Dear Mr. Bohn:

THE COASTAL HIGH-HAZARD ZONE
AS MAPPED FOR THE
NATIONAL FLOOD INSURANCE PROGRAM

Introduction

Maps of the coastal high hazard zone (CHHZ) of the island of Oahu, proposed for use in the application of the National Flood Insurance Program by the City and County of Honolulu, have been made available for public review by the Department of Land Utilization, City and County of Honolulu. This review pertains, not so much to the maps as to the criteria on the basis of which we understand they have been prepared and the management practices proposed for institution within the CHHZ. The comments relate, therefore, not merely to the CHHZ proposed for Oahu but to the CHHZ's proposed for other islands in the State of Hawaii as well.

A draft of this review has been checked by Charles Bretschneider of the Department of Oceanography of the University and by Harold Loomis and Martin Vitousek of the Joint Institute of Marine and Atmospheric Research, Hawaii Institute of Geophysics. So far as I am aware, there is no disagreement among us as to the technical opinions. Dr. Loomis may consider that their expression at this time may delay unduly the initial establishment of the CHHZ and encourage seaward revisions of its boundary for short-sighted economic reasons. I cannot check this possibility out with him further at this time because he is out-of-State. If clarification of his opinion is desirable either he or I will communicate with you later.

The National Flood Insurance Act requires that the boundaries of the hazard areas as delineated on Flood Hazard Boundary Maps (FHBM's) must be objectively determined. The maps should merely represent the cartographic expression of boundary-mapping criteria, and the criteria themselves should be available for and open to review. The criteria for the CHHZ of Oahu are not cited on the maps, but it is our understanding that the boundary of the CHHZ on this island and others is intended to represent the limit of tsunami inundation with an average recurrence interval of 100 years. The location of this limit has been determined as follows:

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1) The 100-year inundation limit is represented by the intersection with the ground of a surface representing 100-year transverse tsunami runup profiles constructed in accordance with curves presented in a memorandum dated 20 May 1977 and unidentified as to authors or issuing agency but prepared by the Pacific Ocean Division, U.S. Army Corps of Engineers (1977).

2) The tsunami runup profiles were based on 100-year tsunami runup heights estimated from site-specific tsunami-runup frequency distributions whose coefficients were published by the Waterways Experiment Station, U.S. Army Corps of Engineers (Houston et al., 1977).

3) The tsunami-runup frequency distributions were based on the runup heights of the highest historic tsunamis at each coastal site as estimated by Houston et al.

Even if the CHHZ continues to represent the 100-year tsunami inundation zone, new information may result in improvement in the means used: 1) to determine the transverse runup profiles; 2) to estimate the 100-year tsunami runup heights along the coast and determine the shorelines relative to the shoreline to which they relate, and 3) determine the frequency distributions of runup-heights at the coastal sites.

Need may arise for determining where the boundary of the CHHZ lies with greater precision than the present maps of the CHHZ permit. Management decisions within the CHHZ may depend upon frequencies of inundation, depths of inundation, or water velocities within the zone. Parts of the methodology used in determining the boundary of the CHHZ may be useful also in tsunami hazard minimization schemes other than that of the National Flood Insurance Program. Hence, definition of the methodology is of greater importance than the maps delineating the limits of the CHHZ. The methodology and the results of each stage of its application should be matters of public record.

Presented in this review are evaluations of each phase of the methodology used in determining the boundary of the CHHZ and of the requirements for management within the CHHZ indicated by the Regulations of the HUD Federal Insurance Administration.
Introduction

Frequency distributions such as those used to estimate 100-year tsunami runups and, in turn, to estimate the extent of 100-year tsunami inundation in order to define the CHHZ, must be based on historic records of runup heights. Surveys of the runups of the more important tsunamis occurring since 1946 have been made around some or all of the major Hawaiian islands. However, for the tsunamis occurring prior to 1946, there are runup records at only a few sites. The earliest record is of a tsunami of unknown origin that affected the Kona coast in 1813 or 1814 (Pararas-Carayannis, 1969). The most complete tsunami runup record in Hawaii is that at Hilo (Cox, 1964) beginning in 1837. Records at Kahului and Honolulu also date from 1837. For some other coastal sites, particularly those on Oahu, and Hawaii, it is possible to compile reasonably complete records of the higher runups since 1946. For coastal sites in general, however, it is necessary to base the frequency distributions on synthetic frequency distributions, at least to the extent of estimating the local runup heights of known historic tsunamis.

