ENGINEERING DESIGN REPORT

for

KUHIO HIGHWAY, REHABILITATION OF WAINIHA BRIDGES

Wainiha, Hanalei, Island of Kauai

TMK: (4) 5-8-06 and (4) 5-8-07

OCTOBER 2012

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
HIGHWAYS DIVISION
ISLAND OF KAUAI

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EXECUTIVE SUMMARY

INTRODUCTION

The objective of this report is to provide HDOT with bridge improvement alternatives for the three (3) Wainiha Bridges and present the preferred alternative.

This report is prepared for Phase I – Conceptual Design / Community Involvement. Phase II – Environmental Assessment, Section 106 and Design Phase will follow.

PROJECT AREA DESCRIPTION

The three (3) Wainiha Bridges are located along Kuhio Highway (Route 560) between mile post 6.5 and 6.7. Kuhio Highway serves as the only roadway linking the Hanalei, Wainiha, and Haena communities. This portion of Kuhio Highway is a part of the Kauai Belt Road. The bridges are within the Kauai Belt Road Historic District listed on the Hawaii and National Registers of Historic Places.

The Wainiha Bridges are positioned near the mouth of Wainiha Stream before it feeds into Wainiha Bay. The bridges are also subject to flooding from storm water runoff.

HISTORY/BACKGROUND

In 2004, Wainiha Bridge #2 suffered permanent damage and was replaced with an ACROW Panel Bridge. In 2007, severe damage to Wainiha Bridge #3 prompted further investigation of the structural conditions of Bridge #1 and Bridge #3. Based on the results of HDOT supplemental inspections, Wainiha Bridges #1 and #3 were determined to be severely structurally deficient. In 2004 and again in 2007, the Governor issued proclamations which allowed for the demolition of all 3 bridges, and their temporary replacement with ACROW Panel Bridges. Attachment E contains the Governor proclamations.

Kauai Belt Road, North Shore Section, is on the Hawaii Register of Historic Places and the National Register of Historic Places. The three (3) Wainiha Bridges were considered as contributing elements to the road's historic integrity. The current temporary ACROW bridges are not considered contributing elements to the historic district. These designations require that any alternatives adhere to *Secretary of the Interior's* (SOI) *Standards for the Treatment of Historic Places*. According to these guidelines, rehabilitation with the bridges being in-fill structures to the overall historic district is the most viable option of the SOI treatment options.

CONSULTATION

The project will follow the use of Context Sensitive Solutions (CSS), a relatively new approach of the Transportation industry that measures the project by its community acceptance, environmental compatibility, engineering and technical functionality and financial feasibility. In developing a CSS process, numerous discussions, meetings, and presentations between HDOT, the Hanalei Roads Committee (HRC), the community, and stakeholders took place to discuss potential design criteria for this project.

Section 106 of the National Historic Preservation Act ensures consultation with the State Historic Preservation Division (SHPD) in the Department of Land and Natural Resources (DLNR) to address concerns regarding historic preservation and review project compliance with the SOI Standards.
Notwithstanding the above, HDOT must proceed with the project in accordance with its mission: *To provide a safe, efficient, accessible, and inter-modal transportation system that ensures the mobility of people and goods, and enhances and/or preserves economic prosperity and the quality of life.* As such, it is HDOT's responsibility to make the final determination on all aspects of the project.

TECHNICAL AND ECONOMIC CONSIDERATIONS

Substructure

Based on the findings of the geotechnical investigation, it was determined that deep foundations consisting of 3-foot diameter drilled shafts with concrete pier caps should be used for the bridge foundations. Concrete piers that support the bridge will extend below the waterline to replicate the previous bridge piers. The use of small-diameter micro piles was considered; however this system was ultimately deemed insufficient to withstand calculated design flood hydraulic loadings.

Superstructure

Four (4) alternative construction methods for bridge superstructures were developed. The alternatives include Pre-Cast and Pre-Stressed Short Span Concrete Planks, Structural Steel Beams, Structural Steel Trusses, and Pre-Cast and Pre-Stressed Long Span Concrete Planks. It was concluded that the last alternative (Pre-Cast and Pre-Stressed Long Span Concrete Planks), which utilizes 78-foot long planks was selected. This design will eliminate the need for additional piers for bridges, and will comply with HDOT's hydraulic capacity criteria.

Additional Bridge Design Elements

Other key design elements considered for these rehabilitated bridges include decking, pedestrian and vehicle railings, and end treatments. In response to public input during previous meetings, bridge decking will be designed to mimic the presence of the wooden planking on the previous bridges. Vehicle railings should be of Structural Steel Tube railings (similar to the Hanalei

Bridge) for the rehabilitated bridges. The pedestrian railings will be constructed out of timber or timber facsimile.

Bridge Design Width

The rehabilitated Wainiha Bridges will be funded 80% by FHWA and 20% by the State of Hawaii. In keeping with community preference and to maintain as much of the character of the rehabilitated bridges as possible and in accordance with Kuhio Highway (Route 560) Historic Road Corridor Plan (KHRCP), the rehabilitated bridges will be of one-lane construction. The single lane bridge design does not meet AASHTO standards and will require a design exception. The rehabilitated for Bridge #1 will have a maximum of 11-foot width consisting of one travel lane. Bridges #2 and #3 will have a maximum of 16-foot clear width, including one 11-foot wide travel lane and a 5-foot wide bike/pedestrian lane.

Order of Magnitude Cost Estimate

Order of magnitude cost estimates were prepared for all four (4) alternatives under consideration for the rehabilitated Wainiha Bridges. The order of magnitude cost estimate for the recommended alternative bridge design of Pre-Cast and Pre-Stressed Long Span Concrete Planks is approximated to be $19,020,000. The cost estimate includes the construction of temporary approach roadways, construction easements, and alternative bridge construction methods.

EVALUATION OF ALTERNATIVES

The four (4) alternatives were evaluated by four (4) criteria: Initial Capital Cost, Operation and Maintenance (O&M) Requirements, Hydraulic Capacity, and Visual Aesthetics. An alternative's ranking is multiplied by a criterion weighting to produce a rating for a given alternative and a specific criterion. Based on the evaluation, the preferred replacement alternative is the Pre-cast and Pre-stressed Long Span Concrete Planks.

DISCUSSION

After carefully comparing the CSS issues with various safety and mobility aspects of the facilities, HDOT has finalized their recommended alternatives for Bridges #1, #2, and #3. However, HRC and the local community prefer to have a width less than 14-feet wide, while HDOT recommends a 16-foot width. The community's reasoning for the narrower bridge width is for traffic calming, and to adhere to the historic nature of the roadway. All parties have agreed to continue working out a solution during the design and environmental permitting phase (Phase II) of the project.

1.0 INTRODUCTION

1.1 Project Description

The State of Hawaii Department of Transportation, Highways Division (HDOT) contracted AECOM Technical Services, Inc. (AECOM), the consultant, to perform a study on three (3) existing structurally deficient bridges in Wainiha, Hanalei, Island of Kauai and provide alternatives to strengthen or replace these bridges.

The tasks of the consultant's study were classified into two (2) phases by HDOT, namely:

- Phase I - Conceptual Design / Community Involvement Phase; and
- Phase II - Environmental Assessment, Section 106 and Design Phase.

This report is prepared for Phase I which involves:

- Study of available plans and documents for the Bridges;
- Conducting public informational meetings to seek public input;
- Consulting with the State Historic Preservation Division (SHPD) in the Department of Land and Natural Resources (DLNR) to address concerns related to historic preservation; and
- Providing a report and conceptual design of four (4) alternatives for the three (3) bridges. The design should be based upon conceptual hydrology, hydraulic, scour, and structural analysis and includes preliminary cost estimate for each alternative.

The objective of this report is to provide HDOT with bridge improvement alternatives for the three (3) Wainiha Bridges and present the preferred alternative.

1.2 Acronyms

The following table details acronyms that are utilized in this report.

Table 1: Acronyms

AASHTO	American Association of State Highway and Transportation Officials	KHPRC	Kauai County Historic Preservation Review Commission
DLNR	Department of Land and Natural Resources	KHRCP	Kuhio Highway (Route 560) Historic Road Corridor Plan, 2005
FEMA	Federal Emergency Management Agency	MSL	Mean Sea Level
FHWA	Federal Highways Administration	NHO	Native Hawaiian Organization
FIRM	Flood Insurance Rate Map	NHS	National Highway System
HABS	Historic American Building Survey	NOE	Nagamine Okawa Engineers
HAER	Historic American Engineering Record	OHA	Office of Hawaiian Affairs
HDOT	Hawaii Department of Transportation	SHPD	State Historic Preservation Division
HHF	Historic Hawaii Foundation	SOI	Secretary of the Interior
HRC	Hanalei Roads Committee	TMK	Tax Map Key

2.0 PROJECT AREA DESCRIPTION

2.1 Location

The three (3) Wainiha Bridges are located along Kuhio Highway (Route 560) between mile post 6.5 and 6.7, which serve as the only roadway between the Hanalei and Haena communities. This portion of Kuhio Highway is a part of the Kauai Belt Road, North Shore Section. The Tax Map Keys (TMK) for these bridges are (4) 5-8-06 and (4) 5-8-07. A project location and vicinity map is presented in **Figure 1** and **Figure 2**. For ease of discussion, these bridges will be referred as Bridge #1, Bridge #2 and Bridge #3 hereinafter.

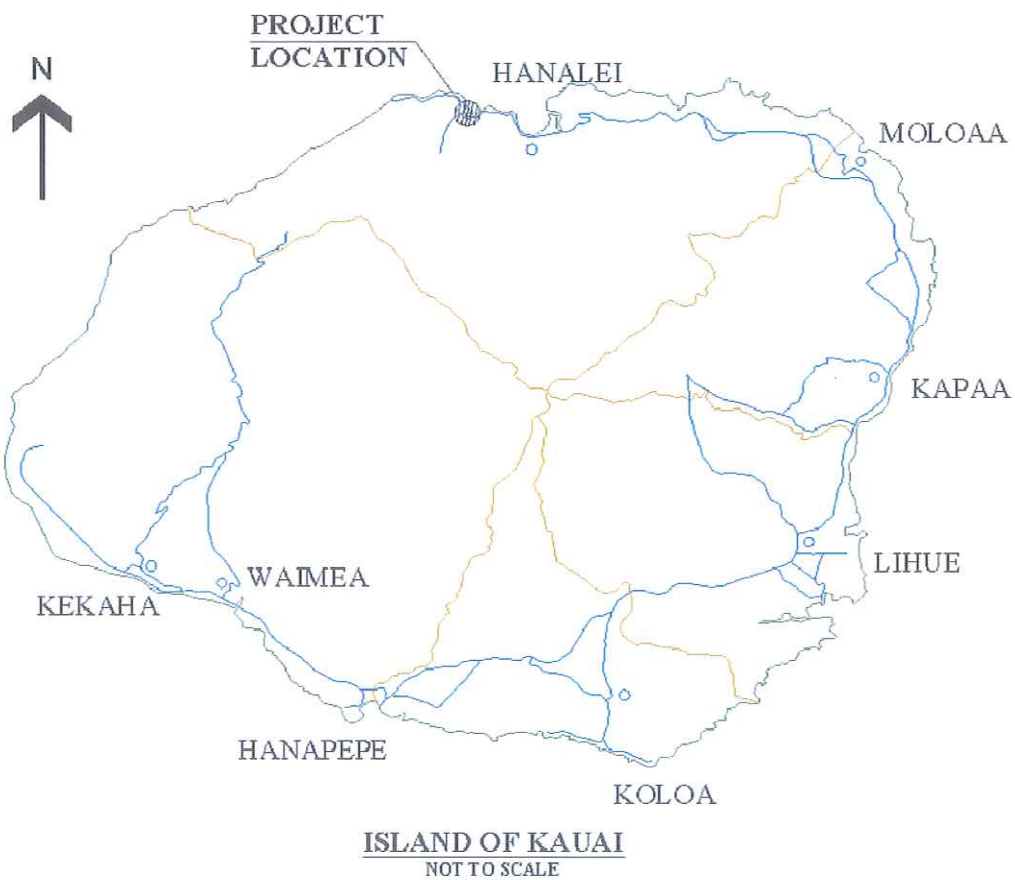

Figure 1: Location Map

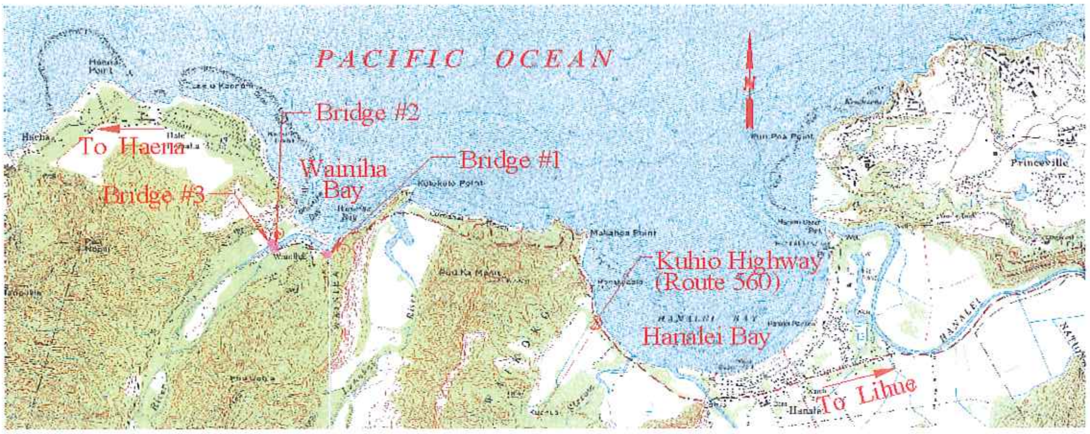

Figure 2: Vicinity Map

2.2 Population and Traffic

According to the 2010 U.S. Census Bureau, the population of the Island of Kauai is estimated to be 67,091 people. The Census for the study areas are as follows:

Hanalei	450
Wainiha	318
Haena	431

Tourism remains an important economic stimulant on the Island of Kauai. Ke'e Beach, Kalalau Valley and the Haena Caves are popular visitor destinations located beyond (west of) the Wainiha Bridges, thus non-resident visitors comprise the bulk of traffic flow across the Wainiha Bridges. The local populace seeking recreation opportunities is another large contributor to the traffic mix. Despite the relatively small year round population that resides beyond the three (3) Wainiha Bridges, the HDOT recorded an average daily traffic count of 4,222 vehicles at the intersection of Kuhio Highway and Wainiha Powerhouse Road in 2003, an average daily traffic count of 3,796 at mile post 6.6 on Kuhio Highway in 2004, and an average daily traffic count of 3,282 between Ananalu Road and Anae Road on Kuhio Highway in 2009.

