MEMORANDUM

DATE: March 26, 2001

TO: Port of Seattle, attn. Michael J. Cheyne

FROM: Michael Bailey, P.E.

RE: MSE Wall Performance During Earthquake
J-4978-19

CC: HNTB, attn. Mr. Jim Thomson, P.E.

Per our discussion this morning here is a summary of our research on the two MSE walls that are noted by Helsell Fetterman (Eglick & Stock, 3/20/01) and GeoSyntec (3/15/01) as having had problems during the February 28 Nisqually earthquake.

Basically Eglick & Stock and GeoSyntec claim that because the recent earthquake caused significant or extensive damage to these two walls, the Corps should carefully scrutinize structural integrity of the Port's proposed wall. GeoSyntec further raise a number of technical questions (mostly the same as already raised in their original 2/16/01 letter) that we are working on responses to.

The 2 MSE walls identified as having "problems" are discussed below.

Summary: 9 to 12-foot High Wall in Tumwater

This MSE wall failed by collapsing during or possibly shortly after the earthquake, and was shown on a number of photos taken by Shannon & Wilson, a local consulting engineer who was doing regional post earthquake damage assessment. Details are scarce because there is reportedly pending litigation, but the following information summarized below was compiled from post earthquake survey notes posted on the web and an email from Shannon & Wilson to Hart Crowser and a member of the Port's ETRB.

In summary:

1) The failed wall was not a RECo wall although it was designed using similar principals.

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2) The failed wall used a plastic reinforcing product (the Port plans to use steel), and plastic reinforcing is particularly susceptible to damage during construction.
3) The wall replaced a previously failed wall at the same site – there is an implication here but not proof, that there may be a defect in the foundation subgrade or possibly that the site investigation and/or design was less than thorough; and
4) A broken water pipe at the top of the wall backfill may have played a part in the failure.

SUMMARY: MSE WALL AT NORTH END OF TERMINAL 5

This MSE wall was briefly mentioned on a web site established by the Earthquake Engineering Research Institute, and a similar site established by the University of Washington, that present preliminary reconnaissance reports on damage due to the earthquake.

Under the heading "Earth Structures" the EERI report simply notes:

> *Liquefaction did cause movements of retaining structures at the Port of Seattle, but the movements were small enough that their function was not compromised.*

The University of Washington web site shows a heading for Terminal 5 on a table entitled "Earthquake Damage Facts and Figures" and notes:

- *North end*
  - *Sand boils on APL property*
  - *MSE wall movement*
    - *Ground cracks – 1-2" wide, 300' long, up to 1" vertical offset*
  - *2" settlement near buildings*

Hart Crowser is not aware of any other publicly available report on the T-5 wall and we do not know who made the original observations that led to these web citations. However, Hart Crowser accomplished detailed observations at T-5 (as a subconsultant to the Port); our observations are presented in the enclosed memo (see Attachment B) and summarized below.

In summary:

1) There are two MSE walls up to about 20 feet in height at T-5, and neither wall failed or was damaged in any significant way. At least one of the walls apparently moved

during the earthquake (as did many structures) but there is little, if any, permanent deformation evident.

2) Movement of one wall during the earthquake is chiefly evident by accumulation of some backfill material that apparently worked its way through the joints in the masonry wall facing. The wall facing is intact and appears undamaged.
3) The ground adjacent to the walls experienced pavement cracks of the magnitude noted above.
4) Soils at the site were previously identified as susceptible to liquefaction; the MSE walls were selected in part to accommodate the poor foundation conditions. No subgrade improvement (stone columns etc.) was used during construction; and
5) The T-5 walls are not a RECo-type wall, although they were designed using similar principals.

For your information, we are aware of only one other MSE wall in the region that experienced any distress due to the recent earthquake. At a 17-foot high MSE wall at a Costco in Tacoma, a nominal 2H : 1V slope behind the wall failed and slid over the top of the wall, and a slight bulge in the wall face is inferred to have been caused by the earthquake.

Please call if you have any questions.

