Tunnels and Underground Stations Technical Memorandum

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Honolulu High-Capacity Transit Corridor
Alternatives Analysis / Draft Environmental Impact Statement

prepared for:
City and County of Honolulu
Federal Transit Administration

prepared by:
Parsons Brinckerhoff Quade & Douglas, Inc.

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Acronyms Used in this Document

AA	Alternatives Analysis
CSC	Composite Section Costs
CTM	Conventional Tunneling Method
DBEDT	Department of Business, Economic Development and Tourism
DP	Development Plan
DTS	Department of Transportation Services
EPBM	Earth Pressure Balance Tunnel Boring Machine
FTA	Federal Transit Administration
HHCTCP	Honolulu High-Capacity Transit Corridor Project
ID	Inside diameter
LPA	Locally-Preferred Alternative
NATM	New Austrian Tunneling Method
OD	Outside diameter
OMPO	Oʻahu Metropolitan Planning Organization
ORTP	Oʻahu Regional Transportation Plan
PR	Puerto Rico
SEM	Sequential Excavation Method
SFM	Slurry Face Tunnel Boring Machine
TBM	Tunnel Boring Machine
TSM	Transportation System Management
UH	University of Hawaiʻi

Chapter 1 Introduction

This report documents the design of tunnels under consideration as part of the Honolulu High-Capacity Transit Corridor Project (HHCTCP). Chapter 1 includes a description of the area where the four tunnels under investigation are located. Chapter 2 describes the variety of underground structures being considered for this project, and the assumptions used to design the underground structures for this project. Chapter 3 summarizes the geotechnical condition along the tunnel alignments being considered. Chapter 4 presents possible construction methods to build underground guideway and stations. Included are recent mining technologies that significantly enhanced tunnel techniques and reduced construction costs. Chapter 5 summarizes the cost estimate to build the underground facilities being considered for this project.

Alternatives Considered

Four alternatives were evaluated in the Alternatives Analysis (AA) report. They were developed through a screening process that considered alternatives identified through previous transit studies, a field review of the study corridor, an analysis of current housing and employment data for the corridor, a literature review of technology modes, work completed by the O‘ahu Metropolitan Planning Organization (OMPO) for its Draft 2030 Regional Transportation Plan, and public and agency comments received during a formal project scoping process held in accordance with requirements of the National Environmental Policy Act (NEPA) and the Hawai‘i EIS Law (Chapter 343, Hawai‘i Revised Statutes). The four alternatives are described in detail in the *Honolulu High-Capacity Transit Corridor Project Alternatives Analysis Definition of Alternatives Report* (DTS, 2006a). The alternatives evaluated in the AA report are as follows:

- No Build Alternative
- Transportation System Management Alternative
- Managed Lane Alternative
- Fixed Guideway Alternative

In December 2006 Honolulu’s City Council selected the Fixed Guideway Alternative as the Locally-Preferred Alternative (LPA). The alignment selected as the LPA does not include any tunnels.

Tunnels Considered

Of the various alignment segments investigated in the AA, as part of the Fixed Guideway Alternative, four included tunnels. These tunnel alignments are located in the Chinatown and Capitol Special Design Districts that have cultural, historical, and environmentally sensitive areas. Tunnels were considered because they would have less long-term environmental impacts and/or better transit operations, as compared to an elevated or an at-grade fixed guideway. The four tunnels are shown in Figure 1-1 and include the following:

- Beretania Street Tunnel
- Waimanu Street Tunnel
- Kawaiahaʻo Street Tunnel
- King Street Tunnel.

It should be noted that the LPA selected by City Council is an elevated Fixed Guideway that follows Nimitz Highway and Halekauwila Street, makai of Chinatown and Downtown; and thereby does not include any of the tunnels. The LPA alignment follows the same alignment that was selected for the Honolulu Rapid Transit Program in 1992.

Beretania Street Tunnel: This alignment is located on the mauka side of Chinatown and Downtown and is located under Beretania Street that has a 5 to 6 traffic lane cross section. Placing the guideway underground minimized the impact to adjacent culturally-significant buildings: Saint Andrews Cathedral, Washington Place, and the State Capital. Length is 5,128 feet or 6,395 feet depending on whether it connects to North King Street or Dillingham Boulevard. On the ʻEwa side, the tunnel has a portal in the Kukui Gardens parking area for the North King Street connection and on properties makai of Kaʻaahi Street for the Dillingham Boulevard connection. On the Koko Head side, the portal is located in the City Municipal Building parking structure. There is one underground station at Fort Street Mall to serve the area along the North King Street connection alignment; and a second underground station makai of ʻAʻala Park for the Dillingham Boulevard connection.

Waimanu Street Tunnel: This tunnel, and the Kawaiahaʻo Street Tunnel, connect to an at-grade fixed guideway on Hotel Street that goes through the central portions of Chinatown and Downtown. They descend into tunnel to minimize impacts to ʻIolani Palace, the State Capitol, and Honolulu Hale. The Waimanu Street Tunnel is 3,840 feet long and has one underground station located next to the City's Municipal Building. The ʻEwa portal is located on Hotel Street just ʻEwa of Richards Street. The Koko Head portal is located on properties makai of Kapiʻolani Boulevard and Koko Head of Dreier Street.

Kawaiahaʻo Street Tunnel: This tunnel is similar to the Waimanu Street tunnel, but is shorter (3,000 feet long). The Koko Head side portal is located on Kawaiahaʻo Street on the Koko Head side of South Street. One underground station at Punchbowl Street would serve the area.

King Street Tunnel: The alignment for this tunnel goes through the central portions of Chinatown and Downtown. The tunnel is located under King Street, which in Chinatown has a 4-lane traffic cross section. The underground alignment minimizes impacts to Chinatown, ʻIolani Palace, King Kamehameha statue, and Honolulu Hale. Of the four tunnels, this is the longest (6,233 feet or 7,003 feet depending on whether it connects to North King Street or Dillingham Boulevard). The ʻEwa side portal location for the Dillingham Boulevard connection is similar to the Beretania Street Tunnel and for the North King Street connection is on properties on the ʻEwa side of Iwilei Road. The Koko Head portal is the same as for the Waimanu Street tunnel. There are 3 underground stations on the Dillingham Boulevard connection alignment: Ka‘aahi Street, Fort Street Mall, and Punchbowl Street. The Ka‘aahi Station is an elevated station on the ‘Ewa side of Liliha Street for the North King Street connection.

During the Honolulu Rapid Transit Program a tunnel alignment under Hotel Street was also considered and compared to a King Street Tunnel alignment. The King Street Tunnel was determined to be a better option because 1) the tunneling environment was found to be superior, 2) the station configurations were more patron friendly, and 3) costs were less. For the HHCTC’s AA, a Hotel Street Tunnel option was not considered. The King Street Tunnel was the same as the previous study, except for an alignment modification on the ‘Ewa side of Nu‘uanu Stream, where a new high-rise building has been constructed.

Table 1-1 includes a summary of the tunnel characteristics.

Table 1-1: Tunnels Considered

Tunnel Name	‘Ewa Tunnel Portal	Koko Head Tunnel Portal	Approximate Tunnel Length	Underground Stations
Beretania Street Tunnel (on Beretania Street/ South King Street alignment)	From North King: Kukui Gardens parking lot From Dillingham: makai side of Ka‘aahi Street	Makai side of Beretania Street through portions of the City’s Municipal parking structure	1.2 miles	• Ka‘aahi – from Dillingham only • Beretania/Fort
Hotel Street/ Waimanu Street Tunnel (on Hotel Street/ Waimanu Street/ Kapi‘olani Boulevard alignment)	Hotel Street between Alakea and Richards Streets	Makai side of Kapi‘olani Boulevard at current BMW dealership	0.7 mile	• King/Kapi‘olani
Hotel Street/ Kawaiaha‘o Street Tunnel (on Hotel Street/ Kawaiaha‘o Street/ Kapi‘olani Boulevard alignment)	Hotel Street Between Alakea and Richards Streets	Kawaiaha‘o Street between South and Curtis Streets	0.6 mile	• State Capitol
King Street Tunnel (on King Street/ Waimanu Street/ Kapi‘olani Boulevard alignment)	From North King: Lot at Iwilei Road and Nimitz Highway From Dillingham: Ka‘aahi Street	Makai side of Kapi‘olani Boulevard at current BMW dealership	1.5 miles	• Ka‘aahi – from Dillingham only • King/Fort Street Mall • King/Punchbowl

The conceptual plan and profile drawing illustrating the alignment of these tunnels and the stations along them are provided in Appendix A.

Types of Underground Structures

"Underground structures" refers categorically to all transit facilities that will be below ground surface when construction is complete. Three types of underground structures are described in this report: U-Wall sections, guideway tunnels (including tunnel portal), and stations.

Underground utilities for water, sewer, electric power, communications, and the like that either serve the transit system, or have to be relocated or otherwise accommodated to build the underground transit structures are not described in this report.

Construction methods for the underground structures are discussed in Chapter 4.

U-Wall Sections

The portion of the guideway that descends from ground level to the tunnel portal constitutes the U-Wall section. The U-Wall structure, or an open-topped box, is required as a transition from the at-grade or aerial transit line to the underground part of the alignment. These structures have the appearance of a pair of retaining walls. For various practical structural and water-tightness reasons, the walls and bottom are typically one structure, thus termed a "U-Wall."

This transition structure is formed by a ramp in an open cut section as shown in Figure 2-1. The vertical portions of the U-Wall retain the ground material on the sides of the guideway. Beyond the tunnel portal, shown in the back of the U-Wall section in Figure 2-1), the guideway is completely enclosed in a tunnel section.

Figure 2-1: U-Wall Section

Guideway Tunnels

The configurations of tunnel sections vary depending on the type of guideway that is enclosed. Transit study terminology uses the term "dual guideway," which is generic for having two tracks ("guideway") for trains operating in opposing directions on individual dedicated tracks. The "dual" term distinguishes the layout from other configurations such as with a single line having operation in both directions, and split configurations where the guideways have different alignments, for instance along different city streets.

Dual guideways can be installed in either a pair of parallel tunnels, with both tunnels being large enough for a single track, or a single tunnel large enough for both tracks.

All guideway tunnels being considered for this project have a dual guideway configuration. A dual guideway can be either horizontal (side by side) or vertical (one on top of the other) depending on the right-of-way available and other constraints. Table 2-1 provides an overview of the guideway layouts.

Table 2-1: Guideway Tunnel Layouts Overview

Guideway Type	Typical Uses	Advantages	Disadvantages
Dual Guideway, two side by side tunnels	• Standard application for most situations. • Required for center platform stations unless a separate transition structure is constructed.	• Least tunnel depth. • Separate tunnels provide emergency egress during emergencies. • Fire/life safety considerations may require separate tunnels.	• Requires two tunneling operations.
Dual Guideway, singe tunnel	• Can be used where right of way is limited. • Side platform stations to accommodate minimum center-to-center track spacing.	• Requires only one tunneling operation.	• Larger tunnel must be deeper to maintain required cover. • Fire/life safety considerations may require divider wall to provide egress during emergencies, particularly involving fire.
Dual Guideway, two vertically stacked tunnels	• Used where right of way is limited. • Usually considered only after traditional side-by-side configurations are not workable. • Rarely, if ever, first choice for tunnel layout	• Fits in least possible right of way.	• Typically requires 3-level station. • Requires two tunneling operations. • Constructability and sequence of construction, especially in poor tunneling conditions, have to be considered in more detail.
Single Guideway, split configurations	• Generally only used where underground structures prohibit one of the dual guideway alternatives.	• Fits in small right of way. • Single tunnel has more latitude for vertical and horizontal curves.	• Requires separate stations for inbound and outbound lines. • At transfer points requires elaborate station design.

Underground Stations

Station type (center or side platform), entrances, space for fare collection and patron cueing, escalators, stairways, elevators, and platforms for both inbound and outbound trains would be determined in preliminary design and were not considered in detail in this study. All underground stations would have these public areas but would also have non-public areas for mechanical/electrical physical plant, drainage, and maintenance.

From the transit operations perspective, center and side platform stations have different traffic (user/patron) circulation patterns and are laid out to fit site-specific need and practicality of transit station entrances.

Center Platform stations are usually adopted to provide the most patron-friendly options from either inbound or outbound trains to most or all station entrances. Twin single-track tunnels with a suitable separation are the simplest form of tunnel construction to connect to a center platform station. A reduction in passenger circulation space and escalator equipment can be achieved with this type of station. Station overall widths are also slightly smaller for center platform stations.

Side platform stations are usually adopted where a single large-diameter bored tunnel with twin tracks or a cut and cover box connects to the station. A transition structure is not needed to widen the track spacing that is otherwise required to accommodate a center platform. Side platform station types are also located in the vicinity of ramps or at the ends of the alignment where track switching using crossovers is required. With minimum center to center track spacing, the length of switches and cross-over is minimized.

Stacked stations with platform levels above one another for each track can also be adopted where the right of way is restricted. However, ease of passenger circulation is reduced with added disadvantages of an increase in depth needed for the tunnels, track separation, and the impact on the alignment configuration on each side of the station.

Stations are also typically described by the number of levels. Typically the first level is the ticketing concourse with lower levels being platforms and/or plant facilities. Table 2-2 presents the variety of station layout options and their typical uses, general advantages, and general disadvantages.

Table 2-2: Station Layouts Overview

Station Type	Typical Uses	Advantages	Disadvantages
Center Platform	• Where the guideway is in twin single track tunnels. • Travel demand and usage is high	• Overall width is less than side platform. • Requires less passenger circulation space and escalator equipment.	• If dual guideway is in single tunnel, requires transition structures.
Side Platform	• Where the guideway is in a single large diameter bored tunnel with twin tracks. • Where the guideway is installed using a cut and cover technique. • In the vicinity of ramps or where track switching using crossovers is required.	• Simple construction.	• Station is slightly wider than center platform type. • More escalator equipment is required.
Stacked Platform	• Where right-of-way is limited.	• Overall width is minimized.	• Passenger circulation is not optimal. • Deep station excavation in poor ground conditions has constructability issues.
2-Level	• Initial systems without interchanges. • Shallow station.	• Relatively least cost. • Better passenger circulation.	• Longer because plant equipment placed at either or both ends of station.
3-Level	• Deeper stations (required by clearances, tunnel form, or interchange layouts). • Interchange Stations.	• Stations can be shorter because plant equipment can be placed vertically.	• Slower passenger circulation due to depth. • More expensive.

General Assumptions for Layout

Tunnel Size

Precedent light rail systems with tunnels were reviewed (San Francisco Muni Central Subway, Tren Urbano (San Juan, PR), and Los Angeles Eastside Extension). At this stage of project development, a tunnel size was selected to be sufficiently large to accommodate the size likely to be needed when a rail system technology is selected. Light rail is a commonly used technology and typically requires the largest tunnel size. Based on precedent, an 18 foot 10 inch internal diameter (ID) tunnel was selected. Assuming a 10-inch-thick segmental precast concrete one-pass tunnel lining is used, the outside diameter (OD) would be 20 feet 6 inches.

Tunnel Depth

Existing structures, geologic conditions, and the overall track profile (vertical alignment) as the transit line goes from either at-grade or aerial structure to tunnel are all factors that are used to determine tunnel depth. In establishing a minimum tunnel depth, a key dimension is the distance from the top of rail to the finished ground surface. Definition of this clearance is important to establishing where the finished tunnel portals will be in relation to the tunnels running under cross streets or other surface features.

Where the tunnel can be built by cut and cover, the least depth is desirable and typically less costly. Avoidance of existing utilities, especially sewers and other drainage structures, usually requires greater tunnel depth. The other major factor in setting tunnel depth is getting the tunnel deep enough to match the depth required at underground stations, particularly where a mezzanine is desired for patron circulation. A mezzanine greatly increases flexibly of use by patrons but typically requires a deeper station and connecting tunnels.

Geologic conditions will often control tunnel depth. In general better rock or soil conditions are better for tunneling. The ideal condition is to set tunnel depth in the most favorable tunneling ground conditions. Geologic conditions and tunneling method control what is practical to construct at least cost and risk.

Apart from all considerations for tunnel depth indicated above, some minimal depth of tunnel is desirable. After the start of tunneling at a portal, a minimum thickness of ground above the tunnel excavation of 1.5 times the tunnel diameter (1.5 OD) was established.

Tunnel Ventilation

Fire/life safety considerations will establish requirements for mechanical ventilation of all underground structures. Later in design, ventilation schemes will need to be established in order to define where mechanical rooms will be needed. Once the basic plan and profile of each alternative is established, ventilation schemes can be established. At this level of study (alternatives analysis), requirements for ventilation typically do not drive definition of an alternative.

Underground Station Size

At this time, underground station configurations are only generally known. Platform length has been set at 280 feet, and nominal total underground station box length of 300 feet was used for layout purposes.

Tunnel Layout Geometry Guidelines

Based on precedent from past and on-going transit projects, the following guidelines were used in the layout of the tunnels.

Tunnel Curvature

The minimum turning radius for tunnel alignment to be constructed using a pressurized face tunnel boring machine (TBM) was set at 450 feet. In very specific situations that site conditions impose, a lesser value may be feasible when special accommodations are made in the design of a TBM. In the case of the Waimanu Tunnel, which has a 400 feet radius curve, the length of tunneling on the curve is short (distance less than 150 feet) and is acceptable. For non-TBM-excavated tunnels, there is typically no limit on how tight a curve can be, and practical transit operations alignment standards would apply.

Grade

Grades are generally set by transit operations considerations, not by tunneling considerations. Grades of up to 6 percent are feasible for rail-operations in a TBM-excavated tunnel; in general, the project guideline is to keep grades less than 3 percent once the track has made the transition from surface or elevated to underground.

Portals

The physical "portal" for the start of tunneling is usually not the same as finished tunnel portal that the public will see. This situation exists where the transit line goes from aerial, or at grade, into a portal approach U-wall section and then to the finished tunnel portal and start of the tunnel. As an example, see the 'Ewa portal for the Waimanu Tunnel on Figure TWAI-1 in Appendix A. The permanent 'portal" is at Sta 1380+20, but the portal for the start of tunneling that was used in the cost estimates is 1383+50. For the final portal, the distance from ground surface to crown (top) of the tunnel can be minimal. It can be on the order of a few feet, but usually is greater to give more distance above the structure to accommodate utilities and landscaping.

Side-by-Side Tunnel Separation

Preferred typical spacing for extended lengths: 2.0 OD center-to-center.

Preferred minimum spacing: 1.5 OD but can be reduced to 1.25 OD center-to-center for transition segments and special situations.

This project is known to have very limited right of way in the downtown Honolulu area with many constraints existing in the form of historic fences, structures, and the like. With the use of ground improvement to stabilize the pillar between adjacent tunnels, clear distances between the extrados of tunnel linings can be less than what results with the 1.25 OD spacing, which gives about a 5-ft-wide pillar. Ground improvement may consist of mechanical reinforcement, grouting, or other appropriate means.

Over/Under Tunnel Separation

Minimum center-to-center spacing in vertical dimension or radial separation distance for transitions from side-by-side to over/under configuration was set at 1.5 OD. An absolute minimum vertical separation is 1.25 OD center-to-center. At this time, there are no situations where this guideline would be applicable.

Chapter 3 Geological Conditions

Geologic conditions are complex along the alignments being considered. Although no new subsurface investigation was undertaken for this study, there is a fair amount of subsurface information available from previous work along similar alignments. Additional understanding of the subsurface has come from the experience of deep building excavations in the downtown Honolulu area. This study has made use of this information to characterize tunnel ground conditions.

Specific subsurface investigations were preformed for transit tunnels during prior transit studies, including: Hotel Street (ICF Kaiser, 1991) and King Street (ICF Kaiser 1992). Where the old and current alignments are the same or in close proximity, specific geologic information is available. For a new tunnel alignment (Beretania Street/King Street), definition of the geologic conditions was based on an understanding of the geologic setting, and extrapolation where thought to be reasonable from the existing borings done for the prior transit studies.

The previous geotechnical studies were considered a conceptual level study. Regardless of which tunnel may be selected, a more detailed geotechnical engineering investigation would need to be performed to provide site-specific information for design, cost estimation, and construction planning.

Geology of O‘ahu and Honolulu

The Island of O‘ahu is comprised of two volcanoes: the Koolau Volcano and the Wai‘anae Volcano. The Wai‘anae Range is the older of the two volcanoes and lies to the west of the younger Koolau Volcano.

The Wai‘anae Volcano is a shield volcano built up by a series of eruptions, which produced the Wai‘anae Volcanic Series. The Wai‘anae Mountains, the eroded remains of the Wai‘anae Volcanic Shield, comprise western O‘ahu.

The Koolau Volcano is an unusually elongate shield volcano built principally by eruptions along a northwest-southeast trending rift zone. The lavas produced during the shield-building phase of the volcano are known as the Koolau Volcanic Series and consist of series of lava flows and ash that can range in thickness from less that 1 foot to several feet. The Koolau Mountains, the eroded remains of the Koolau Volcanic Shield, are approximately 37 miles long, trending northwest-southeast, and comprise approximately two-thirds of O‘ahu (Macdonald et al, 1983).

A long period of volcanic quiescence followed the Koolau shield-building stage, during which erosion occurred and alluvium and marine sediments accumulated along coastal regions. Deep valleys were incised into the bedrock by major streams and subsequently filled with sediments.

Following a long period of volcanic quiescence, volcanic activity resumed. These subsequent eruptions formed cinder cones, such as Diamond Head, and constitute the

Honolulu Volcanic Series. Lavas of the Honolulu Volcanic Series include basalt and ash (Macdonald et al, 1983).

Subsurface Geology

In 1992 12 exploratory borings were drilled along the King Street tunnel alignment, ten in-hole permeability (falling head) tests were performed, and five piezometers were installed. A number of soil borings were also drilled along the Hotel Street tunnel alignment during previous studies. The borings penetrated to a depth of approximately 100 feet below ground surface. The soil and rock encountered in those borings was grouped into the following nine main stratagraphic units:

1. **Basaltic Lava Flows**. Typically dense to very dense, hard, highly to slightly fractured, fresh to moderately weathered, vesicular basalt. Lava flows encountered in this study probably belong to the Honolulu Volcanic Series.
2. **Alluvial Deposits**. Primarily saturated soft to stiff silts and clays and very loose to dense silty sand and gravel. Cemented nodules and basalt boulders are present and should be expected in tunneling through these deposits.
3. **Organic Deposits**. Primarily saturated very soft to medium stiff, highly compressible peat, organic silty sand and sandy silt containing organic fibers and decayed wood fragments. Near Nuʻuanu Stream these organic deposits may also contain flood deposited pebbles, gravel, and boulders.
4. **Lagoonal Deposits**. Consists predominantly of very soft to medium stiff highly compressible sandy and gravelly silt and clay, and very loose to loose silty sand.
5. **Reef Deposits**. Three types of reef deposits were encountered in the exploratory borings.
    a. Coral (Type I). Formed in-place, hard, slightly weathered to unweathered, coral reef.
    b. Coral (Type II). Reworked and recemented coral fragments.
    c. Coralline Sand and Gravel. Generally consists of locally cemented to uncemented calcareous sand (a weak sandstone-like material) and cemented to uncemented coralline gravel, sometimes in a clayey to silty matrix.
6. **Beach Deposit**. Primarily loose to medium dense silty fine sand and poorly graded sand, usually interbedded or associated with reef deposits. Some of the beach deposits are cemented and others contain gravel.
7. **Volcanic Cinders**. Consists primarily of poorly graded sand-sized material and silty sand. In some areas, particularly where the deposit is relatively thick, such as within the infilled channel under Kapiʻolani Boulevard, they appear to be fused or cemented.
8. **Volcanic Tuff**. Typically exhibited as a rock that, as a result of high during volcanic activity, consists of fused volcanic rock particles, closely to moderately

fractured, thinly bedded, but may contains cobble and boulder-sized material also deposit during explosive volcanic activity.

