In Figures 19 and 21, correlations between the number of damaged houses and the number of deaths are shown with the data divided into those four cities, wards, towns and villages located in the inland region and those for cities, wards, towns and villages along the coastal region which suffered damages due to storm surge. As the number of damaged houses, the author used the sum of 2 times the number of washed-away and the number of completely-destroyed, same as in the case of flood hazards, which was obtained by regression analysis. In Figure 19 showing the region which suffered damages due to storm surge, we can clearly distinguish a group with a large number of deaths and a high human casualty ratio. These cities, wards, towns and villages (in the group), being located in the innermost coastal region of Ise Bay with the exception of the city of Handa, were directly struck by the storm surge and suffered severe damages. The casualty ratio was also high for the following two reasons: this region consists of delta or reclaimed land which is low, flat, and spacious, with no natural highland suitable for evacuation; the attack of storm surge happened late in the evening, 9:30 p.m. The city of Handa is located in the coastal plains facing Chita Bay. The city had another suffering of damages due to storm surge when Typhoon 13 struck the region six years before the year of 1959. The human casualty ratio was again extraordinarily high at that time.

There stretches the largest land of elevation zero of Japan in the southern skirts of the Nobi Plains. The storm surge therefore invaded deep into the inland area reaching as far as 20 km from the coastal line. In Figure 19, light circles indicate cities, wards, towns and villages that suffered inundation due to storm surge in spite of their location at the inland not directly facing the coastal line. In comparison with the coastal region, both the scale and the ratio of human casualties are much smaller. Damages due to the storm surge were also brought about to the Chita Peninsula and the coastal region of Mikawa Bay where the tidal level was one to two meters lower than that at the innermost coast of Ise Bay. The Chita Peninsula and the Mikawa coastal region lie in the coastal plains with a stretch of mountains and hilly lands standing behind them. In the figure, data for this group are separately shown for the Chita Peninsula region and the Mikawa coastal region. The boundary of the two regions is shown in Figure 20. A clear difference exists between them in terms of the casualty ratio while a considerable dispersion of data is observed. The Mikawa Bay area which includes the eastern shore of the Chita Peninsula suffered severe damages due to the storm surge that were brought about by Typhoon 3 in 1953. It seems that hazards experience from that typhoon contributed to the mitigation of human casualties. In order to demonstrate quantitatively the difference in the human casualty ratio among these groups, the value of the regression constant (10^A), which is obtained by fixing its slope at unity as in the case of the casualty ratio due to wind-water hazards discussed above, is shown in this figure. The distribution of data points enables us to fit the regression line with the unitary slope without much trouble. Comparison of these values reveals that the casualty ratio of the delta coastal region is three times as high as that of the delta inland region. It can be also seen that the Mikawa coastal region has such a low casualty ratio as 1/2.5 of that of the Chita Peninsula region, or even 1/15 of that of the innermost delta coastal region of Ise Bay. The southern part of the Chita Peninsula has a low casualty ratio of almost the same size as that for the Mikawa coastal region. Such large differences in the human casualty ratio are possible to arise from different topographical conditions or geographical locations, hazards experience and so on. While the administrative authority is responsible for disaster prevention in terms of the transmission of various information on hazards and instruction for evacuation, we should also be concerned with how many of the residents of a region who receive the information and instructions actually do evacuate and do so effectively.

The data on damages due to Typhoon 13, omitted from the figure because it would make the figure messy, would be plotted almost in the middle range of the Mikawa coastal region and the Chita Peninsula region. In 1950, Typhoon Jane struck Osaka and caused large-scale damages while a wide area of the city was inundated by storm surge. The data on damages suffered by the coastal wards (of the City of Osaka) that were directly struck by the storm surge would be plotted in almost the same neighborhood of the casualty ratio as that of the delta inland region. Storm surge happened during daytime in the cases of these two typhoons.

Figure 21 shows the relation between the number of damages and the number of deaths for the cities, wards, towns and villages of the inland which did not suffer damages due to storm surge. With respect to the kind of damages suffered by these cities, wards, towns and villages, we find a large number of the completely-destroyed and the half-destroyed, but a small number of the inundated or none of the washed-away. This leads us to conclude that the deaths were caused by strong wind. The maximum instantaneous wind speed generated by the typhoon reached 40 to 60 m/sec in the inland region of Aichi Prefecture. The data points, indicated by dark circles, for the region struck by strong wind show a distribution that may be fitted by a regression line with the slope of approximate unity. At a range corresponding to the very high casualty ratio in the figure plotted are three data points for the towns and villages at the Mikawa mountain region, which, together with a number of the missing and the washed-away, suggests that the region may have been struck by debris hazards. Iseway Typhoon caused damages due to landslide or debris flow in the mountains of Nara Prefecture and Mie Prefecture as well. The number of deaths reached 72 in the village of Kawakami of Nara Prefecture. To increase the number of data for the region struck by debris hazards, major hazards-struck towns and villages of these two prefectures are also included in the figure.

