Table 6-1: Comparison of Mitigation Options

Criteria	Res. 3 Opt. 1	Res. 3 Opt. 2	Res. 3 Opt. 3	Res. 3 Opt. 4	Res. 4 Opt. 1	Res. 4 Opt. 2	Res. 4 Opt. 4
Relative Cost	L	M	H	H	L	M	H
Traffic Impacts	M	L	L	H	M	L	H
Impact to Historic Structures	H	H	H	H	L/M(1)	L	L
Seismic Perform. (475-yr event)	VG	G	G	G	VG	G	G
Permitting Difficulty	M	M	M	M	L/M(1)	M	L
Constructability	VG	G	G	G	VG	G	G

L = Low
M = Medium
H = High
P = Poor
G = Good
VG = Very Good

(1) Ranking for Fill Option A/Fill Option B

Based on our review of the mitigation options, we recommend that Option 1 be selected for Reservoir 3 if PWB is willing to accept the risk of a lower static FS in exchange for lower construction cost. If PWB would like a higher degree of confidence in the landslide mitigation measures, Option 2 should be implemented at Reservoir 3. For Reservoir 4, we recommend that Option 1 be selected with fill geometry B regardless of what option is chosen for Reservoir 3.

7. CONSIDERATIONS FOR FINAL DESIGN OF MITIGATION MEASURES

7.1 General

Subsurface explorations have been completed over much of the Washington Park Landslide. Many of the explorations in the upper three-fourths of the landslide are from exploratory shafts excavated in the early 1900's. Subsurface information from these explorations is generally anecdotal in nature. Explorations advanced using modern drilling techniques and landslide instrumentation has generally been concentrated near the toe of the landslide. Depending on the mitigation measure selected by PWB, additional subsurface explorations and instrumentation may be necessary to support final design efforts. The following sections discuss data gaps in the existing subsurface information.

7.2 Groundwater

Groundwater conditions in the landslide mass are complex and generally poorly defined. For final design of landslide mitigation measures, it is important to accurately characterize piezometric head at or slightly above the landslide shear zone. In order to properly plan construction, it is also important to characterize perched groundwater conditions within the landslide mass. Perched groundwater would have major impacts on shaft and anchor drilling techniques and could dictate what excavation shoring system is appropriate. The dewatering shaft exploration logs suggest that perched groundwater was present at the time dewatering tunnels were excavated. Groundwater levels appear to be considerably lower at present.

Several of the slope inclinometers installed in the mid- to late-1980's were perforated and set in pea gravel backfill to provide information on depth of shearing and groundwater levels. The slope inclinometer casing and pea gravel backfill extended into bedrock beneath the shear zone. We experienced consistent drill mud losses in recent explorations once bedrock was encountered, indicating there are open fractures in the bedrock. It is likely that groundwater intercepted by the 1980's instruments is being drained down into the bedrock fractures. Water level readings in these instruments could indicate erroneously low groundwater levels.

Before proceeding with final design, we recommend installing additional vibrating-wire piezometers to better define groundwater conditions near the head of the landslide and near the mitigation measures. The number and location of the piezometers required would depend on the mitigation measure selected. Nested vibrating-wire piezometers could be installed in the same borehole to provide information on perched groundwater and groundwater at the shear zone.

7.3 Bedrock

The structural mitigation measures proposed for Reservoirs 3 and 4 involve large numbers of anchors and/or piles founded in bedrock. At present, the current bedrock profile is not defined as accurately as it should be for such a large drilling program. In our experience, it is more cost effective to perform additional explorations than it is to put the risk of bedrock location on the anchor or shaft contractor.

Existing subsurface explorations were generally terminated once bedrock was confirmed at the bottom of the boring. The engineering properties of the bedrock are poorly defined. Before