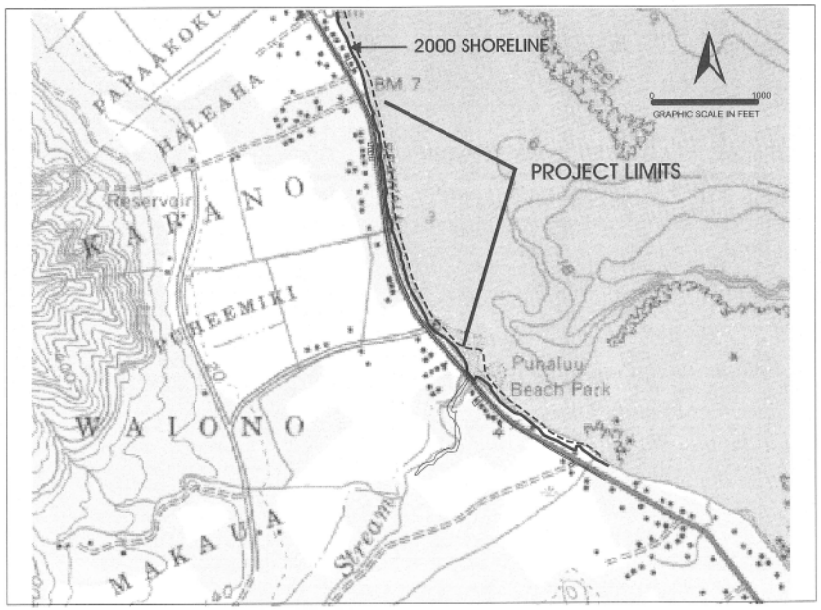
ALTERNATE PLAN - RELOCATE HIGHWAY
HAUULA. OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98



REVETMENT TYPICAL SECTION

REAL ESTATE (R/W ACQUISITION):	$ N/A
PLANNING & PERMITTING:	$ 491,900
ENGINEERING & DESIGN:	$ 491,900
CONSTRUCTION COST:	$4,166,100
TOTAL COST FOR ALTERNATIVE:	$5,149,900

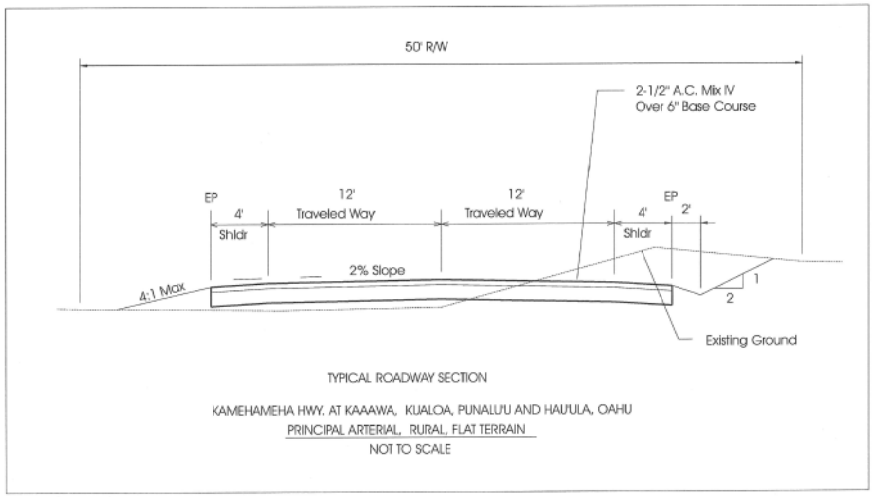




1-30-00

ALTERNATE PLAN - REVETMENT
PUNALUU, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

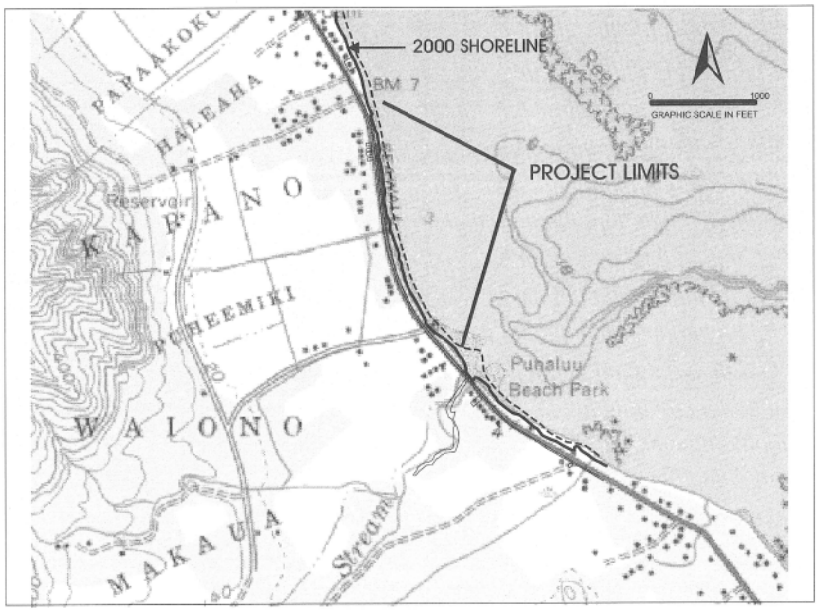


TYPICAL ROADWAY SECTION

KAMEHAMEHA HWY. AT KAAAWA, KUALOA, PUNALU'U AND HAU'ULA, OAHU
PRINCIPAL ARTERIAL, RURAL, FLAT TERRAIN
NOT TO SCALE

REAL ESTATE (R/W ACQUISITION): $ 4,000,000
PLANNING & PERMITTING: $ 1,546,800
ENGINEERING & DESIGN: $ 1,546,800
CONSTRUCTION COST: $13,101,100

TOTAL COST FOR ALTERNATIVE: $20,194,700

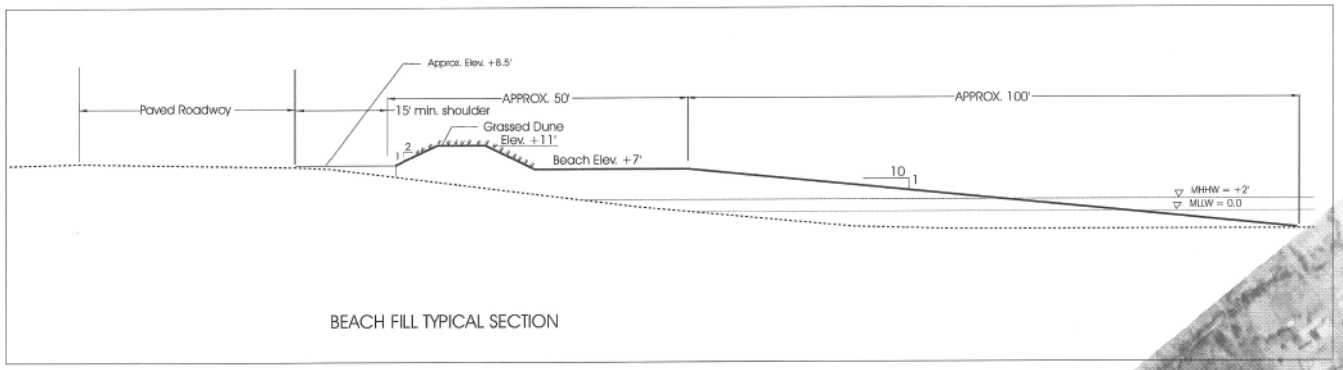




1-30-00

ALTERNATE PLAN - RELOCATE HIGHWAY
PUNALUU, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