9. **Fill** (man-made). Generally consists of silty sand and gravel. The gravel component is predominately composed of coral or basalt. The fill may contain cobbles, boulders, other debris and obstructions.

All of these deposits are considered part of the caprock on the coastal plane of O‘ahu. The fill material was generally located near the surface, but the other deposits were found at a wide variety of depths along the tunnel alignments. Results of the geotechnical exploration indicate that world-wide fluctuations in sea level from approximately 640,000 years ago to present resulted in migrating shorelines and depositions of a wide range of alluvial deposits and marine sediments at various times. The sea level changes also caused periodic erosion of those deposits, creating channels that where later filled in by lava flows, reef deposits, and other alluvial or marine deposits as sea levels continued to change. These factors resulted in the wide variety of relatively thin, horizontally-discontinuous deposits encountered in the borings.

The geology encountered can be most easily described by breaking the tunnel alignments into segments. As in indicator or tunneling conditions, the upper approximately 50 feet of the material encountered in each segment is briefly described below.

- **‘Ewa end (‘A‘ala Park) to Maunakea Street (Chinatown)**. This area contains a major erosional feature that was infilled by organic and lagoonal deposits. Tunnels would be constructed mainly in very soft to soft, highly compressible organic deposits.
- **Maunakea Street to Bethel Street (Chinatown)**. This segment is dominated by a range of reef deposits overlying alluvial deposits, including beach deposits. Tunneling would be in weak rock and mixed-face conditions.
- **Bethel Street (Chinatown) to Punchbowl Street (Capital District)**. Reef deposits are predominate in this section with the alluvial deposits at deeper depths than the previous section. Tunneling would be in weak rock and mixed face conditions.
- **Punchbowl Street (Capital District) to Koko Head end (Kākā‘āko)**. An erosional feature infilled by alluvial deposits and volcanic cinders was encountered in this section. Tunneling would be in alluvium, mixed face and weak rock, but the in-filled section would be tunneling in saturated, flowing ground conditions in the cinders.

During previous studies no borings were advanced along the Beretania Street tunnel alignment. Due to its slightly more mauka position it would be expected that fewer lagoonal and coral deposits would be present and more alluvial and volcanic deposits would be present.

Hydrogeology

The groundwater elevation observed during previous studies generally indicated the groundwater elevation is generally within a few of sea level throughout the study area. Ground surface elevations range from approximately 5 to 25 feet above sea level, with the more mauka Beretania Street being higher than Hotel Street and King Street. Groundwater elevation was observed to fluctuate with ocean tides. For all planning purposes, all tunneling work can be considered to be below the water table.

Geologic Tunneling Constraints

Geologic conditions are the major factor influencing the method of tunnel construction and strongly affect the final design characteristics of the permanent structures. Based on the results of the previous studies the following factors may constrain the construction method and underground structures:

- Groundwater is shallow and most underground construction will take place below the groundwater table in saturated conditions.
- Geologic conditions are comprised of materials considered to be relatively soft, with the exception of basalt (see following regarding basalt), which in construction terms would be “soft-ground” tunneling.
- Basalt, which is extraordinarily hard, would require “hard rock” tunneling methods to excavate, such as by blasting. When tunneling encounters both soft ground and hard rock, a “mixed face” condition exists. If the basalt can be avoided then mixed faced tunneling involving hard rock would be circumvented. It appear possible that the basalt could be avoided in the more makai tunnels but the more mauka Beretania Street tunnel is more likely to encountered the basalt. The level of geotechnical investigation completed thus far is insufficient to establish if basalt can be avoided.
- Other “mixed face” tunneling conditions may be encountered given the interbedded nature and the wide variation in strength or behavior between the relative soft geologic strata, for example cemented coral deposits and potentially flowing beach sand deposits.
- Construction in lagoonal soil deposits, which are very soft, will probably require ground improvement techniques, regardless of the selected tunnel construction method.
- Ground and structure settlement during construction will be an issue throughout the tunnel alignments due to the shallow groundwater and fine-grained nature of many of the soil deposits.
- In open cuts, excavation by blasting or by mechanical methods, such as hoe ram equipment, may be required to excavate through the coral reef deposits.

For some transit structure types, more than one construction method may be applicable. Construction method is important since community and environmental impacts vary considerably between the alternative methods. At one extreme is true tunneling (completely below the ground surface); at the other extreme is cut and cover construction that starts with a deep excavation in which the concrete structures are built, the remaining excavation is then backfilled, and the ground surface (street or other) is finally restored.

This report presents the range of construction methods. Although the emphasis is on the application of tunneling, which typically has the least public impact during construction, the full range of underground structure construction methods was considered. Feasibility with current tunnel construction technology and best available technology are addressed. Cost and risk in general are considered in a qualitative sense.

Guideway Construction

Constructing the tunnel guideway could be performed using a variety of methods, including:

- Cut and Cover
- Bored Tunnels
  - Tunnel Boring Machines (TBMs)
  - Conventional Tunneling

These methods are discussed in the following sections and summarized in Table 4-1.

Table 4-1: Summary of Guideway Construction Methods

Alternative	Primary Uses	Advantages	Disadvantages
Cut and Cover	• Shallow guideway. • Transitions to at-grade or elevated guideway.	• Generally simpler working conditions due to access from surface.	• Significant interference with subsurface utilities. • Requires extensive temporary or permanent utility relocation. • Significant disruptions to at-grade facilities such as roads.
Bored Tunnels in General	• Deep guideway. • Where there is a need to avoid disruption to major city streets, buildings, or utilities.	• Less environmental impact than other methods. • Less utility relocation required compared to cut and cover.	• Typically more costly. • Difficult access due to single point of access and length/depth of tunnel.

Alternative	Primary Uses	Advantages	Disadvantages
TBMs	• Long runs of deep guideway.	• Possible to construct water-tight tunnel in one pass. • Dewatering not required where pressurized-face TBMs are used. • Generally faster than conventional tunneling once underway.	• Tunnel geometry is restricted to the circular shape. • Tunnel curvature is limited by ability of TBM being used.
Conventional Tunneling	• Short runs of deep guideway. • Transitions from guideway to stations or other structures. • Where ground conditions preclude the use of TBMs (hard rock or extreme mixed face).	• Tunnel geometry can be customized to the project. • Faster mobilization for construction compared to TBM. • No limits on tunnel grade or curvature.	• Requires dewatering in saturated conditions. • Higher risk of tunneling problems in unstable ground, such as running/flowing sands. • Requires the removal of a greater volume of material than TBMs.

Cut and Cover

Cut and cover tunnel construction is a traditional method used for over 100 years for underground transit construction. Cut and cover construction is typically employed where guideway is shallow and in the transitions where the guideway rises to ground level and connects to an at-grade or aerial structure. In these transitions the cover to the ground surface reduces, and a cut and cover box is commonly used until the roof slab rises to ground level. Thereafter, the transition structure is formed by a ramp in an open cut section (U-wall).

Construction of cut and cover guideway under city streets involves complex site arrangements to facilitate traffic movements around the work site and usually involves extensive utility diversions prior to commencement of construction. Major utility diversions can take up to two to three years and must be considered as long lead time work on the project critical path before cut and cover construction can commence. Where utilities cannot be diverted, they must span the excavation and are at risk of damage during the excavation and concreting period. In addition, for larger utilities it is not possible to provide excavation support in advance and complex support systems involving highly engineered ground improvement techniques, such as grouting, are sometimes necessary.

Bored Tunnel

Tunnel construction can be accomplished using either Tunnel Boring Machines (TBM) or conventional methods. Either TBM or conventional tunneling is preferable to cut and cover where there is a compelling need to avoid disruption to major city streets, to avoid the environmental impact of open excavations, or to go under existing structures.

Tunnel Boring Machines

In the previous studies of transit in Honolulu (ICF Kaiser, 1991 and 1992), tunneling methods as practiced at that time were considered. For many tunnel projects, the long-established, older tunneling techniques for difficult geologic conditions had questionable applicability because of being too costly or considered to be technically not feasible to construct. Tunneling under compressed air is an example. In the years since those studies, approximately 15 years, there has been substantial, positive change. As elaborated below, methods and equipment that were emerging for use in the early 1990's have been improved to become often a method of choice for tunneling on many difficult tunneling projects. What was previously difficult to construct can now be done with less risk and greater assurance of success.

Tunneling equipment technology changes have generally made tunneling more cost-competitive. The major improvements have come with less risk of tunneling problems, improved quality of tunnel lining with regard to water tightness, and greater assurance that the tunneling project will be completed successfully. The tunneling equipment on its own will not be sufficient to ensure success. Achieving success in construction will also require a program of risk management, and construction contract terms that deal with projects risks in the context of a tunnel construction projects including the selection of competent contractors that bring experienced management and labor to the project.

A variety of soft ground tunneling equipment, which are generically termed "tunnel boring machines" (TBM), are in use to varying degrees around the world at this time. They include:

- Free Air Tunnel Shield
- Compressed Air Tunnel Shield (limited)
- Pressurized/Closed-Face
    - Earth Pressure Balance Machine (EPBM)
    - Slurry Face Machine (SFM)

These TBMs are described in more detail in Appendix B.

The tunnel lining, which is installed as TBM excavation takes place, can also vary. Most commonly the lining material is segmental precast concrete that is assembled to form a ring. Segments and each successive ring of segments are bolted together. Special gaskets made from neoprene or other elastic material placed between all segment joints creates a watertight tunnel lining. When precast tunnel lining with gaskets is installed behind a TBM, this is referred to as a "one-pass" lining. A secondary lining after tunnel excavation is not needed. More details of lining of the tunnel are also described in Appendix B.

The use of pressurized/closed-face TBMs and one-pass precast concrete tunnel lining has become routine globally, as well as in the United States. With the present understanding of site conditions, closed-face TBMs would be required on this project in order to successfully tunnel through the varied soft-ground conditions below the groundwater table. Using TBMs of this type, the dual guideway can be twin single-track tunnels with 2 tunnels each about 20.5 feet in diameter, or one larger tunnel (well over 30 feet diameter) for both tracks. Even with TBM-excavated tunnels, some tunnel excavation by conventional means is typically required for transition and special structures.

Examples of recent and relevant projects that employed the pressurized-face tunneling construction method include:

- Los Angeles MTA, Eastside Extension. Two EPBMs were used that installed one-pass precast segmental concrete tunnel lining to construct light rail transit tunnels. The tunnel was designed for earthquake conditions.
- Portland, Oregon Westside and Eastside Combined Sewage Overflow (CSO) Projects. Slurry-face type pressurized-face EPBMs were used for the Westside project for long tunnels well over 10,000 ft in length with diameters approximately 15 feet. For the in-progress Eastside project, a 25-foot-diameter slurry TBM is being used. Tunnel ground conditions consist of an ancient river deposit of cobbles and gravel under or next to the Willamette River.
- Port of Miami Tunnel. Although construction has not started on this project, design/build procurements are in progress that require the use of either an EPBM or a slurry shield TBM to provide the required tunnel face stability for a pair of 45-foot diameter tunnels. Tunnel face conditions are geologically similar to those in Honolulu with marine deposits of interbedded soil and coral below sea level.

Conventional Tunneling

Excavation by mining rather than the use of TBMs has varying terminology. For the purposes of this report, the following are not different “methods” but different names and acronyms that have resulted from global tunnel practices:

- Conventional Tunneling Method (CTM)
- Sequential Excavation Method (SEM)
- New Austrian Tunneling Method (NATM)

Using conventional tunnel construction methods, the geometry of the tunnel can be customized to the needs of the project and be designed for twin or single tracks. Even with TBM-excavated tunnels, some tunnel excavation by conventional means is typically required for transition and special structures.

These conventional tunneling methods are nowadays commonly used for transitions, short lengths of tunnel where the use of TBMs would be uneconomic, and for ground conditions unsuitable to TBMs. These methods also use mechanical excavation methods such as road headers, impact breakers (hoe-ram), and the like. The specific equipment used for excavation is dependent on ground conditions, in particular rock hardness, groundwater conditions, and permeability.

In Honolulu conventional tunneling using road-headers or manual mining will require, for the mainline tunnels, the use of SEM or the NATM. Each method relies on, depending on ground conditions, minimizing the volume of tunnel excavation that can be physically excavated and gradually enlarging by mining heading and bench or by mining for larger tunnels in a sequential process at multiple headings. It is anticipated that conventional tunneling will be required primarily for cross passage construction or for starter tunnels for TBM assembly and start of tunnel driving from a shaft.

In the process of conventional tunneling, an initial tunnel lining must be placed as the headings (a specific portion of the full face of tunnel being advanced) are excavated, or mined forward in limited lengths. By the use of shotcrete with mesh or fiber reinforcement, and possibly steel dowel ground reinforcement, an initial tunnel lining is established. This initial lining can be strengthened, if necessary, by the use of lattice girders or steel arch rib supports that are shotcreted into the tunnel lining. After tunnel excavation is complete, it is most often necessary and desirable to install a waterproof membrane on the shotcrete initial lining followed by the final cast-in-place concrete lining. The labor input is greater and the rate of excavation with conventional (sequential excavation) tunneling is significantly slower than a one-pass lining erected using a TBM. Therefore, it is economically advantageous to undertake long tunnel drives, the majority of tunneling, wherever possible, using TBMs. However, TBMs cannot tunnel everything, and some conventional tunnel is usually needed.

Station Construction

From the construction perspective, constructability of any underground station becomes a matter of depth and width of excavation, and the impact of construction on the community. Three principal approaches to underground station construction are as follows:

- Cut and cover (bottom up)
- Cover and cut (top down)
- Conventional mining

Unlike the pure transit guideway tunnel segments, the stations typically have irregular shapes. They are an underground building that requires retaining walls in addition to floors and columns like that of a building. Special design and constructability conditions for underground transit stations must be addressed. An example is that deflection of the retaining walls must be considered as part of the initial wall design. Historically-based values of building damage related to ground movement caused by wall deflections from past underground transit stations have resulted in requiring stronger or stiffer walls for purely constructability reasons, not for the final structural loading. Another special requirement is that a soil retaining structure must be adopted where groundwater levels are high to limit final leakage into the structure and, thereby, reduce consolidation settlement where compressible soils are present, which could damage buildings. To minimize settlement where close to buildings, a stiffer structure is commonly adopted. The varying level of stiffness of cut and cover, cover and cut, and open cut construction are shown in Table 4-2.

Table 4-2: Retaining Wall Stiffness

Support Stiffness	Description/examples
High	*Cover and cut construction:* temporary struts installed before permanent works (floors or roof of transit station) are installed at high level..
Moderate	*Cut and cover construction:* temporary struts or tie-backs installed before permanent work (invert/bottom slab of transit station) are installed at low level.
Low	*Cantilever walls, (open cut):* temporary struts of low stiffness or temporary props installed at low level.

Source: CIRIA C580, London 2003.

The types of retaining wall that can be used similarly reflect structure stiffness and water tightness and, generally in urban areas, slurry walls are used where deflections must be tightly controlled and where the risk of significant wall movement cannot be tolerated. Table 4-3 summarizes the types of retaining walls.

Table 4-3: Retaining Wall Types

Wall Type	Advantages	Limitations
Steel Sheet piles	• Provides an economic finish for shallow walls. • No excavation support to be removed. • Suitable as a water-retaining wall. • Can be used as both a temporary and permanent wall. • Lower cost.	• Maximum pile length approximately 100 feet. Practical length substantially less in stratified with hard strata. • Potential declutching in coarse grained soils. • Flexible wall with higher deflection.
Soldier pile and timber lagging	• Can be installed around obstructions such as utility crossings. • Lower cost wall	• Not suitable for long term water retention. • Cannot be used for excavation below groundwater in coarse grained soils.
Contiguous pile (Tangent Pile)	• The lowest cost form of concrete piled wall.	• Not a water retaining solution. • Not a permanent solution in any soil due to gaps between piles, unless a structural facing is applied.
Secant piles	• Possible to construct a permanent water retaining wall. • The material for the primary female piles is either a standard concrete mix, retarded to reduce strength when the secondary piles are constructed or a reduced strength concrete mix.	• The depth is limited by verticality tolerances which may determine the extent of contact of the secant piles. • Water tightness. • More expensive wall.

Wall Type	Advantages	Limitations
Slurry Walls (Cast-in-place concrete diaphragm walls)	• A permanent water-retaining wall. • Can be installed to great depths, provided verticality tolerances can be accepted. • In some circumstances, the face of the diaphragm wall can form the final finish subject to surface cleaning and removal of protuberances. • Use of water stops in the wall joints significantly reduces water paths through joints.	• Horizontal continuity is difficult to achieve between panels. • Cannot follow intricate plan outlines. • The installation equipment is extensive, requiring large site areas for accommodation of the fluid plant, reinforcement cages and the excavation plant. • Disposal of support fluid is costly and dependent on fluid type. • Most expensive wall due to mobilization costs.

Adapted from: CIRIA C580, London 2003

Varying solutions have been developed to expedite the construction of underground stations. Experience has shown that the use of large open site areas fully surrounding the station box, and unhindered by traffic maintenance requirements, permits fast wall installation, particularly using a sophisticated plant (excavation equipment and all related equipment to manage permanent materials and excavated material). Specifically engineered and purpose-built equipment has evolved to permit construction of station walls in difficult ground conditions, such as where hard strata are present. In difficult conditions with varying strata, rock, and boulders, a diaphragm wall can be constructed using a Hydrofraise, which is a drilling machine that has the cutter head or excavators powered by down-the-hole hydraulic motors. It is typically mounted on a crawler crane and uses a slurry system to remove cuttings from the excavation. Although more expensive to mobilize, such specialized equipment gives significant benefits in production rates for wall installation and thus reducing the time needed for site occupation. Ease of access to the site also permits use of multiple units of excavation equipment such as long neck excavators and can allow for alternative methods of concrete works such as precast beam installation for roof slabs or prefabricated reinforcement cages for lower slabs. In addition, construction allowing the use of tower cranes throughout the structural construction period greatly expedites the delivery of equipment and materials to all areas of the excavation. Wherever possible constraints on open excavation should be avoided.

The critical activities in the scheduled completion of an underground station include:

1. Completion of all above and below ground utility diversions including traffic equipment relocations and road signage
2. Completion of traffic diversions allowing work to start
3. Completion of diaphragm wall excavation and concreting
4. Completion of bulk excavation
5. Completion of tunnel breakouts
6. Tunnel connections
7. Completion of station base slab after tunnel connections

8. Completion of remaining structural works
9. Flood-proofing and station cleaning
10. Track installation for equipment delivery
11. Works Train access
12. Escalator delivery
13. Electro mechanical systems and finishes installation
14. Local testing
15. Systemwide testing and test running
16. Trial running
17. Approval for service running

Of the above, items 1 and 2 require detailed interface with, and the approval of, external agencies. Successful coordination with these agencies is critical to a timely start of the works and subsequent compliance with the project schedule and budget. The remaining activities lie within the control of the owner except where these works result in an impact on adjacent residents and users. Typical influences on project progress include third party concerns such as safety, noise, vibration, night-time working particularly during concreting, dust, water discharge from excavation particularly during heavy rain, settlement and ground loss outside the site, and construction traffic. Public perception of each of these activities must be carefully managed in order to facilitate the required completion of the works within the site.

Table 4-4: Summary of Station Construction Methods

Alternative	Primary Uses	Advantages	Disadvantages
Cut and Cover	• Shallow stations in open areas.	• Simple. • Least Costly.	• Significant interference with subsurface utilities. • Significant disruptions to at-grade facilities such as roads.
Cover and Cut	• Shallow stations where impact to community is an issue.	• Reduces community impact relative to cut and cover.	• Significant interference with subsurface utilities.
Mining	• Deep stations. • Where there is a need to avoid disruption to major city streets, buildings, or utilities.	• Less environmental impact than other methods.	• More costly. • In poor ground conditions the costs are considerably higher.

Cut and Cover (Bottom Up)

Cut and cover is the simplest and often least costly for shallower depths. The sequence of cut and cover construction is illustrated in Figure 4-1. Cut and cover, also known as "bottom up" construction has vastly different construction impacts compared to conventional mining and results in a tunnel box structure, and in the context of this report is considered a "tunnel", but construction is not considered "tunneling."

Cover and Cut (Top Down)

Cover and cut, also known as "top down", construction is an important variation from cut and cover (bottom up) construction in that it is intended to reduce community impact by reducing the time the street or other areas are completely committed to construction. The sequence of cover and cut construction is illustrated in Figure 4-2.

Conventional Mining

The principal advantage of a mined station is substantial reduction, to near elimination in some situations, of community impact by construction. Mined stations are typically more costly than cut and cover or cover and cut. Feasibility and cost of construction are controlled largely by geologic conditions. In competent rock, underground stations are readily excavated with conventional mining techniques. For poor ground conditions of weak or poor quality rock, or soil, cost is typically much greater. Where project conditions are compelling, underground transit stations in such conditions are feasible. An example is the Río Piedras underground transit station in San Juan, Puerto Rico. No mined stations are being considered, but more technical details are presented later in this report.

Instrumentation and Monitoring

For all forms of underground works, it is necessary to understand the ground response to underground excavation and, in urban areas, large numbers of arrays of instrumentation are necessary to continuously provide feedback on ground movements, deformation of the excavation support under load, and the impact of settlement on adjacent structures caused by excavation. Instrumentation can be monitored either remotely or by manual means. For instance, a field surveyor monitoring large numbers of instruments may not be able to collate the data and issue the information for review to the engineer until the end of the day or even the day after the readings. Therefore, if a problem arises and is not immediately identified, it may take 8-12 hours after readings have been taken to observe that alert levels have been exceeded. Therefore in inaccessible locations or for significant structures such as buildings, key roads, or utilities where information is required quickly, remote monitoring is usually prescribed. These instruments come with a higher capital cost but this can be offset when consideration of the labor required to undertake less frequent manual readings.