In order to facilitate an easy comparison among all groups of the hazards-struck regions, regression lines (with the unitary slope) for each group are shown together in the figure. The debris-hazards-struck region shows the casualty ratio which equals that of the delta coastal region struck by storm surge, though the scale of casualties is considerably smaller than that of the Chita Peninsula region struck by storm surge. Since wind speed is generally great in the coastal region, damages due to strong wind are presumably included in the damages suffered by those cities, wards, towns and villages which are classified as being in the storm-surge-hazard-struck region. The human casualty ratio of the Mikawa coastal region, if we only look at storm-surge hazards, is presumed very small on the basis of the observation that the casualty ratio of the Mikawa coastal region is one half of that of the inland region struck by strong-wind hazards.

The depth of inundation is the major indicator of the intensity of the external force in the cases of storm surge and flood. In the delta region which suffered widespread storm surge and inundation due to Isewan Typhoon, there are certain wards, towns and villages whose almost entire jurisdiction were under water. In such cases, we compute the average depth of inundation and then obtain the correlation between the value and the damages of the wards, towns and villages. Figure 22 shows the relation between the average depth of inundation and the death rate according to cities, wards, towns and villages. Dark circles in the upper part of the figure indicate the regions (including a town and a village in Mie Prefecture) struck by the storm-surge inundation due to Isewan Typhoon. The average depth of inundation is obtained from the chart showing the distribution of the depth of inundation.

We find that a clear correlation exists except Kanie-cho (town) and Minami-ku (ward), and that the death rate is given by the power function of the depth of inundation. Minami-ku of the City of Nagoya suffered a large number of deaths due to a huge amount of timber which flowed out of seaside timberyards. With the average depth of inundation of Minami-ku which is 1.7 m, the death rate is obtained from the regression equation and then converted into the number of deaths. This number is subtracted from the actul number of deaths, and the difference turns out - 1,000. This difference is considered as corresponding roughly to the incremental number of deaths due to the timber flow. A report says that the amount of timber which flowed out of timber yards in the vicinity of Port Nagoya was about 2,000 ton, the maximum distance traveled by the flow was 3.5 km and the number of deaths due to the timber flow was about 1,500. While the entire town of Kanie-cho was inundated, it suffered a much lower rate in comparison with the coastal region because the flow speed or the speed of rising water level was low in this town of inland location.

It is quite unusual in the case of river flood which takes place at the basin of a mountain valley or at the piedmont area that an entire town or village is inundated. At the time of Kanogawa Suigai (flood) the flat land of Nirayama village was under water in its entire range except the mountain area with few houses. Also in the City of Ito, the central section of the city located in the small valley basin facing the ocean was inundated in its entirety. The death rates of the city and the village are also shown in the figure: they are plotted in a range very close to the regression line for Isewan Typhoon. Here the population of the densely-inhabited district (DID) was used to compute the death rate for the City of Ito. At the time of Isahaya Gou (heavy rain), the central section of the City of Isahaya was inundated in a wide range. The maximum depth of inundation at this time was 3.5 m, from which the average depth of inundation is estimated to have been 2 to 2.5 m and is shown in the figure for reference. In the case of flash flood, we cannot indicate the intensity of the external force only by the depth of inundation because its flow speed is large and moreover it contains debris and trees.

Figure 22 includes the relation between the death rate and the average depth of inundation (measured by the City of Osaka) in the case of Typhoon Jane which brought about storm surge and inundation to the port-neighboring wards of the City of Osaka. If data points are taken from only those wards with 80 per cent or more inundated area, almost perfect linear correlation is recognized in the figure. The death rate is smaller by one digit in comparison with that of Isewan Typhoon. It had not been long since the defeat of the war when Typhoon Jne hazards took place in 1950. Presumably various disaster prevention programs were not established to a sufficient extent at that time. The time of hazards strike may be one reason for the large (apparently puzzling) differences between these two typhoons. While the storm surge happened around 1 p.m. in the case of Typhoon Jane, it happened at 9.30 p.m. in the case of Iseway Typhoon. Also in the cases of Kanogawa Suigai (flood) and Isahaya Suigai (flood) the time of strike was 10 to 11 p.m. There is a strong possibility that the death rate will turn out very different depending on the difference in the results of various activities such as recognition of situation, transmission of information, execution of evacuation, rescue operations and so on while this difference in turn depends on whether hazards take place in daytime or nighttime.