A Traffic Accident Analysis for Kuhio Highway was done by HDOT in July 2008, for the three (3) most recent years of data available. It covered accidents which occurred in the vicinity of a bridge over a 6.3 mile stretch of Kuhio Highway, and encompassed all three Wainiha Bridges. The analysis stated that in that span of time, there were nineteen (19) major accidents in the vicinity of a bridge. One major accident was reported for each of the three Wainiha Bridges, and all three involved collision with wooden railings. Two of the three accidents involved alcohol.

2.3 Hydrology and Hydraulics

All three (3) bridges are subject to flooding from two (2) unrelated mechanisms: tsunamis and storm water runoff. Federal Emergency Management Agency (FEMA) published revised Flood Insurance Rate Map (FIRM) maps for the Island of Kauai in 2005 under the National Flood Insurance Program. The three (3) Wainiha Bridges can be found on Map Number 1500020035E and is found in **Attachment G**. This map identifies the Wainiha Bridges as located in a special flooding hazard area inundated by 100-year flood (ZONE VE). Zone VE is defined as "*Coastal flood with velocity hazard (wave action); base flood elevations determined,*" meaning the area is subject to high wave action (tsunamis). The identified zone VE flood elevation is 27-feet for Bridge #1, 21-feet for Bridges #2, and 18-feet for Bridge #3.

These bridges are also subject to flooding due to stream run-off from a 50-year and 100-year storm event. Rainfall averages approximately 70 inches of rain per year at the three (3) bridge sites. However, the streams carry water from higher elevations where yearly rainfall averages may total as much as 300 inches per year.

Based on the above rainfall averages, the SCS TR-55 method was used to determine the peak discharge of a 50-year and 100-year storm events. Peak discharges for the 50-year and 100-year storm events are in **Table 2** shown below. Utilizing these peak discharges and HEC-RAS modeling software, flood elevations were determined for the three (3) bridges also shown in **Table 2** below.

Table 2 results compare favorably with the FEMA *Flood Insurance Study* for the Island of Kauai which indicates Bridge #2 and Bridge #3 flood elevations to be in excess of 14 and 16-feet for the 50 and 100-year storm events, respectively.

Table 2: Hydrologic Summary

Bridge No.	Basin Size (sq. mi.)	Deck Elev. (ft.)	50-yr Flood Elev. (ft.)	100-yr Flood Elev. (ft.)	Discharge Q_{50} (cfs)	Discharge Q_{100} (cfs)
1	0.28	10.1	5.93	6.26	1,320	1,450
2	27.78	10.0	14.81	15.88	49,670	57,180
3	27.78	14.4	15.00	16.07	49,670	57,180

HDOT's Design Criteria for Highway Drainage requires bridges to be designed with a minimum freeboard of two (2) feet. Freeboard is the vertical distance between the approach design water surface elevation and the low chord of the bridge. All three of the previous bridges did not meet this criterion. Hydraulic analysis indicates that the previous Bridge #1 would not be overtopped by the 50-year or 100-year events, but would not have any freeboard. Previous Bridges #2 and #3 would be overtopped by both the 50-year and 100-year events, along with the approach roadways on both ends of the bridges.

In order for the rehabilitation bridges to meet HDOT's freeboard requirement, the decks of Bridges #1, #2, and #3 would have to be raised by approximately 1'-5", 11'-0", and 6'-7", respectively. It may be feasible to raise Bridge #1 to meet the freeboard requirement, but the road profile of approximately 200 ft of the approach roadways would also have to be raised to tie-in to the bridge. Raising Bridges #2 and #3 to meet the freeboard requirement would require even longer stretches of the approach roadways to be raised and would also require high retaining walls, thus multiplying the estimated construction project cost by 300 percent or more. In addition, unless still more of the approach roadways are raised, Kuhio Highway would be impassable during the 50-year and 100-year events, as the roadway, along with adjacent parcels, would be flooded. In light of these findings, it is considered infeasible to construct the rehabilitation bridges to meet the freeboard requirement. Historically, these extreme infrequent peak flooding events are short-lived in duration, limited to but a few hours.

2.4 Soil Investigation

A geotechnical study was performed by Geolabs, Inc. (July 2010) entitled *Preliminary Geotechnical Engineering Exploration, Wainiha Bridge Improvements, Kuhio Highway.* This report evaluates the subsurface conditions in the vicinity of the bridges and recommends suitable bridge foundations. A copy of this report is found in **Attachment A**.

Boring 1 (B-1) was drilled on the east side of existing Bridge #1. This boring encountered a surface fill layer 5-feet thick underlain by an alluvial deposit 43.5-feet thick. Within this alluvial deposit an 18-foot thick, soft swamp deposit was encountered approximately 17.5-feet below the surface. Below the alluvial deposit, residual and saprolite soil deposits were encountered to the ultimate drill depth of 101-feet. Groundwater was encountered at a depth of approximately 7.4-feet.

Boring 4 (B-4) located on the isthmus between Bridge #2 and #3 and Boring 5 (B-5) located to the west of Bridge #3 were very similar. These borings encountered a surface layer 6-foot thick underlain by an alluvial deposit to a depth of 150-feet (max depth explored). A swamp deposit was again encountered within the alluvial deposit at a depth of 66-feet and was approximately 12-feet thick. Groundwater was encountered at approximately 8.6-feet.

3.0 HISTORY

3.1 Historic Background

The Wainiha Bridges have been an aspect of the Kauai Belt Road for over 100 years. Bridge #1 and #3 were originally constructed in 1904. These bridges were both of wood through-truss construction. By 1921, three (3) bridges were required to cross the Wainiha Stream due to the carving of an alternate stream channel during a storm. The bridge required to span this new stream became known as Bridge #2 and was completed by 1931. In 1946 and 1957 tidal waves damaged all of the Wainiha Bridges except the east span of Bridge #3. All damaged bridges were replaced or repaired in 1957. Finally, in 1966 the east span of Bridge #3 collapsed and was replaced.

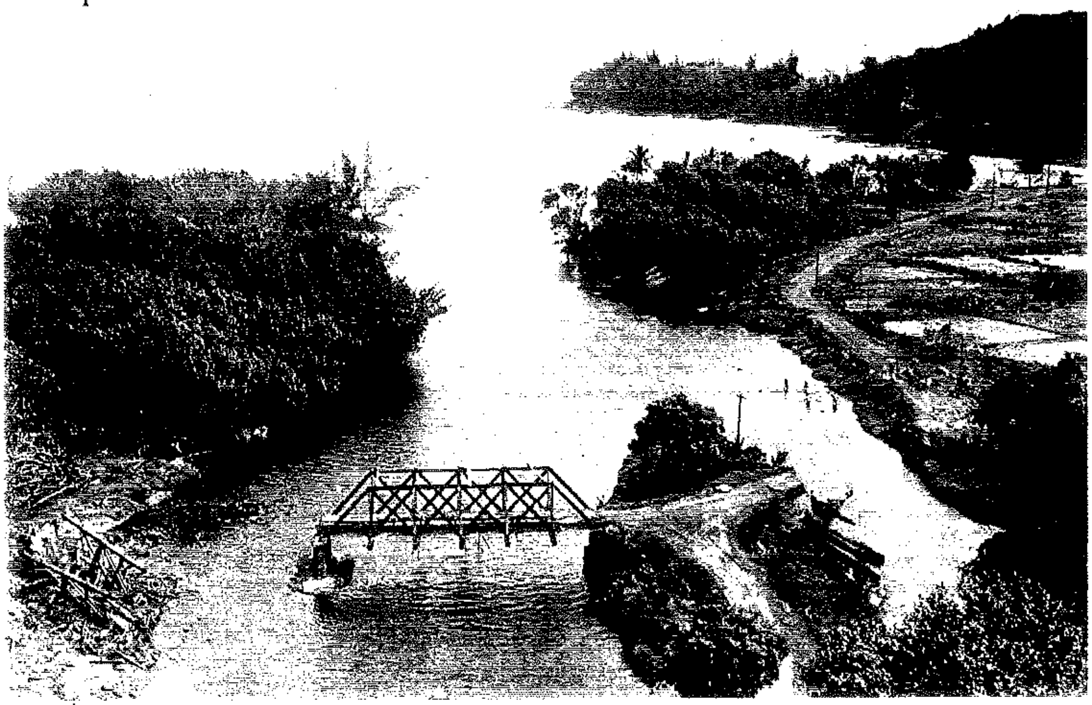

Figure 3: 1957 Photo

3.2 Historic Designation

Kauai Belt Road, North Shore Section was listed on the Hawaii Register of Historic Places on March 29, 2003 and the National Register of Historic Places on February 11, 2004. Particularly, the three (3) Wainiha Bridges, among other bridges, were considered as contributing elements to the road's historic integrity.

All federal projects affecting structures eligible or on the Hawaii or National Register of Historic Places should follow *The Secretary of the Interior, Standards for the Treatment of Historic Properties*. Since the highway which includes these bridges has been placed on the register, any repairs or alterations must comply with the above mentioned standards.

3.3 Recent History

In 2004, Wainiha Bridge #2 suffered permanent damage and an ACROW Panel Bridge (modular steel truss bridge) was installed directly over Bridge #2.

In 2007, Wainiha Bridge #3 was severely damaged and a load test was performed on Bridges #1 and #3. The results and further damaging prompted HDOT to reduce the load limit to 3 tons.

On October 29, 2007, the Governor issued a proclamation which allowed for the temporary installation of ACROW Panel bridges for Wainiha Bridges #1 and #3 (see **Attachment E**). A Historic American Building Survey (HABS) and Historic American Engineering Record (HAER) were prepared and approved to allow for the demolition of all three (3) bridge structures and to construct the ACROW Panel bridges. Only the original abutments and piers remain.

4.0 PREVIOUS BRIDGE CONDITIONS

4.1 General

Section 4.0 summarizes the previous conditions of the three (3) Wainiha Bridges prior to their demolition, and construction of the ACROW Panel bridges in their place. Topics to be discussed include previous bridge descriptions, hydraulics (scour) and structural condition.

4.2 Previous Bridge Descriptions

Wainiha Bridge descriptions were developed through historical document review, bridge inspection reports and visual inspection.

4.3 Structural Condition

The National Bridge Inspection Program is a requirement of the Federal Highway Administration (FHWA) and requires owners of bridges on public roadways to conduct bridge safety inspections. The inspections are required to be completed on a 24-month cycle. Inspections are conducted for the original three (3) Wainiha Bridges on a 24 month cycle. The inspections for the original bridges prior to demolition were conducted in October of 2004 and September 2006 by Nagamine Okawa Engineers, Inc. (NOE). In October of 2007, at the request of HDOT NOE prepared supplemental bridge inspection reports for Bridges #1 and #3 (see **Attachment B** for bridge inspection reports). Based on the recommendation of the supplemental bridge inspection report, a load test was performed by KSF, Inc. in October 2007 (See **Attachment C** for Load Test). At this time, Wainiha Bridge #3 was re-posted at 3 tons when inspectors alerted HDOT to dynamic loading response indicating imminent failure of the bridge.

The FHWA uses the sufficiency rating to evaluate a bridges sufficiency to remain in service. A sufficiency rating of 100 represents an entirely sufficient bridge. A sufficiency rating of 0 represents an entirely deficient bridge. A bridge receiving a sufficiency rating of less than 80 but greater than 50 qualifies the bridge for rehabilitation funding from FHWA. A sufficiency rating of less than 50 qualifies the bridge for replacement funding from FHWA. In order to receive federal funding, the replacement bridge must meet the current geometric, construction and structural standards required for the types and volume of projected traffic on the facility over its design life. **Table 3** summarizes the most recent sufficiency ratings for the Wainiha Bridges discussed later in this section.

Table 3: Sufficiency Rating Summary

Bridge Name	October 2004 Sufficiency Rating
Wainiha Bridge #1	3.0
Wainiha Bridge #2	2.0
Wainiha Bridge #3	2.0

All three (3) of the Wainiha Bridges were structurally deficient and qualified for Highway Bridge Replacement and Rehabilitation funding.