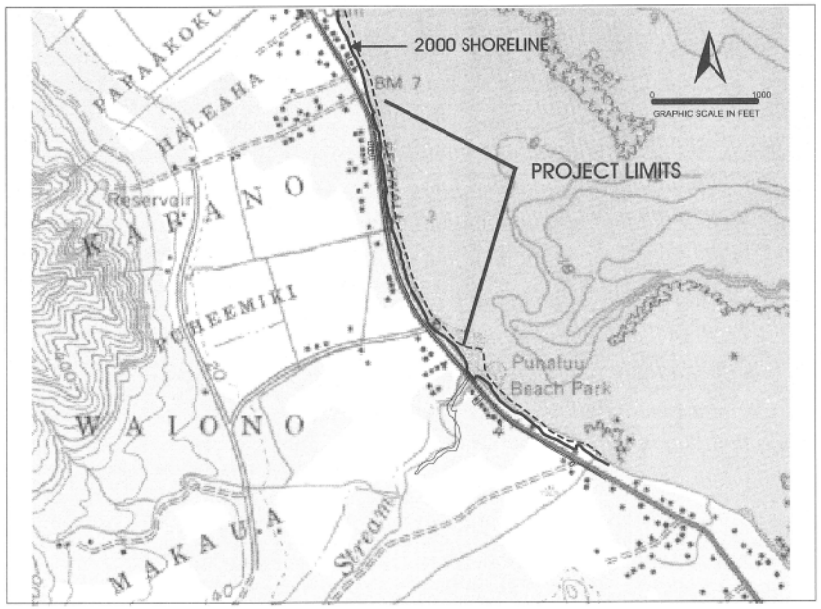


BEACH FILL TYPICAL SECTION

REAL ESTATE (R/W ACQUISITION): $ N/A
PLANNING & PERMITTING: $ 508,500
ENGINEERING & DESIGN: $ 508,500
CONSTRUCTION COST: $4,306,900

TOTAL COST FOR ALTERNATIVE: $5,323,900

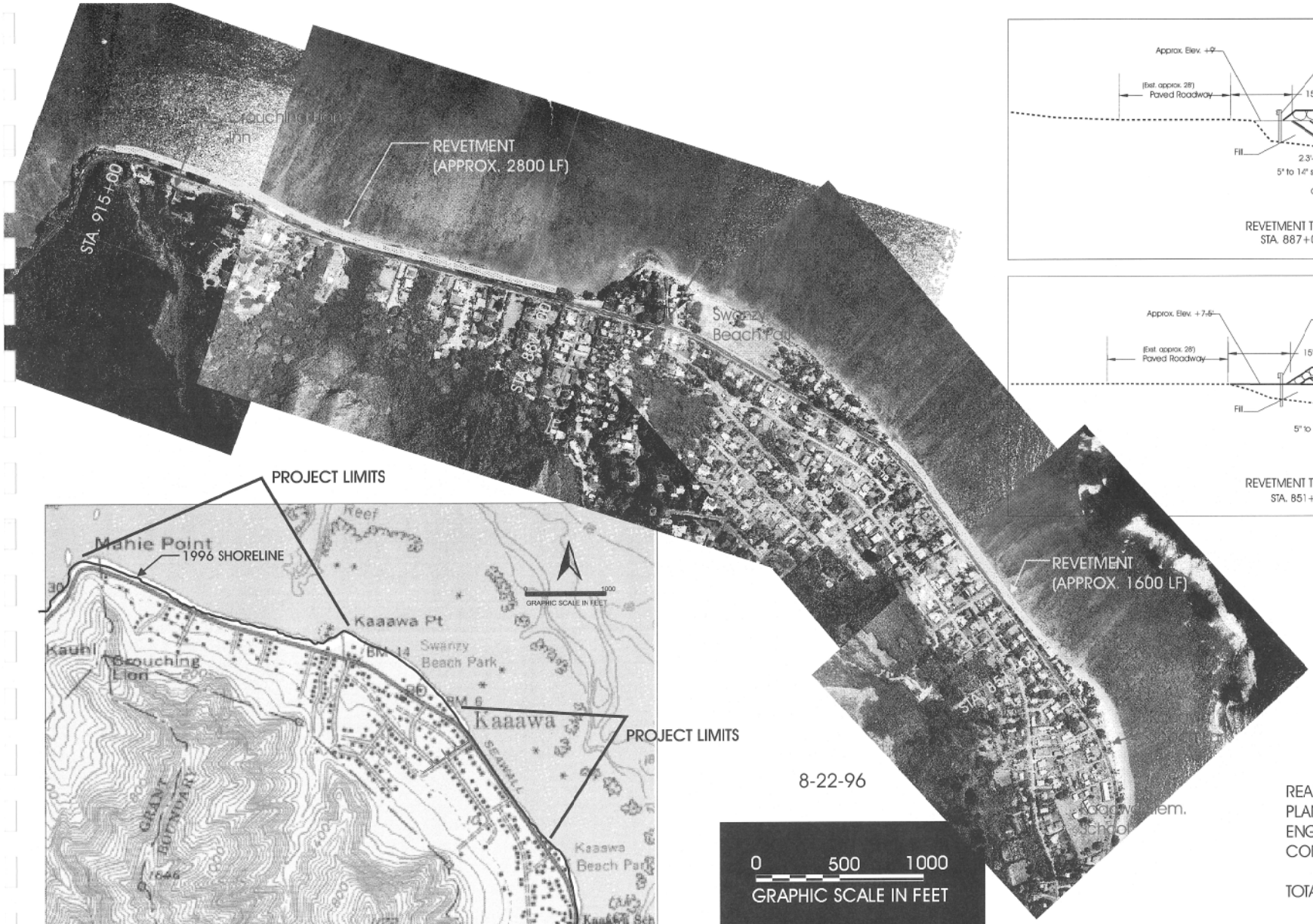
BEACH NOURISHMENT: $ 210,000 / YR

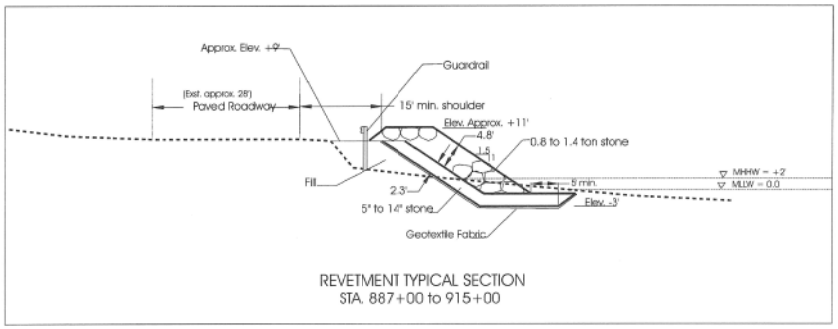




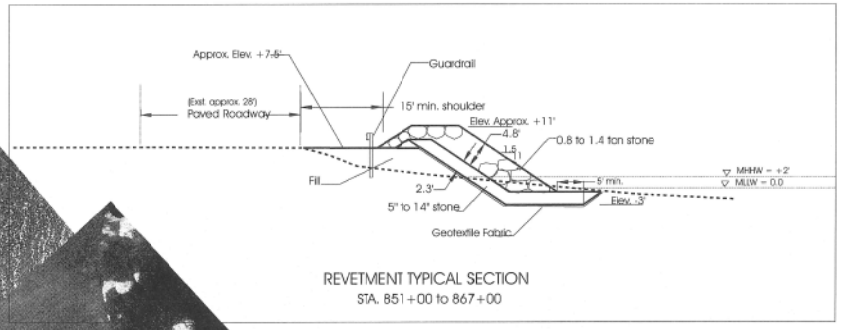
ALTERNATE PLAN - BEACH FILL
PUNALUU, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98





REVETMENT TYPICAL SECTION
STA. 887+00 to 915+00



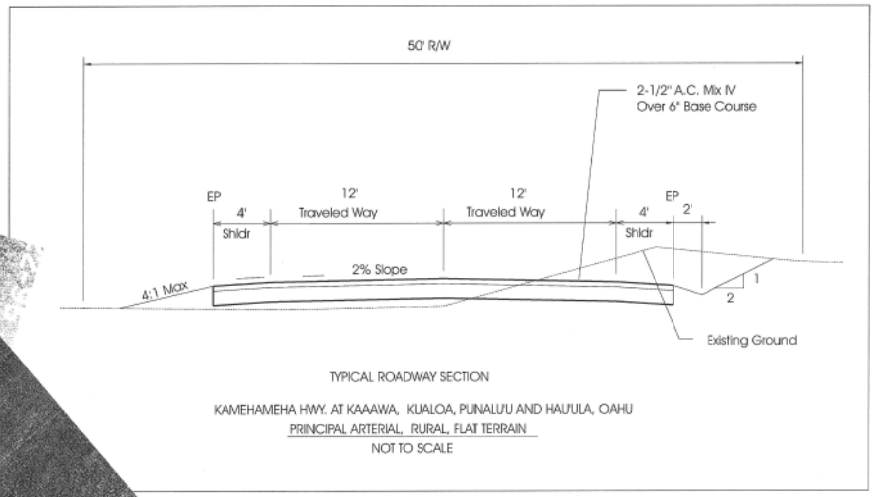
REVETMENT TYPICAL SECTION
STA. 851+00 to 867+00