6. Debris Hazards

Figure 23 shows the relation between the number of damaged houses and the number of deaths involved in Minami-Yamashiro Debris Hazards which struck the towns and villages of Kyoto Prefecture in August 1953. The highest correlation is obtained when identical weights are given to the washed-away and the completely-destroyed. The slope of the regression line is slightly greater than unity as seen in the equations for other hazards. In the case of debris-flow hazards it is difficult to obtain a physical quantity which indicates the intensity of the external force. As mentioned above, however, a high correlation is recognized between the number of damaged houses and human casualties, and this relation enables us to investigate the factors involved in the scale of human casualties.

Figure 24 shows the relation between the number of deaths and the number of damaged houses, the latter of which is computed as the sum of the washed-away, the completely-destroyed and one half of the half-destroyed. Using data on the major landslide or debris-flow hazards which took place during the period of 1965-1982. Since the impact of debris is extremely intense, its possible effects on human casualties is considered substantial even in the case of the half-destroyed. This leads us to give the weight of 0.5 to the half-destroyed. Meanwhile, the correlation in the case of earthquate hazards turns out the highest when the half-destroyed is provided with the weight of 0.2. In general, the number of damaged or inundated houses investigated by the jurisdiction of cities, towns and villages is larger than that investigated by the police: in some cases the former number is more than twice the latter. In order to secure homogeneity of data and also their easy access when we compare a large number of data on various hazards, here we use the police data that are investigated on a consistent basis and then tallied according to the jurisdiction: the city of Tokyo, Hokkaido, and all the other prefectures. We must be aware that the results to be shown here are based on the data on damages that are investigated by the police and tallied over all the urban and rural prefectures of Japan.

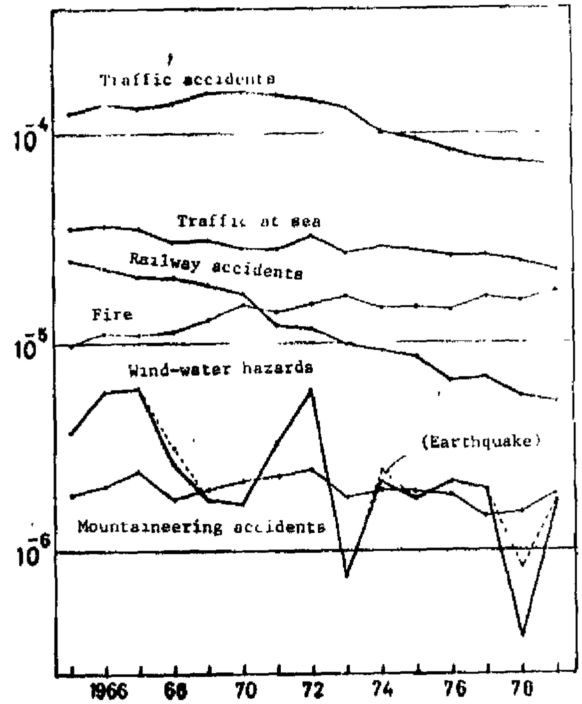
In Figure 24, it is clearly shown that on the one hand all the high ratios of human casualty are attached to those hazards which took place after 10 p.m., namely during midnight hours, while on the other hand, those which took place during the hours of morning-10 p.m. all involved low ratios of human casualty. Comparison of the regression coefficients when we fix the slope at unity, reveals that the casualty ratio in the nighttime cases is three times as high as that in the daytime cases (excluding the two hazards with a high casualty ratio matching up with that in the nighttime cases). We also recognize that hazards which take place in the urban area tend to have a higher casualty ratio than those which strike villages in the mountain area. In Figure 25 the correlation is shown between the number of damaged houses and the number of the injured. While there is no clear difference according to the time of impact, it is nevertheless observed that those data points plotted in the range of a high injury ratio are the cases of nighttime strike.