The three (3) Wainiha Bridges were originally posted with an 8 ton weight limit. This weight limit is insufficient to allow certain types of vehicular traffic across the bridges including: fire and rescue equipment, utility equipment trucks, Highway Division and County maintenance trucks, County garbage trucks, building suppliers and commercial haulers.

According to the HDOT *Final Project Assessment Report,* the previous Wainiha Bridges required a much higher maintenance effort than most of the bridges on Kauai. The previous bridges were initially put in service as temporary structures. Their temporary construction in combination with their age and corrosive environment had necessitated a rigorous maintenance and repair effort, requiring temporary bridge closures and replacement of damaged timber deck planks. Toward the end of its service life in 2005-7, HDOT spent approximately $200,000 on Wainiha Bridge #3 repairs to tension rods and compression struts. With the recent installation of the ACROW Panel bridges, maintenance efforts have been greatly reduced to railing repairs, inspecting and tightening deck bolts, and foliage clearing to maximize sight distance.

4.4 Wainiha Bridge #1

4.4.1 Previous Bridge Description

Bridge #1 was replaced in 1957 in response to the destructive tidal wave that stranded residents on the west side of the Wainiha Stream. This bridge was reconstructed on the existing concrete abutments and consisted of a steel truss with timber decking and railings.

Bridge #1 was comprised of steel King Post trusses and was approximately 42-feet in length and 11-feet in width. The bridge deck was constructed with wooden timbers and was at elevation of approximately 10.10-feet (MSL). This bridge was equipped with wooden railings/guardrails. A 3-inch waterline is attached below the bridge on the upstream side of the bridge.

Following the October 2007 Load Test, Bridge #1 was replaced with a temporary ACROW Panel Bridge. The following photographs illustrate the previous and current conditions of Bridge #1.

Photo 1 : Previous Bridge #1 - Looking from Lihue toward Haena

Photo 2 : Previous Bridge #1 - Trusses (Looking from Makai Side)

Photo 3 : Previous Bridge #1 - Looking from Lihue Side

Photo 4 : Previous Bridge #1 - Looking from Haena toward Lihue

Photo 5 : Current Bridge #1 - Looking from Lihue side

Photo 6 : Current Bridge #1 - Looking from Haena toward Lihue

Over the years, HDOT maintenance crews performed major repair projects on this bridge. A review of HDOT records reveal work done on Wainiha Bridge #1 included:

- Strengthening by the addition of 4-inch x 12-inch timber joists (1969),
- Replacement of timber decking (1983),
- Load testing of the bridge (2002),
- Replacement of timber decking (2004),
- Load testing of the bridge (2007), and
- Remove bridge and install ACROW Panel Bridge (2007).

In addition to the above described projects, HDOT crews frequently performed general repairs to the deck and timber railings due to weathering and as a result of collision damage from errant vehicles. Following the installation of the ACROW Panel Bridge, maintenance efforts have been reduced to inspecting and tightening deck bolts, and foliage clearing to maintain sight distance.

4.4.2 Scour

Scour analysis was performed by West Consultants, Inc. for the previous bridge conditions. Topographic and geotechnical information used in the scour analysis was from AECOM's survey and Geolabs' boring logs. **Table 4** shows the scour analysis results for Bridge #1. Refer to **Attachment D** for the Scour Analysis Report.

Table 4: Previous Bridge #1 Scour Analysis Summary

	Scour Type	Scour Depths (feet)	
		Left Abutment	Right Abutment
Bridge #1	Contraction Scour	3.8	3.8
	Abutment Scour	n/a	n/a
	Total Scour Depth	3.8	3.8
	Total Scour Elev.	-4.3 (MSL)	-4.3 (MSL)

Note: Abutment locations assume one is looking downstream.

4.4.3 Structural Conditions

Inspections by KAI Hawaii (April 2001) and NOE (October 2004) have noted the following defects for Wainiha Bridge #1;

- Spalling of AC pavement at Haena approach adjacent to bridge deck,
- Corrosion of steel girders,
- Heavy corrosion and section loss in steel compression strut at midspan,
- Tension rods, including welded splices, are heavily corroded (scaling and pitted),
- Tension rods are loose (slack) under light vehicular loads on bridge,
- Spalling and scaling along base of Lihue abutment wall,
- Void at base of Lihue abutment wall,
- Embankment erosion behind Haena abutment wall,
- Concrete debris/drift in channel, and
- Structural Sufficiency Rating = 3.0, out of a possible 100.

This rating qualifies the bridge for replacement funding from FHWA.

A Supplemental Bridge Inspection by NOE (October 2007) noted further deterioration and recommended the following;

- Traffic be limited to light private vehicles such as automobiles, vans, SUV's and pickup trucks,
- Reduce posted loading of 8 tons,
- Strictly enforce weight limit,
- Perform a load test and/or structural analysis, and
- Install temporary ACROW Panel Bridge.

A load test was performed by KSF, Inc. (December 2007) and recommended the following prior to the replacement by an ACROW Panel Bridge;

- Posted limit be reduced to 3 tons,
- Larger loads be allowed on a case-by-case review and a truck scale be manned at all times,
- A 24,900-pound fire truck be allowed to cross,
- Maximum speed on the bridges shall be 5 mph, and
- No stopping on the bridge.

Based on the December 2007 load test, Wainiha Bridge #1 was deemed insufficient due to structural deficiencies and was reduced to a 3 ton weight limit by HDOT. These deficiencies led HDOT to condemn the bridge and replace it with a temporary ACROW Panel Bridge.

4.5 Wainiha Bridge #2

4.5.1 Previous Bridge Description

Bridge #2 was replaced in 1957 in response to the destructive tidal wave that stranded residents on the west side of the Wainiha Stream. This bridge was reconstructed on the existing concrete abutments and consisted of steel trusses with timber decking and railings.

Bridge #2 was comprised of one steel truss Queen Post span and was approximately 78-feet in length and 10-feet in width. The bridge deck was constructed with wooden timbers and resided at an elevation of approximately 9.70-feet (MSL). This bridge was also equipped with wooden railings. A 3-inch waterline was attached below the bridge deck on the upstream side of the bridge and a 6-inch waterline was attached below the deck on the downstream side.

Subsequent to the 2001 biennial bridge inspection, Bridge #2 suffered permanent sag in the eastern *makai* corner. The sag was attributed to web crushing of the corroded girders. A temporary ACROW Panel Bridge was placed directly above the Queen Post truss bridge. The Queen Post truss system was eventually removed.

The following photos illustrate both the Queen Post Bridge and the temporary ACROW Panel Bridge (with and without the Queen Post truss system).

Photo 7 : Previous Bridge #2 and #3 - Looking from Hanalei

Photo 8 : Previous Bridge #2 - Looking from Haena Side

Photo 9 : Previous Bridge #2 – Wainiha Stream

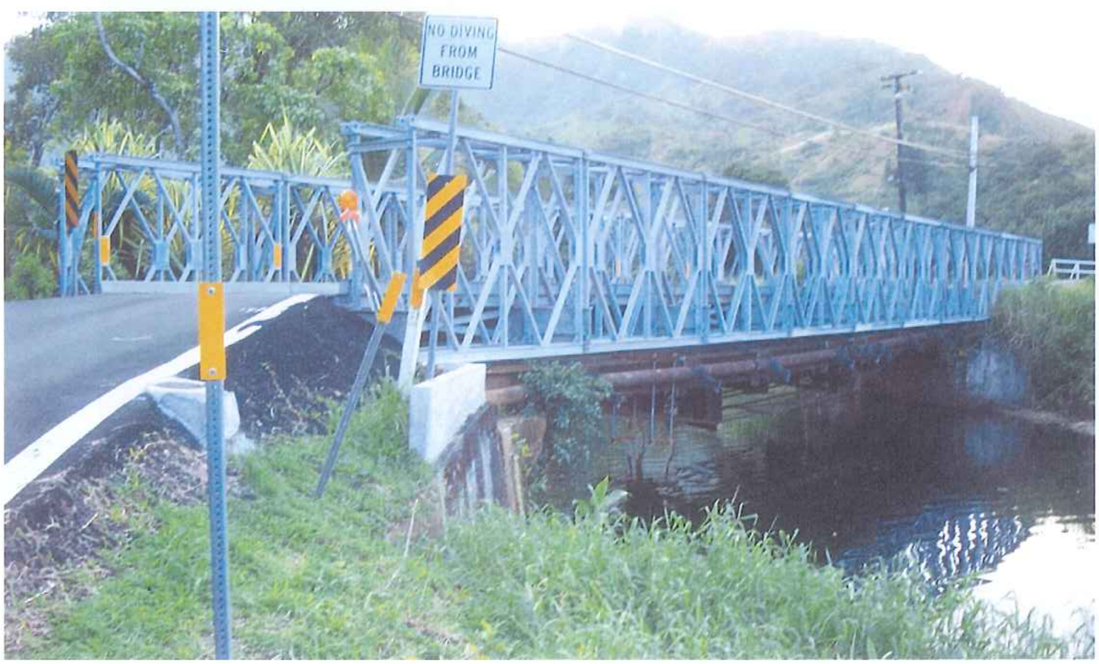

Photo 10 : Current Bridge #2 - ACROW Panel Bridge over Queen Post Truss

Photo 11 : Current Bridge #2 - ACROW Panel Bridge (no Queen Post Truss)

A review of HDOT maintenance records shows the following major repair items for this bridge:

- Strengthening with addition of 4-inch x 12-inch timber joists and structural steel girders (1969);
- Repair timber and steel members (1973),
- Replace timber decking (1983),
- Load testing of the bridge (2002),
- Breaking up and removing large tree debris hung up on upstream tension rods and struts (annually until 2008),
- Install ACROW Panel Bridge over Queen Post Truss Bridge (2004), and
- Remove Queen Post Truss Bridge (2008).

HDOT crews also frequently performed general repairs to the deck and timber railings due to weathering and as a result of collision damage from errant vehicles. Following the installation of the ACROW Panel Bridge, maintenance efforts have been reduced to inspecting and tightening deck bolts, and foliage clearing to maintain sight distance.

4.5.2 Scour

Scour analysis was performed by West Consultants, Inc. for the previous bridge conditions. Topographic and geotechnical information used in the scour analysis was from AECOM's survey and Geolabs' boring logs. **Table 5** shows the scour analysis results for Bridge #2. Refer to **Attachment D** for the Scour Analysis Report.

Table 5: Previous Bridge #2 Scour Analysis Summary

	Scour Type	Scour Depths (feet)	
		Left Abutment	Right Abutment
Bridge #2	Contraction Scour	10.3	10.3
	Abutment Scour	n/a	n/a
	Total Scour Depth	10.3	10.3
	Total Scour Elev.	-13.9 (MSL)	-13.9 (MSL)

Note: Abutment locations assume one is looking downstream.

4.5.3 Structural Conditions

Inspections by KAI Hawaii (April 2001) and NOE (October 2004) had noted the following defects for Wainiha Bridge #2;

- Checks and cracks in timber decking,
- Corrosion of brackets for 8-inch ductile iron pipe,
- Heavy section loss in steel girders,
- Major corrosion of tension bars,
- Heavy corrosion of tension bar to compression strut connections,
- Heavy corrosion of diagonal bracing,
- Visible deflection of the superstructure,
- Significant vibration of bridge under loading,
- Spalls along the top edge of the Haena abutment,
- Vertical cracks in upstream wingwall of Lihue abutment,
- Heavy buildup of soil and vegetation on abutment seats.
- Deterioration of timber railing to post connection,
- Scaling of both abutments in tidal zone,
- Broken tension rods,
- Damaged and displaced timber curb along downstream end,
- Heavy corrosion of compression struts at midspan,
- Deterioration of timber headers at both abutments, and
- Structural Sufficiency Rating = 2.0, out of a possible 100.

This rating qualifies the bridge for replacement funding from FHWA.

Subsequent to the 2004 inspection, Wainiha Bridge #2 was deemed insufficient due to structural deficiencies and was reduced to a 6 ton weight limit by HDOT. These deficiencies led HDOT to condemn the bridge and replace it with a temporary ACROW Panel Bridge (2004). Due to the historic nature of the bridge, the Queen Post Truss system was left untouched until a HABS and HAER could be prepared and approved. The Queen Post Truss system was removed in 2008 following the approval of the HABS and HAER (see Reference).

4.6 Wainiha Bridge #3

4.6.1 Previous Bridge Description

The west span of Bridge #3 was replaced in 1957 in response to the destructive tidal wave that stranded residents on the west side of the Wainiha Stream. The east span was replaced in 1966 upon its failure. This bridge was reconstructed on the existing concrete abutments and consisted of steel trusses with timber decking and railings.

Bridge #3 was a three (3) span bridge. It was comprised of two (2) steel truss Queen Post spans totaling approximately 146-feet in length and 11-feet in width. The third span was much shorter and located on the Haena side of the bridge. It was approximately 24-feet in length and did not utilize tension rods like the other two (2) spans. This bridge had an approximate deck elevation of 14.35-feet (MSL). This bridge was also equipped with wooden railings. A 3-inch waterline is attached below the bridge deck on the upstream side of the bridge and a 6-inch waterline is attached below the deck on the downstream side. The following photographs illustrate the previous and current conditions of Bridge #3.