REAL ESTATE (R/W ACQUISITION):	$ N/A
PLANNING & PERMITTING:	$ 994,000
ENGINEERING & DESIGN:	$ 994,000
CONSTRUCTION COST:	$8,419,100
TOTAL COST FOR ALTERNATIVE:	$10,407,100

ALTERNATE PLAN - REVETMENT
KAAAWA, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98





TYPICAL ROADWAY SECTION

KAMEHAMEHA HWY. AT KAAAWA, KUALOA, PUNALUU AND HAUULA, OAHU
PRINCIPAL ARTERIAL, RURAL, FLAT TERRAIN
NOT TO SCALE

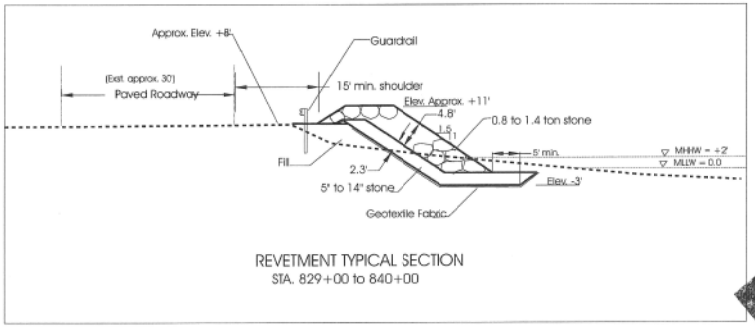
KAAAWA TO KAOLO POINT, 11000 LF BYPASS HWY:

REAL ESTATE (R/W ACQUISITION & RELOCATION COST:	$22,000,000
PLANNING & PERMITTING:	$ 2,684,300
ENGINEERING & DESIGN:	$ 2,684,300
CONSTRUCTION COST:	$22,736,000
TOTAL COST FOR ALTERNATIVE:	$50,104,600

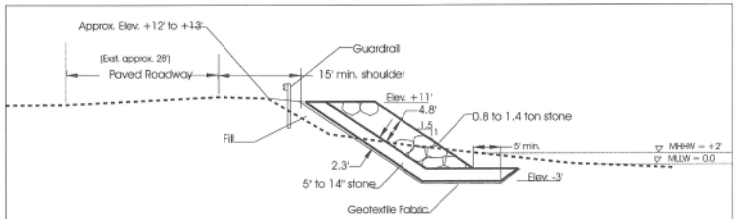
See Kaaawa-Kaolo Pt. Sheet
for continuation

ALTERNATE PLAN - RELOCATE HIGHWAY
KAAAWA, OAHU

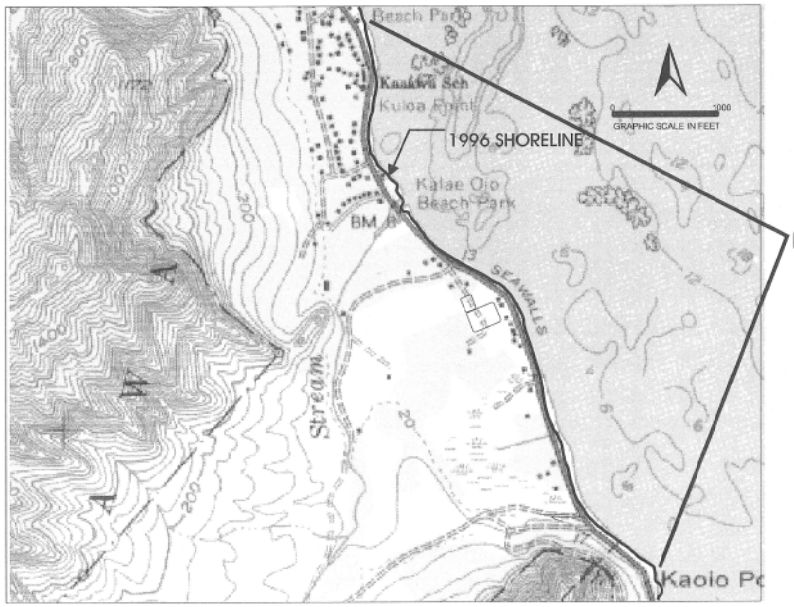
Statewide Highway Shoreline Protection
Project number HWY-08-98

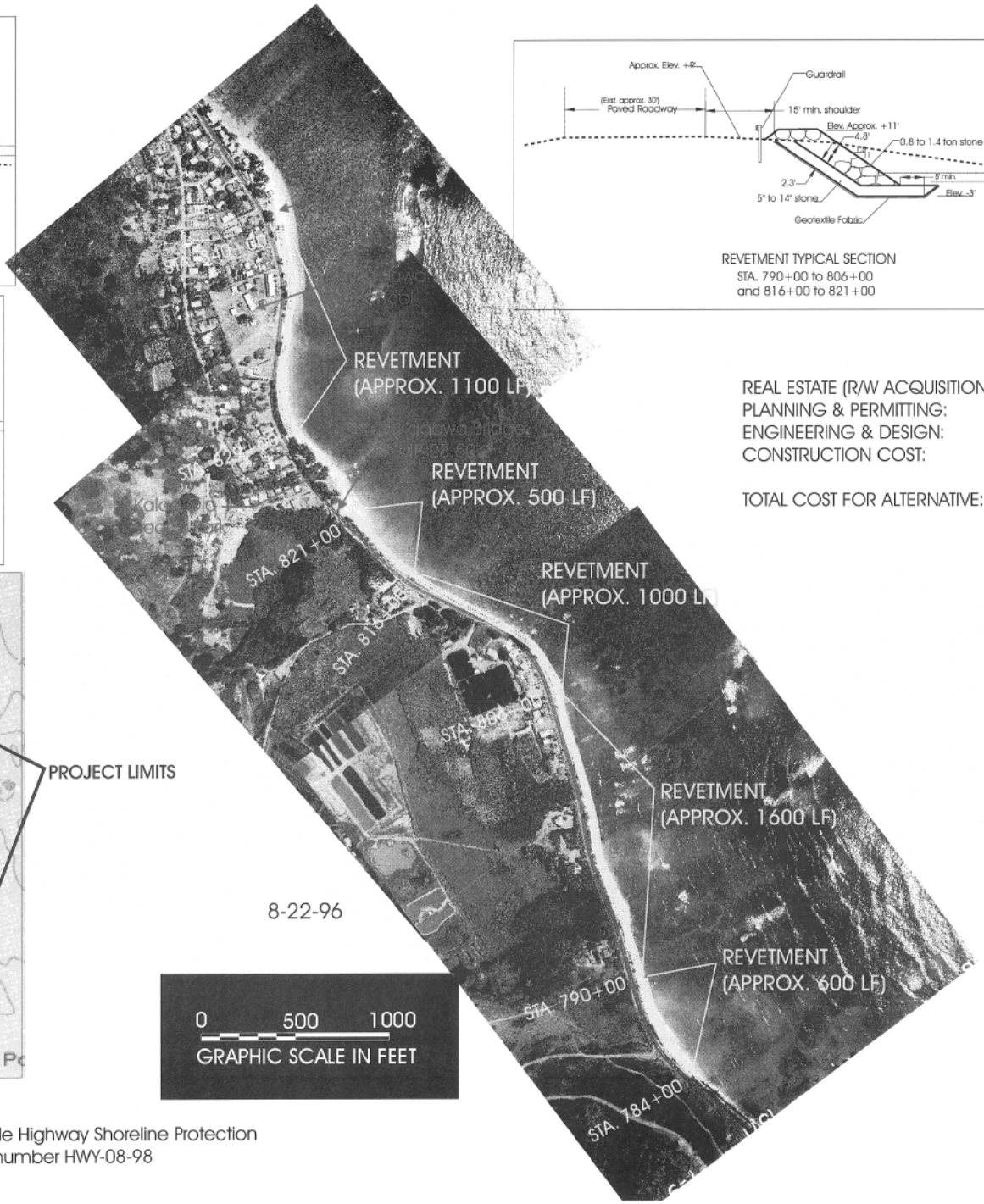


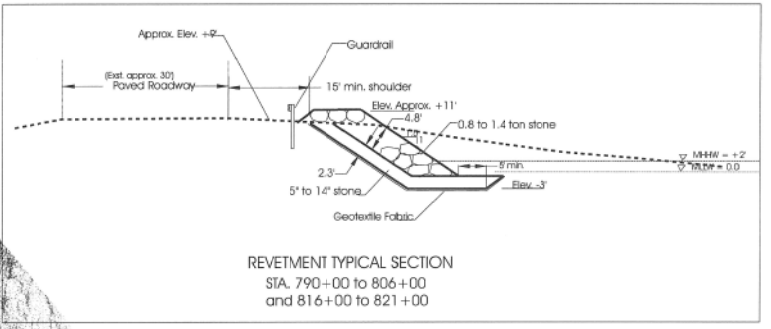
REVETMENT TYPICAL SECTION
STA. 829+00 to 840+00