Houston et al. methodology

The method used by Houston et al. to estimate the runup heights of the historic tsunamis at Hawaiian coastal sites was essentially as follows:

1) They adopted for the analysis the 140-year period beginning with 1837 when the first historical tsunami was reported at Hilo.

2) For reported runup heights of tsunamis occurring during this period, they used the following data:

a) For the following tsunamis, runup measurements compiled by Loomis (1976), more or less well distributed along most Hawaiian coasts: 1946 (E. Aleutians), 1952 (Kamchatka), 1957 (Central Aleutians), 1960 (Chile), and 1964 (Alaska).

b) For an important tsunami locally generated in 1975, runup measurements reported by Loomis (1976), well distributed where significant along coasts of the island of Hawaii.

c) For other tsunamis occurring during the period, runup heights compiled by Pararas-Carayannis (1969). (A revised edition of the Pararas-Carayannis catalog has now been issued as Pararas-Carayannis and Calebaugh, 1977, but the data used by Houston et al. have been little changed.)

3) From the above records they identified 16 tsunamis which, they considered, would include those that were highest at any Hawaiian coastal site. These included, in addition to the tsunamis identified in 2a) and 2b), an
important local tsunami occurring in 1868 and 10 distant tsunamis. The runup records used for the analysis pertained, then, to 14 distant tsunamis and 2 local tsunamis.

4) They assumed that all tsunamis from a given source region would have similar runup patterns along Hawaiian coasts, and that all significant tsunamis came from the following source regions: Kamchatka, the Aleutian Islands, Alaska, South America, the Sanriku coast of Japan (which was the source of a major tsunami in 1896, and another important one in 1933), the Tonga Islands (which was the source of a tsunami in 1919), and the Kau-SE Puna coast of Hawaii (which was the source of important local tsunamis in 1868 and 1975).

5) For a historical or typical tsunami from each of the source regions of Kamchatka, the Aleutian Islands, Alaska, and South America, they synthesized the runup pattern using a hybrid finite-element numerical model, whose nodal points on Hawaiian coasts were spaced generally at distances of 1 to 1-1/2 miles.

a) For the 1960 tsunami from Chile and the 1964 tsunami from Alaska, they used as input to the numerical analysis the estimated seabottom deformations that caused the tsunamis.

b) For typical tsunamis from Kamchatka and the Aleutian Islands they used as inputs sinusoidal disturbances of tsunami period.

6) From the numerical model they synthesized the runup heights of the tsunamis in question at a large number of coastal sites (nodal points of the numerical model) and marigrams at ports where the tsunamis had been recorded. The synthetic marigrams agreed well with actual marigrams but the synthetic runup patterns did not agree well with those indicated by runup surveys of these tsunamis. Hence, for each tsunami among the 14 distant ones identified in 3) that seemed significant along a particular coast, they estimated the actual runup at a number of coastal sites (nodal points of the numerical model) from the typical runup heights for a tsunami from the same source region predicted by the numerical analysis, adjusting these by reference to the historical runup data compiled in 2) giving preference to the historical data as follows:

a) Runup heights reported in the vicinity of each site.

b) Runup heights reported on the same coast as the site.

c) Runup heights reported elsewhere in Hawaii.

7) For the tsunamis from Japan and the Tonga Islands they presumably interpolated, as necessary, between the points at which runups were reported.
8) For the local tsunamis, they interpolated, as necessary, between the points at which the 1975 tsunami runups had been measured and used the 1975 record as a guide to estimating 1868 tsunami runups.

Inadequacies in documentation

Houston et al. published graphs of the longitudinal runup profiles of the 1946 Aleutian tsunami, the 1952 Kamchatkan tsunami, and the 1960 Chilean tsunami along the coasts of Oahu produced by their numerical model before and after adjustment.