Attachment A
Additional Details on 9 to 12-foot High Wall in Tumwater

The wall is an Aztec block wall. Total slope height is 14 to 18 feet; max wall height is 9 to 12 feet. Backslope is approx 3:1. Two geo-grid types of reinforcement were observed—asphalt impregnated polyester biaxial geogrid with a 20 mm x 20 mm aperture, and a polypropylene biaxial geogrid with a 30 mm x 40 mm aperture. Backfill is a slightly gravelly, silty SAND.

According to a city official, the wall was built approx 8 months ago. It was a replacement for a wall that failed in the last rainy season (the previous wall was not an MSE wall). We understand that the City was to have sent Shannon & Wilson the design drawings, construction memoranda, and geotechnical report for the wall, so they could do an analysis to determine the cause of failure, but results have not been made public.

Of note is there was a broken water pipe at the top of the failed slope. It is difficult to tell if the pipe broke because of the earthquake motion or if the pipe was leaking and that contributed to the wall failure.

Attachment B
Additional Details on the Port of Seattle T-5 Wall

MEMORANDUM

DATE: March 26, 2001

TO: Mr. Don Oates, KPFF Consulting Engineers

FROM: Garry E. Horvitz, Hart Crowser, Inc.

RE: **Summary of Field Observations**
Terminal 5 Public Access
J-7549

This memo presents a summary of our observations and recommendations pertaining to the Mechanically Stabilized Earth (MSE) walls at the Public Access area of Terminal 5 in the Port of Seattle. The purpose of our visit was to assess the nature and extent of damage suffered by the MSE walls, if any, and to make recommendations for further action and studies, if necessary.

We visited the site with you to observe the condition of the walls shortly after the February 28, 2001 Nisqually earthquake. The primary purpose of the visit was to note the condition of the existing MSE structures. The MSE walls at the western portion of the Public Access consist of two tall walls approximately 15 to 20 feet in height at their highest point. The two wall systems act as abutments for a short pedestrian access bridge. Subsurface conditions at this location, based on our geotechnical explorations for the project, consist of fill soils overlying marine deposits, which consist of loose to medium dense, silty, fine-grained sand to sandy silt. MSE walls were originally selected for this location because of the very large height requirements for the abutments and given the high cost associated with constructing conventional concrete cantilever retaining walls. Conventional walls would have needed to be pile-supported because of the potential for settlement under the weight of the new fill and to accommodate liquefaction and settlement under a design level seismic event.

MSE walls were selected because of their flexibility and ability to retain their function even after undergoing substantial earthquake-induced settlement.

The condition of the MSE walls at the time of our visit was good. The ground surface at the lower elevations surrounding the base of the walls had obviously undergone some lateral spreading and settlement as evidenced by occasional cracks in the asphalt pavement that extended a number of tens of feet in a direction longitudinal to the bridge spanning between the two abutments. The geosynthetic walls themselves appear to have undergone little permanent deformation or displacement.

Of particular note is the accumulation of wall drainage material (fine rounded gravel) at three locations along the base of the wall at vertical construction joints in the wall. At these locations we observed an accumulation of about one half cubic yard of material that appears to have come from behind the wall. This was unusual because there is no apparent deformation of the wall and no cracking or voids in the wall at these locations. We have concluded that the accumulation of material is due to differential movement of the separate wall segments during the strong seismic shaking. The various segments are free to respond to shaking and it is likely that the harmonic motion of each segment was slightly different. This would result in the construction joints in the wall system opening and closing slightly which would allow the cohesionless drainage gravel to flow from behind the wall before the two segments closed again.

In all respects the MSE walls appear to have preformed well. The walls appear to remain vertical and plumb and very little, if any, permanent deformation of wall segments was observed. Because there appears to be little differential displacement of the wall system either vertically or laterally, it is our opinion that it is unlikely that there is failure of the reinforcement behind the walls. At this point, unless additional evidence of damage becomes apparent, we do not feel that any remedial measures are warranted. The fact that some minor amount of drainage material has been lost from behind the wall would indicate that over time there could be some settlement of the landscaping above and behind the walls. We would recommend that this area be monitored over time and that depressions noted in the ground surface above the walls be noted and backfilled in a timely manner, on an as needed basis.

We trust this memo provides you with the necessary information. If you have any questions, please call at your convenience.