REVETMENT TYPICAL SECTION
STA. 784+00 to 790+00
and 806+00 to 816+00







REVETMENT TYPICAL SECTION
STA. 790+00 to 806+00
and 816+00 to 821+00

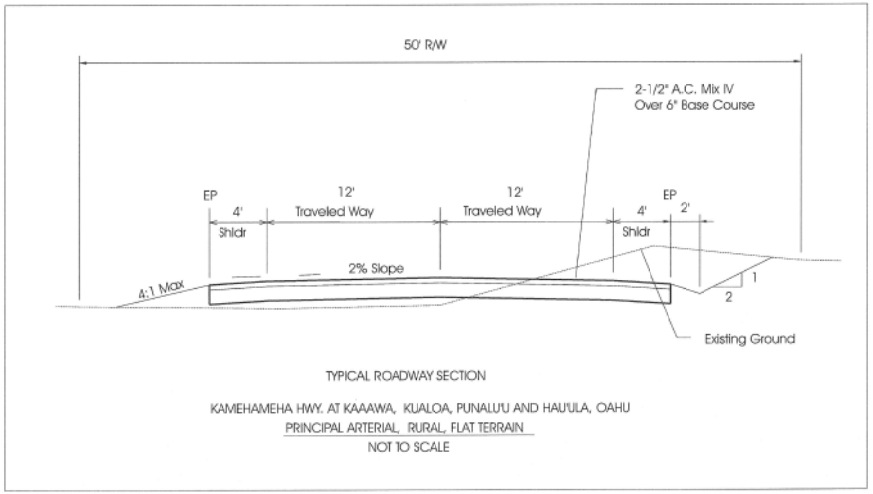
REAL ESTATE (R/W ACQUISITION):	$ N/A
PLANNING & PERMITTING:	$ 1,186,900
ENGINEERING & DESIGN:	$ 1,186,900
CONSTRUCTION COST:	$10,052,900
TOTAL COST FOR ALTERNATIVE:	$12,426,700

8-22-96

0 500 1000
GRAPHIC SCALE IN FEET

ALTERNATE PLAN - REVETMENT
KAAAWA-KAOLO PT., OAHU

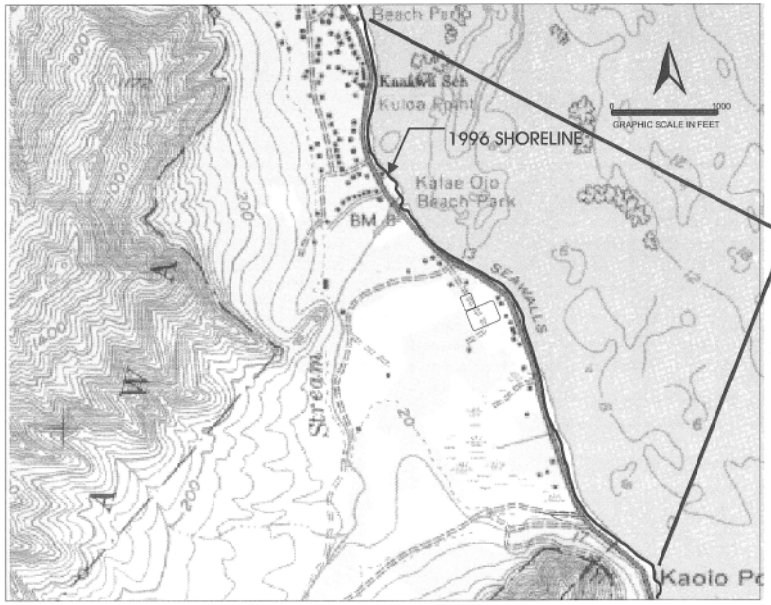
Statewide Highway Shoreline Protection
Project number HWY-08-98



TYPICAL ROADWAY SECTION

KAMEHAMEHA HWY. AT KAAAWA, KUALOA, PUNALU'U AND HAU'ULA, OAHU
PRINCIPAL ARTERIAL, RURAL, FLAT TERRAIN
NOT TO SCALE

See Kaaawa Sheet for continuation



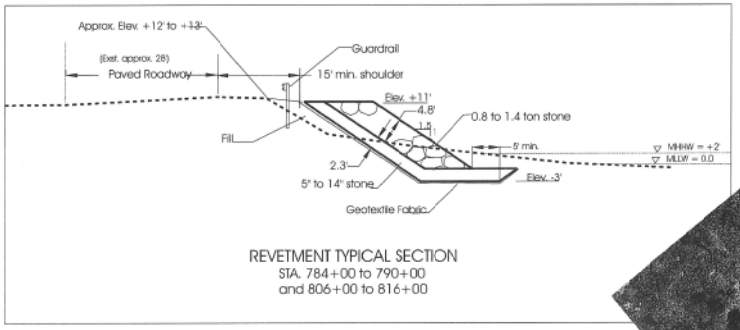


KAAAWA TO KAOLO POINT, 11000 LF BYPASS HWY:

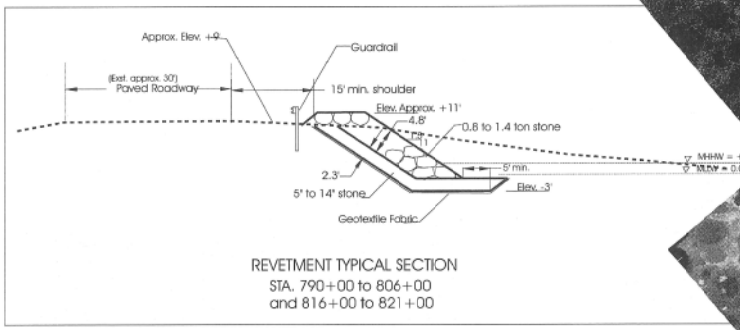
REAL ESTATE (R/W ACQUISITION & RELOCATION COST:	$22,000,000
PLANNING & PERMITTING:	$ 2,684,300
ENGINEERING & DESIGN:	$ 2,684,300
CONSTRUCTION COST:	$22,736,000
TOTAL COST FOR ALTERNATIVE:	$50,104,600

ALTERNATE PLAN - RELOCATE HIGHWAY
KAAAWA-KAOLO PT., OAHU

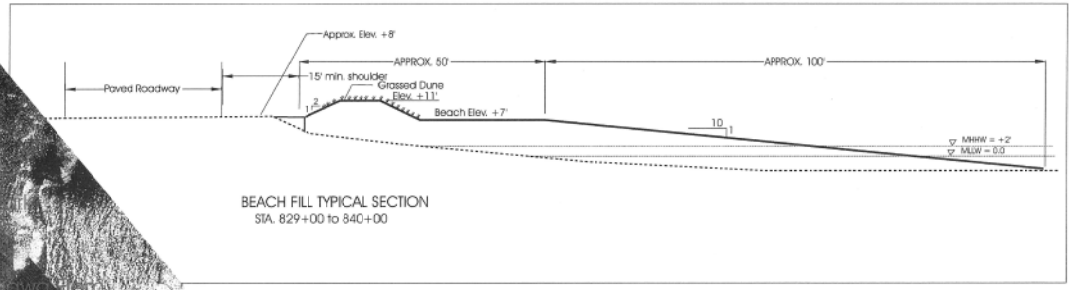
Statewide Highway Shoreline Protection
Project number HWY-08-98