However, their report does not indicate:

a) The factors used to adjust the runups of other historic tsunamis from Kamchatka, the Aleutians, or South America on Oahu;

b) Site-specific runups or runup profiles of the three typical tsunamis and other historic tsunami from the same three regions, before or after adjustment, along the coasts of other islands;

c) Site-specific runups or runup profiles of the 1964 or other historic Alaskan tsunamis (except as reported by Loomis);

d) Site-specific runups or runup profiles of the 1896 or other Japanese tsunamis (except as reported by Pararas-Carayannis);

e) Site-specific runups or runup profiles of the 1868 and 1975 local tsunamis (except as reported by Pararas-Carayannis and by Loomis respectively).

Because the ten tsunamis considered highest at each site (three highest for Molokai) are not identified in the Houston et al. report, and their heights were not tabulated, site by site, there is no means by which future investigators may substitute such future runups or corrected values of the already historic runups among the ten highest (three highest for Molokai) used by Houston et al. so as to improve the frequency distribution estimates in the future.

Tables (or computer files) of the above identified data, should be made publicly available, and the special treatment given Molokai should be made a part of the public record.

Invalid and incomplete historic data

The importance of the inadequacies of documentation is indicated by the fact that the historic runup data used by Houston et al. is in some respects already demonstrably incomplete or invalid or inconsistent with other at least equally reliable data.
As pointed out by Cox and Morgan (1977) certain of the 1975 local tsunami runup heights used in the Houston et al. analysis including the maximum value, were incorrect. Furthermore, the runup values used were referred to the level of the mean-sea-level shoreline after the subsidence which accompanied tsunami generation. For the purposes of land-use management and insurance, the values should be corrected to refer to the level of the pre-subsidence mean-sea-level shoreline. Because Houston et al. used the 1975 local-tsunami longitudinal runup profile as a guide in estimating the 1868 local-tsunami profile, the errors affect the 1868 runup estimates as well.

Cox and Morgan have also identified 19 possible additional local tsunamis occurring in Hawaii in the period from 1813 or 1814 to the present. The identification is certain only in the case of only six of these events. Some of the other 13 may have been storm waves, but many of them may have been distant tsunamis. In total nine were certainly tsunamis of local or distant origin. Cox and Morgan have summarized runup heights reported or estimated for all of these.

Cox has suggested to the Federal Insurance Administration (personal correspondence 2 November 1977, 10 February 1978) that the runup heights associated with all of the events that were certain should be included in a revision of the Houston et al. analysis, even if they may have been caused by storm waves, but there has been no response to the suggestion.

The use of the additional and corrected local-tsunami information will be most significant in the estimation of the frequency distribution of tsunami runups on the southeast coast of the Puna district coast of the Kau district of Hawaii. The only possible significant effects on Oahu would be on the northwest coast.

The reported runup heights of the 1896 Sanriku tsunami used by Houston et al. have been questioned. An investigation by Cox of the historic documentation for this tsunami in Hawaii is in progress. Changes in the estimates of the runup heights are likely to be significant only on the Kona coast of Hawaii.

There are inconsistencies between the locations and even the values of the measured runups of the tsunamis since 1946 as published by Pararas-Carayannis (1969) and as published by Loomis (1976). Cursory examination of the two compilations suggests that neither is wholly reliable. A new compilation based on the original records (and preferably made by someone involved in the original surveys) would be desirable. The differences between the results of such a new compilation and that of Pararas-Carayannis are likely to be significant only locally, but there may be localities of significant differences on most of the islands.

Assumed uniformity of runup pattern of tsunamis from a single source region

Houston et al. have assumed that tsunamis from any single distant source region will have identical runup patterns, the inter-site runup ratios being constant. Differences in the ratios may be expected with either differences in
the direction of approach of the tsunamis to the Hawaiian Islands or in the characteristic period of the tsunamis.

Little difference in the direction of approach to the islands can result in the case of tsunamis from Kamchatka. Historical evidence suggests that tsunamis from Alaska are of relatively little importance in Hawaii. There has been but one significant South American tsunami in the period since 1946 during which extensive surveys have been made of tsunami runups. Runup surveys indicate, however, that the runup patterns of the 1946 tsunami from the eastern Aleutians and the 1957 tsunami from the central Aleutians were distinctly different on the north coasts of at least Kauai and Oahu. The use of the 1946 tsunami runup pattern as typical of those of all Aleutian tsunamis must lead to distinct overestimates of the runup of tsunamis from other parts of the Aleutian Islands at some sites along the northern coasts of Hawaiian Islands and distinct underestimates in others. The differences may be seen by the following comparisons pertaining to places on the north coast of Kauai.