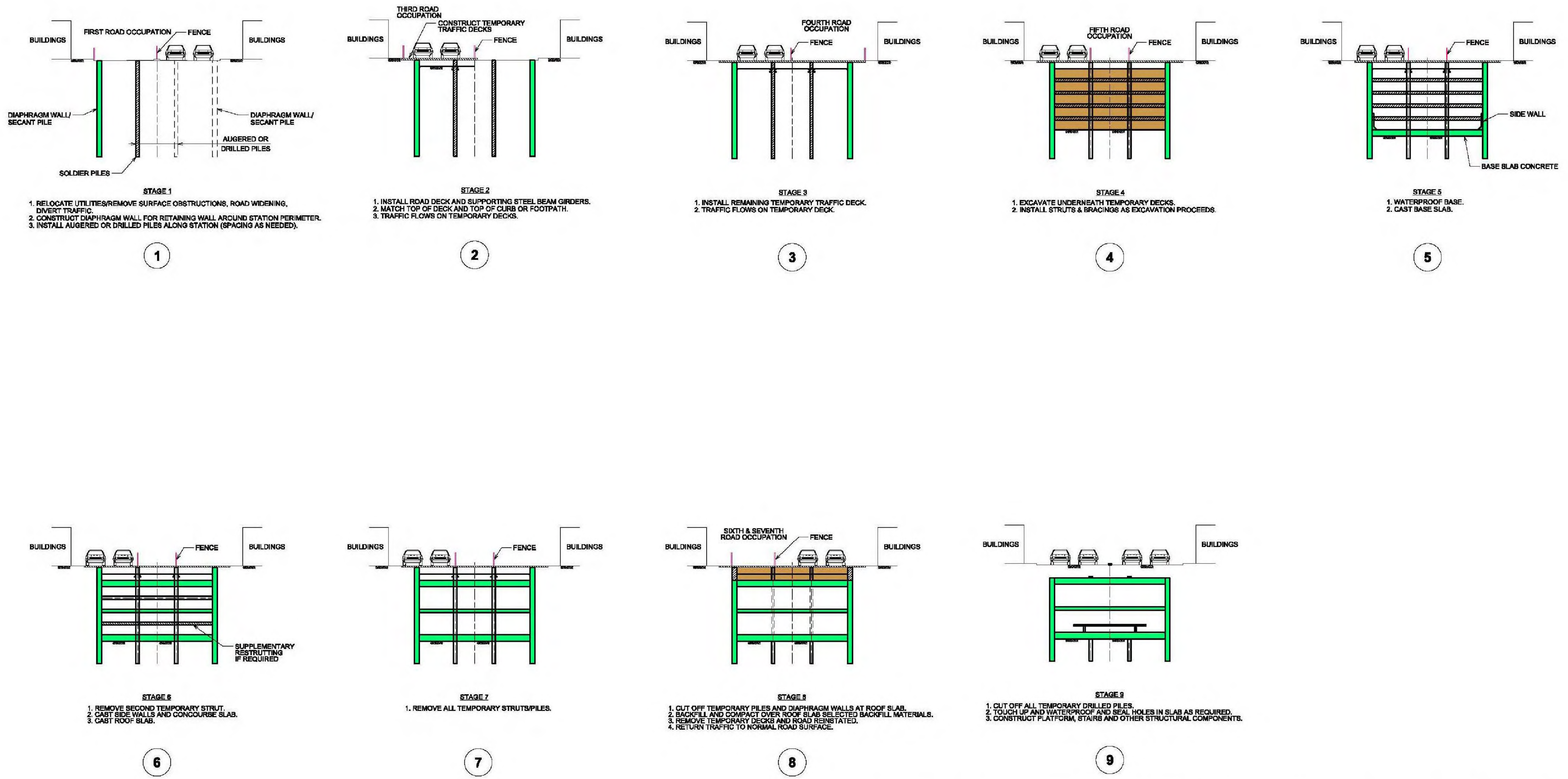

Figure 4-1: Station Excavation and Construction Method using Cut and Cover (Bottom Up)

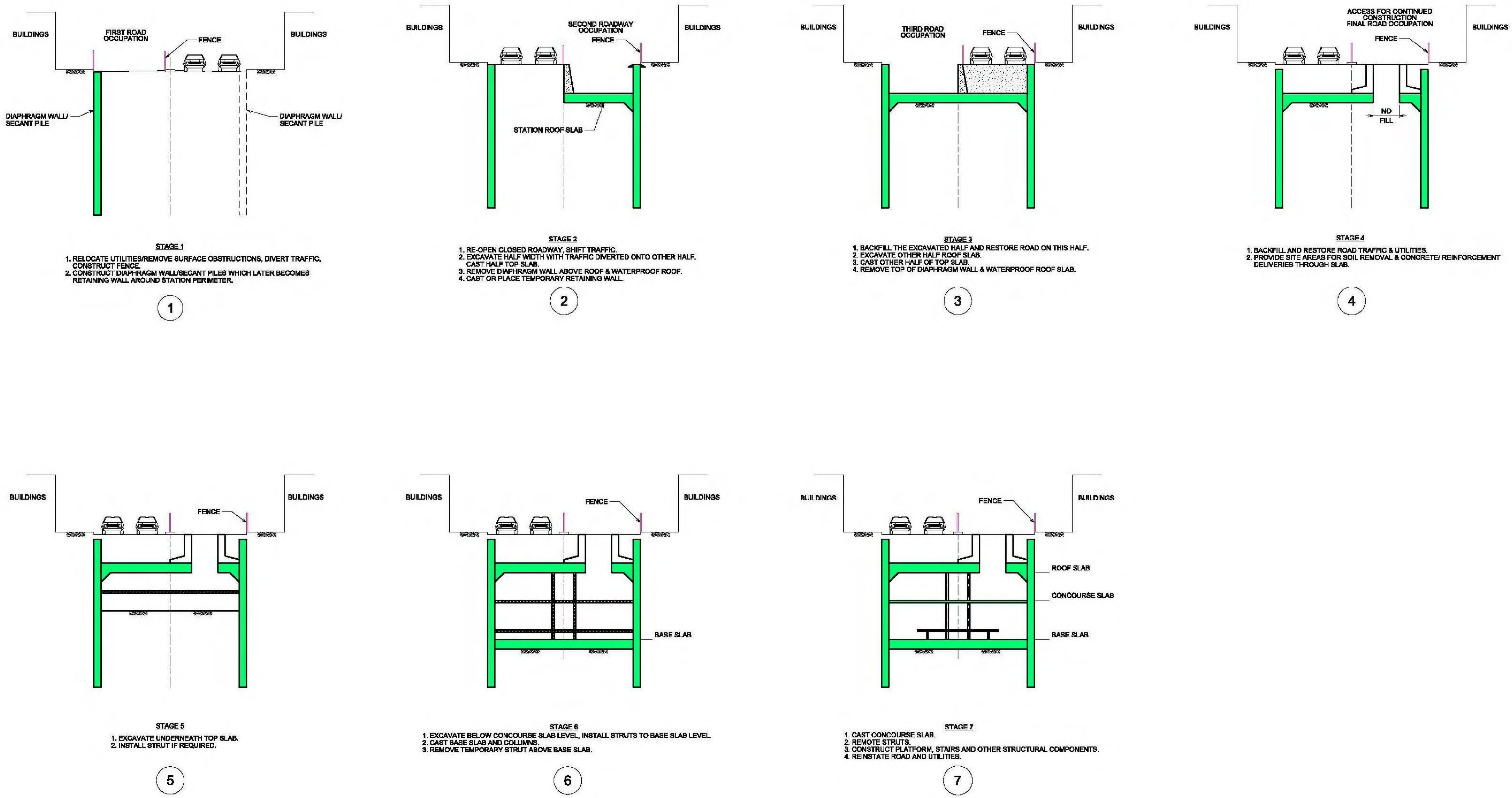

Figure 4-2: Station Excavation and Construction Method using Cover and Cut (Top Down)

Chapter 5 Selected Underground Structures and Cost Estimate

The selected underground structures, the selected method of construction, and cost estimate for each tunnel alignment is summarized in Table 5-1.

Selected Underground Structures

Except for the Kawaiahaʻo Street Tunnel, the design for the HHCTCP tunnels are based on TBM tunneling. The portals of all tunnels constructed using open cut U-wall construction. The plan and profile of the conceptual tunnel alignments is shown on the drawing in Appendix A. The drawings indicate which construction techniques would be used to build the tunnel.

Hotel Street/Kawaiahaʻo Street Tunnel and Station

Because it is relatively short and the surface along its route is relatively open the Hotel Street/Kawaiahaʻo Street tunnel could be built using the cut and cover technique rather than a TBM. Because the cut and cover technique would be used to install the dual guideway, the guideways would be adjacent to each other. The guideway tracks would be approximately 27 feet below the ground surface throughout the approximately 0.6 mile long tunnel.

Because the guideways would be adjacent to each other and not very deep, the King/Kapiʻolani Station would be a side platform station. The station would not have a mezzanine and entrances for outbound and inbound platforms would be separate at ground level.

All Other Tunnels and Stations

All the other tunnels would be bored using an Earth Pressure Balance Machine (EPBM) TBM. TBM tunneling was selected for these longer tunnels over cut and cover in order to (a) limit environmental impacts, (b) limit disruption to street level activities, and (c) lower cost by avoiding utilities. The EPBM was selected due to its ability to tunnel through the saturated soft sediments and mixed-face conditions anticipated.

Two parallel bores with the inbound and outbound guideways side by side in separate tunnels. No over/under tunnels would be required. Outside diameter of the tunnel bores would be approximately 20.5 feet wide. Following the guideline of having approximately a ground cover of at least 1.5 times the tunnel diameter, the top (crown) of the tunnel would be at least 31 feet below ground level; therefore, the guideway track would be at least 46 feet below ground level. Due to ground surface elevation variation, the guideway track would reach depths of up to approximately 62 feet.

Although the bulk of the tunnels would be bored/mined using an EPBM, some other construction methods would be required near the portals. Both open cut (U-wall) and cut and cover construction methods would be used near the portals in order to obtain the depth where EPBM could take over.

With the guideway being at sufficient depth and the inbound and outbound in side by side tunnel configuration, the underground stations would be 2-level center platforms with the first level being a ticketing concourse and the second level being the platform level.

Cost Estimate

Cost estimates were generated for each tunnel alignment and are summarized in Table 5-1. The cost estimate details are provided in Appendix C. The cost estimates presented in this report are strictly for the construction of the underground tunnel structure and do not include utility relocation costs, underground station costs, track work that would be installed in the tunnels, or transit system controls that would be installed in the tunnels (i.e. train control systems and ventilation). The cost estimates to relocate utilities and build the stations were presented in the *Capital Costing Memorandum* for the project. The cost estimates presented here do include labor and materials to excavate the tunnel and build the reinforced concrete tunnel structures, including walls, piles, tie-backs, and one-pass precast tunnel lining segments, among other structural items.

The cost estimate was generated by estimating the units of excavation and structure indicated to be required. A resource-based cost estimating approach was used, which is like that used by heavy construction tunnel contractors. Cost of labor and materials are used directly in this approach for the major cost item, tunneling. Labor rates appropriate for Hawai‘i, work crew sizing, and productivity assumption were based on past experience performing similar tunnel projects. Costs were appropriately marked up to account for Hawai‘i’s construction materials plus the mobilization of required equipment to the islands.

Table 5-1: Summary of Alignment Construction Methods and Cost Estimates

Tunnel Method	Sta. Start	Sta. End	Length	Tunnel Construct Cost Estimate	Tunnel Construct Cost with 35% Contractor Markup	Cost per Foot (included in tunnel CSC*)
			(feet)	($ 000)	($ 000)	($ 000)
King Street Tunnel from Dillingham						
Tunnel Type						
U-Wall	1308+25	1312+05	380	4,487		
Cut and Cover	1312+05	1315+55	350	12,857		
EPBM Side by Side	1315+55	1378+89	6,334			
EPBM Side by Side	1402+21	1408+90	669			
Total EPBM Side by Side Length			7,003			23.4
Total EPBM (two 20.5' dia. bores)			14,006	85,242		
Cut and Cover	1408+90	1411+90	300	10,889		
U-wall	1411+90	1415+40	350	4,532		
Total Tunneling			8,383	118,007	159,310	
Center Platform Stations						
Ka'aahi	1318+10	1321+10	300			
King/Bethel	1342+25	1345+25	300			
King/Punchbowl	1365+20	1368+20	300			
King Street Tunnel from North King						
Tunnel Type						
U-wall	1341+00	1345+00	400	5,420		
Cut and Cover	1345+00	1348+50	350	13,102		
EPBM Side by Side	1348+50	1351+45	296			
EPBM Side by Side	1326+20	1378+89	5,269			
EPBM Side by Side	1402+21	1408+90	669			
Total EPBM Side by Side Length			6,233			25.2
Total EPBM (two 20.5' dia. bores)			12,466	79,017		
Cut and Cover	1408+90	1411+90	300	10,997		
U-wall	1411+90	1415+40	350	4,532		
Total Tunneling			7,632	113,068	152,641	

Tunnel Method	Sta. Start	Sta. End	Length (feet)	Tunnel Construct Cost Estimate ($ 000)	Tunnel Construct Cost with 35% Contractor Markup ($ 000)	Cost per Foot (included in tunnel CSC*) ($ 000)
Center Platform Stations						
King/Bethel	1342+25	1345+25	300			
King/Punchbowl	1365+20	1368+20	300			
Beretania Street Tunnel from Dillingham						
Tunnel Type						
U-Wall	1309+50	1313+30	380	4,157		
Cut and Cover	1313+30	1316+80	350	11,393		
EPBM Side by Side	1316+80	1331+36	1,456			
EPBM Side by Side	1331+51	1367+50	3,599			
Total EPBM Side by Side Length			5,055			
Total EPBM (two 20.5' dia. bores)			10,110	67,120		
Cut and Cover	1367+50	1371+00	350	11,206		
U-Wall	1371+00	1373+60	260	2,851		
Total Tunneling			6,395	96,727	130,581	21.0
Center Platform Stations						
Ka'aahi	1320+00	1323+00	300			
Beretania/Fort	1345+25	1348+25	300			
Beretania Street Tunnel from North King						
Tunnel Type						
U-Wall	1343+40	1346+80	340	3,673		
Cut and Cover	1346+80	1349+00	220	7,161		
EPBM Side by Side	1349+00	1352+59	359			
EPBM Side by Side	1331+51	1367+50	3,599			
Total EPBM Side by Side Length			3,958			
Total EPBM (two 20.5' dia. bores)			7,916	52,554		
Cut and Cover	1367+50	1371+00	350	11,206		
U-Wall	1371+00	1373+60	260	2,851		
Total Tunneling			5,128	77,445	104,551	21.0
Center Platform Station						
Beretania/Fort	1345+25	1348+25	300			

Tunnel Method	Sta. Start	Sta. End	Length (feet)	Tunnel Construct Cost Estimate ($ 000)	Tunnel Construct Cost with 35% Contractor Markup ($ 000)	Cost per Foot (included in tunnel CSC*) ($ 000)
Hotel Street Tunnel to Kawaiaha'o Street						
Tunnel Type						
U-wall	1377+00	1380+20	320	3,368		
Cut and Cover	1380+20	1403+80	2,360	56,036		
U-wall	1403+80	1407+00	320	3,810		
Total Tunneling			3,000	63,214	85,339	29.3
Side Platform Station						
State Capitol	1387+00	1390+00	300			
Hotel Street Tunnel to Waimanu Street						
Tunnel Type						
U-wall	1377+00	1380+20	320	5,186		
Cut and Cover	1380+20	1383+50	330	11,353		
EPBM Side by Side	1383+50	1408+90	2,540			
Total EPBM Side by Side Length			2,540			
Total EPBM (two 20.5' dia. bores)			5,080	44,392		
Cut and Cover	1408+90	1411+90	300	9,230		
U-wall	1411+90	1415+40	350	3,664		
Total Tunneling			3,840	73,825	99,664	26.7
Center Platform Stations						
King/Kapi'olani	1397+80	1400+80	300			

Note: The start and end stations are illustrated on the drawings in Appendix A.

Total EPBM accounts for two side by side tunnels; although the length of the alignment could be 2,540 feet, because two tunnels are required the EPBM would bore two tunnels 2,540 feet long for a total of 5,080 feet.

* CSC = Composite Section Costs. CSCs are used to calculate total project costs as explained in the *Capital Costing Memorandum*. CSCs for tunnels were based on a unit cost per route foot of tunnel. In the case of the King Street tunnels the CSC was derived by multiplying the total tunneling cost by a 3% general condition factor and then dividing that by the length of EPBM tunneling (not length of total tunneling). In the case of the other tunnels the CSC was derived by multiplying the total tunneling cost by a 3% general condition factor and then dividing that by the total tunneling length. Although the calculation is slightly different the ultimate outcome is the same.

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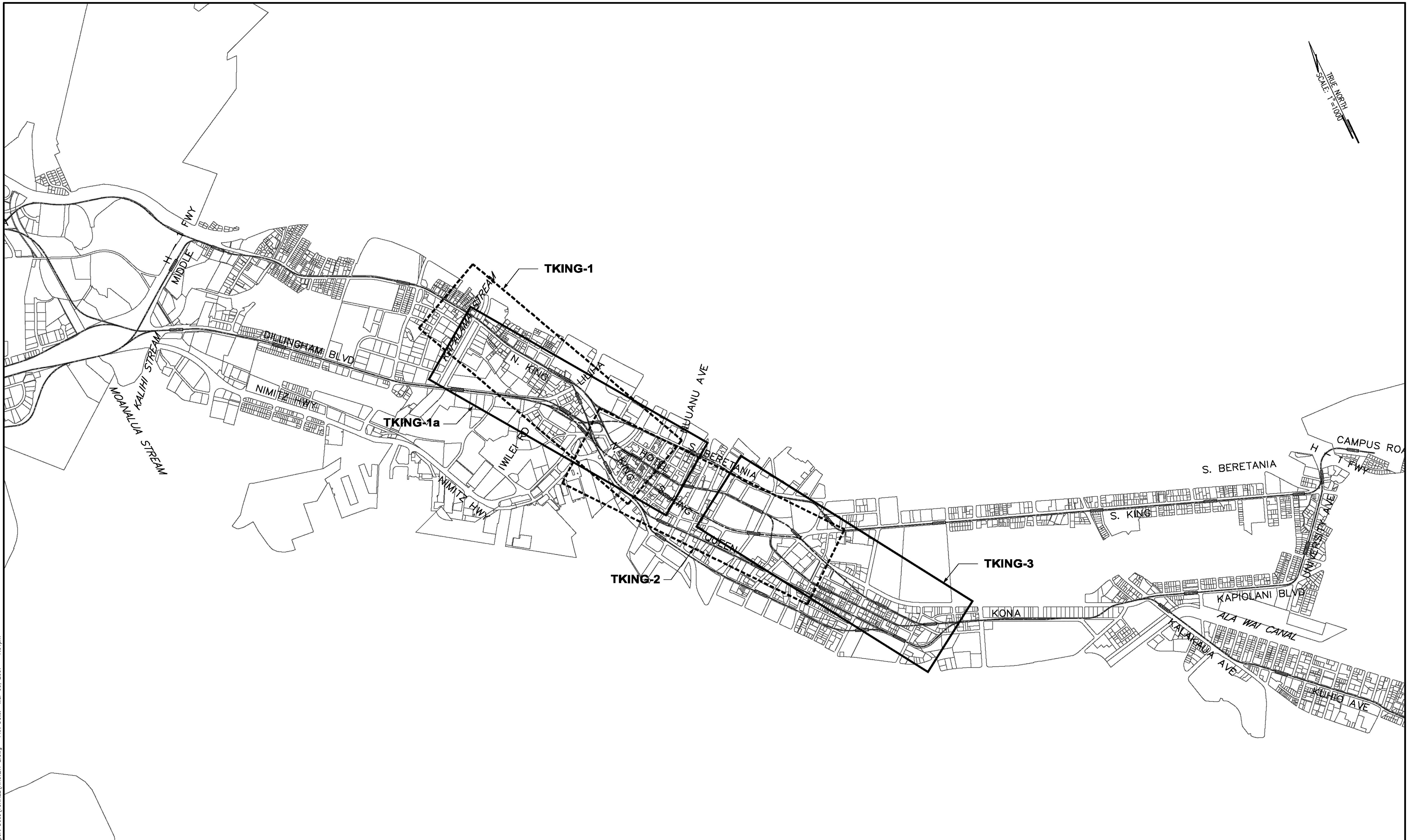
Appendix A Conceptual Plan and Profile Drawings of Tunnel Alignments under Consideration



PARSONS BRINCKERHOFF

CITY & COUNTY OF HONOLULU
DEPARTMENT OF TRANSPORTATION SERVICES

HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT ALTERNATIVES ANALYSIS

SCALE: 1000 0 1000 2000

KEY MAP
FIXED GUIDEWAY ALTERNATIVE
TUNNEL ALIGNMENT
(KING STREET)

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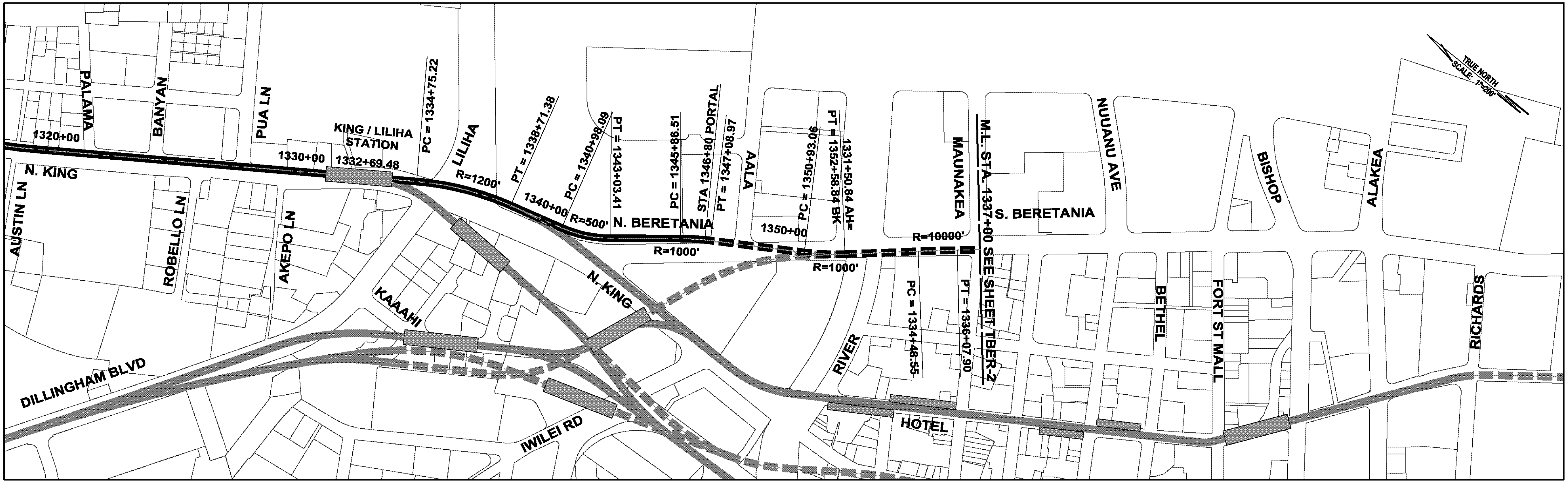