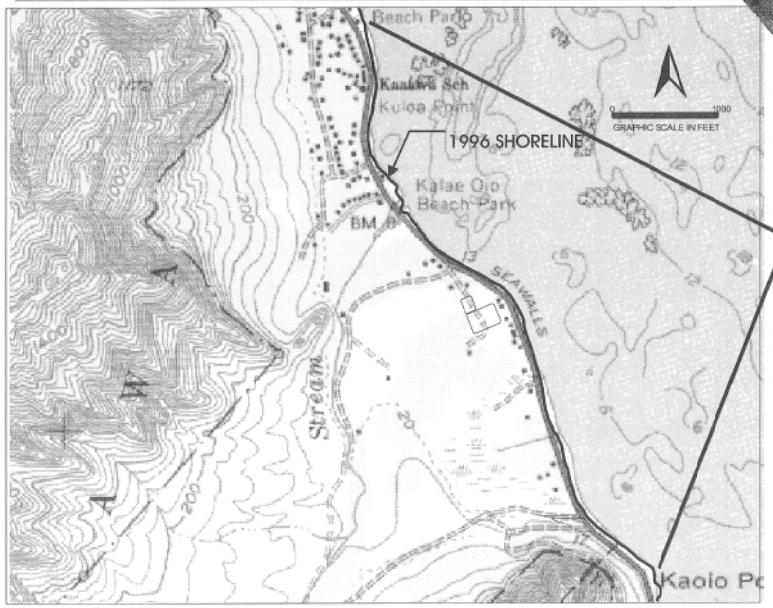
REVETMENT TYPICAL SECTION
STA. 784+00 to 790+00
and 806+00 to 816+00



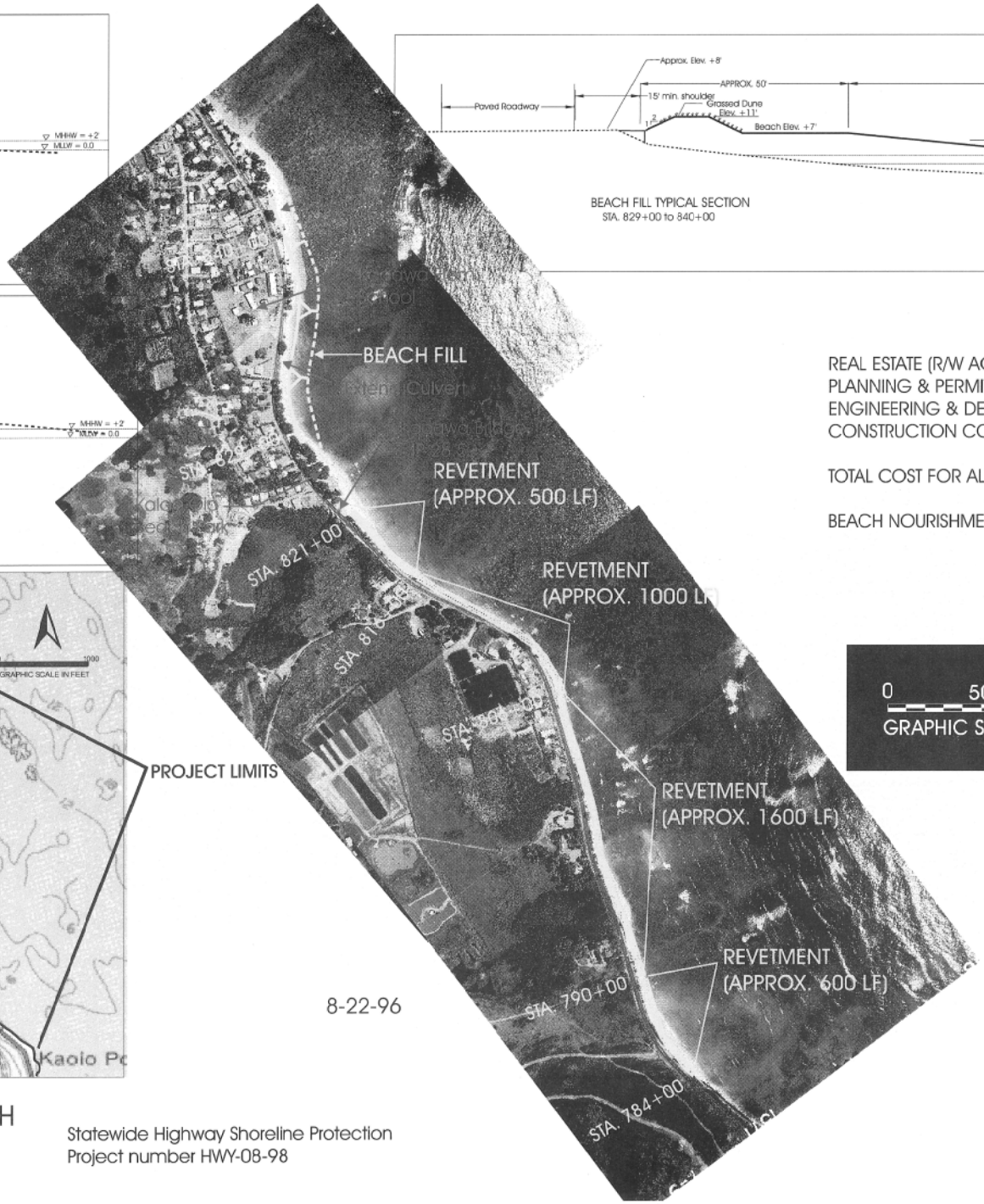
REVETMENT TYPICAL SECTION
STA. 790+00 to 806+00
and 816+00 to 821+00



BEACH FILL TYPICAL SECTION
STA. 829+00 to 840+00



PROJECT LIMITS



8-22-96

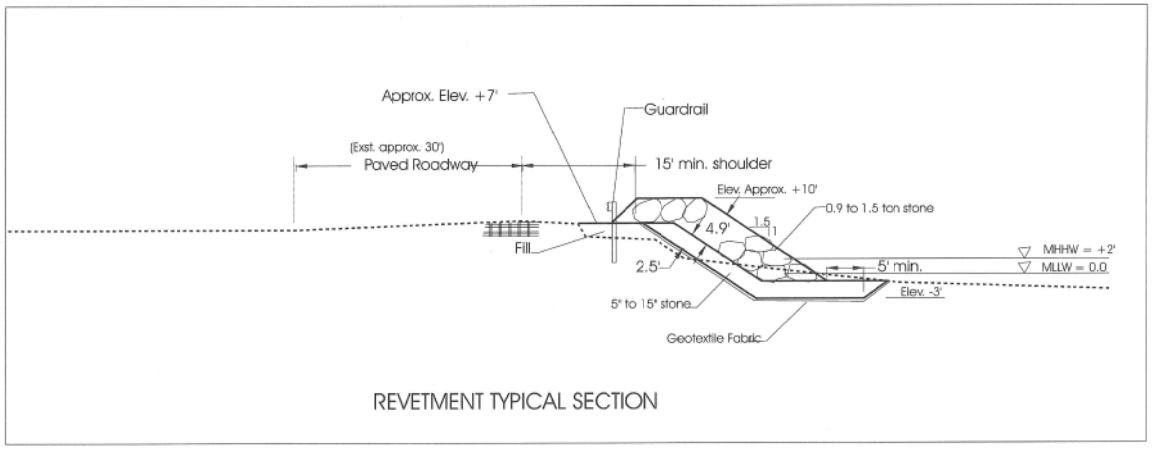
REAL ESTATE (R/W ACQUISITION): $ N/A
PLANNING & PERMITTING: $ 1,269,000
ENGINEERING & DESIGN: $ 1,269,000
CONSTRUCTION COST: $10,748,500