Photo 12 : Previous Bridge #3 – Looking from Makai Side

Photo 13 : Previous Bridge #3 – Looking at Bridge #3 towards Haena

Photo 14 : Current Bridge #3 – Looking from Ala 'Eke Road towards Haena

HDOT maintenance records show the following major repair items for this bridge:

- Strengthening with the addition of 4-inch x 12-inch timber joists and structural steel girders (1969);
- Repair of timber and steel members (1973);
- Replace timber decking (1983);
- Repair, clean and paint metal members (1993);
- Load testing of the bridge (2002);
- Repair of tension rods and structural steel repair of 6 compression struts (2005);
- Load testing of the bridge (2007); and
- Remove bridge and install ACROW Panel Bridge (2007).

Similar to Bridges #1 and #2, HDOT maintenance crews were performing regular timber repair, railing repair and painting. Following the installation of the ACROW Panel Bridge, maintenance efforts have been reduced to inspecting and tightening bolts, foliage clearing to maximize sight distance, and replacing mirror on the Haena end due to repeated unlawful thefts.

4.6.2 Scour

Scour analysis was performed by West Consultants, Inc. for the previous bridge conditions. Topographic and geotechnical information used in the scour analysis was from AECOM's survey and Geolabs' boring logs. **Table 6** shows the scour analysis results for Bridge #2. Refer to **Attachment D** for the Scour Analysis Report.

Table 6: Previous Bridge #3 Scour Analysis Summary

	Scour Type	**Scour Depths (feet)**			
		Left Abutment	**Pier Left**	**Pier Right**	**Right Abutment**
Bridge #3	Contraction Scour	9.0	9.0	9.0	9.0
	Pier Scour	n/a	7.7	14.5	n/a
	Abutment Scour	8.1	n/a	n/a	n/a
	Total Scour Depth	17.1	16.7	23.5	9.0
	Total Scour Elev.	-14.8 (MSL)	-14.4 (MSL)	-28.0 (MSL)	-13.5 (MSL)

Note: Abutment and pier locations assume one is looking downstream.

4.6.3 Structural Conditions

Inspections by KAI Hawaii (April 2001) and NOE (October 2004) have noted the following defects for Wainiha Bridge #3:

- Inadequate and rotted wood railing,
- Displacement of timber curb,
- Corroded steel girders,
- Corroded and broken tension rods,
- Spalling of Haena abutment,
- Scour around left pier,
- Soil build up on bridge seats,

- Embankment erosion and pavement undermining, and
- Structural Sufficiency Rating = 2.0, out of a possible 100.

This rating qualifies the bridge for replacement funding from FHWA.

A supplemental bridge inspection by NOE (October 2007) noted further deterioration and recommended the following:

- Perform a load test and/or structural analysis to determine operating rating,
- In absence of a load test the bridge should be closed to vehicular traffic, and
- Install temporary ACROW Panel Bridge.

A load test was performed by KSF, Inc. (December 2007) and recommended the following prior to the replacement by an ACROW Panel Bridge:

- Posted limit be reduced to 3 tons,
- Larger loads be allowed on a case-by-case review and a truck scale be manned at all times,
- A 24,900-pound fire truck be allowed to cross,
- Maximum speed on the bridges shall be 5 mph, and
- No stopping on the bridge.

Based on the December 2007 load test, Wainiha Bridge #3 was deemed insufficient due to structural deficiencies and was reduced to a 3 ton weight limit by HDOT. These deficiencies led HDOT to condemn the bridge and replace it with a temporary ACROW Panel Bridge.

5.0 HISTORIC BRIDGE GUIDELINES

5.1 Application of Secretary of the Interior (SOI) Standards for the Treatment of Historic Properties

Kauai Belt Road, North Shore Section, is on the Hawaii Register of Historic Places and the National Register of Historic Places. The three (3) Wainiha Bridges were considered as contributing elements to the road's historic integrity. These designations require that any rehabilitation or replacement alternatives adhere to SOI standards.

The SOI standards present guidelines for **preserving, rehabilitating, restoring** and **reconstructing** these properties. These guidelines are defined and evaluated in the following sections.

5.1.1 Preservation

Preservation is defined as the act or process of applying measures necessary to sustain the existing form, integrity, and materials of a historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction. New exterior additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project.

Preservation is not applicable to this project for the following reasons:

- The previous bridges and their structural members were badly deteriorated and corroded and they would have been unsafe to preserve;
- Bridge inspection reports recommend replacement of the three (3) bridges; and
- Due to further deterioration and corrosion (in addition to damage received from errant vehicles and overloaded trucks), the bridges were deemed unsafe and were condemned. A HABS and HAER was prepared and approved, and all three (3) bridges were replaced with temporary (ACROW) bridge. Preservation is not an option.

5.1.2 Rehabilitation

Rehabilitation is defined as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values.

Rehabilitation is applicable to this project for the following reasons:

- The previous bridges and their structural members were badly deteriorated and corroded and it would have been unsafe to repair or alter the materials;
- Due to further deterioration and corrosion (in addition to damage received from errant and overweight vehicles), the bridges were deemed unsafe and were condemned. A HABS and HAER was prepared and approved, and all three (3) bridges were replaced with temporary (ACROW) bridges;

- However, it may be possible to preserve "features" which "convey its historical, cultural, or architectural values."
- The Kuhio Highway is a designated historic district and thus the bridges can be viewed as "infill" structures within the historic district.

5.1.3 Restoration

Restoration is defined as the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project.

Restoration is not applicable to this project for the following reasons:

- Restoration is more applicable to buildings than bridges;
- There are no added features requiring removal; and
- There are no missing architectural elements.

5.1.4 Reconstruction

Reconstruction is defined as the act or process of depicting by means of new construction: the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location.

Reconstruction could be applicable to this project for the following reasons:

- The bridges and their structural members were badly deteriorated and corroded and it would have been unsafe to repair or alter the material;
- Due to further deterioration and corrosion (in addition to damage received from errant and overweight vehicles), the bridges were deemed unsafe and were condemned. A HABS and HAER was prepared and approved, and all three (3) bridges were replaced with temporary (ACROW) bridges;
- However, the exact replication of the old bridge is not desirable as new technologies and rehabilitation compatible to the district are preferable.

5.1.5 Historic Road Corridor Plan

The culmination of HDOT's planning project, Kuhio Highway (Route 560) Roadway Corridor Plan, resulted in a document entitled *Kuhio Highway (Route 560) Historic Road Corridor Plan (KHRCP).* Excerpts from the KHRCP "Introduction":

"This planning document has been developed to provide the Hawaii State Department of Transportation (HDOT), Highways Division, with a framework for decision making and actions on Kuhio Highway, Route 560. It focuses on a specific concept for the highway involving rural-historic road design intended to protect the corridor's natural and historic conditions and characteristics. The provisions of this document do not apply to all HDOT highway facilities, but only to the Kauai District office and the management and operations of Route 560."

"The HDOT will specifically use this document as a working plan to provide the necessary direction for current and long-term actions regarding preservation, rehabilitation, restoration, reconstruction and improvement, and repair and maintenance work on Route 560 over the next 25 years."

The KHRCP serves as a community framework for HDOT Highways Division – in regards to Kuhio Highway. The corridor plan addresses specifically one-lane bridges and states: "Replacement of any one-lane bridges should:

1) be reconstructed, as much as practical, with bridge similar in design;
2) have a single 12 feet-wide travel lane and 2 feet-wide shoulders;
3) have parapets or rails that are designed to be in character with the existing one-lane bridges along Route 560;
4) accommodate pedestrian/bicycle access within or outside of the bridge;
5) have a posted load of 15 tons and be capable of accommodating 18-ton fire trucks and other public utility or service vehicles; and
6) incorporate AASHTO guidance on crash-tested features."

The Hanalei Roads Committee (HRC) is comprised of members who contributed to the Corridor Plan from the Kuhio Highway Community Advisory Committee. In meetings held with the HRC, it was conveyed that the bridge guidelines in the Corridor Plan were to be used as a framework, and that subsequent design could deviate slightly from the KHRCP.

6.0 SAFETY, MOBILITY, AND COMMUNITY

6.1 Public Safety

Public safety is of critical concern to HDOT for this and every project. The previous Wainiha Bridges (before the ACROW Panel bridges) were built approximately fifty years ago. Those bridges were built as a temporary solution in response to the devastating tsunami in 1957. They did not meet today's design standards and were not envisioned to handle the volume and vehicular loading of today's traffic. As mentioned in **Section 2.2**, major accidents have occurred at the previous Wainiha Bridges. Traffic safety shall be a key component in the design of the rehabilitated bridges.

For over fifty years those bridges were exposed to a harsh marine environment and experienced a vast increase in vehicular weight and usage. These factors caused significant degradation of the bridges' structural integrity and eventual closure.

The present ACROW Panel Bridges were installed under an emergency condition (Bridge #2 installed 2004 and Bridges #1 and #3 installed 2007) due to deterioration, corrosion, and damage caused by errant vehicles and overloaded trucks. Refer to **Attachment E** for the September 22, 2004 and October 29, 2007 Governor's Proclamations to install the temporary bridges.

6.2 Mobility

Efficient mobility of people and goods is another component of HDOT's mission. This means that movement of vehicles, pedestrians, and all roadway users over these bridges is a principal factor to be considered in this project. Highway users must be allowed to travel across the Wainiha Bridges and access desired goods, services, and activities without *unreasonable* difficulty or delays.

6.3 Wainiha Community

Successful transportation projects also consider the community in which the particular facility exists. HDOT seeks to develop projects which enhance and/or preserve the economic prosperity and quality of life of those in the surrounding areas. For the Wainiha community, some stakeholders are interested in perpetuating a "rural" lifestyle. Thus, preserving certain aspects of Kuhio Highway along the project area is of vital concern to them. Public outreach efforts, including the Context Sensitive Solutions process (described in **Section 6.7** below), have been, and will continue to be, included in the project. HDOT is also committed to preserving the historic integrity of Kuhio Highway, as the project is located in a designated historic district.

Clearly, it can be difficult to achieve consensus on how best to address community concerns, as "quality of life" is a subjective characteristic. At times, it may seem as if the goals of safety, mobility, and community responsiveness are at odds with each other. It is HDOT's commitment to weigh all project goals in development of the final design of this project.

6.4 Design Standards

HDOT issued the *Statewide Uniform Design Manual for Streets and Highways* (October 1980, updated 1984). These guidelines are used in the design of all new public roadways to be constructed. In addition, reconstruction of the Wainiha Bridges will be funded 80% by FHWA and 20% by the State of Hawaii. To obtain this funding, the replacement structures must meet the current geometric criteria and structural standards required for the types and volumes of projected traffic on the facility over its design life. Guidance is contained in the document entitled *A Policy on Geometric Design of Highways and Streets 2004* issued by AASHTO. This document is commonly referred to as the "green book". Additionally, AASHTO has developed specific guidelines for the design of bridges. These guidelines are documented in the *AASHTO LRFD Bridge Design Specifications* (4^{th} Edition, 2007).

In developing and applying standards such as those mentioned above, transportation agencies seek to provide design guidance on critical features which supports the construction of safe and efficient facilities for all users. However, those standards are not intended to supersede the application of sound principles by experienced and knowledgeable design professionals and transportation officials. As such, HDOT is able to consider a range of solutions, and incorporate some flexibility in application of standards in the final design.

6.5 Design Exceptions

The Code of Federal Regulations (CFR 23 625) provides that exceptions may be given on a project basis to designs which do not conform to the minimum criteria as set forth in the standards, policies, and standard specifications for: experimental features on projects and projects where conditions warrant that exceptions be made.

Although all exceptions from accepted standards and policies should be justified and documented in some manner, the FHWA has established fourteen (14) "Controlling Criteria" requiring formal approval. Design exceptions to these controlling criteria can, in the most part, be easily identified and defined.

For instances where one or more of the following fourteen (14) "Controlling Criteria" cannot be met, a Design Exception Report must be prepared.

1) *Design Speed
2) *Lane Width
3) *Shoulder Width
4) *Bridge Width
5) *Structural Capacity
6) Horizontal Alignment
7) Vertical Alignment
8) Grades
9) *Stopping Sight Distance
10) Cross Slopes
11) Superelevation
12) Vertical Clearance
13) *Horizontal Clearance (except "clear zone")
14) Hydraulics

* Controlling Criteria cannot be met

The "Category" of the Design Exception will determine the approving agency (HDOT, FHWA, or both). The following factors shall determine the "Category" of the Design Exception and required approval:

1) Is the issue an exception to the thirteen (13) "Controlling Criteria"?
2) Are Federal funds being utilized?
3) *Is the project on an NHS (National Highway System) route and/or Interstate?
4) *What is the estimated construction cost?

*The route designation and cost criteria will determine the oversight authority (State or Federal) for Federal-Aid projects.

CATEGORY 1:
- Exception to the thirteen "Controlling Criteria"
- Federal-Aid
- Project is on the NHS
- CATEGORY 1A: Federal oversight
  - DESIGN EXCEPTION SUBMITTED FOR FHWA APPROVAL
- CATEGORY 1B: State oversight
  - DESIGN EXCEPTION SUBMITTED FOR HDOT APPROVAL; COPY TO FHWA

CATEGORY 2:
- Exception to the thirteen "Controlling Criteria"
- State funds only
- Project is on the NHS
- Estimated construction cost is not considered
  - DESIGN EXCEPTION SUBMITTED FOR HDOT APPROVAL; COPY TO FHWA

CATEGORY 3:
- Exception to the thirteen "Controlling Criteria"
- Federal-Aid
- Project is **NOT** on the NHS
- Estimated construction cost is not considered
  - DESIGN EXCEPTION SUBMITTED FOR HDOT APPROVAL; COPY TO FHWA

CATEGORY 4:
- Exception to the thirteen "Controlling Criteria"
- State funds only
- Project is **NOT** on the NHS
- Estimated construction cost is not considered
  - DESIGN EXCEPTION SUBMITTED FOR HDOT APPROVAL

CATEGORY 5:
- **NOT** an exception to the thirteen "Controlling Criteria"
- Funding source is not considered
- Project is on the NHS
- Estimated construction cost is not considered
  - NO DESIGN EXCEPTION REQUIRED; DOCUMENTATION FOR FILES ONLY

Based on the above factors, a Category 3 Design Exception will be pursued for this project.