When heavy rain falls upon a mountain region damages are often caused by a large-scale flood as well as landslide and debris flow. It is usually the case that the number of damaged houses due to flood hazards is relatively greater than that due to debris hazards. Figure 26 shows separately those hazards where landslide and debris flow were combined with a large-scale flood at a valley basin as in the cases of Minami-Kinki Suigai (flood) in 1953, Uetsu Suigai (flood) in 1967 and Nagasaki Suigai (flood) in 1982. Those debris hazards shown in Figure 25 caused no death and a small number of damaged houses while flooding of a river took place. In Figure 26 most data points are distributed in the neighborhood of a single regression line, which indicates that they have almost an identical casualty ratio. There are, however, two data points which largely deviate from the group: Kanogawa Suigai and Nagasaki Suigai have the casualty ratio 6.5 times as large as the rest. A possibility thus exists that human casualties could increase to such a large extent depending on the degree of awareness and preparedness of residents against the danger of hazards.

Figure 27 shows the variation according to the time of impact in the casualty ratio involved in debris hazards. It is clearly recognized that a peak of the human casualty ratio lies in the hours between 10 p.m and 4 a.m., that is, in the range of midnight hours.

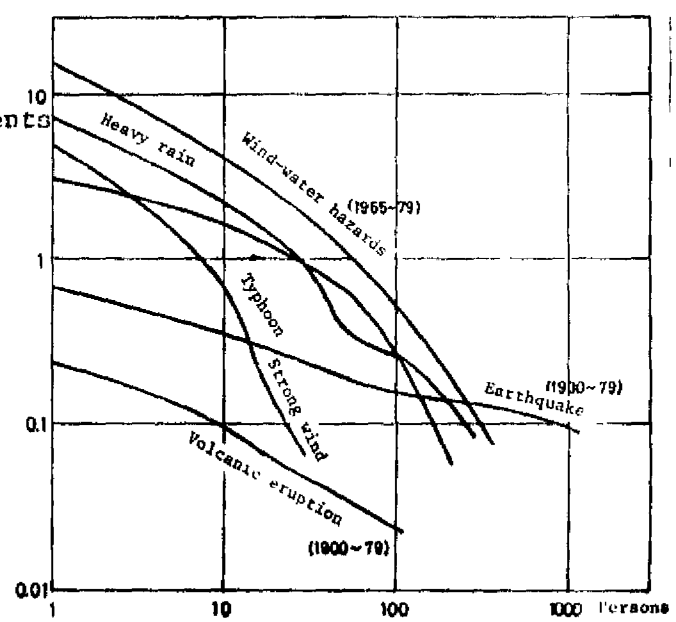
F I G U R E S

The number of deaths
Total population



<u>Figure</u> 1. Changes over time in the death rates (The number of death is taken from the Police White Paper).

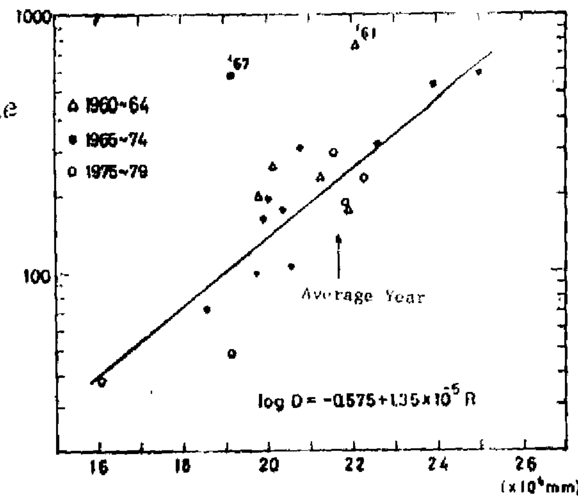
The frequency of events with the number of deaths exceeding N (The frequency of events per year)



The number of deaths (N)

Figure 2. The relation between the number and frequency of deaths due to natural hazards

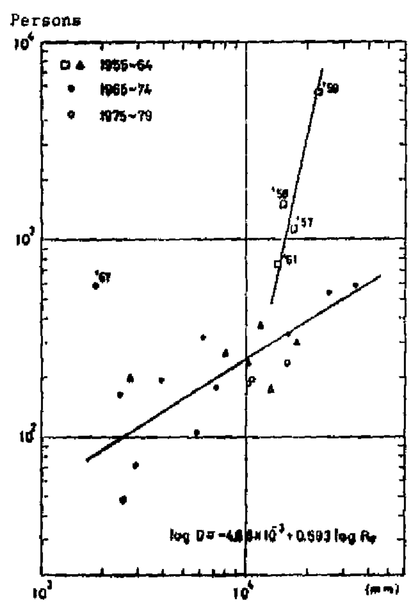
The number of deaths due to water hazards (D)



