found off the Pacific coast.

Historical documents, that were newly found in recent years, make us suspect that the epicenter of the last earthquake in 1854 might be very close to the coast. This finding, when it was released in 1976, caused much public unrest in Shizuoka Prefecture.

Although no symptom that suggests immediate occurrence of a great earthquake has been found, a Prediction Council for the Tokai area was formed as a sub-organization of the Coordinating Committee for Earthquake Prediction. The Council, headed by T. Hagiwara, a professor emeritus at the University of Tokyo, consists of five university professors working in Tokyo.

Quite a dense observation network of instruments, including an array of sea bottom seismographs, tiltmeters, volume strainmeters, tide gauges, and instruments for monitoring groundwater level and radon contents and the like, is set up over the Tokai area. Most of the observed data are telemetered direct or via respective organizations responsible for the observation to the Japan Meteorological Agency (JMA) on the real-time, on-line basis.

It is planned that the Tokai area be designated an 'area under intensified measures against earthquake disaster' by the Large-Scale Earthquake Counter-measures Act.

Source: "The Large-Scale Earthquake Countermeasures Act and the Earthquake Prediction Council in Japan", Tsuneji Rikitake, EOS Trans August 7, 1979.

LIVERMORE (U.S.) EARTHQUAKES

The Livermore area to the east of Berkeley, San Fransisco, was shaken by two earthquakes on 24 and 26 January, 1980. Both earthquakes were in the magnitude range 5 - 5½ (M^L). The earthquakes were widely reported, as they caused minor damage and some radiation leakage at the Lawrence Livermore Laboratory. Although the earthquakes are relatively small, four points are worthy of interest:

- The first principal shock was followed by two others with M^L greater than 4 in rapid succession, one 53 seconds and the other 97 seconds after. This repetition gave a relatively long duration to the shaking.

- Buckling and anchor bolt damage occurred in wine and water tanks. The winery had 208 cylindrical steel tanks of which 70 (full) tanks suffered a medium level of damage, and 24 sustained severe damage. Most of the anchors of these type tanks had failed and the shells were buckled extensively. The tanks were constructed of 12 to 14 gauge stainless steel, were from 6 - 22' high with a height to diameter ratio of between .8 and 3.0.

- The Lawrence Livermore Laboratory received considerable non-structural damage, particularly to ceilings.

- The zone of observable surface deformation is at least 6 kms long, and at one site at least 70 mm of right slip is apparent. The fault was previously classified as inactive, though apparently subsequent investigation revealed considerable evidence of Holoscene activity.

Reference:

Various articles and summaries in the E.E.R.I. Newsletter Volume 14, No. 2, March, 1980.

KAIWHARAWHARA RECLAMATION

In 1979, the Wellington Harbour Board applied for authority to reclaim 3.9 ha of land at Kaiwharawhara longside the Wellington urban motorway east of the existing reclamation and floating dock. The proposed reclamation was intended to provide an access way and service corridor for the construction of a relocated oil berth. In May, 1980, after a short period of public discussion, the Ministry of Transport approved the reclamation.

The proposed reclamation and oil berth sits astride the active Wellington fault. It is an extraordinary indictment on our planning procedures that this could have occurred without a full technical evaluation of the earthquake hazard and associated risks. Although the Ministry of Works, is unable to construct a building within 20 m of an active fault, it appears that the Ministry of Transport can authorise a major industrial development astride a plate boundary. The purpose of this article is to document this aspect of the proposal, the objections, and the recommendations of the Ministry of Transport.

The Harbour Board Proposal:

In support of its application, the Harbour Board commissioned an Environmental Impact Assessment and Feasibility Study and an Environmental Impact Report. The following quotes are taken from the first report.

> "The fault is not actually a line but is composed of sheer zone of shattered rocks caused by past vertical and trans-current movements. In the Kaiwharawhara region its position is not accurately known, but estimates range from directly beneath the Hutt Road to 400 m from the present shoreline .....
>
> As well as the risk of fault movement there is a danger of sand liquefaction due to earth vibrations. There has been no local experience of this phenomena occurring in the last century with quakes (SIC) on the modified Mercalliscale of up to

V.I. and V.I.I. being recorded and with epicentres as close as 100 km to Wellington. It appears that a stronger quake or a quake with a nearer epicentre would be necessary to put the recommended reclamation at risk. It has not been possible, within the scope of this investigation to determine the sensitivity of liquefactions of dredge sand available for reclamation.