The Design Exception Report will also include several other design variances. Request for Design Variances will include:

1. Roadway Wearing Surface
2. Bridge Guardrails
3. Bridge Clearance Over Stream
4. Pedestrian Rail Picket Spacing
5. Pedestrian Rail Height
6. Roadway Turning Radius
7. Guardrail End Treatment

6.6 Tort Liability

Tort liability establishes a responsible party (State of Hawaii) to provide safe transportation facilities. Abolition of Sovereign Immunity in recent years has exposed the State to financial liability resulting from accidents on or caused by delinquent transportation facilities. As a result, the State has a responsibility to design, build, and maintain safe transportation facilities. A failure to do so will expose the State to higher liability and risk.

Due to the desire of the community to preserve the historic integrity of Route 560's bridges, DOT is willing to prepare designs based on: 1-lane, 11 feet and 16 feet wide, etc. while still incorporating as many safety features as possible.

Appendix E of the KHRCP states: "Increasingly, courts are recognizing that safe and efficient transportation services require flexible highway design standards in order to conserve and enhance the environmental, scenic, historic, and community resources or our land. Safe design can be accomplished in a variety of ways, not just following one uniform standard in a world that is not confined to one set of conditions."

6.7 Context Sensitive Solutions

Context Sensitive Solutions is a relatively new approach of the Transportation industry for planning, designing, engineering, permitting and implementing successful projects. Although the term "Context Sensitive Solutions" is relatively new, the principles of CSS have been embodied in various legislative acts as far back as the Highway Beautification Act of 1965 and the National Environmental Policy Act of 1969.

In 1995, Congress passed the National Highway System Designation Act, emphasizing, among other things, flexibility in highway design to further promote preservation of historic, scenic, and aesthetic resources. This act provided funding capabilities for transportation enhancements and supported applications to modify design standards for the purpose of preserving important historic and scenic resources. Most importantly, the Act extended these considerations to federally funded transportation projects not on the National Highway System.

FHWA defines Context Sensitive Solutions (CSS) or Context Sensitive Design as:

> "A collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility. CSS is an approach that considers the total context within which a transportation improvement project will exist."

We believe that the foundation of CSS is to bring together key ingredients in a consensus building process that embodies all aspects of context sensitive solutions:

1. CREDIBLE PROCESS
2. PARTNERSHIPS
3. CREATIVE IDEAS
4. PEOPLE

CREDIBLE PROCESS includes conducting as open and broad based community participation process as possible, to ensure representation from all parts of the community through the Hanalei Roads Committee (HRC) and to foster involvement by HRC in a process that results in a consensus vision for the overall design solution.

PARTNERSHIPS include building trust and relationships between FHWA, HDOT, the Engineering Consulting team members, and HRC to carry out an exemplary involvement program that will achieve world class award-winning design solutions.

CREATIVE IDEAS should include all project partners thinking "outside the box" to formulate, evaluate and reconfigure design solutions that achieve the community's vision, respond to the community, environment and transportation context and address the many needs and issues that emerge during the process.

PEOPLE are the fourth key ingredient because they link the first three ingredients. People generate creative ideas, people conduct a credible process, and interested people are designated as stakeholders. HDOT and the Engineering Consulting Team will listen, be respectful of the important contribution of each of the participants, and communicate with the Hanalei Roads Committee, and affected agencies. Our responses will be nonjudgmental to build trust. We will encourage participation and ask pertinent questions to ensure that all issues are discussed.

The remaining steps require that the Preliminary Engineering Design Report be completed and approved. The CSS process will continue during the Final Design until the design is completed and approved.

HDOT and the Engineering Consulting Team will be diligent in ensuring that if the final design varies from the vision and concepts established and included in the Preliminary Engineering Design Report, all stakeholders are notified and public meetings are held to notify the public of the circumstances surrounding the need for the variance. Any such variances will also be described in the Draft and Final Environmental Assessments, which are part of a process also designed to afford stakeholders the opportunity to provide input on projects.

With Context Sensitive Solutions, the success of a project is now measured by its community general acceptance, historic and environmental compatibility, engineering and technical functionality, safety, and financial feasibility.

7.0 CONSULTATION

7.1 Existing Plans and Documents

Past construction plans and documents available for the Wainiha Bridges and adjacent Kuhio Highway were reviewed. No formal record of the highway right-of-way exists. The right-of-way, as well as other property boundary information was obtained from a 1947 subdivision map that was filed in circuit court. This is the only map with property information that the State possesses for the project area.

7.2 State Historic Preservation Division (SHPD)

Various communications have been conducted with SHPD and Historic Hawaii Foundation (HHF) to address the concerns regarding historic preservation. Because of the historic nature of Route 560 and Wainiha Bridges being a part of the route, per the SOI standards, evaluation of design alternatives for the bridges were followed in the order of **preservation**, **rehabilitation**, **restoration** and **reconstruction**.

SHPD and FHWA have indicated that modifications made to any of the Wainiha Bridges will be considered an "adverse effect." Adverse effects will require a Memorandum of Agreement (MOA) between all affected parties including, but not limited to, HDOT, FHWA, Kauai County Historic Preservation Review Commission (KHPRC), and SHPD in accordance with Section 106 of the National Historic Preservation Act. Office of Hawaiian Affairs (OHA), Hui Malama, other concerned Native Hawaiian Organizations (NHO), HRC, HHF and the Advisory Council on Historic Preservation (ACHP) must be afforded an opportunity to comment.

7.3 Community Consultation

The following list documents consultation with the community for this report:

- March 2, 2005 – Public Informational Meeting with the general public to present background and project information;
- July 12, 2005 – Public Informational Meeting with the general public to present alternatives under consideration and seek input on the various alternatives;
- February 17, 2006 – Small Group Community Meeting with residents living adjacent to Wainiha Bridge #2 and #3 to discuss application of SOI standards leading to discussion to replace bridges;
- February 18, 2006 –Meeting with Hanalei Roads Committee to discuss application of SOI standards leading to discussion to replace bridges;
- May 3, 2006 –Meeting with user groups such as utilities, public safety agencies, Chamber of Commerce and trucking agencies to discuss application of SOI standards leading to discussion to replace bridges;
- May 23, 2006 –Meeting with Hanalei Roads Committee to recapitulate status of small group community meetings;
- May 12, 2008 –Meeting with Hanalei Roads Committee to discuss the planning process and design of the new Wainiha Bridges;

- December 17, 2008 –Meeting with Hanalei Roads Committee to review HRC's Table of Design Elements, introduce additional design team members, and discuss status and strategy;
- October 29, 2009 –Meeting with Hanalei Roads Committee to provide a status update of the revisions to the Preliminary Engineering Report;
- April 11, 2011 - Meeting with Hanalei Roads Committee to provide a status update of the revisions to the Preliminary Engineering Report;
- June 6, 2011 - Meeting with Hanalei Roads Committee to provide a status update of the revisions to the Preliminary Engineering Report; and
- January 26, 2012 – Final Public Informational Meeting with the general public to present background, findings and recommendations. Meeting conducted in accordance with Section 106 Procedures of the National Historic Preservation Act and the National Environment Policy Act (NEPA).

Minutes of these meetings are included in **Attachment F**.

8.0 TECHNICAL AND ECONOMIC CONSIDERATIONS

8.1 Substructure

Based on the findings discussed in **Section 2.4**, it was determined that deep foundations consisting of drilled shafts should be used for bridge foundations. These shafts should extend through the loose to very soft alluvial and swamp deposits, and into the underlying medium stiff to hard and medium dense to very dense alluvial deposits and stiff to hard residual and saprolitic soils. The drilled shafts would derive support principally from adhesion between the drilled shaft and the medium stiff to hard and medium dense to very dense alluvial soils and stiff to hard residual and saprolitic soils encountered in the borings. It is recommended that these shafts be 3-feet in diameter with embedment depths of about 75-feet to 125-feet below the planned bottom of footing elevations. Larger diameter shafts may be considered to reduce the embedment depths. It should be noted that cobbles and boulders should be anticipated during drilled shaft installation within the surface fill layer and the alluvial deposits encountered at the site.

Drilled shafts will be used for both bridge abutments and bridge piers. Drilled shafts will be joined by concrete pier caps to provide structural rigidity and support elements of the bridge superstructure. Piers within the stream will extend below the waterline to mimic the look of existing concrete piers.

Construction of drilled shafts for Bridges #2 and #3 will require the use of temporary cofferdams in portions of the Wainiha Stream. These cofferdams will provide a suitable work area for the drill rig installing the shafts. However, in the event of a major storm during construction, the work area may become flooded. This is typical of similar construction sites. Contractors and HDOT project management must keep up with weather forecasts and take preventive measures to reduce risks during construction. Once the water levels have subsided, the cofferdams will again allow the work area to be used for construction.

The use of small diameter micropiles was considered for the bridge foundations. Due to the large lateral loading and deep scour depths, a significantly large number of micropiles would be required for Wainiha Bridge #3. Micropiles are much more susceptible to damage than the larger drilled shafts because of their small size. Furthermore, the micropiles would be exposed under scour conditions and could be damaged by boulders and debris. If the micropiles are damaged during scour, the damage may not be detectable from the surface. Because of the above, the use of micropiles is not considered appropriate for the project.

A scour analysis report was prepared by West Consultants, Inc. entitled *Wainiha Bridges Kuhio Highway, Preliminary Hydraulic and Scour Analysis* (Attachment D). It was originally done in September 2005 and revised May 2011. This report establishes scour depths for the three (3) bridges. The calculated scour depths assume the same hydraulic data used for the previous bridges and applied to the 3-foot diameter drilled shafts recommended by Geolabs, Inc. Scour depths based upon a 100-year storm event are summarized in **Table 7**.

Table 7: Future Conditions Scour Results (100-year Storm Event)

		Scour Depths (feet)				
	Scour Type	**Lft Abutment**	**Pier Left**	**Pier Center**	**Pier Right**	**Rt Abutment**
Bridge #1	Contraction Scour	1.8	no pier	no pier	no pier	1.8
	Abutment Scour	n/a	no pier	no pier	no pier	n/a
	Total Scour Depth	1.8	no pier	no pier	no pier	1.8
	Total Scour Elev.	-2.3 (MSL)	no pier	no pier	no pier	-2.3 (MSL)
Bridge #2	Contraction Scour	10.4	no pier	no pier	no pier	10.4
	Pier Scour	n/a	no pier	no pier	no pier	n/a
	Abutment Scour	n/a	no pier	no pier	no pier	n/a
	Total Scour Depth	10.4	no pier	no pier	no pier	10.4
	Total Scour Elev.	-14.0 (MSL)	no pier	no pier	no pier	-14.0 (MSL)
Bridge #3	Contraction Scour	5.4	5.4	no pier	5.4	5.4
	Pier Scour	n/a	6.0	no pier	9.4	n/a
	Abutment Scour	8.1	n/a	no pier	n/a	n/a
	Total Scour Depth	13.5	11.4	no pier	14.8	5.4
	Total Scour Elev.	-11.2 (MSL)	-9.1 (MSL)	no pier	-19.3 (MSL)	-9.9 (MSL)

Note: Abutment and pier locations assume one is looking downstream.

The shaft lengths recommended by Geolabs, Inc. take into account the 100-year scour event effects as determined by West Consultants.

8.2 Superstructure

Nishimura, Katayama and Oki (NKO) and KSF Inc. identified four (4) alternative construction methods for bridge superstructures during their structural analysis. The alternatives included two (2) schemes with pre-cast and pre-stressed concrete planks, structural steel beams and structural steel trusses. These construction methods are described below.

8.2.1 Alternative #1: Pre-cast and Pre-stressed Short Span Concrete Planks

The first alternative considered the use of pre-cast and pre-stressed concrete planks for the superstructure. A pictorial concept is shown in **Figure 4**.