TOTAL COST FOR ALTERNATIVE: $13,286,500

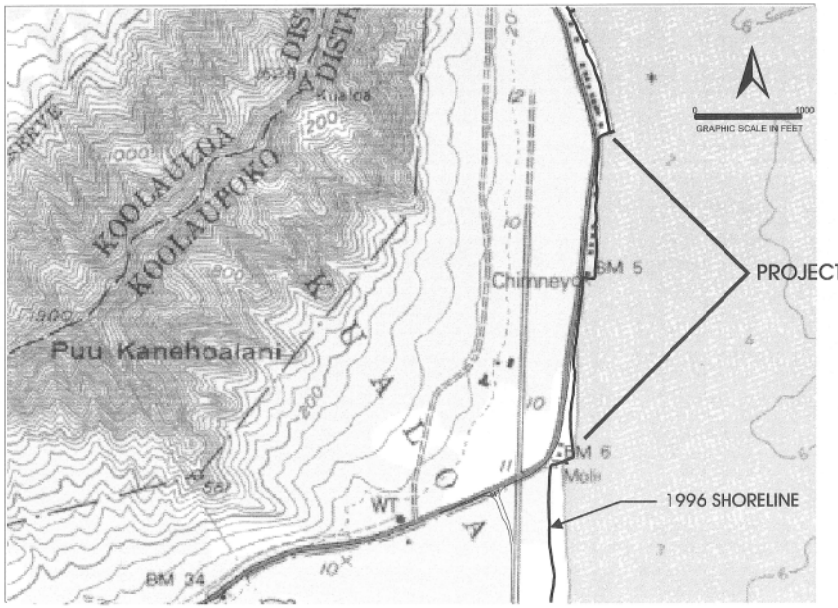
BEACH NOURISHMENT: $ 70,000 / YR

ALTERNATE PLAN - REVETMENT + BEACH
KAAAWA-KAOLO PT., OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

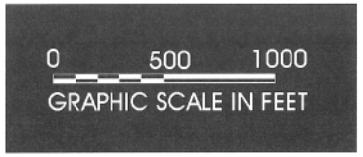


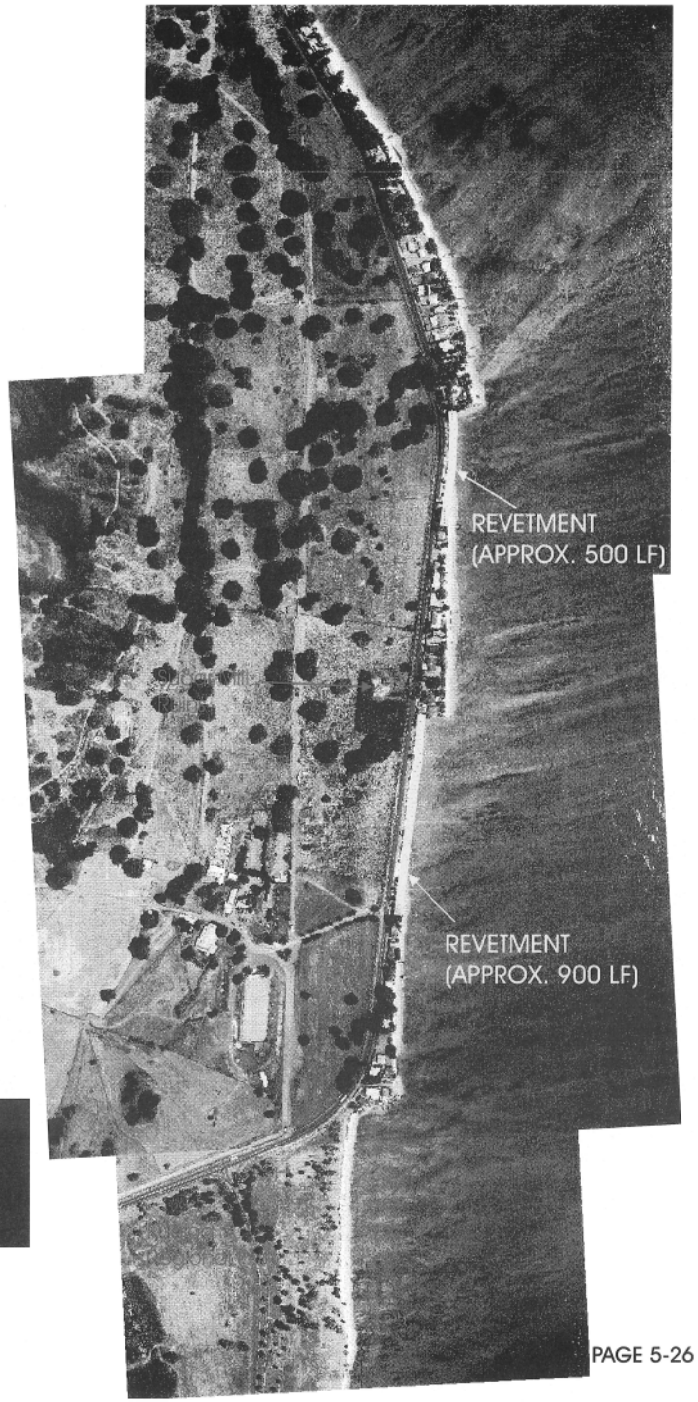
REVETMENT TYPICAL SECTION



REAL ESTATE (R/W ACQUISITION):	$ N/A
PLANNING & PERMITTING:	$ 270,000
ENGINEERING & DESIGN:	$ 270,000
CONSTRUCTION COST:	$2,286,800
TOTAL COST FOR ALTERNATIVE:	$2,826,800

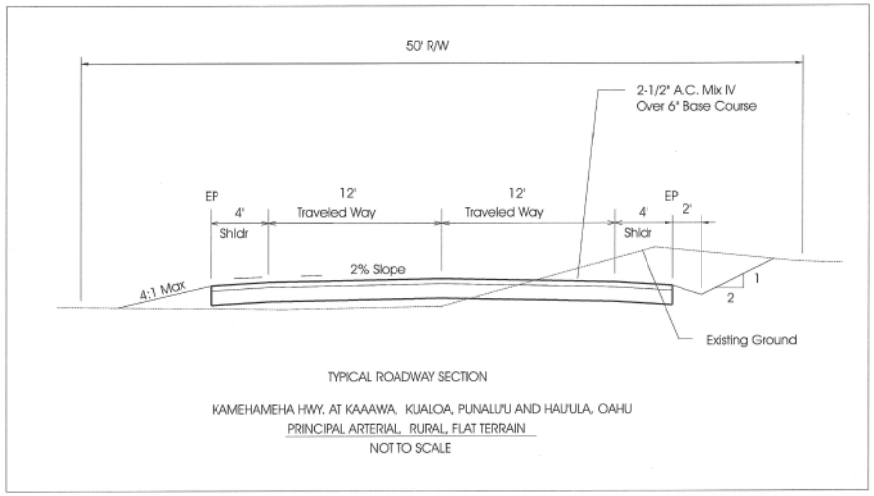
8-22-96





ALTERNATE PLAN - REVETMENT
KUALOA, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98