The third seismic risk is the situation where neither the fault moves, nor does liquefaction take place, but where tremor causes damage to structures such as link spans and wharves.

Most of the Wellington business district is constructed on reclamations and this has been carried out with full knowledge of the risks from seismic factors discussed above. While this in itself provides no real justification for adding to a given risk situation, it does indicate public acquiescence of a relatively high level of risk from seismic activity.

By comparison with the City Centre development, which is composed mainly of high rise buildings, the proposed Port development at Kaiwharawhara would pose a much lower order of risk to human life. The daytime density of a person on a reclamation would be extremely low compared with the density in the central business district due, at least partly, to the capital intensive nature of the facilities planned. In addition, the structures envisaged are both lower and fewer than would be found in the city with a correspondingly reduced danger that these structures may fall or collapse.

An earth for reclamation of the type recommended would be easily reinstated in the case of fault movement but this would not be the case if mass liquefaction occurred.

It is considered that the element of risks from seismic activity is an acceptable one. Although the precise location of the sheer zone of the fault line is uncertain, this is not thought to be a critical problem. Little or no design changes could be recommended in regard to facilities such as communication and reticulation lines that would render them more resistant to an extensive fault movement. However, it is considered that further work in locating the extent of the zone might be useful in allowing such items as silos, fixed uploading equipment and buildings to be kept clear of the zone or movement.

With careful design and after further investigation of both the fault line position and the susceptibility of liquefaction of fill material, it is considered that the earthquake risk of the proposed Port developments zone is an acceptable one."

Paragraph 4 is surely incorrect. Furthermore the possibility of an oil spillage in the harbour is not discussed.

Objections:

The Ministry of Transport's review of the Harbour Board's application with respect to the seismic problem is reproduced below.

"Sea Bed Sediments

Very soft, deep layers of mud are known to exist in the Kaiwharawhara area. Although the reports' authors believe these are unlikely to cause problems to the access reclamation the DSIR (11) and Mr R.J. Bentley (5) were concerned that a full evaluation of the harbour substrata should be carried out.

Before further port development is commenced at Kaiwharawhara it will be necessary to evaluate the stability of the sediments underlying the area, and the effect of sand liquifaction in the event of a major earthquake. Discussions are presently being held with the DSIR on the matter. Appendix VII demonstrates the willingness of the Harbour Board to implement available scientific advice. Discussions on these issues should continue through the design stage of the project.

Seismic

The EIR fails to assess the danger of siting the access reclamation and oil berth on the Wellington fault zone.

Presumably further assessment was considered unnecessary in the light of the EIA & FS's conclusion that "... the element of risk from seismic activity is an acceptable one." This lack of concern is clearly illustrated in table 12 of the EIA & FS which does not include any data on the comparative risk, cost or impact of earthquake damage for the Korokoro, Gracefield or Kaiwharawhara sites. As the EIR envisages the access reclamation to be the first stage of major port development, the lack of comprehensive seismic data is a serious deficiency. The only Harbour Board comment of real help on this aspect is that earthquake risks need to be recognised and designed for accordingly. This is the sort of matter on which the Ministry of Transport would seek technical advice from the Ministry of Works and Development and DSIR and if necessary request further study on by the Harbour Board before giving plan approval to the works under section 178 of the Harbours Act 1950.