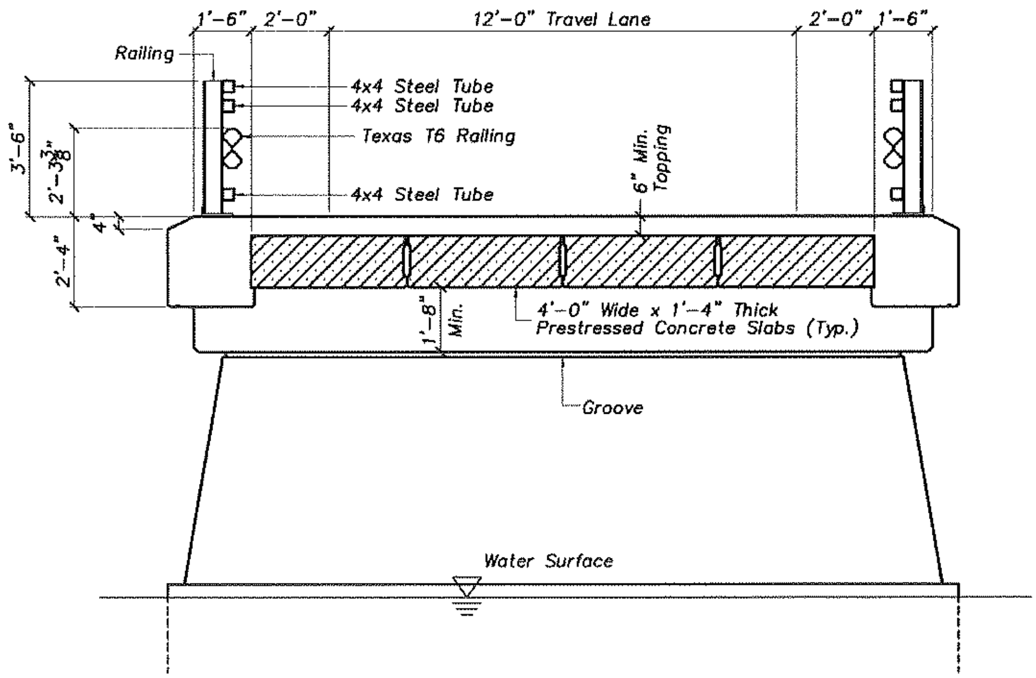

Figure 4: Pre-cast, Pre-stressed Short Span Concrete Plank – Section View

Advantages and disadvantages for this bridge type are detailed below.

Advantages:
- Most resistant to deterioration of the four (4) superstructure alternatives;
- Pre-cast, pre-stressed concrete planks can be manufactured in Hawaii;
- Concrete formwork will only be required at the outer edges of the new bridges to place the cast-in-place concrete topping and at each pier to place the cast-in-place concrete pier caps; and
- Pre-cast members can be transported to the site.

Disadvantages:
- Can be used only for Bridge #1 for existing span;
- The span lengths for Bridge #2 and #3 will have to be reduced from 75-feet to 38-feet; and
- A pier must be added for Bridge #2 and a total of 3 piers must be used for Bridge #3. Additional piers in the stream will obstruct the waterway and affect scour.

8.2.2 Alternative #2: Structural Steel Beams and Girders

The second alternative considered the use of structural steel beams and girders for the superstructure. A pictorial concept is shown in **Figure 5**.

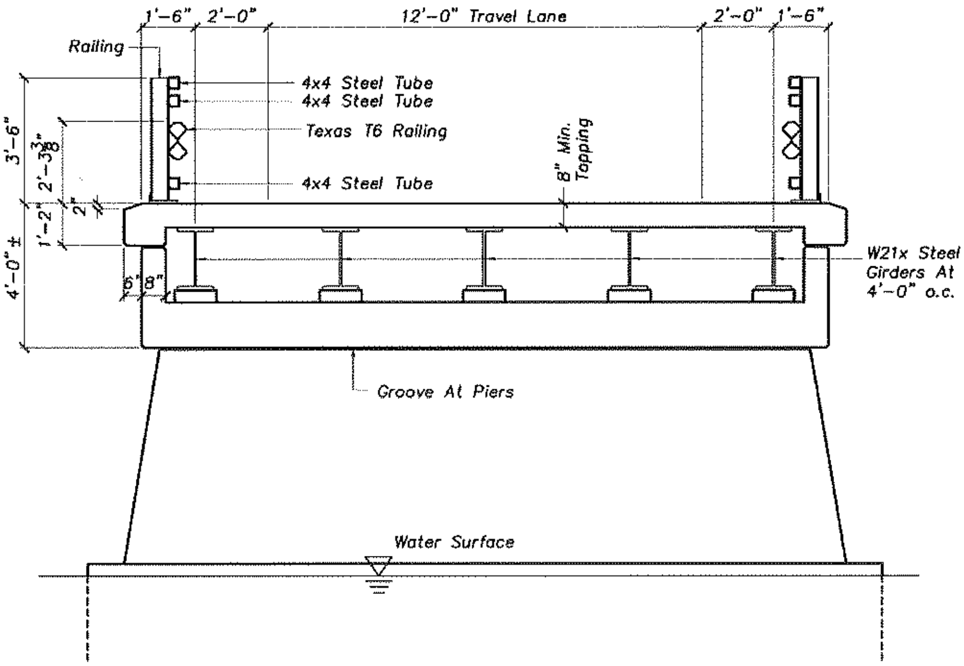

Figure 5: Structural Steel Beams and Girder – Section View

Advantages and disadvantages for this bridge type are detailed below.

Advantages:

- This bridge superstructure will be lighter than pre-cast, pre-stressed concrete planks and will be easier to transport to the project site.

Disadvantages:

- Will be more costly than pre-cast, pre-stressed concrete planks alternative;
- Has a larger cross-sectional height relative to that of the pre-cast, pre-stressed concrete planks;
- Structural steel members must be shipped to Hawaii from the mainland or elsewhere;
- Structural steel will require much more rigorous and costly routine maintenance than pre-cast concrete bridges in order to prevent deterioration and repair corrosion damage; and
- A pier must be added for Bridge #2 and a total of 3 piers must be used for Bridge #3. Additional piers in the stream will obstruct the waterway and affect scour.

8.2.3 Alternative #3: Structural Steel Truss

The third alternative considered the use of Structural Steel Trusses for the superstructure. A pictorial concept is shown in **Figure 6**.

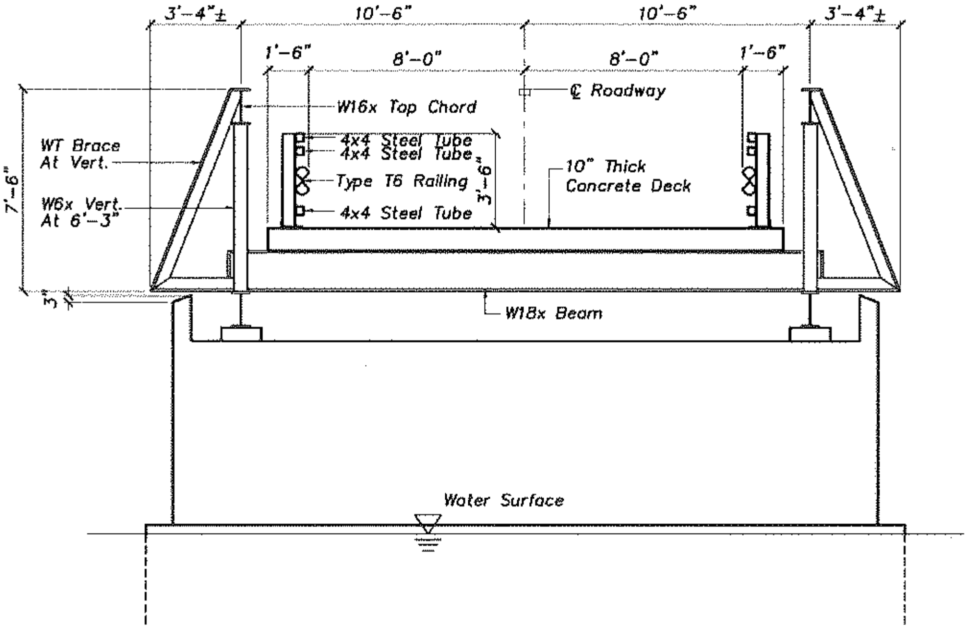

Figure 6: Structural Steel Truss – Section View

Advantages and disadvantages for this bridge type are detailed below.

Advantages:

- Though heavier than Structural Steel Beams and Girders, this bridge superstructure is lighter than pre-cast, pre-stressed concrete planks and will be easier to transport to the project site.

Disadvantages:

- Most costly alternative of the four (4) alternatives;
- Structural steel will require much more rigorous and costly routine maintenance than pre-cast concrete bridges in order to prevent deterioration and repair damage from corrosion;
- Steel trusses will provide much more surface area than structural steel beams and girders that is subject to corrosion;
- Potential for reduced visibility due to truss members;
- Structural steel members must be shipped to Hawaii from the mainland or elsewhere;
- Will require intensive welding and assembly work most likely performed at the job site; and
- A pier must be added for Bridge #2 and a total of 3 piers must be used for Bridge #3. Additional piers in the stream will obstruct the waterway and affect scour.

8.2.4 Alternative #4: Pre-cast and Pre-stressed Long Span Concrete Planks

The fourth alternative considered the use of longer, deeper pre-cast and pre-stressed concrete planks for the superstructure. Spans range from 60-feet to 70-feet, reducing the number of piers within the stream to two (2) for Bridge #3. A pictorial concept for Bridges #2 and #3 is shown in **Figure 7**.

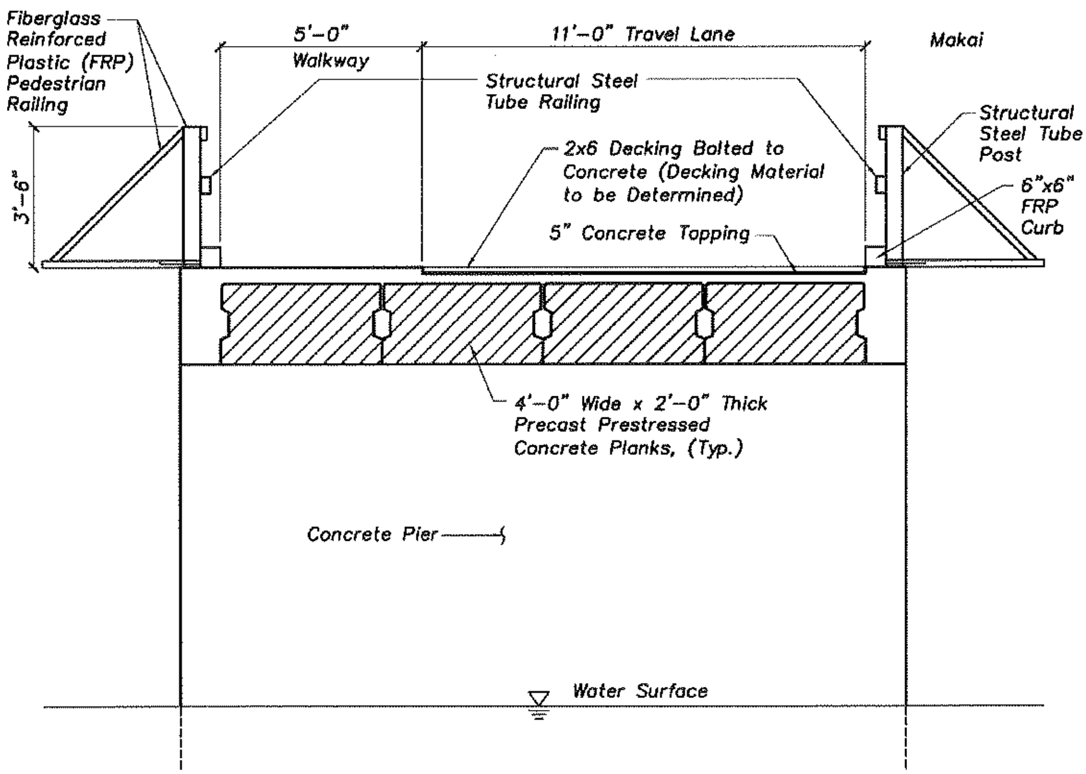

Figure 7: Pre-cast, Pre-stressed Long Span Concrete Plank – Section View

Advantages and disadvantages for this bridge type are detailed below.

Advantages:
- Fewer piers in the stream which improves hydraulics and lessens the chance of debris blocking the stream;
- Least amount of work in the stream;
- Most resistant to deterioration of the four (4) superstructure alternatives;
- Pre-cast, pre-stressed concrete planks can be manufactured in Hawaii;
- Most economical of the four (4) bridge alternatives; and
- Concrete formwork will only be required at the outer edges of the new bridges to place the cast-in-place concrete topping and at each pier to place the cast-in-place concrete pier caps.

Disadvantages:

- More load on each pier which affects the foundations. Larger shafts may be required which requires larger equipment. Accessing the site with large pieces of equipment could be problematic.
- Because of the weight and length of the prestressed planks, they may need to be constructed at the site.

* A removable pedestrian railing separating the walkway and travel lane had been proposed. The railing would/could be removed during emergency conditions. The removable railing was omitted as an alternative due to concerns expressed by members of the North Shore Community at the January 26, 2012 Public Informational Meeting that the removable railings would be subject to vandalism or theft.

8.3 Bridge Design Span Lengths

Dimensions discussed in this section are subject to change during the Design phase of the new Wainiha Bridges. The final bridge dimensions will be subject to approval by HDOT.

In general, HDOT's design criteria require the hydraulic openings of the new bridge to be equal to or greater than that of the previous bridge. This report proposes alternatives that increase the number of piers, which would reduce the hydraulic opening width dimension at the bridge. However, elimination of the previous inverted trusses will provide more freeboard and maintain hydraulic openings for these new bridges. The proposed hydraulic openings for the new bridges with additional piers should be equivalent to the existing hydraulic openings. Final bridge design will include hydraulic calculations to verify that it meets or exceeds the existing capacity condition.

The first three (3) alternatives studied utilized shorter 39-foot spans similar to Bridge #1. Shorter design span lengths were considered to improve constructability and cost considerations. This alternative would use smaller structural elements which would ease construction and simplify material transport.

The last alternative utilized planks that are up to 76-feet in length. Bridge #1 would be a single span plank bridge similar to the previous bridge. Bridge #2 would have one 76-foot span and no intermediate piers, similar to the previous bridge. Bridge #3 would have two (2) piers and the overall length of the bridge will increase from 170-feet to 200-feet, creating a wider channel and increasing the hydraulic capacity of the bridge.