Total annual rainfall (R)

<u>Figure 3.</u> The relation between the total annual rainfall (the sum of annual rainfall reported by 127 meteorological observatories in Japan) and the annual number of deaths due to water hazards (the sum of the number of deaths due to typhoon and that due to rain on the basis of the police investigated data)

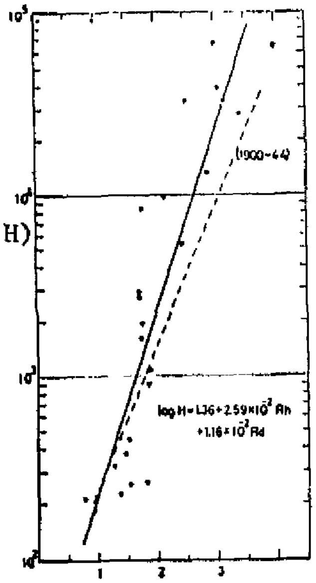
The number of deaths due to water hazards (D)



The total rainfall exceeding the annual average (Re)

<u>Figure 4.</u> The relation between the number of deaths per year due to water hazards and the total rainfall exceeding the annual average (the sum of that part of annual rainfall which exceeded the average annual value of 127 meteorological observatories in Japan)

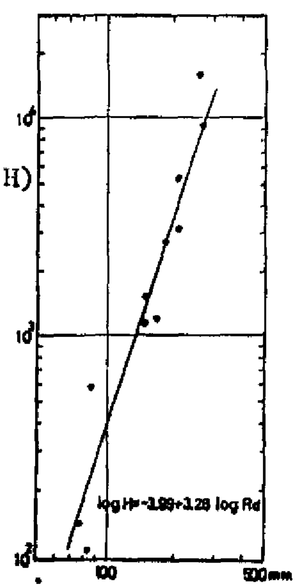
The number of inundated houses (H)



Intensity of rainfall

<u>Figure 5.</u> The relation between the intensity of rainfall and the number of inundated houses (above and below floor level) in the City of Nagoya (1965-80)

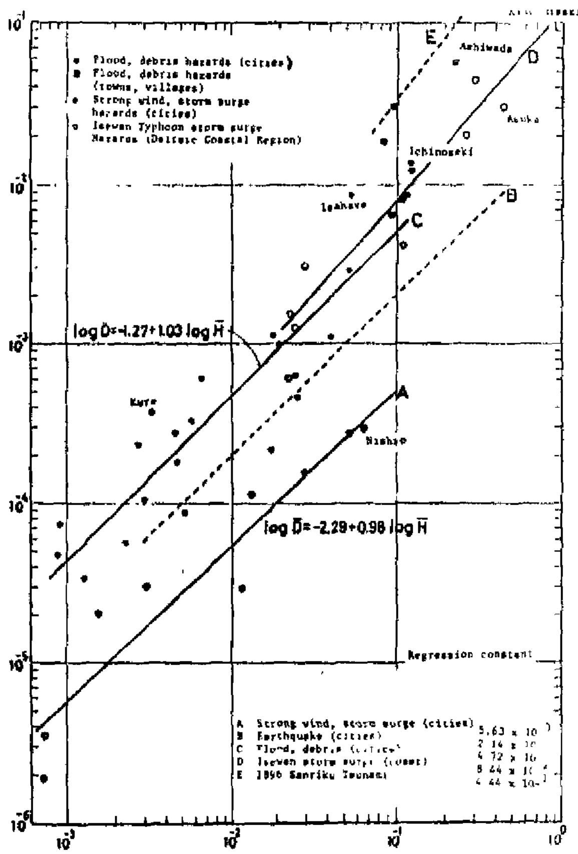
The number of inundated houses (H)



Daily maximum rainfall (Rd)

<u>Figure 6.</u> The relation between the intensity of rainfall and the number of inundated houses (above and below floor level) in the city of Yokohama (1910-72)