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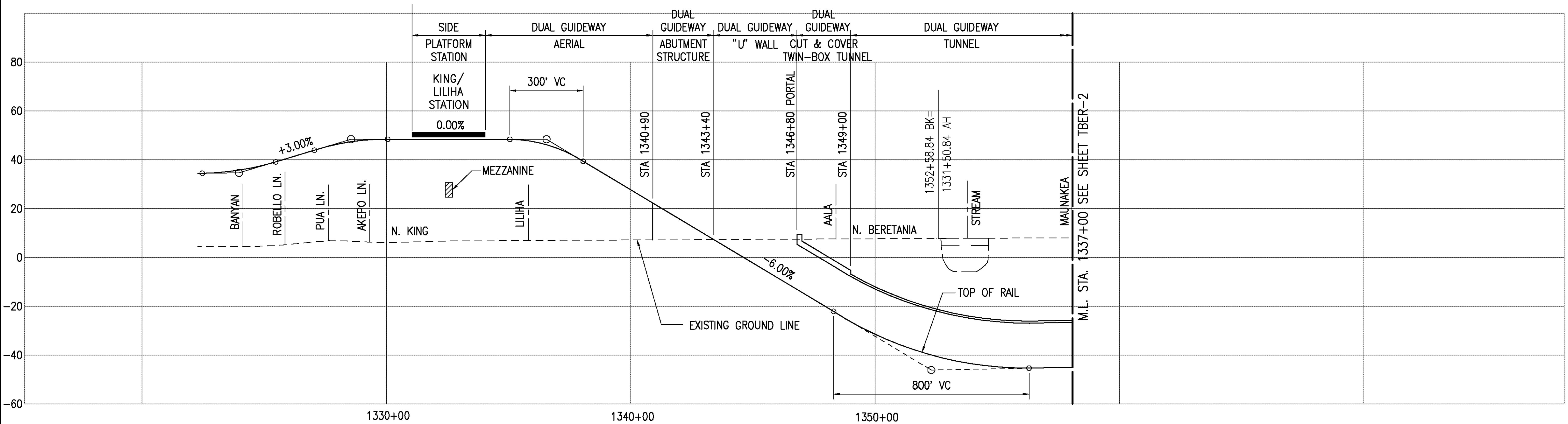

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CITY & COUNTY OF HONOLULU
DEPARTMENT OF TRANSPORTATION SERVICES

HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT ALTERNATIVES ANALYSIS

SCALES: HORIZ. 200 0 200 400; VERT. 20 0 20 40 (SCALE IN FEET)

PLAN AND PROFILE
FIXED GUIDEWAY ALTERNATIVE
BERETANIA STREET TUNNEL
(SHEET 1 OF 3)

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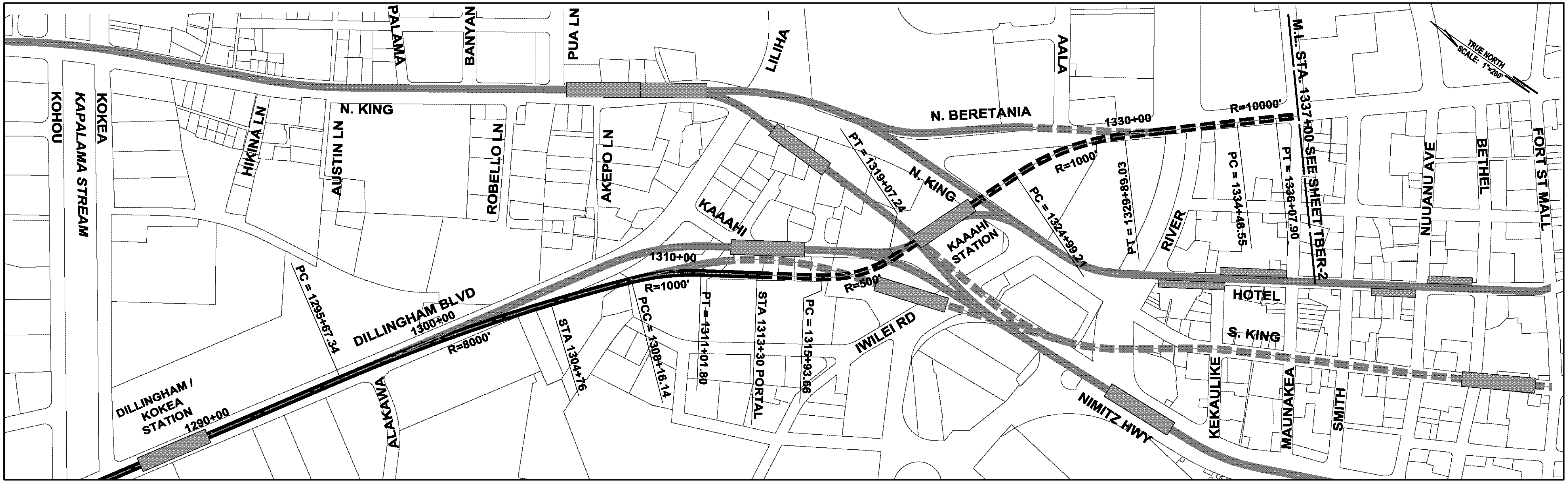

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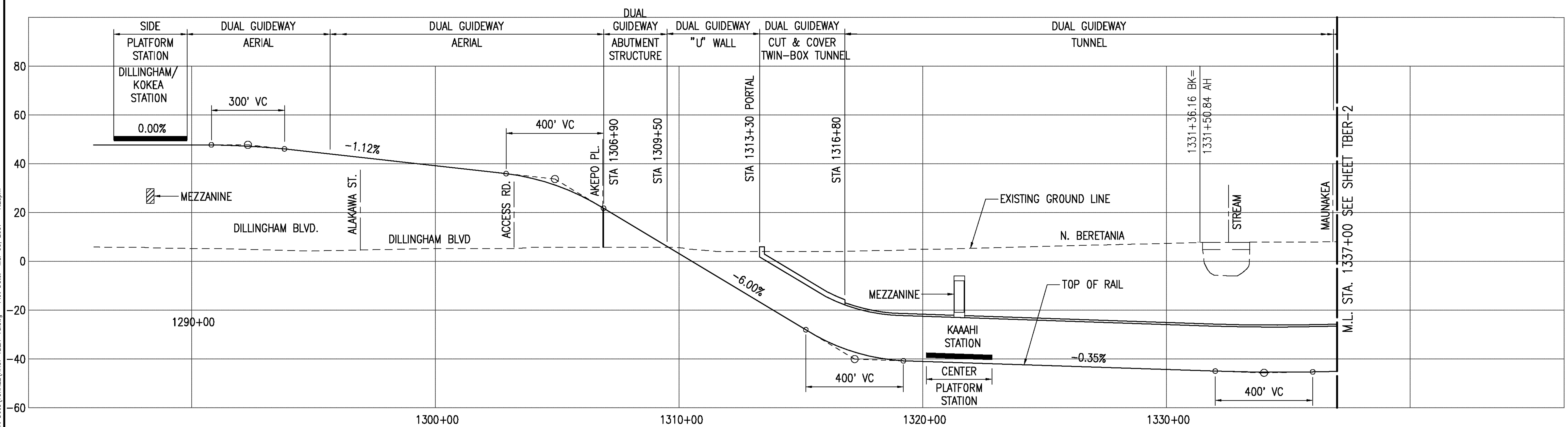

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HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT ALTERNATIVES ANALYSIS

SCALES: HORIZ. 200 0 200 400 VERT. 20 0 20 40 (SCALE IN FEET)

PLAN AND PROFILE
FIXED GUIDEWAY ALTERNATIVE
BERETANIA STREET TUNNEL
(SHEET 2 OF 3)

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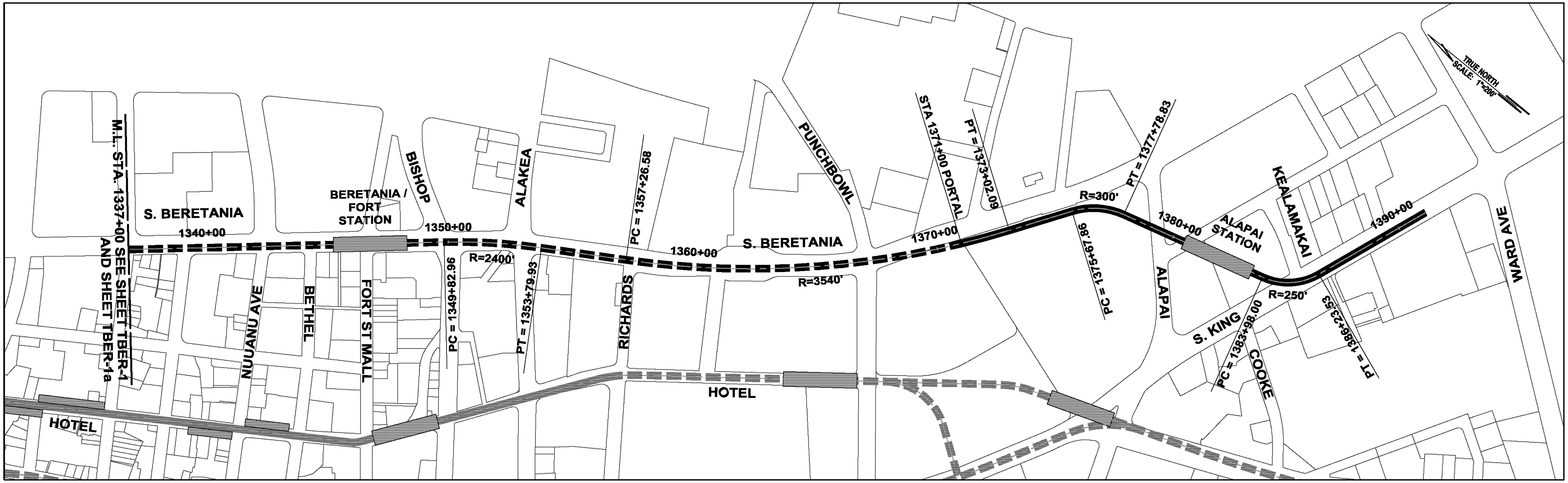

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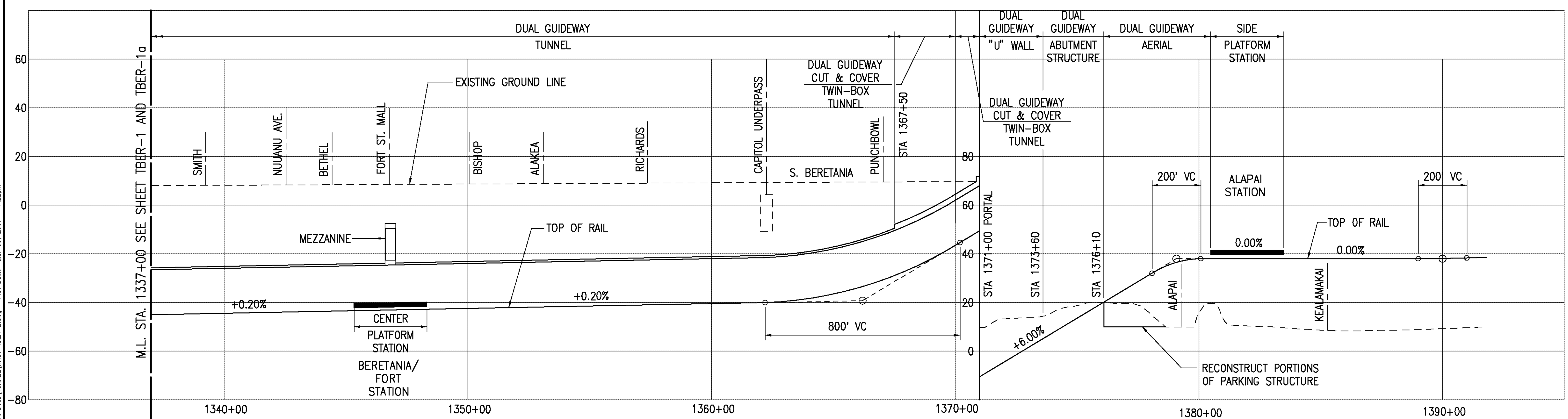

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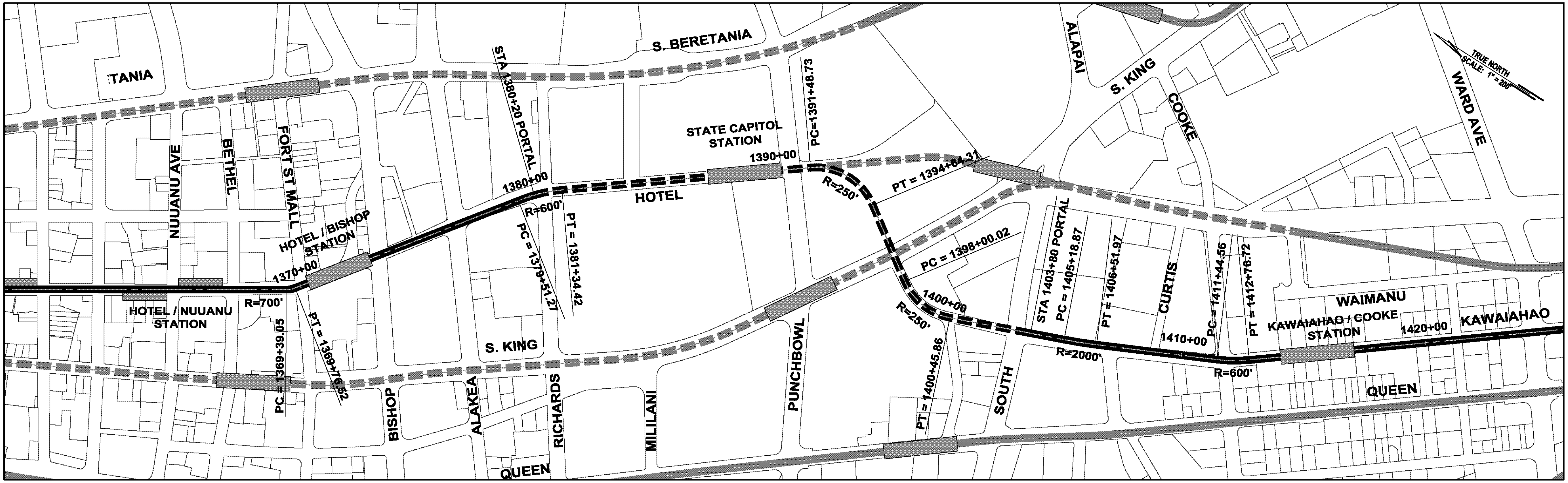

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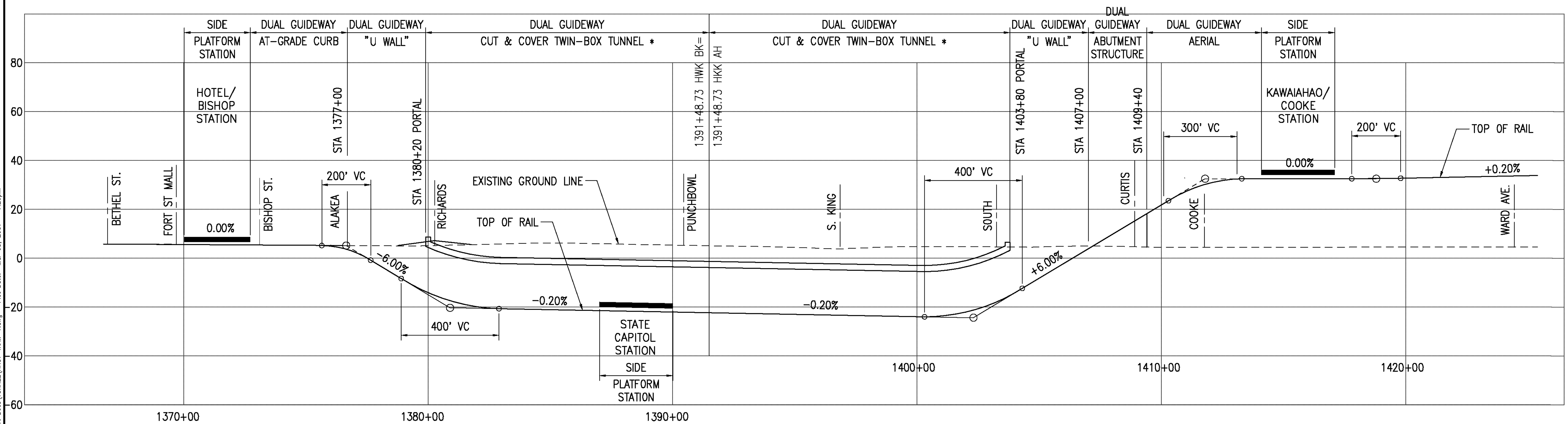

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HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT ALTERNATIVES ANALYSIS

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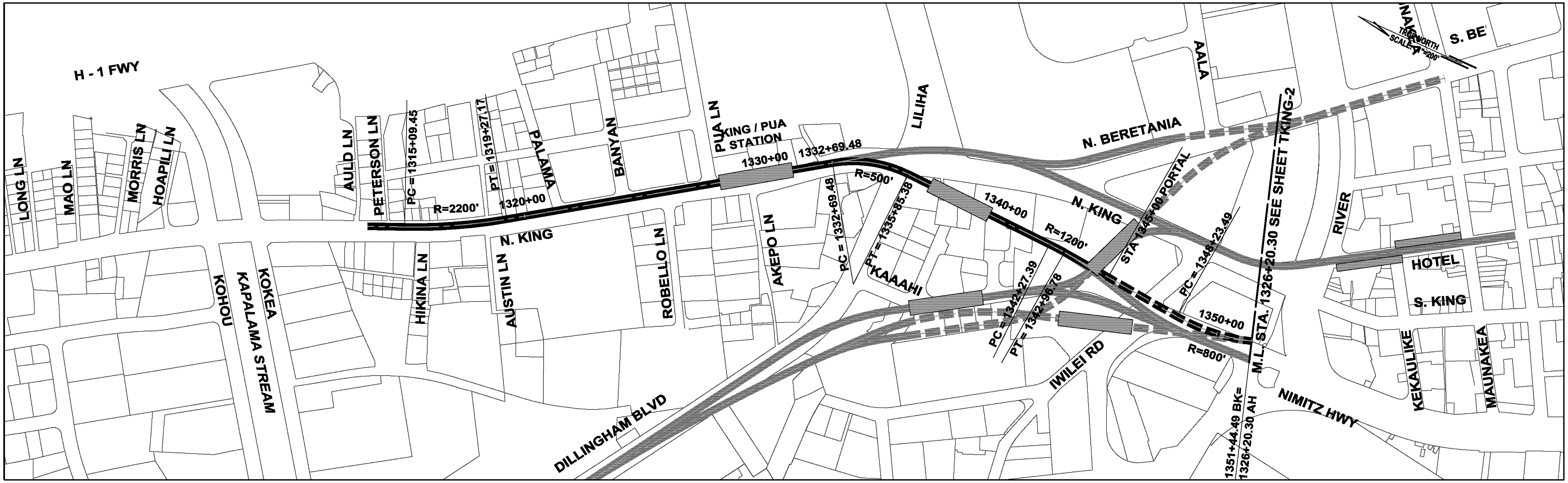

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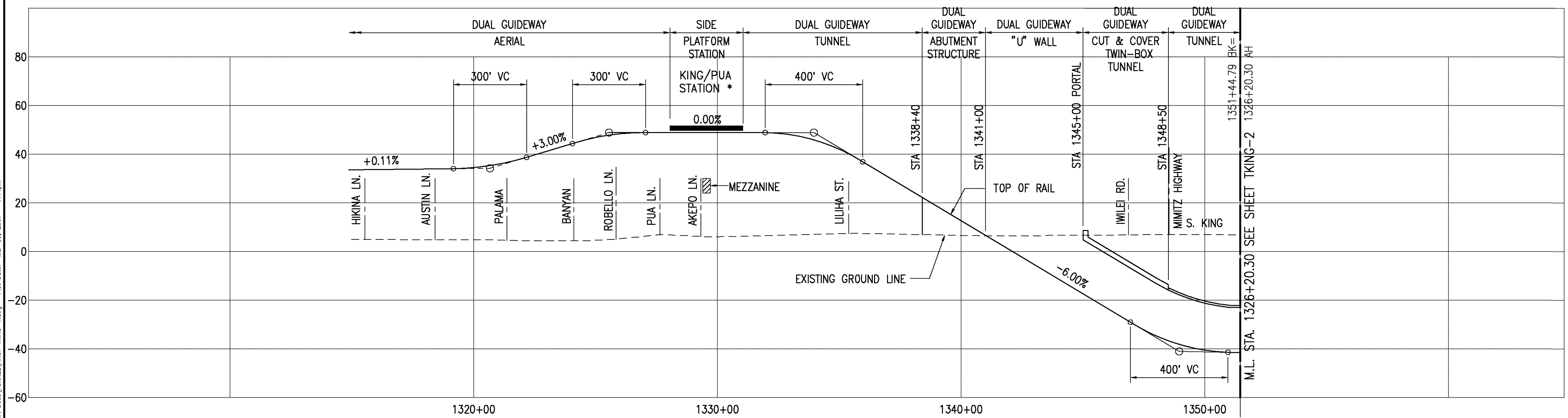

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HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT ALTERNATIVES ANALYSIS

SCALES: HORIZ. 200 0 200 400; VERT. 20 0 20 40 (SCALE IN FEET)

PLAN AND PROFILE
FIXED GUIDEWAY ALTERNATIVE
KING STREET TUNNEL
(SHEET 1 OF 4)

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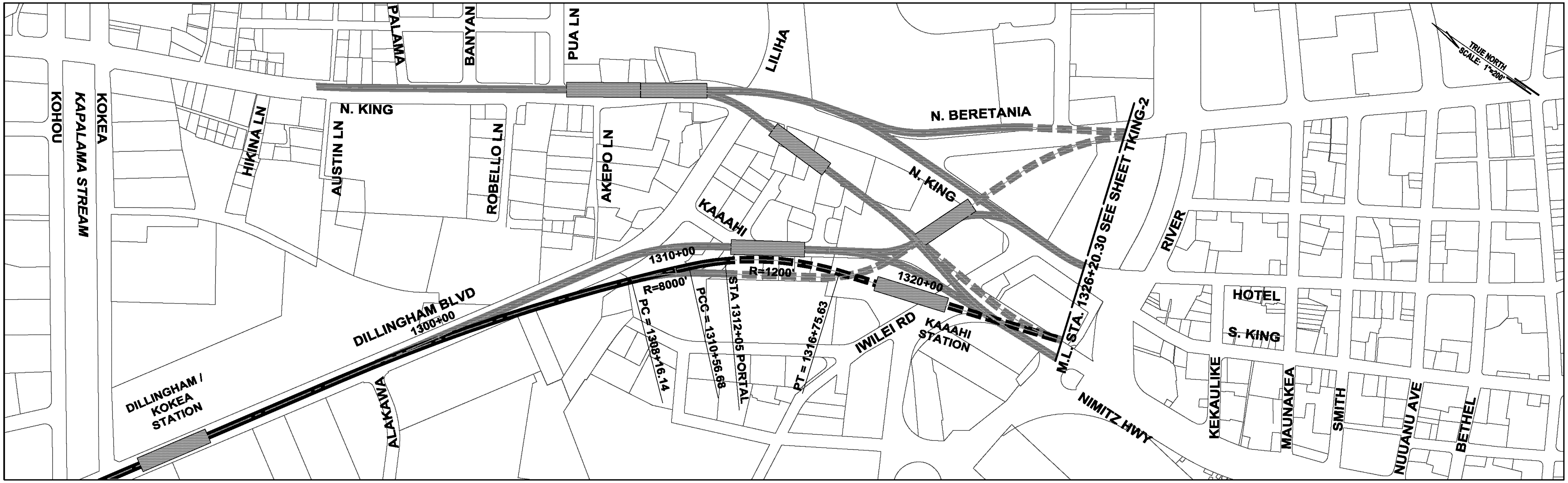