Based on HDOT's hydraulic capacity criteria, it is concluded that Alternative #4 (Pre-cast, Pre-stressed Long Span Concrete Plank) would be selected.

Currently, Bridge #1 is a single span bridge. The previous bridge had a clear span from abutment face to abutment face of 38-feet and 6-inches. Bridge #1 replacement will be designed as a single 39-foot span bridge. The following figure illustrates this single 39-foot span length.

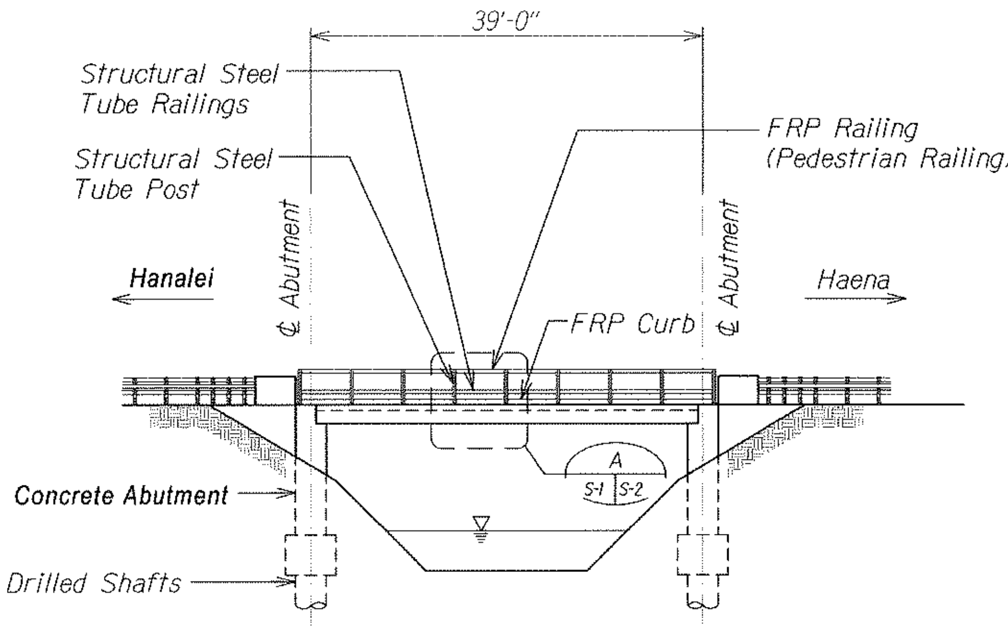

Figure 8: Bridge #1, 39-foot Single Span - Elevation View

Bridge #2 currently utilizes a longer 78-foot span supported on each end by abutments. Bridge #2 replacement will utilize a single 76-foot span configuration which will not require a new pier to support it. A single span replacement bridge for Bridge #2 is depicted below. This depiction shows the use of drilled shafts in combination with pier caps that extend below Wainiha Stream's waterline.

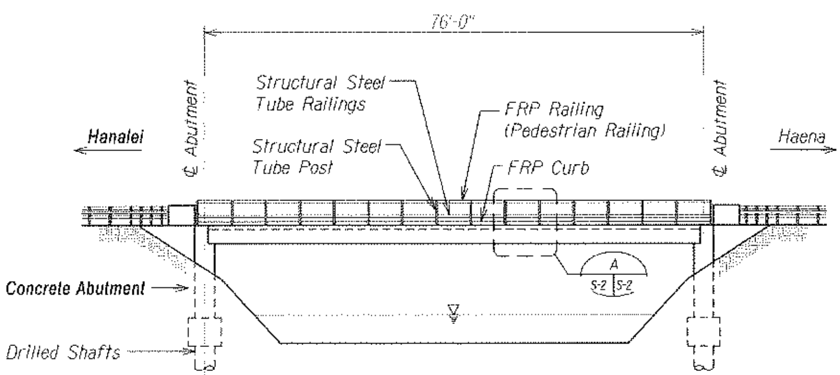

Figure 9: Bridge #2, 76-foot, Single Span - Elevation View

The previous Bridge #3 was comprised of two (2) 73-foot spans (146-feet total) as well as a third 24-foot span supported by concrete abutments at each end and two (2) concrete piers in the middle. The new Bridge #3 will use the same 3-span design which will not require additional support piers.

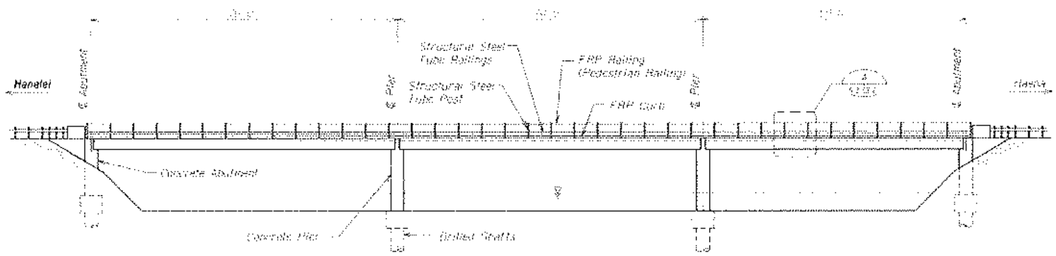

Figure 10: Bridge #3, 200-foot, 3-Span - Elevation View

8.4 Additional Bridge Design Elements

Other key design elements considered for these replacement bridges include decking, pedestrian and vehicle railings, and end treatments.

Bridge decking will be designed to mimic the placement of the timber planking on the previous bridges. Replacement design will incorporate timber or timber facsimile for the traveled way surface. This type of decking is in response to public input received during various meetings. It should be noted that in a wet environment such as that found at the Wainiha Bridges, timber planks experience increased wear and/or rot. This results in a need for replacement periodically, which adds considerably to HDOT's maintenance workload and material costs as well as major traffic stoppages.

All bridges will utilize vehicular railings. It is proposed to use Structural Steel Tube (SST) Railings for the replacement bridges that comply with Test Level 2 (TL-2) of the AASHTO standards. The bridges will be designed to accommodate vehicular, pedestrian, and bicycle traffic. Therefore, pedestrian railings will be provided to meet a height requirement similar to the railing heights on the previous bridges. The pedestrian railings will be constructed out of timber or timber facsimile (possibly Fiber reinforced Plastic) to minimize the maintenance work as previously mentioned for the decking.

Railing picket spacing will mimic the original spacing. As much as possible, railings will allow peak flood flows to pass through with minimal obstruction. The railings will also facilitate queued drivers' sighting of other vehicles traversing the bridges. A Design Exception will be required.

Approach railings to the bridges will utilize standard W-beam guardrails. These guardrails will transition to the SST railings at all bridge ends. A concrete pedestal will be used to transition the W-beam to the SST railing.

8.5 Alignment

Reconstruction of the Wainiha Bridges must consider both the horizontal and vertical alignment. The current Wainiha Bridges #2 and #3 sit skewed to each other. This creates a line-of-sight problem for traffic approaching Bridge #2 from the east and traffic approaching Bridge #3 from the west. Often, vehicles enter the two (2) bridges simultaneously and one vehicle is forced to back up to provide a travel-way for the other.

However, the local community prefers that the replacement bridges for the three (3) Wainiha Bridges be constructed as close to the existing horizontal alignment as possible. This alignment is perceived by the community as traffic calming. It will be proposed that a minor adjustment be made to the alignment to reduce the skew. The primary purpose for the realignment is to improve the mobility between Bridge #2 and #3 and to improve sight distance. In addition, the realignment would minimize the damage currently being experienced to Bridge #3 as vehicles negotiate the skewed transition from Bridge #2 to Bridge #3.

The vertical alignment will remain similar to the previous bridges as a result of community input as well. The new bridge deck elevations will be designed as close as possible to the previous bridge deck elevations. As a result, Bridge #2 and Bridge #3 will experience overtopping during a 50-year or 100-year storm event. Hydraulic analysis shows that Bridge #1 will not be overtopped by the large storm events. Designing all of the bridges to an elevation above the 100-year storm event elevation is not justified or practicable. Not only would this cause the bridges to be unacceptably elevated and expensive to construct, but the approach roadways are situated well below these storm water elevations, and when flooded would render the bridges unusable in the event of a major storm.

8.6 Bridge Design Width

AASHTO design standards state that minimum bridge clear width must be 38-feet (22-feet wide travel way and two (2) 8-feet wide shoulders). This is based upon an average daily traffic count in excess of 2,000 vehicles per day at a posted speed limit of 15 mph. In keeping with KHRCP guidelines and SOI standards, rehabilitated Bridges #2 and #3 will be 16-feet in width. This includes an 11-foot wide single lane for traffic with a 5-foot wide walkway. Bridge #1 will be 11-feet in width with no walkway (requires land acquisition to provide walkway). The single lane bridge design will require a design exception.

8.7 Bridge Design Loading

AASHTO requires a minimum design loading for new bridges on local rural roadways to be HS-20. The replacement bridges will be designed for HS-20 loading and posted for 15-tons per discussions with various community as well as user groups. Bridge design of HS-20 will be sufficient to accommodate the needs of vehicular traffic such as emergency vehicles as well as delivery and utility service trucks.

8.8 Construction Site Access and Bypass

The Waioli, Waipa, and Waikoko Bridges are located between Hanalei Town and the project site. All three (3) bridges are posted at 8 tons and have narrow widths that may severely restrict the delivery of construction material and equipment to the three (3) Wainiha Bridge sites. The selected contractor will need to work out material and equipment delivery logistics with HDOT prior to the start of the Wainiha Bridges construction.

8.9 Order of Magnitude Cost Estimate

An order of magnitude cost estimate for the four (4) alternatives under consideration for the Wainiha Bridges is presented below. These costs will consist of the construction of temporary approach roadways; construction easements, and alternative bridge construction methods. The cost of cofferdams is included in the appropriate line items for the alternative bridge construction methods.

Cost estimates presented below are based on construction beginning in the year 2012. The amounts should be increased at a compounded annual rate of a minimum of 5% per year for every year that construction is scheduled to begin after 2012.

ACROW Panel bridges are proposed for all temporary bypass bridges. The cost for the erection of the proposed ACROW Panel bridges is estimated to be $1,275 per square foot. The condition of Wainiha Bridges #1, #2, and #3 had deteriorated to a point where the State viewed them as unsafe and has replaced all the bridges with temporary ACROW Panel bridges.

Approximately 400-linear feet (LF) of temporary detour bridges will be required for the three (3) Wainiha Bridges. This includes 100 LF for Bridge #1, 100 LF for Bridge #2, and 200 LF for Bridge #3. This report assumes that all temporary bridges will be constructed to provide bypass during the course of this project by reusing the existing ACROW Panel bridges to reduce cost. The total length of ACROW system bridges required at these sites were determined based on information provided by the topographic survey and visual observations during a visit to the project site.

The economic analysis assumes that all temporary bridges will be removed upon completion of the project. NKO's report estimated removal costs to be on the order of $150/square foot, or $190/square foot in 2012 dollars.

For the four (4) alternatives under consideration, an order of magnitude cost estimate is developed on the following pages.

ALTERNATIVE #1 - PRE-CAST / PRE-STRESSED SHORT SPAN CONCRETE PLANKS

1. Construction of temporary approach roadways 12,000 SF x $115/SF	$ 1,380,000
2. Acquire temporary construction easements 7,000 SF x $1050/SF	$ 735,000
3. Construction of temporary detour bridges at the Wainiha Bridge sites. Relocate ACROW Panel bridges. 400 LF x 18 FT x $130/SF	$936,000
4. Removal of the temporary detour bridges and approach roadways at the Wainiha Bridge sites. 400 LF x 18 FT x $190/SF	$ 1,368,000
5. Construction of the pre-cast, pre-stressed concrete alternative as the replacement method for the Wainiha Bridges.	
Bridge #1	$ 1,925,000
Bridge #2	$ 4,462,000
Bridge #3	$ 8,710,000

ALTERNATIVE #1 ORDER OF MAGNITUDE COST ESTIMATE
Pre-cast and Pre-stressed Short Span Concrete Planks
(2012 Construction Costs) **$ 19,516,000**

ALTERNATIVE #2 - STRUCTURAL STEEL BEAMS AND GIRDERS

1. Construction of temporary approach roadways 12,000 SF x $115/SF	$ 1,380,000
2. Acquire temporary construction easements 7,000 SF x $105/SF	$ 735,000
3. Construction of temporary detour bridges at the Wainiha Bridge sites. Relocate ACROW Panel bridges. 400 LF x 18 FT x $130/SF	$936,000
4. Removal of the temporary detour bridges and approach roadways at the Wainiha Bridge sites. 400 LF x 18 FT x $190/SF	$ 1,368,000
5. Construction of the structural steel beams and girders alternative as the replacement method for the Wainiha Bridges.	
Bridge #1	$ 2,439,000
Bridge #2	$ 5,425,000
Bridge #3	$ 10,154,000

ALTERNATIVE #2 ORDER OF MAGNITUDE COST ESTIMATE
Structural Steel Beams and Girders (2012 Construction Costs) **$ 22,437,000**