DSIR (11) described "the lack of ... seismic and/or drill hole data in the vicinity of the reclamation (as) worrisome ..." and concluded that "... evaluation of the substrata is essential." They pointed out that the presence of potentially unstable sedimentary layers at the

Kaiwharawhara site suggested liquefaction could result from severe earthquake generated shaking. The DSIR advised that further investigation of the load bearing capacity was necessary. This seemed especially important when one of the main exit routes from Wellington is located close to the proposed oil berth. In the event of emergency Mr R.J. Bentley (5), D.L. and G.R. Stevens (41) and the Nature Conservation Council (32) all questioned the wisdom of siting an oil berth on a potentially dangerous and highly unstable area. Mr R.J. Bentley described the concentration of water and oil supply pipes, the motorway, railway and other services in the Kaiwharawhara area, and thus on the Wellington fault, as "a cause of great concern" and emphasised the need for "much greater investigation and review before this proposal is approved."

As indicated in paragraph 3.3 above, discussions with the DSIR are continuing in an effort to improve the information base for designing the work.

While accepting the points made in this regard as important ones it should be borne in mind that the site for the new oil berth will be considerably safer than the existing one, and a severe earthquake along the fault line could well cause far more damage through destruction of the road and rail links than through destruction of the access reclamation."

The N.Z. National Society for Earthquake Engineering became aware of the issue while the Ministry of Transport were evaluating the objections to the development. In association with the New Zealand Geomechanics Society and the Geological Society of New Zealand, a joint press release was drafted and released on 26 September 1979 -

"Proposed Reclamation at Kaiwharawhara

Further investigations have been called for to assess the suitability of the Kaiwharawhara site before decisions are made to proceed with reclamation for an oil storage facility for the Wellington Harbour Board. This call was made in a combined statement issued today by the New Zealand National Society for Earthquake Engineering, the New Zealand Geomechanics Society and the Geological Society of New Zealand.

The Societies point out that the proximity of the Wellington fault to the proposed reclamation provides an additional hazard for this site, above that for other possible sites in the Wellington region. The Wellington fault is one of the major active faults in New Zealand. The fault is well defined near Tinakori Road and in the Hutt Valley, but off Kaiwharawhara its location is not known with certainty. One of the recommendations of the Societies is for a thorough investigation to locate the fault in the vicinity of the site.

The Wellington fault is expected to move approximately once every 1,000 years plus or minus 200 or 300 years. The date of last movement is not known but some carbon dating evidence suggest it could have been 900 years ago. Fault movements may occur along a length of as much as 50km. In the Kaiwharawhara area the fault crush zone comprises a 500 to 1,000 metres width of shattered greywacke rock. Movement of the fault could result in relative displacements of at least 5 metres both horizontally and vertically. The results of such movements are likely to be slumping of the ground and possible large soil movement caused by liquefaction of the marine sands under the reclamation. The hazards associated with liquefaction of the sands at this site could include large scale oil spillage into the harbour and fire obstructing the main access route into and out of Wellington.

The Societies acknowledge that the risk of strong shaking is common to all structures in the Wellington region, and the risk of liquefaction of marine sands is also present at other sites around the harbour. However, because of the additional hazard associated with the proximity to the Wellington fault, they recommend investigations additional to those conducted to date for this site. These should include location of the fault, drilling to determine the liquefaction potential of the marine sands, assessment of the risk of rupture of the fault and evaluation of the economic and environmental consequences of failure of the reclamation. These investigations should be completed before significant investment is made."

MINISTRY OF TRANSPORT RECOMMENDATIONS -

It is clear that the Ministry of Transport were disappointed that the Harbour Board did not provide sufficient explanation or justification of the reclamation, and that the alternatives were not discussed and properly discounted. The number of issues were raised with the Harbour Board, including "... that the Board is prepared to proceed having regard to D.S.I.R. advice.", and assurances were received on this question. The Ministry finally recommended -

1. That an order in Council for an access reclamation to a new oil berth at Kaiwharawhara be granted.

2. That investigation by the Board with the D.S.I.R. continue, to improve the information base on which the design details of the reclamation can be developed.

3. That the Harbour Board should progress the design work for the construction of the oil berth at the same time reclamation work proceeds, so that project completion in the shortest possible time frame can be achieved.

At the present time the Harbour Board have no plans for exploratory drilling in the area, and no plans for a seismic risk analysis of any kind. However they are likely to seek DSIR advice on the design of buildings on the reclamation for strong shaking.

R.J. Bentley