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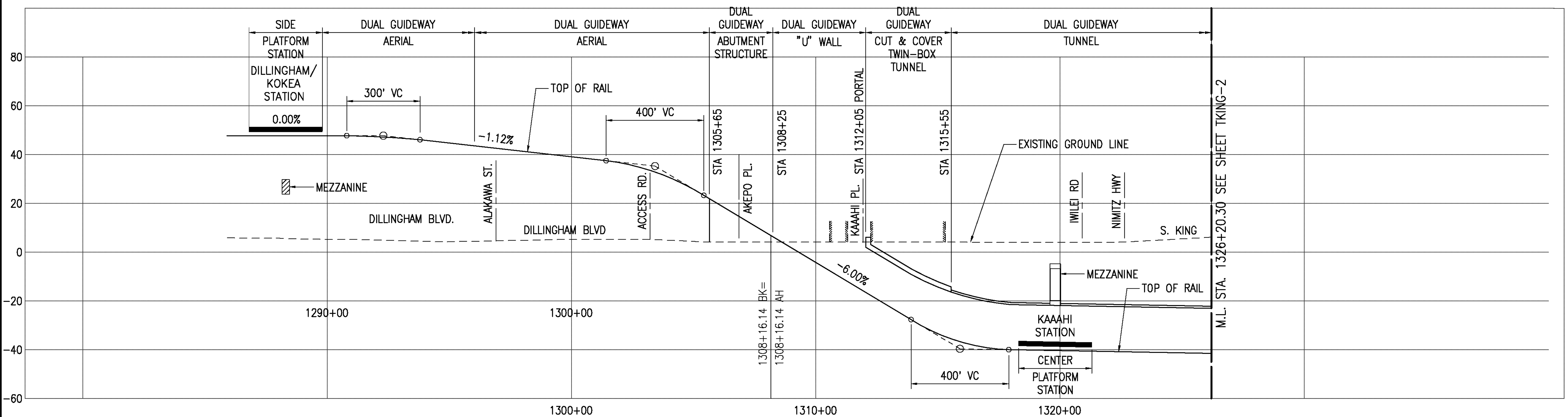

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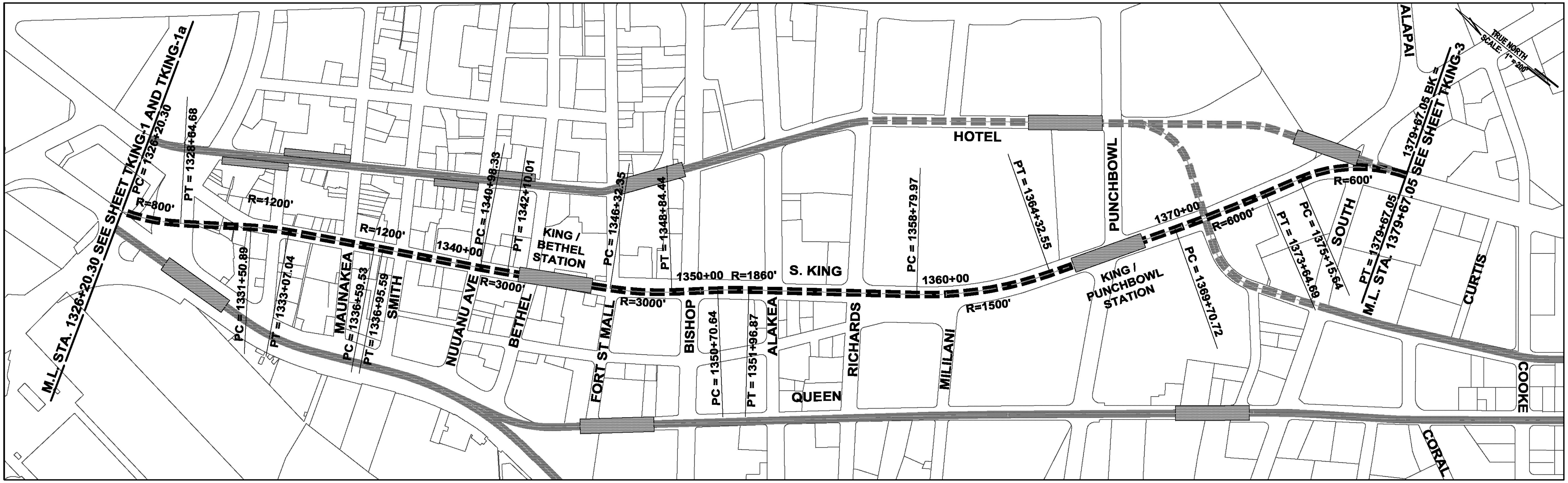

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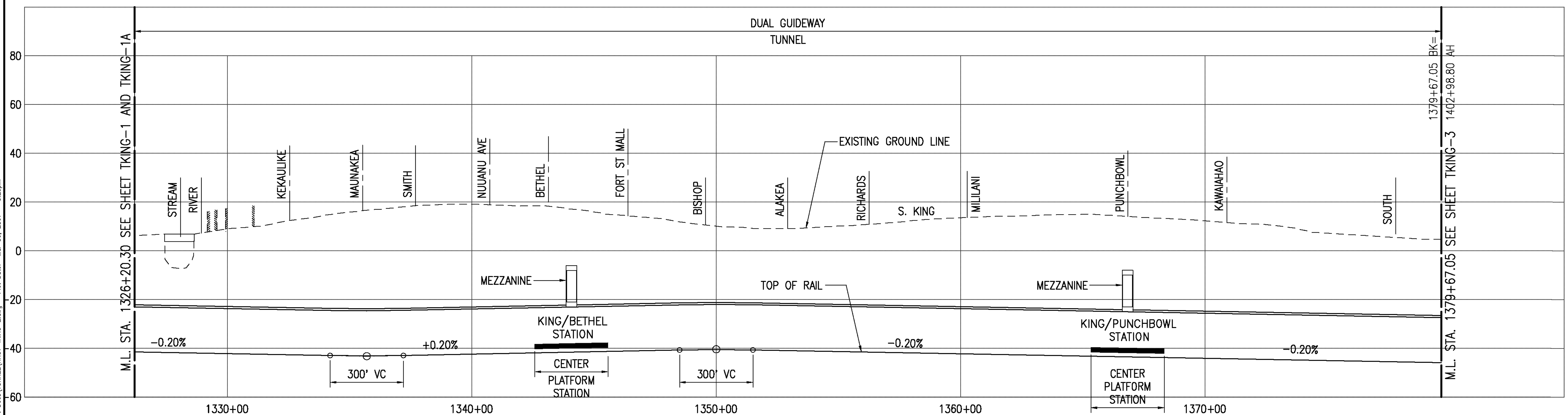

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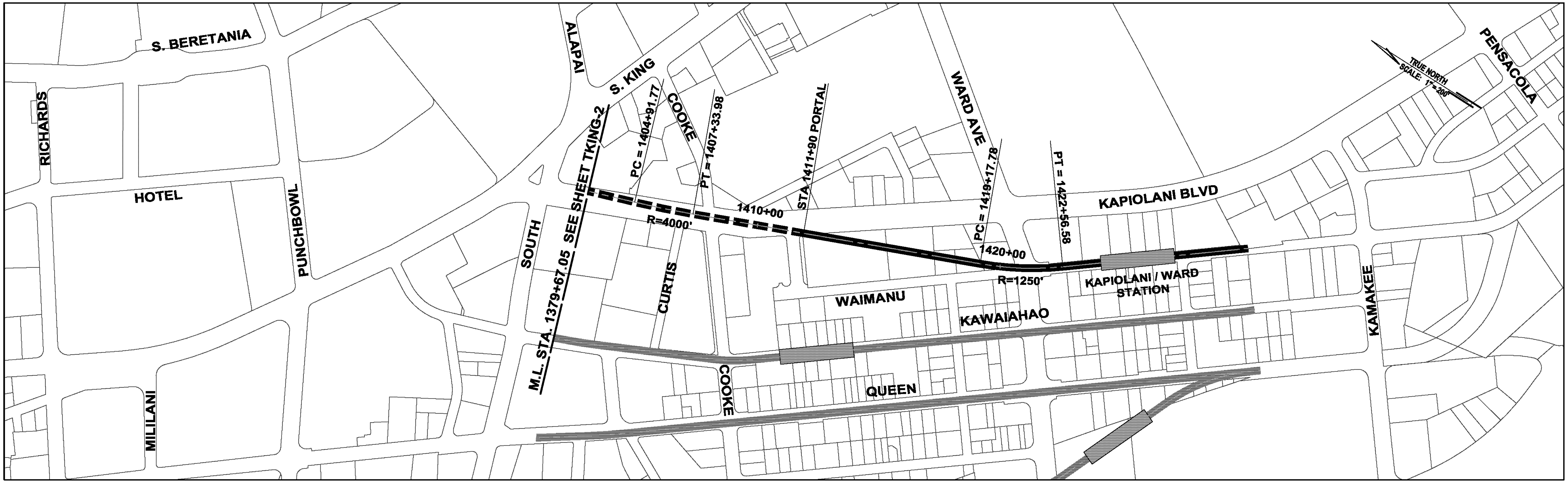

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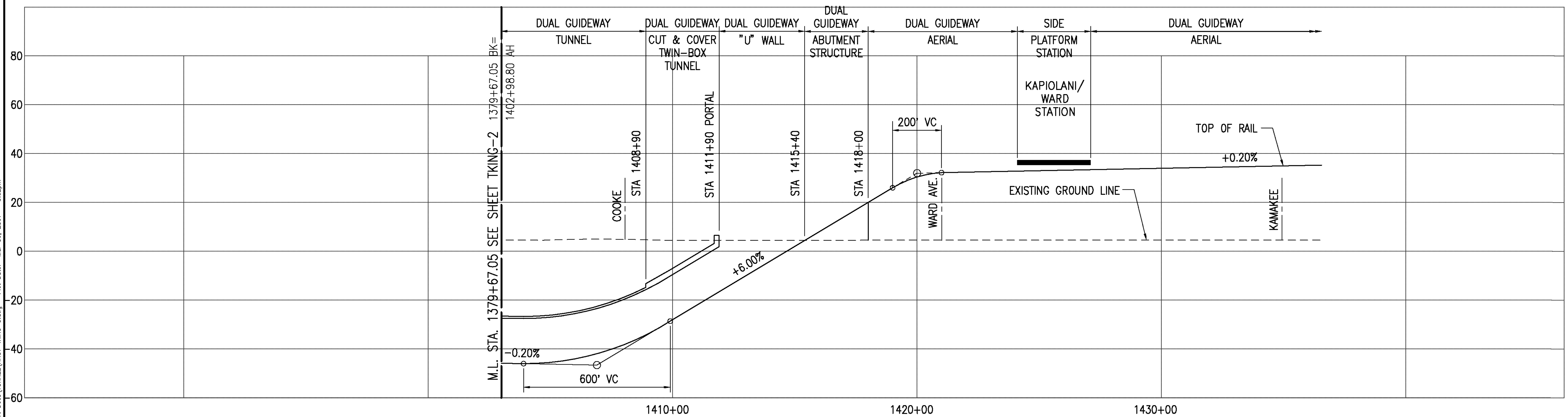

PARSONS BRINCKERHOFF	CITY & COUNTY OF HONOLULU DEPARTMENT OF TRANSPORTATION SERVICES	**HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT ALTERNATIVES ANALYSIS**	SCALES: HORIZ. 200 0 200 400; VERT. 20 0 20 40 (SCALE IN FEET)	**PLAN AND PROFILE** **FIXED GUIDEWAY ALTERNATIVE** **KING STREET TUNNEL** **(SHEET 4 OF 4)**

PAGE NO. __
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DATE: 10/06/06

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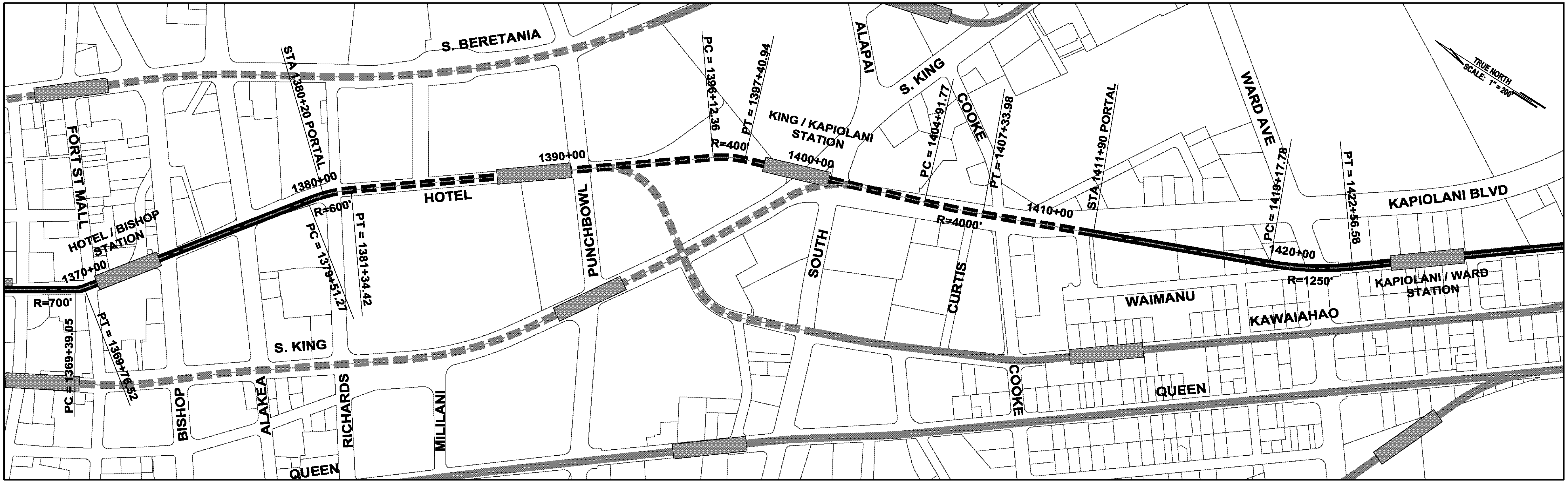

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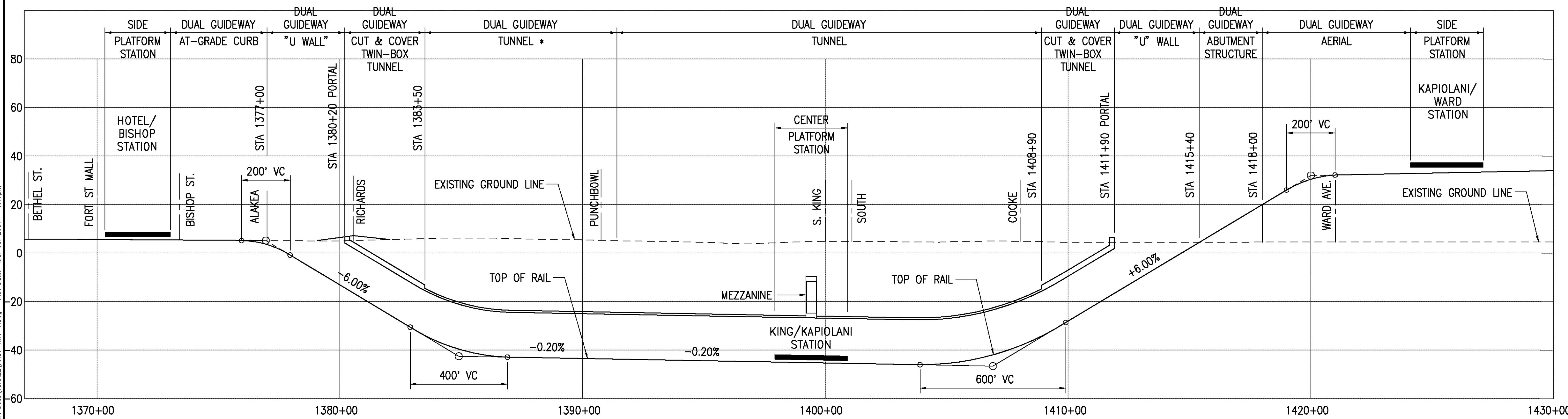

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DEPARTMENT OF TRANSPORTATION SERVICES

HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT ALTERNATIVES ANALYSIS

SCALES: HORIZ. 200 0 200 400
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Appendix B Details of Tunnel Boring Machine Types Available

Appendix B Details of Tunnel Boring Machine Types Available

Modern types of tunneling equipment and tunnel lining were assumed in the prior work undertaken in the early 1990's. At that time, the methods were considered the best-available but were still considered to be emerging technology. Since that time, and by the time this project is expected to start procurement under any form of contract delivery system, there will have been nearly 20 years of tunneling technology improvement since the early studies. Today, in 2006, the use of pressurized face TBMs and one-pass precast concrete tunnel lining proposed for projects like this, has become routine globally, as well as in the United States.

The following sections provide an overview of TBMs available today.

Tunnel Shield, Tunneling In Free Air

Included here for completeness, the simplest tunneling system and generally the least costly TBM is a tunnel shield with the tunnel face open for excavation in soft ground. The shield provides protection for workers excavating at the tunnel face and permits the erection of a tunnel lining at the rear of the tunnel shield. Therefore excavation protection is installed around but not during tunnel driving in front of the machine except for stoppages. For much of the 20^{th} century, this was known as soft-ground tunneling with a shield, or a "shield-driven tunnel." The stability of the excavation at the front of the shield was very much dependent on the quality of the ground conditions at the tunnel face.

Tunneling has become increasingly mechanized over the years. Tunnels of typically smaller size are still built, dependent on ground conditions, with these open-faced shields using a wide variety of diggers that range from standard rubber-tired back hoes, to all sorts of customized hydraulically operated excavators, all with varying success. From this development in soft-ground tunneling equipment, the terminology "digger shield" emerged.

The tunnel boring machine shown in Figure B-1, a "digger shield," was used to tunnel sections of the Los Angeles transit system in the 1990's. A cross-section of this machine is shown in Figure B-2. Notable are the hydraulically operated breasting plates on periphery of top heading of tunnel shield and the hydraulic digger, which was adapted from backhoe and refined specifically for tunneling. The major disadvantage of this type of open-face is that the ground must be dewatered in advance of tunneling.

Figure B-1: Typical Open-Face "Digger Shield" for Tunneling

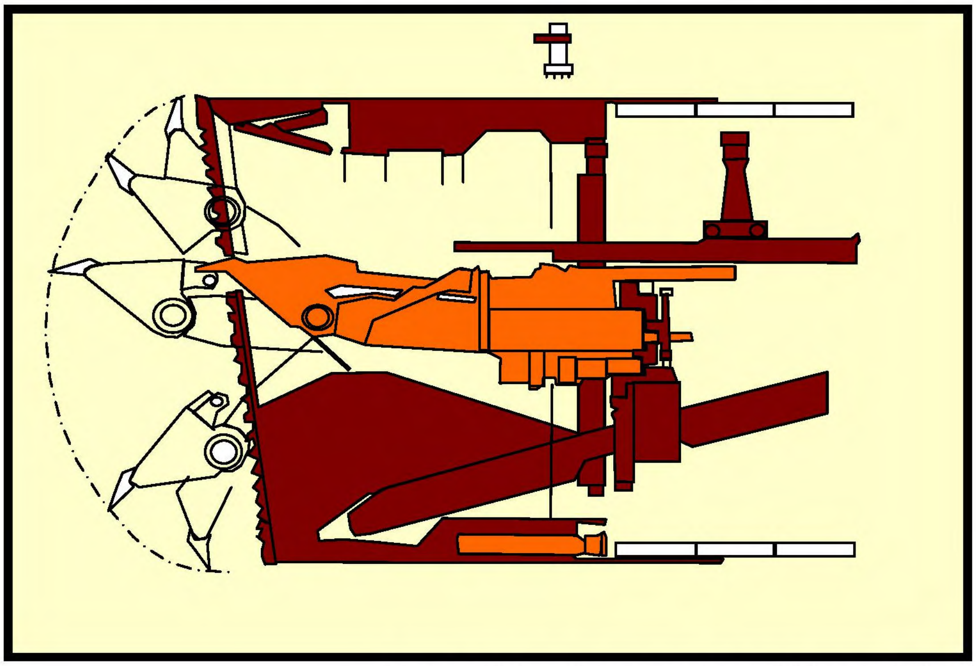

Figure B-2: Cross-section of Digger Shield

Tunnel Shield, Compressed Air Tunneling

The tunnel shield was adapted to use compressed air where either the ground was very weak, like soft clay, or the ground was saturated, such as sand that could not be dewatered. The compressed air could either be used to provide support to the tunnel face for impermeable materials such as clay or provide a counter balance to water pressure for more permeable materials; however, in high permeability soil, air loss could be significant and result in loss of face support resulting in collapse of the excavation. Using compressed air requires the pressurization of the full length of tunnel; therefore, workers in the tunnel are in a hyperbaric chamber. Decompression chambers are required for both workers and materials and, depending on the air pressure applied, up to three decompression chambers could be required to permit 24 hour working. Until relatively recently, the incidence of decompression sickness was relatively frequent, particularly at higher working pressures and the incidence of bone necrosis resulted in many "sand hogs" becoming incapacitated at a young age. Gradually, tightening of statutory limits on compressed air working over the past twenty years has limited the use of open shields. As decompression times were lengthened and lower limits set on working pressures, so higher labor costs and concerns at the health impact of high compressed air pressures have reduced the usage of this type of shield.

As a specific example for this project, tunneling in the Nuuanu Stream area will be in very weak soil, which would have required compressed air tunneling if pressurized face tunneling technology had not developed. In addition to the use of compressed air for excavation protection, building protection by ground treatment or underpinning would be required generally for adjacent structures with shallow foundations as the zone and magnitude of settlement associated with open face shields would have had an impact on adjacent structures. Significant utility protection requirements would also have been of concern.

Pressurized Face Tunneling

Two main types of pressurized face TBMs for soft ground are now in use and there are a number of derivatives of each either developed or currently under development. The two principle types are the Earth Pressure Balance Machine (EPBM) and the Slurry Face Machine (SFM). A "mix-shield" is a manufacturer's product terminology and generally refers to a special TBM which combines the characteristics of both types of machine but which requires some downtime to change over from one type to the other.

Earth Pressure Balance Machine (EPBM)

Examples of EPBMs are shown in Figure B-3 with a cutterhead designed for soil. These machines were used on the LA County Metropolitan Transportation Authority's Metro Gold Line Eastside Extension.

The EPBM transmits the pressure to the face mechanically, through the soil grains, and is reduced by means of friction over the length of the screw conveyor. Control is obtained by matching the volume of soil displaced by forward motion of the shield with the volume of soil removed from the pressurized face by the screw conveyor and the soil finally is deposited (at ambient pressure) on the conveyor or muck car. There is direct connection between the face of the machine and the rear of the EPMB at the spoil discharge point. For protection against inflows, gates can be provided at the end of the Archimedes screw conveyor located immediately at the discharge point. Primary gate valves can also be installed at the bottom of the screw if sufficient space is available. During excavation these gates are normally left open to allow flow of spoil and there is always direct connection to the face during excavation. Figure B-4 provides a schematic of an EPBM.