<table>
<thead>
<tr>
<th>Maximum Runup Heights, Feet</th>
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<tr>
<td>Haena</td>
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<tr>
<td>1946</td>
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<tr>
<td>1957</td>
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</table>

Rather than forcing the 1957 tsunami runups to fit the 1946 pattern, it would be best to apply the Houston et al. numerical analysis model to a typical source in the central Aleutians and use the results to estimate the runups of tsunamis from this source area along coasts where runups were not actually surveyed.

The effect of tsunami wave period on the tsunami runup patterns is so uncertain and the data on period of the older tsunamis is so meager that adjustment of tsunami runups for wave period is probably not warranted.

Alternative means for estimating tsunami runups

A number of alternative numerical analysis schemes have been developed for estimating, from the source characteristics of a tsunami, the behavior of the tsunami at a distant coast. None seem superior to the Houston et al. scheme as judged from the comparison of calculated and actual marigraphic records. The correlation between marigraphic wave heights and runup heights even in the vicinity of the marigraphic status is not good. However, no alternative can be proved superior to the Houston et al. scheme in predicting runup heights.
Frequency Distributions and 100-Year Values of Tsunami Runups

Introduction

The value of the tsunami runup at a coastal site that is likely to be experienced with an average frequency of once in 100 years must be determined from a frequency distribution of tsunami runup pertinent to the site.

Houston et al. methodology

Houston et al. (1977) estimated runup frequency distributions for the coastal sites representing nodal points in their numerical analysis scheme (see previous section). They assumed that the distributions were in the form:

\[ H = -B - A \log F \]  

where \( H \) = runup height at a site

\( F \) = average frequency of recurrence at the site of tsunamis of height equal to or exceeding 17.

A and B = coefficients to be determined by fitting equation (1) to the historic runups at the site.

For the historic runups at the sites they used the values estimated by means described in the previous section of the review. The coefficients A and B were determined by least squares regressions of height on log frequency.

Noting that the log-linear distribution of equation (1) applied at Hilo only to the higher, less frequent tsunamis (Cox, 1964), Houston et al. applied the regression analyses, according to their report, to the ten tsunami runups that were highest at each site. However, according to Houston (personal communication), the runup heights estimated for sites along the coasts of Molokai were so low that they applied the regression analysis to only the three runups that were highest at these sites.

The principal results of their analyses were published in the form of graphs of the A and B coefficients along the coasts of each of the islands. The numbered sites, representing numerical-model nodal points along the coasts, totalled 154 for Hawaii, 81 for Maui, 55 for Molokai, 34 for Lanai, 105 for Oahu, 55 for Kauai, and 19 for Niihau. In addition, it appears that, by some means, Houston et al. estimated frequency distributions for intermediate points, because the coefficient values graphed are not merely interpolated between the numbered sites but, in some cases, show peaks or troughs between the numbered sites.

Houston et al. also published values of 10-year tsunami runups at the numbered sites, calculated as 0.7 times the tenth highest estimated runups.
Estimated 100-year tsunami runups may readily be calculated from values of the A and B coefficients read from the published graphs as:

\[ H_{100} = -B - A \log \left( \frac{1}{100} \right) = 2A - B \]

In general, the values of the coefficients may be read from the graphs to the nearest foot, and the 100-year tsunami runup heights may thus be estimated to nearly the same accuracy.

Alternative assumptions as to frequency distribution

The use of equation (1) implies the assumption that the frequency distribution of the higher tsunami runups at a coastal locality follows an exponential law. This assumption is in agreement with the findings or assumptions of Cox (1964), Wiegel (1965, 1970), Adams (1970), Rascón and Villareal (1975) and Wybro (1976). Solov'ev (1970, 1972) found that the exponential distribution applied to tsunami intensities rather than runups, but his analyses pertained to the intensities along coasts adjacent to the areas in which the tsunamis were generated. Attempts to improve frequency distribution estimates were made by Rascón and Villareal by the use of Bayesian statistics, and by Wybro assuming a double-exponential (Gumbel) model, but the improvements are either too slight or too questionable to encourage the use of a more complicated form of frequency distribution for the purposes of the National Flood Insurance Program.