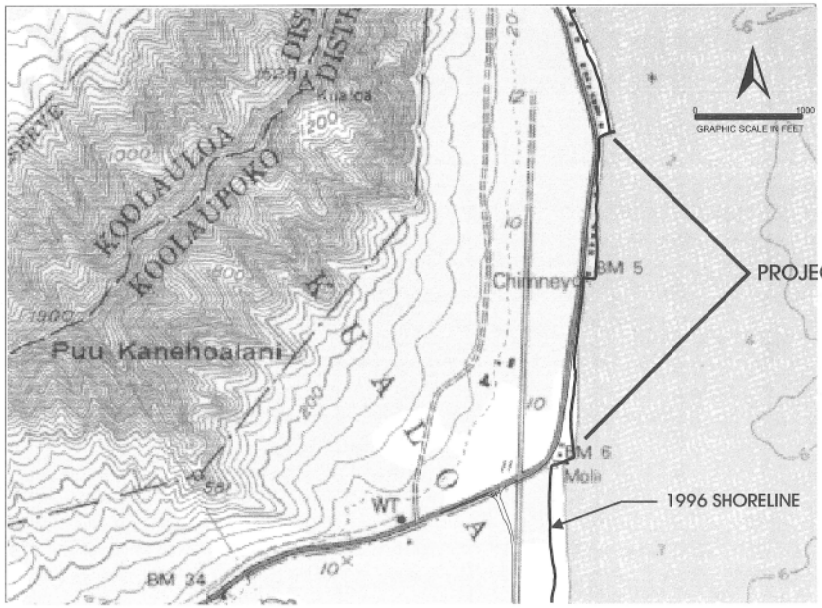


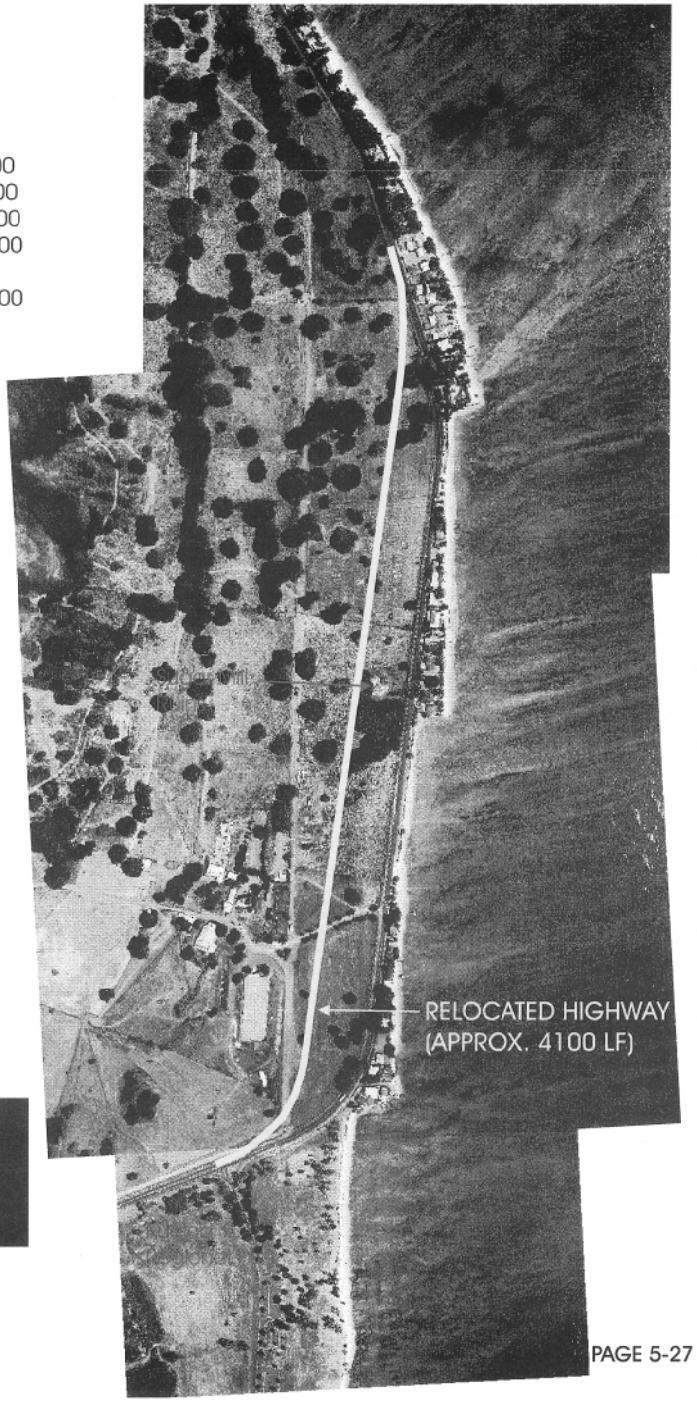
TYPICAL ROADWAY SECTION

KAMEHAMEHA HWY. AT KAAAWA, KUALOA, PUNALU'U AND HAU'ULA, OAHU
PRINCIPAL ARTERIAL, RURAL, FLAT TERRAIN
NOT TO SCALE

REAL ESTATE (R/W ACQUISITION): $ 700,000
PLANNING & PERMITTING: $ 678,600
ENGINEERING & DESIGN: $ 678,600
CONSTRUCTION COST: $5,747,500

TOTAL COST FOR ALTERNATIVE: $7,804,700





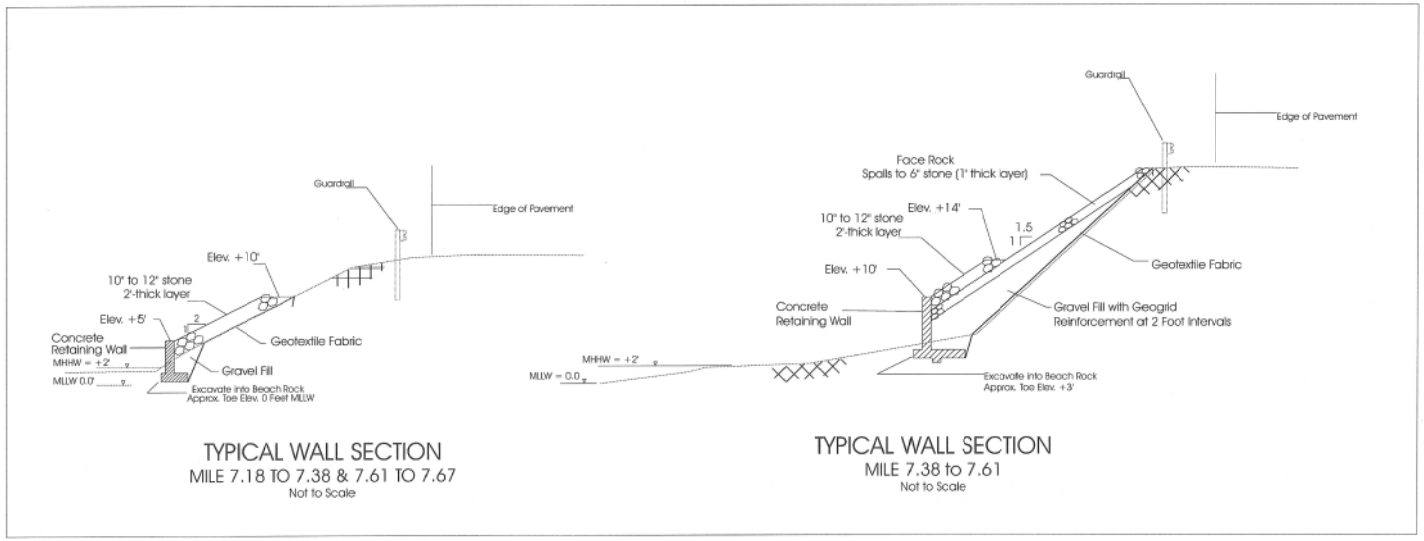
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0 500 1000
GRAPHIC SCALE IN FEET

ALTERNATE PLAN - RELOCATE HIGHWAY
KUALOA, OAHU

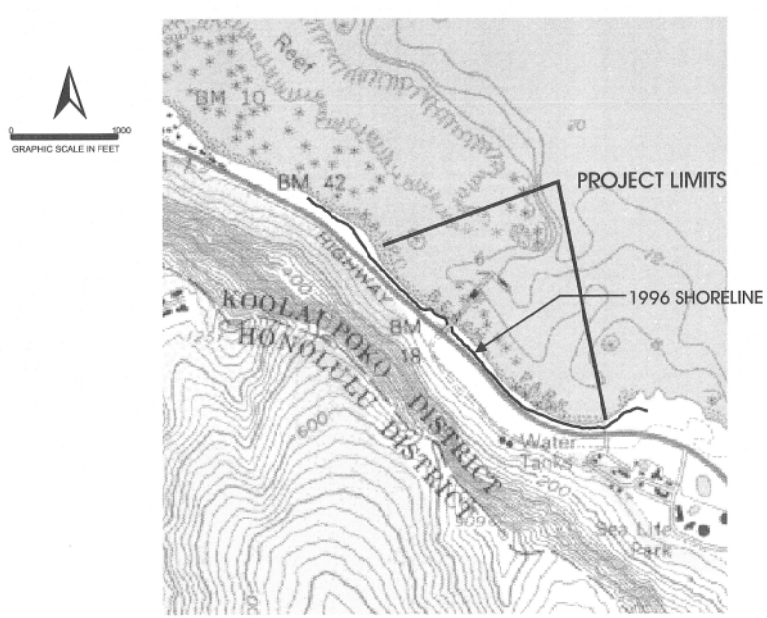
Statewide Highway Shoreline Protection
Project number HWY-08-98

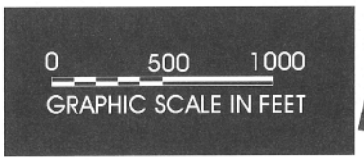
REAL ESTATE (R/W ACQUISITION):	$ N/A
PLANNING & PERMITTING:	$ 361,400
ENGINEERING & DESIGN:	$ 361,400
CONSTRUCTION COST:	$3,061,100
TOTAL COST FOR ALTERNATIVE:	$3,783,900