Figure B-3: EPBM Used to Los Angeles Transit

Courtesy LA County Metropolitan Transportation Authority

Clearly, the range of natural geologic conditions that will result in suitably plastic material to transfer the earth pressure to the face and, at the same time, suitably frictional to form the “sand plug” in the screw conveyor is rather limited – generally only combinations of fine sands and silts. It is also now common to provide soil conditioning to improve the material characteristics of the *in-situ* soil and to reduce the wear on roller cutters and bits at the head of the machine. This conditioning can achieve the plasticity needed to operate the machine effectively.

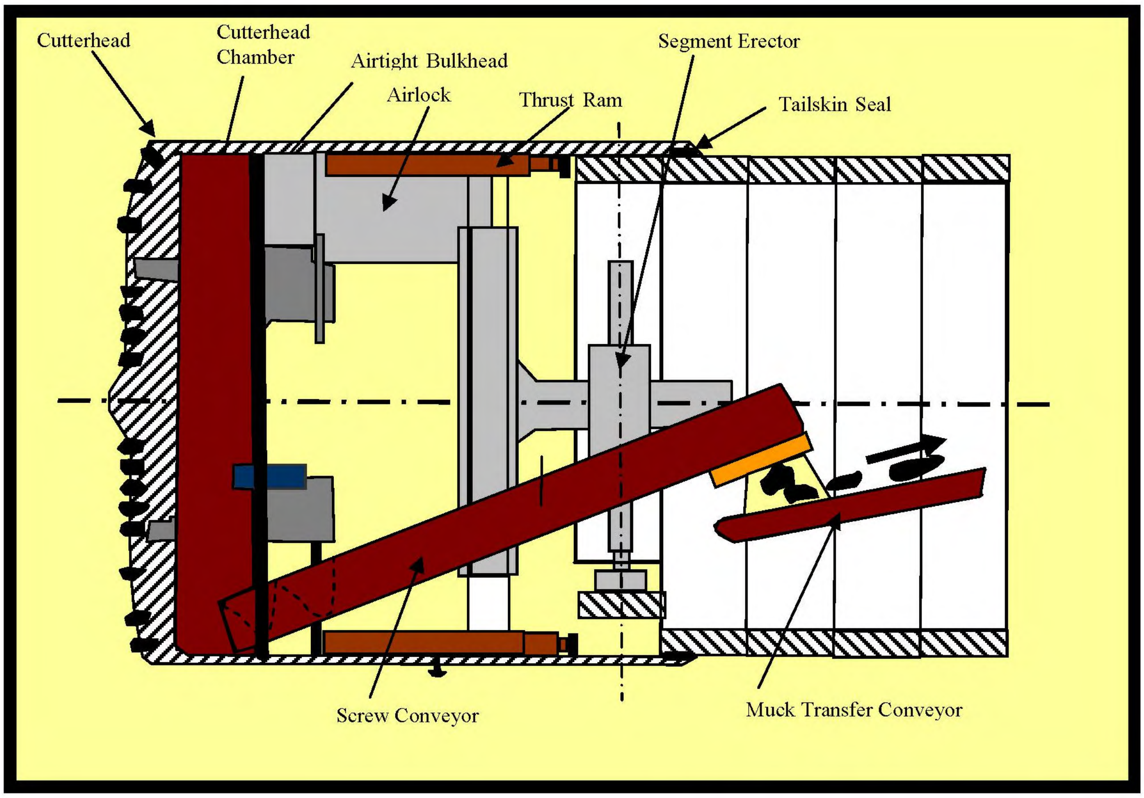

Figure B-4: Cross-section of EPBM
Courtesy of AFTES

Slurry Face Machine (SFM)

An example of a SFM at a fabrication plant in Germany is shown in Figure B-5. This machine was used for crossing under the Nile River during construction of the Cairo Metro tunnels in sands below the water table. This machine was subsequently modified to accommodate boulders formed from petrified forest in a subsequent phase of the project. The modifications included provision of a suitably sized opening in the cutterhead so that a crusher could be installed behind the cutterhead to break up the boulders.

The SFM transmits pressure to the face hydraulically through a viscous fluid formed by material cut in the face and mixed with a relatively dense slurry (basically bentonite and water). The face pressure can be either controlled directly by pressurization of the slurry or indirectly by means of a plenum chamber filled with air under pressure which acts directly on the bentonite slurry. This air bubble provides a more effective control of the face pressure and thus the excavated face. In conjunction with the slurry, the excavation can be controlled by means of pressure sensors in the cutterhead, pressure gages, and control valves via a piping system with pressure controlled by increasing or decreasing the air pressure. By this system a much more precise and more consistent pressure control is attained. Figure B-6 provides a cross section of a SFM.

Figure B-5: Slurry Face Machines
Left courtesy of Herrenknecht; Right courtesy National Authority for Tunnels, Cairo, Egypt

The undesirable aspect of this system is that a separation plant has to be built and operated at the surface to separate the slurry from the soil cuttings for disposal and permit re-use of the slurry. Finding a site for the slurry separation that is satisfactory is difficult in urban areas and finding a final disposal sites acceptable to the public can be a challenge.

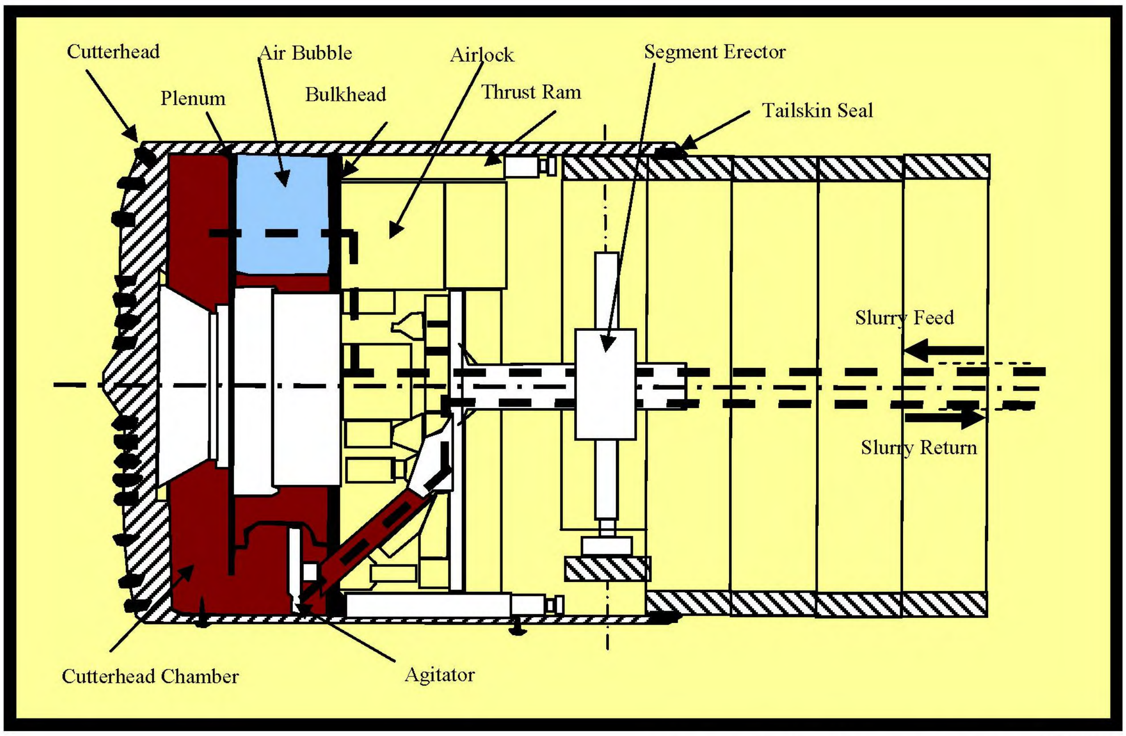

Figure B-6: Cross-section of SFM
Courtesy AFTES

Tunnel breakouts

One of the higher risk areas of tunneling is at the tunnel breakout from the station or driving shaft. At this location, only partial face pressure can be developed in front of the face. The tunnel face pressure is contained by glands located around the outside of the tailskin and these have an unfortunate tendency to leak during the initial drive. At the start of the initial drive, operator experience of the machine in the anticipated ground conditions is limited and this experience can only be gained by understanding the ground response to tunneling operations which does take time to develop. A higher risk of ground loss can therefore be expected at these locations and development of the correct solution to the break-out/break-in design is fundamental to tunnel stability at these locations. A typical break out detail developed on Cairo Metro in sands below ground water level is shown in Figure B-7. Initially the simple design on the left was adopted. Unfortunately through experience, a more complex design which lowered risk had to be developed to overcome the shortcomings in the initial concept. This revised concept allowed for the problems associated with jet grouting where leakage paths can frequently arise due to necking of the jet grout columns.

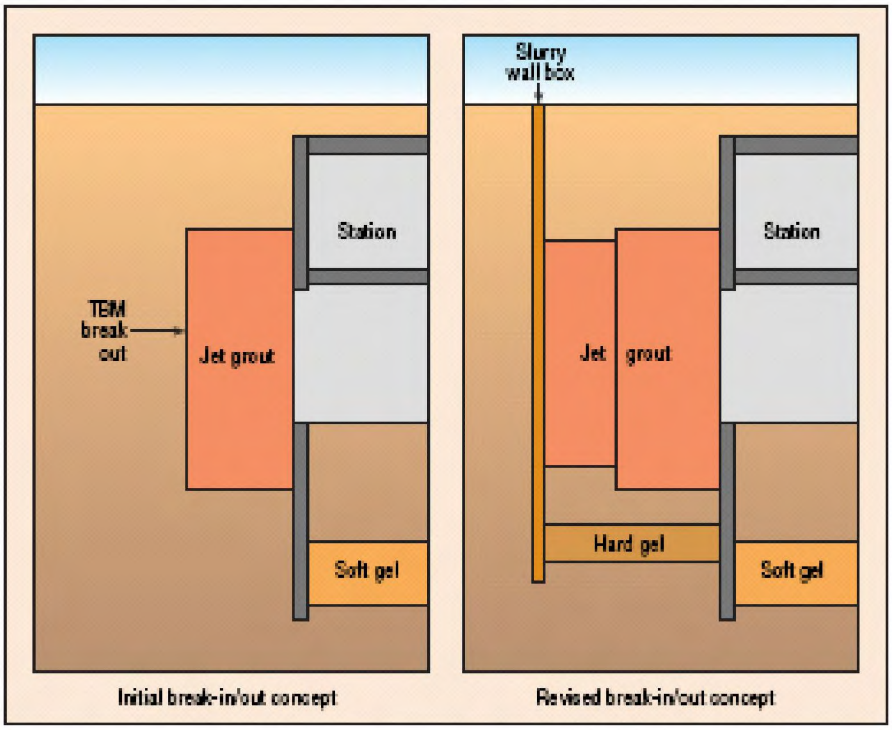

Figure B-7: Tunnel Breakout Plan in Difficult Ground Conditions

Figure B-8 shows an EPBM breaking into a station under ideal conditions.

Figure B-8: EPBM Completing Tunnel Drive

Tunnel Linings

Inherent with all of the TBM tunneling considered in this study is that the tunnel lining would be constructed of segmental precast concrete segments. Installed as tunneling progresses, the lining serves to maintain a stable tunnel opening immediately behind the machine. With the concrete segments designed and fabricated to specific quality standards, the lining is also the final lining, and is called a "one-pass" lining.

Water tightness and durability are the primary requirements of the tunnel lining, in addition to fundamental structural adequacy. The intent would be to have a dry tunnel on completion. State of the practice now is that a substantially dry, durable tunnel lining for a transit tunnel can be constructed with a one-pass segmental precast concrete tunnel lining fitted with a combination of hydrophilic and neoprene gaskets. The most recent example is the successful tunneling completed in 2006 for the Los Angeles MTA Eastside Extension, which completed 9,500 feet of 22 foot diameter tunnel.

In this study for Honolulu, other tunneling linings and materials were considered. Of emerging use in tunnels is steel fiber-reinforced concrete tunnel segments. Better durability is achievable for this type of segment, which has steel fibers as reinforcement instead of traditional reinforcing bars. For the alternatives analysis, it was not necessary to define the specific type of precast segments.

A less-costly initial tunnel lining of circular steel ribs with timber lagging could be used as an initial lining where ground and groundwater conditions permit. The final lining would be cast-in-place concrete. However, this type of tunnel lining was considered to be not practical since it cannot be used with pressurized-face TBMs that are envisioned to be required and can result in significant ground settlement.

The following photographs show:

- Figure B-9: a completed precast lining in a dry tunnel with invert concrete completed ready for track concrete. Note that the walkway is formed of precast conduits sitting on steel brackets supported by bolts drilled into the linings.
- Figure B-10: Segments stored near the driving shaft arranged as single tunnel linings fitted with gaskets and ready to be lowered to the machine.
- Figure B-11: A completed precast lining.

Figure B-9: Detail of Precast Lined Twin Track Tunnel during Track Installation

Figure B-10: Storage of Precast Lining Segments at Tunnel Site

Figure B-11: One-pass Precast Concrete Line Single Track Tunnel

Design of the segment connections has developed over a number of years and now these are generally standardized as shown in Figure B-12. The design of the segments has been developed to achieve a fast installation time and tunnel linings have increased in length and therefore weight due to the development of segment erectors. Care has to be taken with the design of these connections particularly where high groundwater pressures and ram pressures must be considered. Similarly gaskets must be sized to suit the anticipated water pressures and the material constituents in the ground. Where there are significant levels of chloride ions, considerations should also be given to providing a membrane protection to the back of the lining to avoid corrosion of the rebar or spalling of concrete in the tunnel lining, as has been adopted in Singapore (Transit), Hong Kong (Transit) and Denmark (Storebaelt).

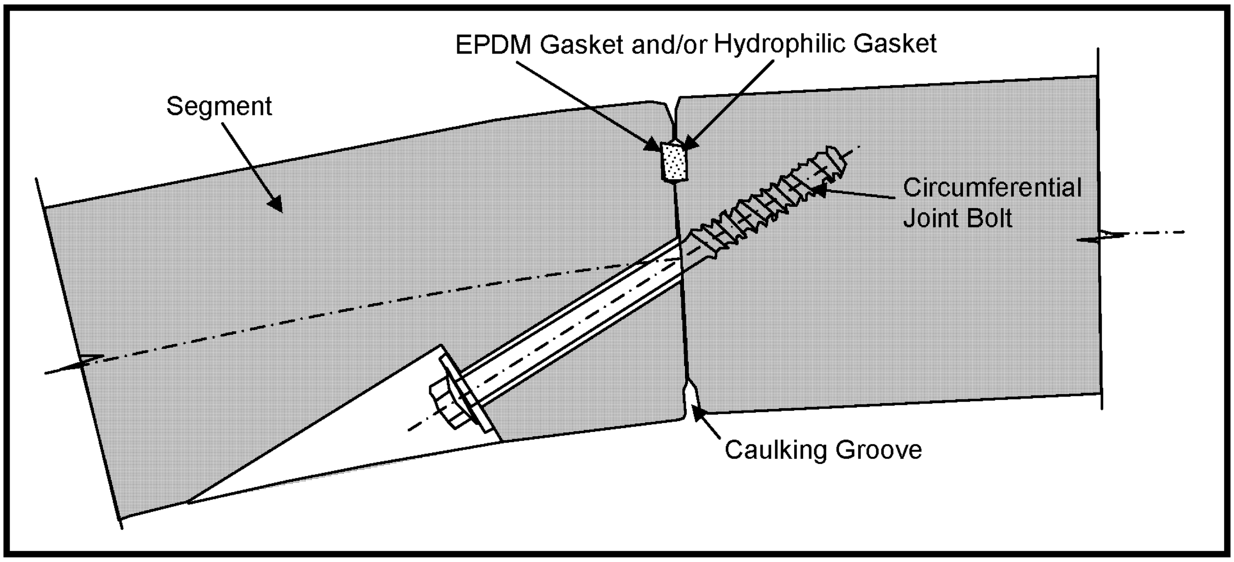

Figure B-12: Typical segment details at radial joint.

Relevant Precedents for Pressurized Face Tunneling

As examples of the state of the practice in tunneling, 3 tunnel projects are briefly described to illustrate what is possible for the Honolulu Transit Project.

Los Angeles MTA, Eastside Extension

Successful tunneling was completed recently (end 2006) for 1.8 miles of 22 foot diameter tunnel for extension of light rails transit service to the East Los Angeles. It is comparable to Honolulu in regard to tunneling directly under city streets in an important commercial are of the city. Two new EPBMs (see Figure B-3) were used successfully. A one-pass precast concrete tunnel lining was use and was designed for earthquake conditions. Two underground stations were built by cut and cover along that segment of tunnel.

Portland, Oregon Westside and Eastside CSO Projects

Two tunneling projects in Portland, Oregon used slurry-face type pressurized-face machines (SFM). The technical publication by Gribbon et al (2004) summarizes the unique contracting method for this project and the use of SFM in a weak rock. The first project ("Westside Combined Sewage Overflow (CSO) Project") constructed 3.5 miles of 15-foot-diameter tunnel. Figure B-13 shows the completed Westside tunnel with a curve and one-pass precast concrete lining completed using a SFM. The second project, which is in progress in 2007 ("Eastside CSO Project"), will use a 25-foot-diameter SFM for 6 miles of tunneling. These two project serve to demonstrate that tunneling using pressurized face TBMs are becoming a mature technology that can be used in difficult tunneling conditions. In the case of these Portland tunnels the tunnel ground conditions consisted of an ancient river deposit of cobbles and gravel under or next to the Willamette River.

Figure B-13: Portland Westside CSO Tunnel with Curve

Port of Miami Tunnel, Miami, Florida

This is a proposed project that will construct a pair of bored roadway tunnels under the Main Channel of the Port of Miami, Miami, Florida. Relevance to tunneling in Honolulu is that the tunnel ground conditions have some similarities and pressurized face tunneling is being required. The project is in the early stage of procurement of a design-build concessionaire to undertake final design, construction, and operation of the facility.

Like Honolulu, the project is at or below sea level and the geologic conditions in both locations, despite the global distance between them, are primarily the result of climatic fluctuations resulting in sea level changes during the Pleistocene Epoch. Fluctuations of sea levels caused changes of depositional environments, various combinations of sediments and coral were created. In the case of Honolulu, deposition of basalt from active volcanic activity adds another dimension of complexity to the geologic setting. In some areas, the contacts between hard rock, weak rock, and soil are gradual; in other areas they are inter-fingered or inter-bedded.

For the Miami tunnel, it is a contract requirement that a pressurized face tunnel boring machine be used to excavate the bored tunnel. Either an EPBM or a SFM are considered feasible to provide the required face stability at the tunnel face. With the size of the excavated face on the order of 40 feet in diameter, and with the known variations in geology, the TBM will encounter both cemented and non-cemented materials in the face at the same time. This is likely to be a similar geologic condition for tunneling in downtown Honolulu, except that a smaller TBM, on the order of 21 feet diameter, will be required.

The Miami tunnel has construction issues that apply to those in Honolulu. With an EPBM it is critical that the face pressure be maintained at all times by forming and maintaining a satisfactory sand plug in the screw conveyor. With a SFM there is a risk of loss of slurry in zones of porous, high permeability limestone, resulting in a reduction in face pressure that will promote face instability and uncontrolled inflow of water and soil into the cutting chamber.

Appendix C Cost Estimate Details

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Bid Description	Client#	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total
21000		14,006.00	LF	605,359	38,237,776	33,010,209	8,559,477	24,218,242	13,981,896	118,007,599		118,007,599	8,425.50	41,302,660	159,310,259	11,374.43	11,374.43	159,310,266.58
KING ST. OPTION #1 1315+55 TO 1408+90				43.22	2,730.10	2,356.86	611.13	1,729.13	998.28	8,425.50			35.0 %	2,948.93				
21100		*380.00*	*LF*	*26,934*	*1,694,521*	*1,370,287*	*348,371*	*519,769*	*554,165*	*4,487,113*		*4,487,113*	*11,808.19*					
TUNNEL U-WALL 1308+25 TO 1312+05				*70.88*	*4,459.27*	*3,606.02*	*916.77*	*1,367.81*	*1,458.33*	*11,808.19*								
21105		*16,480.00*	*SF*	*11,559*	*727,040*	*776,175*	*163,083*	*345,398*	*464,085*	*2,475,782*								
U-WALL SLURRY WALL SOE				*0.70*	*44.12*	*47.10*	*9.90*	*20.96*	*28.16*	*150.23*								
21110		*4,504.00*	*BCY*	*2,174*	*126,573*		*9,685*	*37,471*	*90,080*	*263,810*								
U-WALL STR. EXCAV.				*0.48*	*28.10*		*2.15*	*8.32*	*20.00*	*58.57*								
21115		*1,126.00*	*CY*	*3,381*	*211,209*	*274,046*	*37,243*	*34,210*		*556,708*								
U-WALL INVERT CONCRETE 2.5FT THICK				*3.00*	*187.57*	*243.38*	*33.08*	*30.38*		*494.41*								
21120		*985.00*	*CY*	*8,642*	*554,615*	*283,837*	*110,088*	*89,771*		*1,038,311*								
U-WALL WALL CONC. 3.5FT THICK				*8.77*	*563.06*	*288.16*	*111.76*	*91.14*		*1,054.12*								
21125		*172.00*	*CY*	*1,175*	*75,084*	*36,228*	*28,271*	*12,919*		*152,503*								
U-WALL WALKWAY CONCRETE 3.5 X3.5FT				*6.84*	*436.54*	*210.63*	*164.36*	*75.11*		*886.64*								
21200		*350.00*	*LF*	*68,643*	*4,336,516*	*3,270,201*	*843,321*	*1,205,897*	*3,201,290*	*12,857,225*		*12,857,225*	*36,734.93*					
CUT&COVER BOX 1312+05 TO 1315+55				*196.12*	*12,390.05*	*9,343.43*	*2,409.49*	*3,445.42*	*9,146.54*	*36,734.93*								
21205		*31,122.00*	*SF*	*20,274*	*1,281,502*	*1,545,931*	*353,483*	*645,907*	*766,530*	*4,593,353*								
CUT&COVER BOX SLURRY WALL SOE				*0.65*	*41.18*	*49.67*	*11.36*	*20.75*	*24.63*	*147.59*								
21210		*18,738.00*	*BCY*	*9,038*	*526,073*		*57,731*	*155,732*	*374,760*	*1,114,296*								
CUT&COVER BOX EXCAV.				*0.48*	*28.08*		*3.08*	*8.31*	*20.00*	*59.47*								
21212		*206.00*	*EA.*						*2,060,000*	*2,060,000*								
F&I TIEBACK ANCHORS									*10,000.00*	*10,000.00*								
21215		*2,064.00*	*CY*	*5,476*	*341,565*	*485,552*	*32,664*	*52,412*		*912,194*								
CUT&COVER BOX INVERT CONC. 3.25FT THIC				*2.65*	*165.49*	*235.25*	*15.83*	*25.39*		*441.95*								
21220		*1,361.00*	*CY*	*13,209*	*858,510*	*406,771*	*135,444*	*145,922*		*1,546,648*								
CUT&COVER BOX WALL CONC. 2.5FT THICK				*9.71*	*630.79*	*298.88*	*99.52*	*107.22*		*1,136.41*								
21225		*2,064.00*	*CY*	*12,874*	*834,696*	*628,317*	*138,789*	*117,049*		*1,718,851*								
CUT&COVER ROOF CONC. 3.25FT THICK				*6.24*	*404.41*	*304.42*	*67.24*	*56.71*		*832.78*								
21230		*272.00*	*CY*	*1,869*	*118,509*	*57,291*	*24,431*	*20,403*		*220,634*								
CUT&COVER WALKWAY CONC. 7X3FT				*6.87*	*435.70*	*210.63*	*89.82*	*75.01*		*811.16*								
21235		*467.00*	*CY*	*5,655*	*361,598*	*118,885*	*100,310*	*63,865*		*644,658*								
CUT&COVER INTERIOR WALL CONC. 2FT THI				*12.11*	*774.30*	*254.57*	*214.80*	*136.76*		*1,380.42*								
21240		*1,271.00*	*CY*	*244*	*14,063*	*27,454*	*469*	*4,605*		*46,591*								
CUT&COVER BACKFILL				*0.19*	*11.06*	*21.60*	*0.37*	*3.62*		*36.66*								
21300		*14,006.00*	*LF*	*425,579*	*26,891,815*	*24,146,626*	*6,272,382*	*20,976,253*	*6,955,039*	*85,242,113*		*85,242,113*	*6,086.11*					