Alternative means of distribution fitting

Wybro (1976) found that, by normalization to the maximum historical runup height, the historical tsunami runup heights at Hilo, Kahului, and Honolulu could be fit by a frequency distribution formula involving but one site-specific coefficient instead of two. Recognizing that Hilo and Kahului are on northeast coasts of Hawaii and Maui, respectively, and that Honolulu is on the south coast of Oahu, Cox (1978) suggests that tsunami runup distributions more generally might best be fit by such a formula.

Alternative period of record

The Houston et al. analytic scheme, applying to tsunamis during the 140 year period of record since 1837, has been proposed as a replacement for schemes proposed by Taniguchi (1973) for Hawaii and by R.M. Towill Corp. (1976) for Oahu based on the period of record since 1946. Extensive surveys have been made of the runups of the important tsunamis since 1946. The runup data for tsunamis occurring earlier than 1946 is meager except at a very few sites. However, as pointed out by Houston et al., it is clear from the long-term historical record that the period since 1946 has been one of extraordinarily high tsunami runups in Hawaii, and 100-year runup estimates produced by extrapolation from the 32-year record since 1946 would be too high. Hence analysis of the runup heights of the longer time period, even if these must be synthesized by some means such as employed by Houston et al. is superior to an analysis based on the shorter-time record alone.
Transverse Runup Profiles and Inundation Limits

Introduction

If the reported or estimated runup height of a tsunami applies to the limit of inundation, the extent of inundation may be determined from a contour map or ground profile as the distance inland from the shoreline to the point on the ground whose altitude is equal to the runup height (assuming altitude and runup height are referred to the same datum).

Some of the runup heights reported for historic tsunamis apply to the limits of inundation. Others, however, were measured as the heights reached by the water at trees or against buildings within the inundation zone. To estimate the extent of inundation from runup heights pertinent to such intermediate locations it is necessary to know the location to which the runup height applies, the direction of water movement inland from that point, the ground profile in that direction, and either the profile of highest water level in that direction or the total energy associated with the runup height and the energy profile in that direction.

Cox (1976) expressed the opinion that, in the absence of contradictory information, it might reasonably be assumed that historical runup heights applied at locations 200 feet inland from the shoreline, and on this basis Houston et al. considered that 100-year tsunami runups estimated from their frequency distributions should apply at this distance. From the Houston et al. graphs of the A and B coefficients one may then construct a longitudinal near-shore 100-year runup profile, that is one lying parallel to and 200-feet inland of the shoreline.

In the absence of contradictory information it may be assumed that the direction of water movement in tsunami inundation is perpendicular to the shoreline. Hence the runup surface inland from the longitudinal runup profile is definable as the locus of transverse runup profiles (normal to the shoreline) connecting with the longitudinal runup profile. The estimated inundation limit is represented by the intersection of this runup surface with the ground.

Bretscheider and Wybro--POD scheme

On the basis of reported runup profile of the 1946 Aleutian and 1960 tsunamis, Bretschneider and Wybro (1976) have provided a means for estimating the transverse runup slopes as follows:

\[
\frac{dh}{dx} = - \left[ \tan \alpha + \frac{n^2 g F^2 h V^2}{(1.486)^2} \right] \left( \frac{F^2}{2} + 1 \right)^{-1}
\]

where  
- \( h = \) runup height above ground = \( H - A \)
- \( H = \) runup height above sea level
- \( A = \) ground elevation above sea level
- \( \alpha = \) ground slope in degrees
- \( n = \) Manning's friction factor
- \( g = \) acceleration of gravity
- \( F = \) Froude number
On the basis of the Bretschneider and Wybro equation, the Pacific Ocean Division, Corps of Engineers; (1977) (POD) has constructed curves by which the runup height at the inundation limit, and hence the inundation distance, may be determined by either a numerical or a graphical scheme. It is presumably through the use of these curves that the 100-year inundation limit or boundary of the CHHZ has been determined on the basis of the longitudinal runup profile indicated by the work of Houston et al.