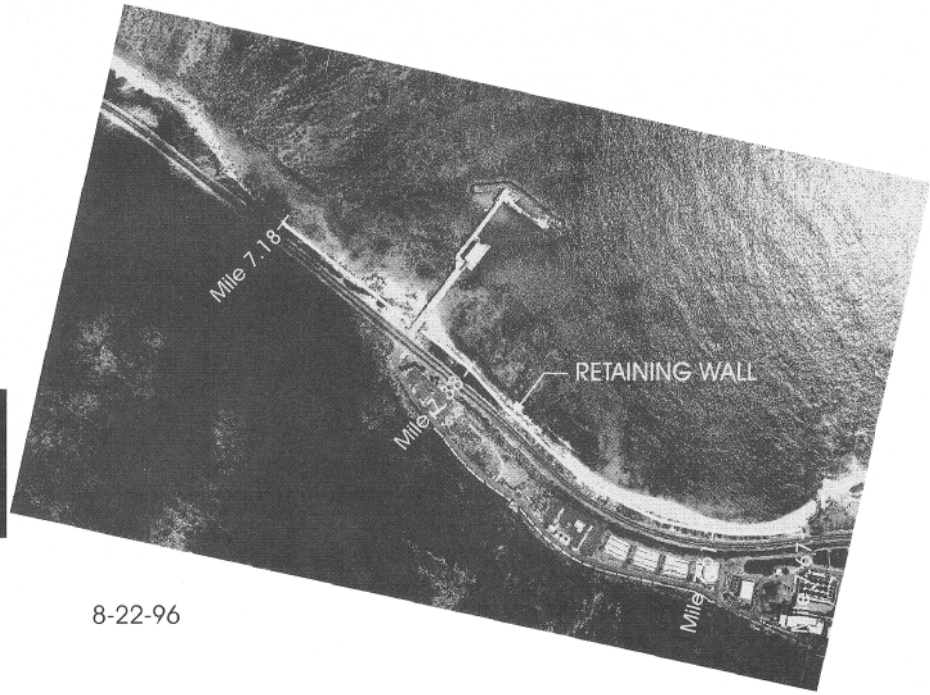


TYPICAL WALL SECTION
MILE 7.18 TO 7.38 & 7.61 TO 7.67
Not to Scale

TYPICAL WALL SECTION
MILE 7.38 to 7.61
Not to Scale





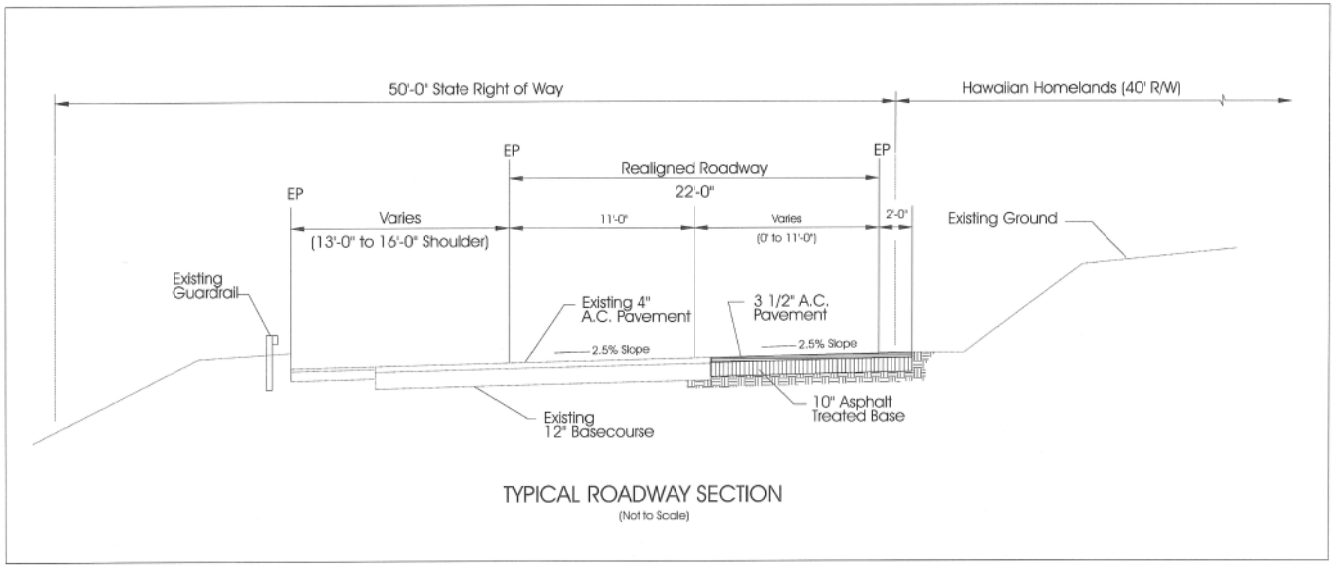


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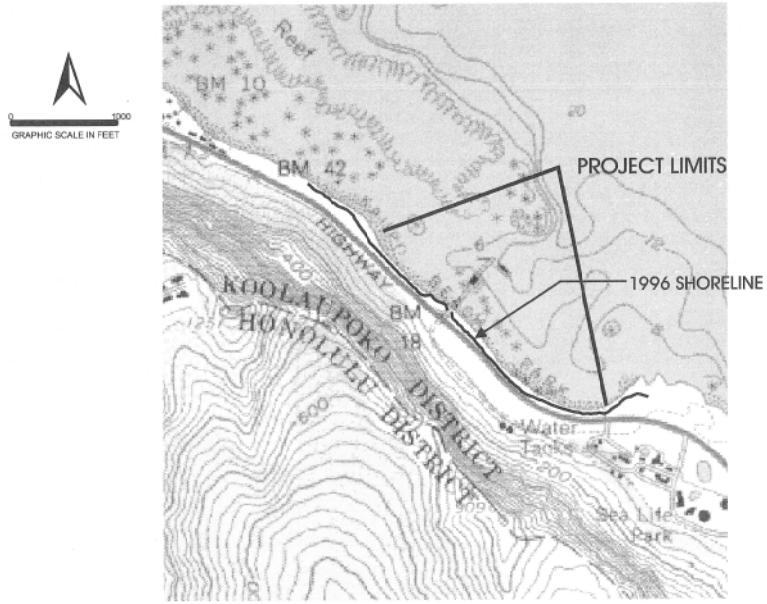
ALTERNATE PLAN - HARDENING
MAKAPUU PIER, OAHU

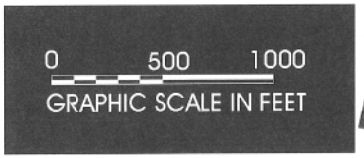
Statewide Highway Shoreline Protection
Project number HWY-08-98

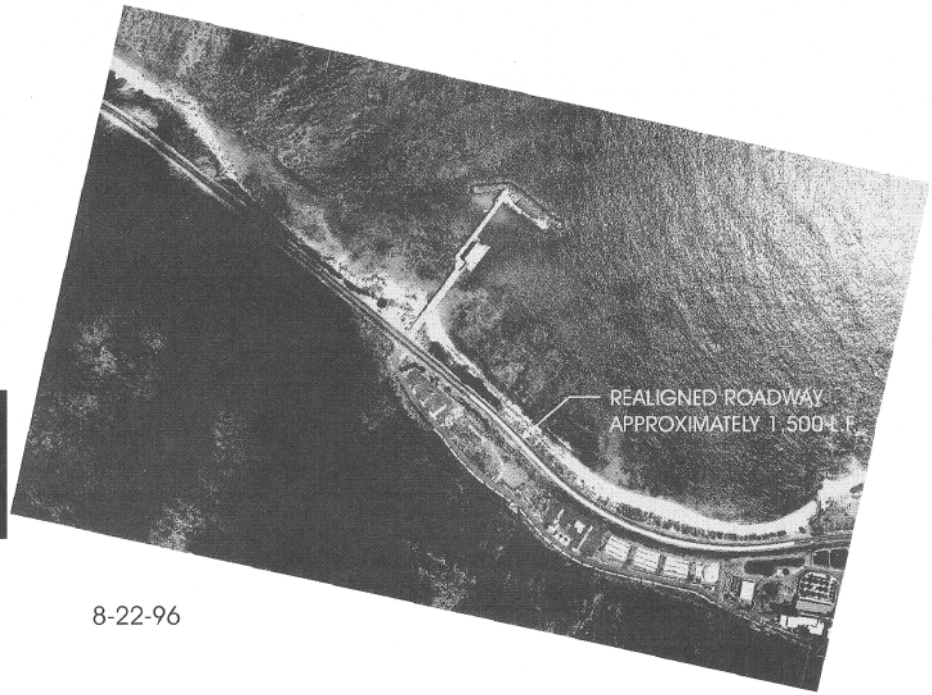
REAL ESTATE (R/W ACQUISITION):	$ N/A
PLANNING & PERMITTING:	$ 119,000
ENGINEERING & DESIGN:	$ 119,000
CONSTRUCTION COST:	$1,007,800
TOTAL COST FOR ALTERNATIVE:	$1,245,800



TYPICAL ROADWAY SECTION
(Not to Scale)







8-22-96

ALTERNATE PLAN - REALIGN HIGHWAY
MAKAPUU PIER, OAHU

Statewide Highway Shoreline Protection
Project number HWY-08-98