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Client# / Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total
KING ST. TUNNEL EXCAV.&LINING			30.39	1,920.02	1,724.02	447.84	1,497.66	496.58	6,086.11								
21305	1.00	LS	14,946	927,816		448,657	170,563	750,000	2,297,036								
SETUP PORTAL AREA@ 1315+55			14,946.88	927,815.78		448,657.19	170,562.63	750,000.00	2,297,035.60								
21310	1.00	LS	1,435	90,213		39,625	8,447		138,285								
SETUP PORTAL AREA@ 1408+90			1,435.94	90,212.97		39,624.91	8,447.32		138,285.20								
21315	1.00	EA	30,046	1,865,895		411,530	9,009,608		11,287,032								
EPBM@1315+55			30,046.80	1,865,894.92		411,529.56	9,009,607.50		11,287,031.98								
21320	1.00	SET	19,702	1,200,013	3,360	84,249	387,384		1,675,006								
TRAILING GEAR@ 1315+55			19,702.40	1,200,013.14	3,360.00	84,248.93	387,383.90		1,675,005.97								
21325	1.00	LS						1,446,500	1,446,500								
PREPARE PORTAL@1315+55								1,446,500.00	1,446,500.00								
21330	1.00	LS						1,402,500	1,402,500								
PREPARE PORTAL@ 1408+90								1,402,500.00	1,402,500.00								
21335	1.00	LS	4,031	247,129		17,299	77,186		341,614								
RAIL EQUIPMENT@ 1315+55			4,031.00	247,128.65		17,299.01	77,186.46		341,614.12								
21340	14,006.00	LF	355,416	22,560,749	24,143,266	5,271,022	11,323,065	3,356,039	66,654,140								
MINE TUNNELS 1315+55 TO 1408+90			25.38	1,610.79	1,723.78	376.34	808.44	239.61	4,758.97								
21400	300.00	LF	57,139	3,612,700	2,792,009	759,141	1,000,748	2,724,561	10,889,159		10,889,159	36,297.20					
CUT&COVER BOX 1408+90 TO 1411+90			190.47	12,042.33	9,306.70	2,530.47	3,335.83	9,081.87	36,297.20								
21405	25,826.00	SF	16,900	1,067,877	1,325,819	294,060	536,294	704,221	3,928,271								
CUT&COVER BOX SLURRY WALL SOE			0.65	41.35	51.34	11.39	20.77	27.27	152.11								
21410	15,517.00	BCY	7,484	435,642		47,807	128,963	310,340	922,752								
CUT&COVER BOX EXCAV.			0.48	28.08		3.08	8.31	20.00	59.47								
21415	171.00	EA						1,710,000	1,710,000								
F&I TIEBACK ANCHORS								10,000.00	10,000.00								
21420	1,769.00	CY	4,760	297,478	416,355	30,627	46,477		790,937								
CUT&COVER BOX INVERT CONC. 3.25FT THIC			2.69	168.16	235.36	17.31	26.27		447.11								
21425	1,167.00	CY	11,334	737,053	348,735	129,770	124,992		1,340,550								
CUT&COVER BOX WALL CONC. 2.5FT THICK			9.71	631.58	298.83	111.20	107.11		1,148.71								
21430	1,769.00	CY	10,455	679,142	538,514	139,047	94,329		1,451,032								
CUT&COVER ROOF CONC. 3.25FT THICK			5.91	383.91	304.42	78.60	53.32		820.26								
21435	233.00	CY	1,372	85,927	48,985	19,916	13,945		168,772								
CUT&COVER WALKWAY CONC. 7X3FT			5.89	368.78	210.23	85.48	59.85		724.35								
21440	400.00	CY	4,726	303,551	101,829	97,713	53,774		556,868								
CUT&COVER INTERIOR WALL CONC. 2FT THI			11.82	758.88	254.57	244.28	134.44		1,392.17								

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ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Client# Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	Balanced Bid Total	Balanced Bid Unit Price	Bid Price	Bid Total
21445	*545.00*	*CY*	*104*	*6,030*	*11,772*	*201*	*1,975*		*19,979*								
CUT&COVER BACKFILL			*0.19*	*11.06*	*21.60*	*0.37*	*3.62*		*36.66*								
21500	*350.00*	*LF*	*27,061*	*1,702,224*	*1,431,087*	*336,262*	*515,576*	*546,841*	*4,531,990*		*4,531,990*	*12,948.54*					
TUNNEL U-WALL 1411+90 TO 1415+40			*77.32*	*4,863.50*	*4,088.82*	*960.75*	*1,473.07*	*1,562.40*	*12,948.54*								
21505	*15,280.00*	*SF*	*10,891*	*684,580*	*831,251*	*151,629*	*331,328*	*447,281*	*2,446,069*								
U-WALL SLURRY WALL SOE			*0.71*	*44.80*	*54.40*	*9.92*	*21.68*	*29.27*	*160.08*								
21510	*4,978.00*	*BCY*	*2,403*	*139,885*		*10,705*	*41,412*	*99,560*	*291,561*								
U-WALL EXCAVATION			*0.48*	*28.10*		*2.15*	*8.32*	*20.00*	*58.57*								
21515	*1,037.00*	*CY*	*3,147*	*196,615*	*252,511*	*28,595*	*31,924*		*509,646*								
U-WALL INVERT CONCRETE 2.5 FT THICK			*3.03*	*189.60*	*243.50*	*27.57*	*30.79*		*491.46*								
21520	*1,089.00*	*CY*	*9,552*	*613,012*	*313,835*	*121,661*	*99,173*		*1,147,681*								
U-WALL WALL CONCRETE 3.5 FT THICK			*8.77*	*562.91*	*288.19*	*111.72*	*91.07*		*1,053.89*								
21525	*159.00*	*CY*	*1,067*	*68,132*	*33,490*	*23,672*	*11,739*		*137,033*								
U-WALL WALKWAY CONCRETE 3.5X3.5FT			*6.71*	*428.50*	*210.63*	*148.88*	*73.83*		*861.84*								
22000	12,466.00	LF	575,032	36,297,961	30,740,539	8,673,038	23,162,928	14,193,099	113,067,566		113,067,566	9,070.08	39,573,648	152,641,214	12,244.60	12,244.60	152,641,183.60
KING ST. OPTION #2 1348+50 TO 1408+90			46.13	2,911.76	2,465.95	695.74	1,858.09	1,138.54	9,070.08			35.0 %	3,174.53				
22100	*400.00*	*LF*	*32,400*	*2,038,618*	*1,650,895*	*400,062*	*639,266*	*690,857*	*5,419,699*		*5,419,699*	*13,549.25*					
TUNNEL U-WALL 1341+00 TO 1345+00			*81.00*	*5,096.55*	*4,127.24*	*1,000.16*	*1,598.17*	*1,727.14*	*13,549.25*								
22105	*20,736.00*	*SF*	*14,179*	*893,374*	*967,831*	*203,193*	*433,128*	*577,077*	*3,074,603*								
U-WALL SLURRY WALL SOE			*0.68*	*43.08*	*46.67*	*9.80*	*20.89*	*27.83*	*148.27*								
22110	*5,689.00*	*BCY*	*2,746*	*159,873*		*12,233*	*47,330*	*113,780*	*333,216*								
U-WALL STR. EXCAV.			*0.48*	*28.10*		*2.15*	*8.32*	*20.00*	*58.57*								
22115	*1,185.00*	*CY*	*3,392*	*211,101*	*288,272*	*29,486*	*32,643*		*561,502*								
U-WALL INVERT CONCRETE 2.5FT THICK			*2.86*	*178.14*	*243.27*	*24.88*	*27.55*		*473.84*								
22120	*1,244.00*	*CY*	*10,875*	*697,885*	*358,557*	*131,036*	*112,929*		*1,300,407*								
U-WALL WALL CONC. 3.5FT THICK			*8.74*	*561.00*	*288.23*	*105.33*	*90.78*		*1,045.34*								
22125	*172.00*	*CY*	*1,206*	*76,385*	*36,235*	*24,114*	*13,237*		*149,970*								
U-WALL WALKWAY CONCRETE 3.5 X3.5FT			*7.02*	*444.10*	*210.67*	*140.20*	*76.96*		*871.92*								
22200	*350.00*	*LF*	*71,407*	*4,502,901*	*3,310,878*	*876,986*	*1,281,021*	*3,130,293*	*13,102,079*		*13,102,079*	*37,434.51*					
CUT&COVER BOX 1345+00 TO 1348+50			*204.02*	*12,865.43*	*9,459.65*	*2,505.67*	*3,660.06*	*8,943.69*	*37,434.51*								
22205	*33,516.00*	*SF*	*21,718*	*1,373,294*	*1,538,697*	*379,520*	*695,306*	*911,073*	*4,897,890*								
CUT&COVER BOX SLURRY WALL SOE			*0.65*	*40.97*	*45.91*	*11.32*	*20.75*	*27.18*	*146.14*								
22210	*20,961.00*	*BCY*	*10,387*	*605,200*		*66,411*	*179,501*	*419,220*	*1,270,333*								
CUT&COVER BOX EXCAV.			*0.50*	*28.87*		*3.17*	*8.56*	*20.00*	*60.60*								

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Client# / Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total
22215	386.00	EA						1,800,000	1,800,000								
F&I TIEBACK ANCHORS								4,663.21	4,663.21								
22220	2,064.00	CY	5,476	341,565	485,552	32,664	52,412		912,194								
CUT&COVER BOX INVERT CONC. 3.25FT THIC			2.65	165.49	235.25	15.83	25.39		441.95								
22225	1,361.00	CY	13,209	858,510	406,771	135,444	145,922		1,546,648								
CUT&COVER BOX WALL CONC. 2.5FT THICK			9.71	630.79	298.88	99.52	107.22		1,136.41								
22230	2,064.00	CY	12,874	834,696	628,317	138,789	117,049		1,718,851								
CUT&COVER ROOF CONC. 3.25FT THICK			6.24	404.41	304.42	67.24	56.71		832.78								
22235	272.00	CY	1,413	89,378	57,184	22,559	14,305		183,427								
CUT&COVER WALKWAY CONC. 7X3FT			5.20	328.60	210.24	82.94	52.59		674.36								
22240	467.00	CY	5,655	361,598	118,885	100,310	63,865		644,658								
CUT&COVER INTERIOR WALL CONC. 2FT THI			12.11	774.30	254.57	214.80	136.76		1,380.42								
22245	3,494.00	CY	670	38,659	75,472	1,289	12,659		128,080								
CUT&COVER BACKFILL			0.19	11.06	21.60	0.37	3.62		36.66								
22300	12,466.00	LF	386,457	24,408,886	21,491,970	6,299,500	19,715,632	7,100,546	79,016,534		79,016,534	6,338.56					
KING ST. TUNNEL EXC.&LINING			31.00	1,958.04	1,724.05	505.33	1,581.55	569.59	6,338.56								
22305	1.00	LS	14,946	927,816		448,657	170,563	750,000	2,297,036								
SETUP PORTAL AREA@ 1348+50			14,946.88	927,815.78		448,657.19	170,562.63	750,000.00	2,297,035.60								
22310	1.00	LS	1,435	90,213		39,625	8,447		138,285								
SETUP PORTAL AREA@ 1408+90			1,435.94	90,212.97		39,624.91	8,447.32		138,285.20								
22315	1.00	EA	30,046	1,865,895		411,530	9,009,608		11,287,032								
EPBM@1348+50			30,046.80	1,865,894.92		411,529.56	9,009,607.50		11,287,031.98								
22320	1.00	SET	19,702	1,200,013	3,360	84,249	387,384		1,675,006								
TRAILING GEAR@ 1348+50			19,702.40	1,200,013.14	3,360.00	84,248.93	387,383.90		1,675,005.97								
22325	1.00	LS						1,446,500	1,446,500								
PREPARE PORTAL@1348+50								1,446,500.00	1,446,500.00								
22330	1.00	LS						1,402,500	1,402,500								
PREPARE PORTAL@ 1408+90								1,402,500.00	1,402,500.00								
22335	1.00	LS	4,031	247,129		17,299	77,186		341,614								
RAIL EQUIPMENT@ 1348+50			4,031.00	247,128.65		17,299.01	77,186.46		341,614.12								
22340	12,466.00	LF	316,294	20,077,821	21,488,610	5,298,140	10,062,444	3,501,546	60,428,562								
MINE TUNNELS 1348+50 TO 1408+90			25.37	1,610.61	1,723.78	425.01	807.19	280.89	4,847.47								
22400	300.00	LF	57,706	3,645,331	2,855,709	760,229	1,011,433	2,724,561	10,997,264		10,997,264	36,657.55					
CUT&COVER BOX 1408+90 TO 1411+90			192.35	12,151.10	9,519.03	2,534.10	3,371.44	9,081.87	36,657.55								
22405	25,826.00	SF	16,900	1,067,877	1,325,819	294,060	536,294	704,221	3,928,271								

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Client# / Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total
CUT&COVER BOX SLURRY WALL SOE			*0.65*	*41.35*	*51.34*	*11.39*	*20.77*	*27.27*	*152.11*								
22410	*15,517.00*	*BCY*	*7,484*	*435,642*		*47,807*	*128,963*	*310,340*	*922,752*								
CUT&COVER BOX EXCAV.			*0.48*	*28.08*		*3.08*	*8.31*	*20.00*	*59.47*								
22415	*171.00*	*EA*						*1,710,000*	*1,710,000*								
F&I TIEBACK ANCHORS								*10,000.00*	*10,000.00*								
22420	*1,769.00*	*CY*	*4,760*	*297,478*	*416,355*	*30,627*	*46,477*		*790,937*								
CUT&COVER BOX INVERT CONC. 3.25FT THIC			*2.69*	*168.16*	*235.36*	*17.31*	*26.27*		*447.11*								
22425	*1,167.00*	*CY*	*11,334*	*737,053*	*348,735*	*129,770*	*124,992*		*1,340,550*								
CUT&COVER BOX WALL CONC. 2.5FT THICK			*9.71*	*631.58*	*298.83*	*111.20*	*107.11*		*1,148.71*								
22430	*1,769.00*	*CY*	*10,455*	*679,142*	*538,514*	*139,047*	*94,329*		*1,451,032*								
CUT&COVER ROOF CONC. 3.25FT THICK			*5.91*	*383.91*	*304.42*	*78.60*	*53.32*		*820.26*								
22435	*233.00*	*CY*	*1,372*	*85,927*	*48,985*	*19,916*	*13,945*		*168,772*								
CUT&COVER WALKWAY CONC. 7X3FT			*5.89*	*368.78*	*210.23*	*85.48*	*59.85*		*724.35*								
22440	*400.00*	*CY*	*4,726*	*303,551*	*101,829*	*97,713*	*53,774*		*556,868*								
CUT&COVER INTERIOR WALL CONC. 2FT THI			*11.82*	*758.88*	*254.57*	*244.28*	*134.44*		*1,392.17*								
22445	*3,494.00*	*CY*	*670*	*38,662*	*75,473*	*1,289*	*12,660*		*128,083*								
CUT&COVER BACKFILL			*0.19*	*11.07*	*21.60*	*0.37*	*3.62*		*36.66*								
22500	*350.00*	*LF*	*27,061*	*1,702,224*	*1,431,087*	*336,262*	*515,576*	*546,841*	*4,531,990*		*4,531,990*	*12,948.54*					
TUNNEL U-WALL 1411+90 TO 1415+40			*77.32*	*4,863.50*	*4,088.82*	*960.75*	*1,473.07*	*1,562.40*	*12,948.54*								
22505	*15,280.00*	*SF*	*10,891*	*684,580*	*831,251*	*151,629*	*331,328*	*447,281*	*2,446,069*								
U-WALL SLURRY WALL SOE			*0.71*	*44.80*	*54.40*	*9.92*	*21.68*	*29.27*	*160.08*								
22510	*4,978.00*	*BCY*	*2,403*	*139,885*		*10,705*	*41,412*	*99,560*	*291,561*								
U-WALL STR. EXCAV.			*0.48*	*28.10*		*2.15*	*8.32*	*20.00*	*58.57*								
22515	*1,037.00*	*CY*	*3,147*	*196,615*	*252,511*	*28,595*	*31,924*		*509,646*								
U-WALL INVERT CONCRETE 2.5FT THICK			*3.03*	*189.60*	*243.50*	*27.57*	*30.79*		*491.46*								
22520	*1,089.00*	*CY*	*9,552*	*613,012*	*313,835*	*121,661*	*99,173*		*1,147,681*								
U-WALL WALL CONCRETE 3.5 FT THICK			*8.77*	*562.91*	*288.19*	*111.72*	*91.07*		*1,053.89*								
22525	*159.00*	*CY*	*1,067*	*68,132*	*33,490*	*23,672*	*11,739*		*137,033*								
U-WALL WALKWAY CONCRETE 3.5 X3.5FT			*6.71*	*428.50*	*210.63*	*148.88*	*73.83*		*861.84*								
Totals:			1,180,391	74,535,737	63,750,748	17,232,514	47,381,170	28,174,994	231,075,165		231,075,165		80,876,307	311,951,472			311,951,450.18

Code between Balanced Bid & Bid Price: U=Unbalanced, F=Frozen, C=Closing Biditem (item to absorb unbalancing differences).

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid#	Client# Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	------Balanced Bid------ Unit Price	Bid Price	Bid Total
[bracketed numbers represent adjusted quantities]																		
** in front of the Biditem indicates a Non-Additive item																		
Markup on Resource Costs														80,876,307				
********* TOTAL	JOB =====>			1,180,391	74,535,737	63,750,748	17,232,514	47,381,170	28,174,994	231,075,165		231,075,165		80,876,307	311,951,472			311,951,450.18

Spread Indirects On TOTAL COST Spread Markups On TOTAL COST Spread Addons&Bonds On TOTAL COST

-----Estimate Notes-----
Bid Date: Owner: Engineering Firm:
Estimator in Charge:

Desired Bid (if specified)= 0.00 Sort: Hold Acct: N Subitem: Y NonAdd: N
Last Summary on 09/01/2006 at 2:23 PM.
Last Spread on 09/01/2006 at 2:23 PM.

NOTE: Biditems that are subitems (have a parent biditem) are printed in italics.

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Client# Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total
21000	10,110.00	LF	487,393	30,717,243	25,235,965	7,110,527	20,716,455	12,946,814	96,727,004		96,727,004	9,567.46	33,854,451	130,581,455	12,916.07	12,916.07	130,581,467.70
DILLINGHAM- BERETANIA-S.KING ST. TUN			48.21	3,038.30	2,496.14	703.32	2,049.11	1,280.59	9,567.46			35.0 %	3,348.61				
21100	*380.00*	*LF*	*25,377*	*1,586,674*	*1,263,177*	*322,786*	*438,997*	*545,497*	*4,157,130*		*4,157,130*	*10,939.82*					
DILLINGHAM- BERETANIA-S.KING PORTAL@1			*66.78*	*4,175.46*	*3,324.15*	*849.44*	*1,155.25*	*1,435.52*	*10,939.82*								
21110	*11,520.00*	*SF*	*9,027*	*565,458*	*551,113*	*146,481*	*245,937*	*400,257*	*1,909,245*								
SLURRY WALL@1313+30			*0.78*	*49.08*	*47.84*	*12.72*	*21.35*	*34.74*	*165.73*								
21120	*7,262.00*	*BCY*	*3,462*	*201,436*		*22,158*	*59,580*	*145,240*	*428,414*								
PORTAL EXCAV.@1313+30			*0.48*	*27.74*		*3.05*	*8.20*	*20.00*	*58.99*								
21130	*2,118.00*	*CY*	*5,088*	*320,810*	*494,536*	*48,456*	*49,659*		*913,462*								
PORTAL INVERT CONC. @1313+30			*2.40*	*151.47*	*233.49*	*22.88*	*23.45*		*431.29*								
21140	*739.00*	*CY*	*7,799*	*498,970*	*217,528*	*105,691*	*83,820*		*906,009*								
PORTAL WALL CONC @1313+30.			*10.55*	*675.20*	*294.35*	*143.02*	*113.42*		*1,225.99*								
21200	*260.00*	*LF*	*17,572*	*1,098,270*	*849,763*	*239,265*	*299,107*	*364,743*	*2,851,148*		*2,851,148*	*10,965.95*					
BERETANIA-SOUTH KING PORTAL@1371+00			*67.59*	*4,224.12*	*3,268.32*	*920.25*	*1,150.41*	*1,402.86*	*10,965.95*								
21210	*7,560.00*	*SF*	*5,907*	*370,698*	*362,611*	*96,294*	*161,574*	*265,363*	*1,256,540*								
SLURRY WALL @1371+00			*0.78*	*49.03*	*47.96*	*12.74*	*21.37*	*35.10*	*166.21*								
21220	*4,969.00*	*BCY*	*2,390*	*139,108*		*15,302*	*41,172*	*99,380*	*294,962*								
PORTAL EXCAV. @1371+00			*0.48*	*28.00*		*3.08*	*8.29*	*20.00*	*59.36*								
21230	*1,449.00*	*CY*	*4,009*	*250,761*	*338,283*	*40,980*	*39,860*		*669,883*								
PORTAL INVERT CONC. @1371+00			*2.77*	*173.06*	*233.46*	*28.28*	*27.51*		*462.31*								
21240	*506.00*	*CY*	*5,264*	*337,703*	*148,869*	*86,690*	*56,501*		*629,763*								
PORTAL WALL CONC. @1371+00			*10.40*	*667.40*	*294.21*	*171.32*	*111.66*		*1,244.59*								
21300	*350.00*	*LF*	*59,571*	*3,750,423*	*2,869,995*	*841,526*	*1,081,237*	*2,849,619*	*11,392,801*		*11,392,801*	*32,550.86*					
DILLINGHAM-BERETANIA-S.KING CUT&COVE			*170.20*	*10,715.49*	*8,199.99*	*2,404.36*	*3,089.25*	*8,141.77*	*32,550.86*								
21310	*29,014.00*	*SF*	*19,448*	*1,228,399*	*1,315,935*	*335,706*	*605,022*	*967,299*	*4,452,360*								
CUT&COVER SLURRY WALL@1313+30			*0.67*	*42.34*	*45.36*	*11.57*	*20.85*	*33.34*	*153.46*								
21320	*18,116.00*	*BCY*	*8,718*	*507,405*		*55,815*	*150,181*	*362,320*	*1,075,721*								
CUT&COVER EXCAV.@1313+30			*0.48*	*28.01*		*3.08*	*8.29*	*20.00*	*59.38*								
21325	*152.00*	*EA*						*1,520,000*	*1,520,000*								
F&I TIEBACK ANCHORS@1313+30								*10,000.00*	*10,000.00*								
21330	*1,951.00*	*CY*	*5,025*	*314,427*	*455,620*	*47,903*	*48,096*		*866,045*								
CUT&COVER INVERT SLAB CONC.@1313+30			*2.58*	*161.16*	*233.53*	*24.55*	*24.65*		*443.90*								
21335	*272.00*	*CY*	*1,777*	*113,277*	*57,291*	*31,549*	*19,584*		*221,701*								
CUT&COVER WALKWAY CONC.@1313+30			*6.53*	*416.46*	*210.63*	*115.99*	*72.00*		*815.08*								
21340	*965.00*	*CY*	*9,064*	*588,649*	*284,422*	*136,889*	*99,912*		*1,109,871*								