For selection of the curve pertinent to a particular coastal site, the POD has tabulated values of the Manning friction factor, n, for typical ground, vegetation, and development conditions. The POD has also listed areas in which tsunami inundation has been in the form of bores to which the Foude number $F = 2$ applies. In other areas they suggest the use of $F = 1$ pertinent to non-bore conditions.

Alternative schemes

A number of means have been suggested for estimating runup heights at tsunami inundation limits from the heights of tsunami waves at the shoreline. Most of these apply, however, to runups on uniform slopes such as beaches and hence are not applicable to tsunami inundation over terrains of varying slopes and roughness. None of which we are aware approaches the utility of the Bretschneider and Wybro scheme, especially as its use has been facilitated by the POD curves.

Limitations

Where the direction of water movement in tsunami inundation may be expected to be other than normal to the shoreline, the Bretschneider and Wybro scheme may still be applied, the ground profile to be used and the runup profile to be constructed being those in the direction of water movement. However, the scheme is incapable of taking into account the effects of convergences of inundation such as are expectable at points or of divergences such as are expectable at bays. The effects of convergence and divergence may be locally significant.

The Bretschneider and Wybro scheme makes no allowance for the effects of differences in wave period on runup profiles. Wave periods are clearly important. The runup profiles of tides, whose periods are about 12 or 24 hours, are essentially flat. The runup profiles of wind waves of periods as much as 30 seconds, inundating fairly flat ground, are steep. Tsunamis, which may have apparent wave periods in the range from several minutes to an hour or more have intermediate runup-profile slopes. However, because the Bretschneider and Wybro scheme is based on the observed runup profiles of the 1946 tsunami, which had apparent periods in Hawaii of about 15 minutes and of the 1960 tsunami which had apparent periods in Hawaii ranging from 15 to 30 minutes, the effect of differences in wave period may not be great.
Summary of Possible Improvements in Methodology

In the foregoing sections a number of improvements in the methods used to determine the CHHZ boundary have been suggested. These, and some more general possible improvements are summarized below. Because it may be considered appropriate to defer actual establishment of the CHHZ pending some of the improvements, an indication is given of the time required for implementation of each possible improvement by the symbols:

I. Within a few weeks.
II. Within a couple of months.
III. Within a year or two.
IV. Unpredictable but probably not for some years.

(1) Formal identification of the methodology used in determining the boundary of the CHHZ. I

(2) Public availability of tabulations (or computer file) of runup estimates for all sites produced by numerical model for type tsunamis from Kamchatka, Aleutians, Alaska, and South America. I

(3) Public availability of tabulations (or computer file) of factors used for adjustment of numerical model results for all historic tsunamis from regions identified above. I

(4) Public availability of tabulations (or computer file) or tsunamis assumed 10 highest at each site, with estimated runup heights. I

(5) Application of numerical model to a typical central Aleutian tsunami, and reestimation of runups of tsunami from that region. II

(6) Correction of erroneous values of historic runups. I

(7) Insertion, in tabulation in (4), of the corrected values in (5), and projection from them, as appropriate. II

(8) Insertion in tabulation in (4) of now-compiled measured or estimated runups of other tsunamis and projections from them, as appropriate. II

(9) Checking all historic runups used in analysis. III

(10) Improvement in means for runup estimation for historic tsunamis. IV

(11) Formal recognition of special criteria used in Molokai analysis. I

(12) Consideration of use of frequency distribution applied to normalized runups per Wybro (1976). I
(13) Revision of frequency distribution per (12), if advisable.  
(14) Checking of historic runup record and frequency distribution at Hilo.  
(15) Checking of historic runup records and frequency distributions at Kahului and Honolulu.  
(16) Development and application of improved frequency distribution models if indicated by (14) and (15).  
(17) Improvement in means for determining transverse runup profiles.  
(18) Revision of CHHZ boundary on the basis of:  
    (a) (5), (6), (7), (13), and (14)  
    (b) (9), (15), and (16)  
    (c) (10), and (17)
Management Practices

As important as the location of the boundary of the CHHZ are the management practices to be established in its use. A City and County of Honolulu ordinance regulating land use and structural design in the CHHZ has not yet been proposed, hence the only comments that can now be made concerning tsunami hazard management with respect to the CHHZ relate to the National Flood Insurance Program regulations issued by the Federal Insurance Administration. A comprehensive review of these complex regulations will not be attempted here, but it seems worthwhile to point out a few questionable provisions.