ALTERNATIVE #3 - STRUCTURAL STEEL TRUSSES

1. Construction of temporary approach roadways 12,000 SF x $115/SF		$ 1,380,000
2. Acquire temporary construction easements 7,000 SF x $105/SF		$ 735,000
3. Construction of temporary detour bridges at the Wainiha Bridge sites. Relocate ACROW Panel bridges. 400 LF x 18 FT x $130/SF		$936,000
4. Removal of the temporary detour bridges and approach roadways at the Wainiha Bridge sites. 400 LF x 18 FT x $190/SF		$ 1,368,000
5. Construction of the structural steel trusses alternative as the replacement method for the Wainiha Bridges.		
	Bridge #1	$3,318,000
	Bridge #2	$ 7,101,000
	Bridge #3	$ 13,821,000

ALTERNATIVE #3 ORDER OF MAGNITUDE COST ESTIMATE
Structural Steel Trusses (2012 Construction Costs) **$ 28,659,000**

ALTERNATIVE #4 - PRE-CAST / PRE-STRESSED LONG SPAN CONCRETE PLANKS

1. Construction of temporary approach roadways 12,000 SF x $115/SF		$ 1,380,000
2. Acquire temporary construction easements 7,000 SF x $105/SF		$ 735,000
3. Construction of temporary detour bridges at the Wainiha Bridge sites. Relocate ACROW Panel bridges. 400 LF x 18 FT x $130/SF		$936,000
4. Removal of the temporary detour bridges and approach roadways at the Wainiha Bridge sites. 400 LF x 18 FT x $190/SF		$ 1,368,000
5. Construction of the pre-cast, pre-stressed concrete alternative as the replacement method for the Wainiha Bridges.		
	Bridge #1	$ 1,593,000
	Bridge #2	$ 3,717,000
	Bridge #3	$ 9,291,000

ALTERNATIVE #4 ORDER OF MAGNITUDE COST ESTIMATE
Pre-cast and Pre-stressed Long Span Concrete Planks
(2012 Construction Costs) **$19,020,000**

SUMMARY OF ORDER OF MAGNITUDE COST ESTIMATE

A summary of the total order of magnitude cost estimates for each alternative for the project is presented below:

1.	Pre-cast and pre-stressed short span concrete planks	**$ 19,516,000**
2.	Structural steel beams and girders	**$ 22,437,000**
3.	Structural steel trusses	**$ 28,659,000**
4.	Pre-cast and pre-stressed long span concrete planks	**$ 19,020,000**

9.0 EVALUATION OF ALTERNATIVES

This section will evaluate the four (4) superstructure alternatives discussed in **Section 8.2**. Four (4) criteria will be used in this evaluation: Initial Capital Cost, Operational and Maintenance (O&M) Requirements, Hydraulic Capacity, and Visual Aesthetics. Numerical scores resulting from the assessment will be summed up in a matrix.

The four (4) alternatives will be evaluated in relation to each criterion. A ranking between 0 and 1 will be assigned to each alternative. A value of 0 is least favorable and a value of 1 is most favorable. Each criterion will also be assigned a weighting relative to the other criteria. An alternative's ranking will be multiplied by a criterion weighting to produce a rating for a given alternative and a specific criterion.

Criterion weighting will be assigned as 25% for Capital Cost, 25% for O&M Requirements, 25% for Hydraulic Capacity, and 25% for Visual Aesthetics. The historical nature of Route 560 (which includes its bridges) results in the higher-than-usual weighting (25%) for Visual Aesthetics.

A matrix will be developed to tabulate the results of the alternatives' evaluations. The alternative receiving the greatest cumulative total will be recommended for the replacement of the three (3) Wainiha Bridges.

The environmental, social, and safety impacts of the four (4) alternatives under consideration will not be included in this evaluation. All impacts for these factors are considered equal for all four (4) alternatives under consideration. These impacts were discussed in the preceding sections of this report.

9.1 Capital Cost

A review of **Section 8.9** (Order of Magnitude Cost Estimate) indicates that the Pre-cast, Pre-stressed Concrete Plank (Long Span) method of construction has the lowest initial capital cost of $19,020,000. It will be assigned a value of 1. The high capital cost alternative is the Structural Steel Truss method of construction. This alternative will be assigned a value of 0. Pre-cast, Pre-stressed Concrete Planks (Short Span) and Structural Steel Beams and Girders are the median cost alternatives. The price differentials for these alternatives are 95% and 65% respectively of that between the low cost (Long Span Concrete Planks) and the high cost (Trusses) alternatives. Therefore these alternatives will be assigned values of 0.95 and 0.65 respectively.

Rankings for these four (4) alternatives will be determined by multiplying their assigned values by the criterion weighting of 25%.

Short Span Concrete Planks:	0.25 x 0.95 = 0.24
Structural Steel Beams and Girders:	0.25 x 0.65 = 0.16
Structural Steel Trusses:	0.25 x 0.00 = 0.00
Long Span Concrete Planks:	0.25 x 1.00 = 0.25

9.2 O&M Requirements

The marine environment near the Wainiha Bridges has been found to be highly corrosive to steel where the salt air reacts strongly with metals. This corrosion leads to the loss of the metallic construction material along with structural weakening. It leads also to increased maintenance efforts to repair corroded and damaged areas as well as increased efforts at preventive maintenance through the application of protective coatings.

The first and last alternatives utilize pre-cast and pre-stressed concrete planks while the other two (2) alternatives utilize structural steel. The concrete plank alternatives also utilize steel rebar for reinforcement but this rebar is encased in concrete and not directly exposed to the salt air environment. These alternatives will be assigned a value of 1.00.

On the other hand, the two (2) remaining alternatives utilize structural steel that is directly exposed to the corrosive marine atmosphere and will experience greater amounts of steel degradation due to corrosion. Both alternatives will require repeated applications of protective coatings. However, corrosion still is expected to occur despite the coating of the structural members. This will result in increased maintenance efforts to replace or repair these types of bridges. The second alternative (Steel Beams) and the third alternative will be assigned a value of 0.00.

Rankings for these four (4) alternatives will be determined by multiplying their assigned values by the criterion weighting of 25%.

Short Span Concrete Planks:	0.25 x 1.00 = 0.25
Structural Steel Beams and Girders:	0.25 x 0.00 = 0.00
Structural Steel Trusses:	0.25 x 0.00 = 0.00
Long Span Concrete Planks:	0.25 x 1.00 = 0.25

9.3 Hydraulic Capacity

The primary purpose for a bridge is to provide an elevated corridor for vehicles and pedestrians over an obstruction. When that obstruction is a running stream or river, the governing design criteria is typically the ability to allow the same amount of water to pass under the bridge. **Section 8.3** (Bridge Design Span Lengths) discussed HDOT's design criteria requiring the hydraulic openings of the new bridge to be equal to or greater than that of the existing bridge.

Three (3) of the proposed alternatives require an additional pier for Bridges #2 and #3. The Long Span Concrete Plan alternative would not require any additional piers. Thus, the Long Span Concrete Plan alternative will be assigned a value of 1.00 while the remaining alternatives will be assigned a value of 0.00.

Rankings for these four (4) alternatives will be determined by multiplying their assigned values by the criterion weighting of 25%.

Short Span Concrete Planks:	0.25 x 0.00 = 0.00
Structural Steel Beams and Girders:	0.25 x 0.00 = 0.00
Structural Steel Trusses:	0.25 x 0.00 = 0.00
Long Span Concrete Planks:	0.25 x 1.00 = 0.25

9.4 Visual Aesthetics

The previous Wainiha Bridges were defined as contributing elements to the historic integrity of Route 560. This contribution is primarily derived from the one-lane nature of the bridges and its unique look, feel, and sound. The previous bridges were also low-profile in nature with protruding support members that braced the wooden bridge railings. In addition, the Visual Aesthetics takes into account the adherence to the recommendations set forth in the KHRCP.

All four (4) proposed replacement alternatives are similar in that they maintain the one-lane nature of the existing bridges. The Concrete Plank alternatives (Short and Long Span) and the Structural Steel Beam alternative are low-profile alternatives that look relatively similar to the Wainiha Bridges. However, the Long Span Concrete Plank alternative would utilize fewer piers than the Short Span Concrete Plank and Structural Beam Alternatives. The Structural Steel Truss alternative provides a look that is not in character with the existing bridges. Its look is more similar to that of the replacement ACROW bridges. The Short Span Concrete Plank alternative and Structural Steel Beam alternative will be assigned a value of 0.50 each. The Structural Steel Truss alternative will be assigned a value of 0.00 and the Long Span Concrete Plank alternative will be assigned a value of 1.00.

Rankings for these four (4) alternatives will be determined by multiplying their assigned values by the criterion weighting of 25%.

Short Span Concrete Planks:	0.25 x 0.50 = 0.13
Structural Steel Beams and Girders:	0.25 x 0.50 = 0.13
Structural Steel Trusses:	0.25 x 0.00 = 0.00
Long Span Concrete Planks:	0.25 x 1.00 = 0.25

The following tabular matrix summarizes the evaluations presented.

Table 8: Alternative Evaluation Matrix

Alternative	Capitol Cost	O&M Reqm'ts	Hydraulic Capacity	Visual Aesthetics	Total
Pre-cast/Pre-stressed Short Span Concrete Planks	0.24	0.25	0.00	0.13	**0.62**
Structural Steel Beams and Girders	0.16	0.00	0.00	0.13	**0.29**
Structural Steel Trusses	0.00	0.00	0.00	0.00	**0.00**
Pre-cast/Pre-stressed Long Span Concrete Planks	0.25	0.25	0.25	0.25	**1.00**

As seen in **Table 8**, the preferred rehabilitation alternative is the Pre-cast and Pre-stressed Long Span Concrete Planks.

10.0 CONCLUSION

10.1 Summary of Findings

- All three (3) Wainiha Bridges are part of Kuhio Highway Historic District on the National and Hawaii Register of Historic Places;
- All three (3) Wainiha Bridges are subject to the SOI's Standards for the Treatment of Historic Places;
- All three (3) Wainiha Bridges were severely structurally deficient and have been removed from service and replaced with ACROW Panel bridges;
- Treating the bridges as infill into the historic district following the SOI for Rehabilitation is the only viable option of the SOI treatment options;
- 80% of bridge funding will be provided by FHWA resulting in the bridges being subject to AASHTO Standards;
- One-lane bridges will require a design exception (widths of 16 and 11-feet);
- 50-year base flood elevation will be higher than Bridges #2 and #3;
- 100-year base flood elevation will be higher than Bridges #2 and #3;
- Bridges may be overtopped by tsunami events as well;
- Existing scour elevations for the three (3) Wainiha Bridges were determined to be;

  Bridge #1 – minus (-) 4.3-feet MSL at both abutments
  Bridge #2 – minus (-) 13.9-feet MSL at both abutments
  Bridge #3 – minus (-) 14.8-feet MSL at left abutment
  minus (-) 14.4-feet MSL at left pier
  minus (-) 28.0-feet MSL at right pier
  minus (-) 13.5-feet MSL at right abutment

10.2 Recommendations

- Rehabilitation of the Kuhio Highway Historic District for all three (3) Wainiha Bridges;
- New Bridges should be of one-lane vehicle travel configuration;
- Bridges #1 should have a maximum of 11-feet width (one 11-feet travel lane);
- Bridges #2 and #3 should have a maximum of 16-feet width (one 11-feet travel lane and a 5-feet bike/pedestrian lane);
- Bridges shall be aligned within the existing historic right-of-way to the extent practicable while complying with AASHTO geometric requirements;
- Bridges should be designed for AASHTO HS20 loading (posted 15 ton weight limit);
- Bridge foundations should be deep, drilled shafts 3-feet in diameter (larger diameter shafts may be considered to reduce embedment depths);
- Pier caps should extend below the stream waterline to replicate the previous bridge piers;
- Bridge superstructure should be of Pre-cast, Pre-stressed Long Span Concrete construction with bridge rails and approach guardrails;
- Bridge Railings should be of Structural Steel Tube (similar to Hanalei Bridge);
- Bridge spans should be based on utilizing up to 78-foot long concrete planks. This will eliminate the need for additional piers on Bridges #2 and #3;
- Deck planks shall be constructed of timber or timber facsimile; and
- Bridge pedestrian railings shall be constructed of timber or timber facsimile.

10.3 Discussion

In trying to create a Context Sensitive Solution (CSS) following the SOI standards, numerous discussions, meetings, and presentations between HDOT and the Hanalei Roads Committee (HRC) took place to establish the design criteria for this project.

After carefully comparing the CSS issues with the safety and mobility aspects of the facilities, HDOT has finalized their recommended alternatives for Bridges #1, #2, and #3. However, HRC and the local community have not accepted the proposed alternatives. The primary point of disagreement involves the bridge width for Bridges #2 and #3. HRC prefers to have a width less than 14-feet wide, while HDOT, FHWA, and AASHTO standards require a 16-foot clear width, as set forth in the KHRCP. At the January 26, 2012 Public Meeting conducted in accordance with Section 106 Procedures of the National Historic Preservation Act and the National Environment Policy Act (NEPA), the local community insisted upon 11-feet wide bridges as they existed before removal in 2004 and 2007. The community's reasoning for the narrower bridge width is for traffic calming, and to adhere to the historic nature of the roadway. The parties have agreed to continue working out a solution as we work through the Section 106 Process and the Environmental Assessment.

Figure 11 through **Figure 16** are renderings of the proposed Wainiha Bridges #2 and #3.

Figure 11: Rendering of Bridge #3 with Photo

Figure 12: Rendering of Bridge #3

Figure 13: Rendering of Bridge #2 and #3

Figure 14: Rendering of Bridge #2 and #3

Figure 15: Rendering of Bridge #2 and #3

Figure 16: Rendering of Bridge #3

11.0 REFERENCES

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