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Bid Description	Client#	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total
CUT&COVER WALL CONC.@11313+30				9.39	610.00	294.74	141.85	103.54		1,150.13								
21345		311.00	CY	3,558	228,985	79,173	82,906	40,762		431,827								
CUT&COVER INTERIOR WALL CONC.@1313+3				11.44	736.29	254.58	266.58	131.07		1,388.51								
21350		1,672.00	CY	10,729	697,321	508,986	142,842	94,116		1,443,265								
CUT&COVER ROOF CONC.@1313+30				6.42	417.06	304.42	85.43	56.29		863.20								
21355		7,804.00	CY	1,248	71,960	168,570	7,916	23,564		272,010								
CUT&COVER BACKFILL@1313+30				0.16	9.22	21.60	1.01	3.02		34.86								
21360		350.00	LF	58,690	3,699,684	2,822,208	823,312	1,061,145	2,799,249	11,205,598		11,205,598	32,015.99					
DILLINGHAM-BERETANIA-S.KING CUT&COVE				167.69	10,570.52	8,063.45	2,352.32	3,031.84	7,997.85	32,015.99								
21365		28,578.00	SF	19,177	1,212,178	1,349,668	331,019	596,598	922,509	4,411,972								
CUT&COVER SLURRY WALL@1371+00				0.67	42.42	47.23	11.58	20.88	32.28	154.38								
21370		17,837.00	BCY	8,584	499,591		54,955	147,867	356,740	1,059,153								
CUT&COVER EXCAV.@1371+00				0.48	28.01		3.08	8.29	20.00	59.38								
21372		152.00	EA						1,520,000	1,520,000								
F&I TIEBAACKS@1371+00									10,000.00	10,000.00								
21375		1,951.00	CY	5,153	322,522	455,620	48,667	50,137		876,945								
INVERT SLAB CONC.@1371+00				2.64	165.31	233.53	24.94	25.70		449.48								
21378		272.00	CY	1,777	113,277	57,291	31,549	19,584		221,701								
WALKWAY CONC.@1371+00				6.53	416.46	210.63	115.99	72.00		815.08								
21380		965.00	CY	9,064	588,649	284,422	127,285	99,912		1,100,267								
WALL CONC.@1371+00				9.39	610.00	294.74	131.90	103.54		1,140.17								
21382		311.00	CY	3,558	228,985	79,173	82,906	40,762		431,827								
INTERIOR WALL CONC.@1371+00				11.44	736.29	254.58	266.58	131.07		1,388.51								
21385		1,672.00	CY	10,729	697,321	508,986	142,843	94,116		1,443,266								
ROOF CONC.@1371+00				6.42	417.06	304.42	85.43	56.29		863.20								
21390		4,030.00	CY	644	37,161	87,050	4,088	12,169		140,467								
CUT&COVER BACKFILL@ 1371+00				0.16	9.22	21.60	1.01	3.02		34.86								
21400		10,110.00	LF	326,181	20,582,193	17,430,822	4,883,638	17,835,970	6,387,705	67,120,327		67,120,327	6,639.00					
BERETANIA-SOUTH KING TUNNEL EXC.&LINI				32.26	2,035.83	1,724.12	483.05	1,764.19	631.82	6,639.00								
21410		1.00	LS	15,010	932,686		455,931	170,563	750,000	2,309,180								
SETUP PORTAL AREA@1316+80				15,010.88	932,685.85		455,931.04	170,562.63	750,000.00	2,309,179.52								
21415		1.00	LS	1,435	90,213		39,625	8,447		138,285								
SETUP PORTAL AREA@1371+00				1,435.94	90,213.07		39,624.91	8,447.32		138,285.30								
21420		1.00	EA	30,046	1,865,896		397,469	9,009,607		11,272,971								
EPBM@1316+80				30,046.80	1,865,896.21		397,468.73	9,009,606.50		11,272,971.44								

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Bid Description	Client# Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total
21425	*1.00*	*SET*	*19,702*	*1,200,013*	*3,360*	*84,249*	*387,384*		*1,675,006*								
TRAILING GEAR@1316+80			*19,702.40*	*1,200,013.14*	*3,360.00*	*84,248.93*	*387,383.90*		*1,675,005.97*								
21430	*1.00*	*LS*						*1,446,500*	*1,446,500*								
PREPARE PORTAL@1316+80								*1,446,500.00*	*1,446,500.00*								
21432	*1.00*	*LS*						*1,402,500*	*1,402,500*								
PREPARE PORTAL @ 1371+00								*1,402,500.00*	*1,402,500.00*								
21435	*1.00*	*LS*	*4,031*	*247,129*		*17,299*	*77,186*		*341,614*								
RAIL EQUIPMENT@1316+80			*4,031.00*	*247,128.65*		*17,299.01*	*77,186.46*		*341,614.12*								
21450	*10,110.00*	*LF*	*255,954*	*16,246,256*	*17,427,462*	*3,889,065*	*8,182,783*	*2,788,705*	*48,534,271*								
MINE TUNNELS 1316+80 TO 1371+00 (2-TUNN			*25.32*	*1,606.95*	*1,723.78*	*384.68*	*809.38*	*275.84*	*4,800.62*								
22000	5,080.00	LF	373,159	23,444,623	16,791,055	5,301,868	17,067,941	11,219,453	73,824,940		73,824,940	14,532.47	25,838,729	99,663,669	19,618.83	19,618.83	99,663,656.40
HOTEL-WAIMANU-KAPIOLANI ST. TUNNEL(			73.46	4,615.08	3,305.33	1,043.67	3,359.83	2,208.55	14,532.47			35.0 %	5,086.36				
22100	*320.00*	*LF*	*29,896*	*1,860,341*	*1,889,736*	*355,339*	*485,265*	*595,559*	*5,186,240*		*5,186,240*	*16,207.00*					
HOTEL-WAIMANU-KAPIOLANI PORTAL @ 138			*93.43*	*5,813.57*	*5,905.43*	*1,110.43*	*1,516.45*	*1,861.12*	*16,207.00*								
22110	*9,720.00*	*SF*	*7,613*	*476,911*	*866,543*	*123,557*	*207,498*	*340,739*	*2,015,248*								
SLURRY WALL@1380+20			*0.78*	*49.06*	*89.15*	*12.71*	*21.35*	*35.06*	*207.33*								
22120	*12,741.00*	*BCY*	*6,074*	*353,413*		*38,875*	*104,532*	*254,820*	*751,641*								
PORTAL EXCAV.@1380+20			*0.48*	*27.74*		*3.05*	*8.20*	*20.00*	*58.99*								
22130	*3,567.00*	*CY*	*9,033*	*571,268*	*831,347*	*90,157*	*94,419*		*1,587,191*								
PORTAL INVERT CONCRETE@1380+20			*2.53*	*160.15*	*233.07*	*25.28*	*26.47*		*444.97*								
22140	*652.00*	*CY*	*7,174*	*458,749*	*191,846*	*102,750*	*78,816*		*832,160*								
PORTAL WALL CONCRETE@1380+20			*11.00*	*703.60*	*294.24*	*157.59*	*120.88*		*1,276.32*								
22200	*350.00*	*LF*	*22,883*	*1,429,735*	*1,050,149*	*291,491*	*399,368*	*492,784*	*3,663,526*		*3,663,526*	*10,467.22*					
HOTEL-WAIMANU-KAPIOLANI PORTAL@1411			*65.38*	*4,084.96*	*3,000.43*	*832.83*	*1,141.05*	*1,407.95*	*10,467.22*								
22210	*10,200.00*	*SF*	*7,580*	*473,762*	*394,427*	*123,516*	*218,089*	*359,004*	*1,568,799*								
SLURRY WALL@1411+90			*0.74*	*46.45*	*38.67*	*12.11*	*21.38*	*35.20*	*153.80*								
22220	*6,689.00*	*BCY*	*3,189*	*185,543*		*20,410*	*54,880*	*133,780*	*394,612*								
PORTAL EXCAV.@1411+90			*0.48*	*27.74*		*3.05*	*8.20*	*20.00*	*58.99*								
22230	*1,951.00*	*CY*	*4,875*	*306,627*	*455,315*	*46,390*	*47,873*		*856,205*								
PORTAL INVERT CONCRETE@1411+90			*2.50*	*157.16*	*233.38*	*23.78*	*24.54*		*438.85*								
22240	*681.00*	*CY*	*7,239*	*463,802*	*200,406*	*101,175*	*78,526*		*843,910*								
PORTAL WALL CONCRETE@1411+90			*10.63*	*681.06*	*294.28*	*148.57*	*115.31*		*1,239.22*								
22300	*330.00*	*LF*	*59,249*	*3,721,538*	*2,858,202*	*836,902*	*1,117,876*	*2,818,594*	*11,353,112*		*11,353,112*	*34,403.37*					
HOTEL-WAIMANU-KAPIOLANI CUT&COVER@			*179.54*	*11,277.39*	*8,661.22*	*2,536.07*	*3,387.50*	*8,541.19*	*34,403.37*								

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Client# Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	Balanced Bid Total	Balanced Bid Unit Price	Bid Price	Bid Total
22310	*30,807.00*	*SF*	*19,383*	*1,224,591*	*1,365,244*	*339,826*	*641,296*	*1,010,714*	*4,581,671*								
CUT&COVER SLURRY WALL@1380+20			*0.63*	*39.75*	*44.32*	*11.03*	*20.82*	*32.81*	*148.72*								
22315	*144.00*	*EA*						*1,440,000*	*1,440,000*								
F&I TIEBACKS@1380+20								*10,000.00*	*10,000.00*								
22320	*18,394.00*	*BCY*	*8,852*	*515,186*		*56,671*	*152,484*	*367,880*	*1,092,221*								
CUT&COVER BOX EXCAV.@1380+20			*0.48*	*28.01*		*3.08*	*8.29*	*20.00*	*59.38*								
22330	*1,839.00*	*CY*	*5,142*	*321,297*	*429,474*	*48,071*	*51,003*		*849,846*								
CUT&COVER BOX INVERT CONC.@1380+20			*2.80*	*174.71*	*233.54*	*26.14*	*27.73*		*462.12*								
22335	*257.00*	*CY*	*1,936*	*122,046*	*54,131*	*32,501*	*21,023*		*229,700*								
CUT&COVER WALKWAY CONC.@1380+20			*7.53*	*474.89*	*210.63*	*126.46*	*81.80*		*893.77*								
22340	*909.00*	*CY*	*8,986*	*580,003*	*267,377*	*134,652*	*98,076*		*1,080,108*								
CUT&COVER WALL CONC.@1380+20			*9.89*	*638.07*	*294.14*	*148.13*	*107.89*		*1,188.24*								
22345	*293.00*	*CY*	*3,371*	*216,952*	*74,591*	*81,370*	*38,612*		*411,525*								
CUT&COVER INTERIOR WALL CONC.@1380+2			*11.51*	*740.45*	*254.58*	*277.71*	*131.78*		*1,404.52*								
22350	*1,577.00*	*CY*	*10,189*	*661,499*	*480,066*	*135,016*	*89,196*		*1,365,776*								
CUT&COVER ROOF CONC.@1380+20			*6.46*	*419.47*	*304.42*	*85.62*	*56.56*		*866.06*								
22355	*8,672.00*	*CY*	*1,387*	*79,964*	*187,319*	*8,796*	*26,186*		*302,265*								
CUT&COVER BACKFILL@1380+20			*0.16*	*9.22*	*21.60*	*1.01*	*3.02*		*34.86*								
22360	*300.00*	*LF*	*49,196*	*3,103,151*	*2,232,684*	*718,833*	*862,924*	*2,312,277*	*9,229,868*		*9,229,868*	*30,766.23*					
HOTEL-WAIMANU-KAPIOLANI CUT&COVER@			*163.99*	*10,343.84*	*7,442.28*	*2,396.11*	*2,876.41*	*7,707.59*	*30,766.23*								
22365	*23,064.00*	*SF*	*15,579*	*983,824*	*989,221*	*268,200*	*481,554*	*762,937*	*3,485,736*								
CUT&COVER SLURRY WALL@1411+90			*0.68*	*42.66*	*42.89*	*11.63*	*20.88*	*33.08*	*151.13*								
22370	*11,467.00*	*BCY*	*5,518*	*321,173*		*35,329*	*95,061*	*229,340*	*680,903*								
CUT&COVER BOX EXCAV.@1411+90			*0.48*	*28.01*		*3.08*	*8.29*	*20.00*	*59.38*								
22375	*132.00*	*EA*						*1,320,000*	*1,320,000*								
F&I TIEBACKS@1411+90								*10,000.00*	*10,000.00*								
22380	*1,672.00*	*CY*	*4,933*	*307,412*	*390,463*	*46,758*	*49,253*		*793,886*								
CUT&COVER BOX INVERT CONC.@1411+90			*2.95*	*183.86*	*233.53*	*27.97*	*29.46*		*474.81*								
22382	*233.00*	*CY*	*1,988*	*124,566*	*49,076*	*34,115*	*21,524*		*229,281*								
CUT&COVER WALKWAY CONC.@1411+90			*8.53*	*534.62*	*210.63*	*146.42*	*92.38*		*984.04*								
22385	*826.00*	*CY*	*8,080*	*522,230*	*242,957*	*127,892*	*88,187*		*981,266*								
CUT&COVER WALL CONC.@1411+90			*9.78*	*632.24*	*294.14*	*154.83*	*106.76*		*1,187.97*								
22387	*267.00*	*CY*	*3,092*	*199,048*	*67,971*	*79,082*	*35,364*		*381,465*								
CUT&COVER INTERIOR WALL CONC.@1411+9			*11.58*	*745.50*	*254.57*	*296.19*	*132.45*		*1,428.71*								
22390	*1,433.00*	*CY*	*9,581*	*620,664*	*436,230*	*124,792*	*84,047*		*1,265,733*								

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid# / Client# / Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total
CUT&COVER ROOF CONC.@1411+90			6.69	433.12	304.42	87.08	58.65		883.27								
22395	2,628.00	CY	420	24,232	56,766	2,666	7,935		91,599								
CUT&COVER BACKFILL@1411+90			0.16	9.22	21.60	1.01	3.02		34.86								
22400	5,080.00	LF	211,933	13,329,858	8,760,284	3,099,303	14,202,508	5,000,240	44,392,193		44,392,193	8,738.62					
HOTEL-WAIMANU-KAPIOLANI TUNNEL EXC.&			41.72	2,623.99	1,724.47	610.10	2,795.77	984.30	8,738.62								
22410	1.00	LS	15,010	932,686		455,931	170,563	750,000	2,309,180								
SETUP PORTAL AREA@1383+50			15,010.88	932,685.85		455,931.04	170,562.63	750,000.00	2,309,179.52								
22415	1.00	LS	1,435	90,213		39,625	8,447		138,285								
SETUP PORTAL AREA@1408+90			1,435.94	90,213.07		39,624.91	8,447.32		138,285.30								
22420	1.00	EA	30,046	1,865,896		397,469	9,009,607		11,272,971								
EPBM@1383+50			30,046.80	1,865,896.21		397,468.73	9,009,606.50		11,272,971.44								
22425	1.00	SET	19,702	1,200,013	3,360	84,249	387,384		1,675,006								
TRAILING GEAR@1383+50			19,702.40	1,200,013.14	3,360.00	84,248.93	387,383.90		1,675,005.97								
22430	1.00	LS						1,446,500	1,446,500								
PREPARE PORTAL @ 1383+50								1,446,500.00	1,446,500.00								
22432	1.00	LS						1,402,500	1,402,500								
PREPARE PORTAL @ 1411+90								1,402,500.00	1,402,500.00								
22435	1.00	LS	4,031	247,129		17,299	77,186		341,614								
RAIL EQUIPMENT@ 1383+50			4,031.00	247,128.65		17,299.01	77,186.46		341,614.12								
22450	5,080.00	LF	141,706	8,993,921	8,756,924	2,104,730	4,549,321	1,401,240	25,806,137								
MINE TUNNEL 1383+50 TO 1408+90 (2-TUNNE			27.89	1,770.46	1,723.80	414.32	895.54	275.83	5,079.95								
23000	2,360.00	LF	341,716	21,515,683	15,758,234	3,925,646	6,109,066	12,095,613	59,404,241		59,404,241	25,171.29	20,791,485	80,195,726	33,981.24	33,981.24	80,195,726.40
HOTEL-KAWAIAHAO-KAPIOLANI ST.CUT&C			144.79	9,116.81	6,677.22	1,663.41	2,588.59	5,125.26	25,171.29			35.0 %	8,809.95				
23100	320.00	LF	20,678	1,287,856	1,044,065	266,938	347,375	421,901	3,368,135		3,368,135	10,525.42					
HOTEL-KAWAIAHAO-KAPIOLANI PORTAL@14			64.62	4,024.55	3,262.70	834.18	1,085.55	1,318.44	10,525.42								
23110	8,580.00	SF	6,972	435,629	485,409	111,426	184,128	304,681	1,521,273								
PORTAL SLURRY WALL@1403+80			0.81	50.77	56.57	12.99	21.46	35.51	177.30								
23120	5,861.00	BCY	2,794	162,574		17,883	48,086	117,220	345,763								
PORTAL EXCAV.@1403+80			0.48	27.74		3.05	8.20	20.00	58.99								
23130	1,784.00	CY	4,671	293,016	416,515	45,283	46,154		800,968								
PORTAL INVERT CONCRETE@1403+80			2.62	164.25	233.47	25.38	25.87		448.97								
23140	474.00	CY	6,239	396,637	142,141	92,346	69,006		700,130								
PORTAL WALL CONC.@1403+80			13.16	836.79	299.88	194.82	145.58		1,477.07								
23200	2,360.00	LF	321,038	20,227,827	14,714,169	3,658,708	5,761,691	11,673,712	56,036,107		56,036,107	23,744.11					
HOTEL-KAWAIAHAO-KAPIOLANI-CUT&COVE			136.03	8,571.11	6,234.82	1,550.30	2,441.39	4,946.49	23,744.11								

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid#	Client# / Bid Description	Quantity	Unit	Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	Balanced Bid Total	Balanced Bid Unit Price	Bid Price	Bid Total
23210		155,760.00	SF	106,287	6,707,802	6,846,348	1,822,025	3,256,774	5,170,592	23,803,542								
	CUT&COVER SLURRY WALL@1380+20-1403+8			0.68	43.06	43.95	11.70	20.91	33.20	152.82								
23220		89,156.00	BCY	37,456	2,179,641		239,760	645,017	1,783,120	4,847,539								
	CUT&COVER EXCAV.@1380+20-1403+80			0.42	24.45		2.69	7.23	20.00	54.37								
23225		472.00	EA						4,720,000	4,720,000								
	F&I TIEBACKS@ 1380+20-1403+80								10,000.00	10,000.00								
23230		8,566.00	CY	25,836	1,610,000	2,045,246	190,108	258,529		4,103,884								
	CUT&COVER INVERT CONC.@1380+20-1403+			3.02	187.95	238.76	22.19	30.18		479.09								
23235		1,836.00	CY	13,708	854,517	386,707	127,191	146,125		1,514,540								
	CUT&COVER WALKWAY CONC.@1380+20-140			7.47	465.42	210.62	69.28	79.59		824.91								
23240		6,556.00	CY	60,830	3,930,442	1,928,495	593,146	660,814		7,112,896								
	CUT&COVER WALL CONC.@1380+20-1403+80			9.28	599.52	294.16	90.47	100.80		1,084.94								
23245		2,098.00	CY	20,529	1,330,144	534,101	253,466	238,748		2,356,460								
	CUT&COVER INTERIOR WALL CONC.@1380+2			9.79	634.01	254.58	120.81	113.80		1,123.19								
23250		7,342.00	CY	50,920	3,300,136	2,235,032	398,345	452,485		6,385,999								
	CUT&COVER ROOF CONC.@1380+20-1403+80			6.94	449.49	304.42	54.26	61.63		869.79								
23255		34,177.00	CY	5,468	315,145	738,239	34,666	103,198		1,191,247								
	CUT&COVER BACKFILL@1380+20-1403+80			0.16	9.22	21.60	1.01	3.02		34.86								
Totals:				1,202,269	75,677,549	57,785,254	16,338,040	43,893,462	36,261,879	229,956,185		229,956,185		80,484,665	310,440,850			310,440,850.50

Code between Balanced Bid & Bid Price: U=Unbalanced, F=Frozen, C=Closing Biditem (item to absorb unbalancing differences).
[bracketed numbers represent adjusted quantities]
** in front of the Biditem indicates a Non-Additive item

Markup on Resource Costs											80,484,665			
********* TOTAL	JOB =====>	1,202,269	75,677,549	57,785,254	16,338,040	43,893,462	36,261,879	229,956,185		229,956,185	80,484,665	310,440,850		310,440,850.50

Spread Indirects On TOTAL COST Spread Markups On TOTAL COST Spread Addons&Bonds On TOTAL COST

-----Estimate Notes-----
Bid Date: Owner: Engineering Firm:
Estimator in Charge:

Desired Bid (if specified)= 0.00 Sort: Hold Acct: N Subitem: Y NonAdd: N

ESTIMATE SUMMARY - COSTS & BID PRICES

Bid#	Client# / Bid Description	Quantity	Unit / Manhours	Direct Labor	Perm Matl	Constr Matl	Equip-Ment	Sub-Contr	Direct Total	Indirect Charge	Total Cost	Total Cost Unit Price	Markup	------Balanced Bid------ Total	Unit Price	Bid Price	Bid Total

Last Summary on 06/15/2006 at 10:09 AM.
Last Spread on 06/15/2006 at 2:16 PM.

NOTE: Biditems that are subitems (have a parent biditem) are printed in italics.