No problem is seen with the provisions of the regulations regarding insurance. Risk premium rates are to be established in accordance with standard actuarial methods except as the insurance is subject to federal subsidy (Reg. 1911.7). The actual risk of flooding at any depth above ground level at any site in the CHHZ may be determined from the frequency distribution of tsunami runups near shore at the location in question, the transverse runup profile pertinent to the location, and the ground elevation at the site. The questionable provisions relate to the regulations pertaining when flood zoning is complete and the CHHZ has been established (Reg. 1910.3 (e)).

These regulations differentiate between zones of the CHHZ that will be subject to flooding of less than 3 feet in the case of a base (100-year) flood, designated VO, and those that will be subject to flooding of more than 3 feet in the case of a base flood, designated VI-30 in the regulations but abbreviated as VN here.

The regulations that require permits for construction in the CHHZ, the submission of pertinent data in the applications and review of this data, which are applicable even before the CHHZ is determined, are appropriate.

However, Reg. (e)(1)(c)(2) requires that the lowest floor of new residential structures in the VN zone be above the base-flood level. Reg. (e)(1)(c)(3), relating to non-residential structures is similar except that it allows flood proofing to the base-flood level. Regulation (e)(5) requires that the space below the lowest floor be open or surrounded only by "breakaway walls". Regulation (e)(6) prohibits the use of fill in the support of the structures. Although it is clear the proper precautions in the CHHZ have in many instances not been taken in the past, this combination of regulations is unduly stringent for several reasons:

i) The use of a structure such as a bath house requires that it be placed close to the shoreline and hence, often within the VN zone. Such use is incompatible with flood proofing; and raising the structure on piles would make it an unsightly feature in an area where esthetics are of great importance. The use may fully justify the risk of minor tsunami damage so long as the structure remains intact so that its washing away will not jeopardize nearby structures. The owners may be quite willing to accept the risk.
ii) By the means used to determine the transverse runup profiles, the boundary of the CHHZ itself may be shifted seaward by the use of fill. The Civic Center of Hilo has been constructed, for example, in an originally tsunami-prone area made safe by raising the ground level using fill.

iii) Even in the case of residential structures, the regulation is in some cases too stringent. A few residences have been sensibly constructed in tsunami-prone but low-risk areas with the main floor elevated above the tsunami-prone level through the use of piles or reinforced concrete posts anchored to substantial pads, and with the space below the main floor closed with "breakaway" walls (as suggested in the regulation), but with this space used for incidental or intermittent residential purposes. The risk to persons in such structures is taken care of by the tsunami warning system. The owners have been quite aware of and quite willing to accept the tsunami risk to the structures and their contents. The construction should be allowed so long as there is no public subsidy of the insurance on the structures and no claim for public relief in case of their damage.

Reg. (e)(1)(c)(7) requires that the lowest floor of new residential structures in the VO zone be above the crown level of the nearest street, and reg. (e)(1)(c)(8) makes the same requirement in the case of non-residential structures unless flood proofing is provided to above the crown level of the nearest street. To whatever extent these regulations may be appropriate in the case of stream flood management, there are clearly cases in which they are inappropriate in tsunami hazard management. They would require that a structure be elevated to be located downhill from the nearest street be elevated (or flood proofed) to the crown level of the street even though the street would in no way affect the inflow or the outflow of the tsunami floodwaters and indeed even if the street were completely outside of the CHHZ.

Regulation (e)(8) wisely prohibits the destruction of protective sand dunes in the VN zones. However, this prohibition extends also to mangrove stands. Although the removal of mangroves may be undesirable for several environmental reasons not restricted to tsunami management, the removal may be desirable in some locations, for example at stream mouths in order to pass stream floods. Incidentally, certain other types of vegetation are as effective as mangroves in reducing tsunami inundation.
References


Yours very truly,

[Signature]

Doak C. Cox
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DCC/1mk

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