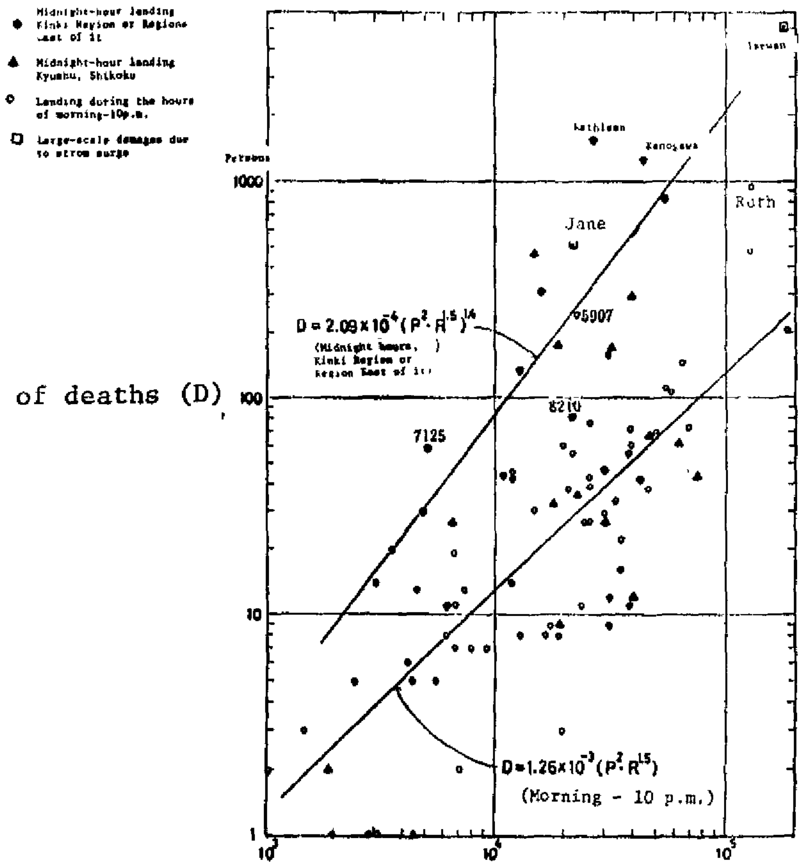
The death rate ($\bar{D}$)



The ratio of completely collapsed and **washed-away** houses ($\bar{H}$)

<u>Figure 7.</u> The relation between the ratio of **completely** collapsed and washed-away houses. (By the unit **of cities**, towns, villages)

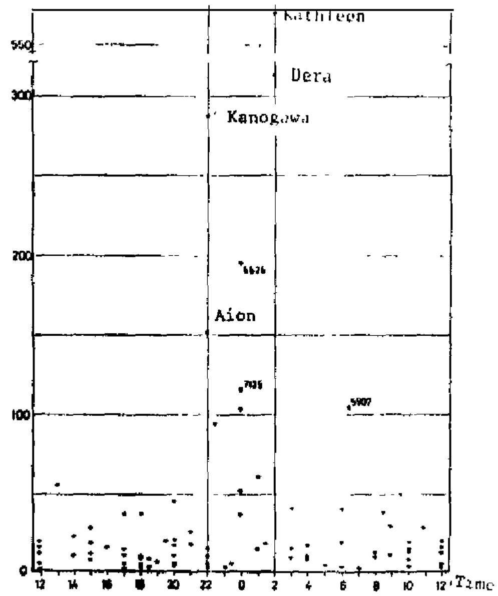
The number of deaths (D)



The intensity of typhoon at landing time

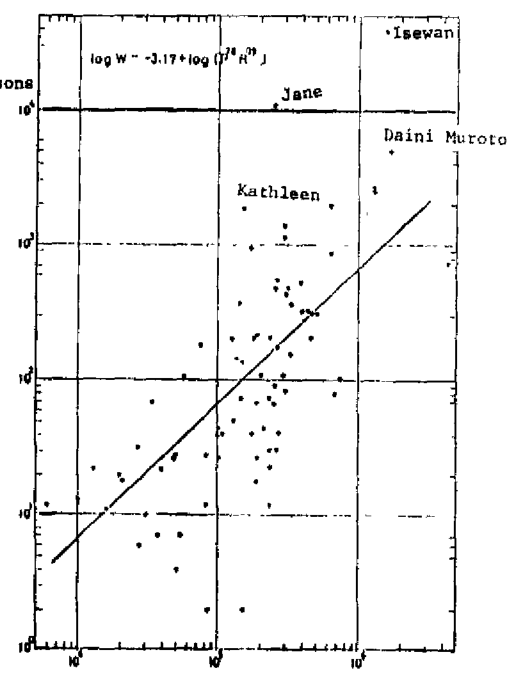
<u>Figure 8.</u> The relation between the intensity of typhoon at landing time and the number of deaths (1946-82, 88 typhoons). P = (1010 - central atmospheric pressure at landing time) mb, R: the radius of the greatest circular Isobar

The human casualty ratio



<u>Figure 9.</u> Hourly changes in the human casualty ratio due to typhoon hazards

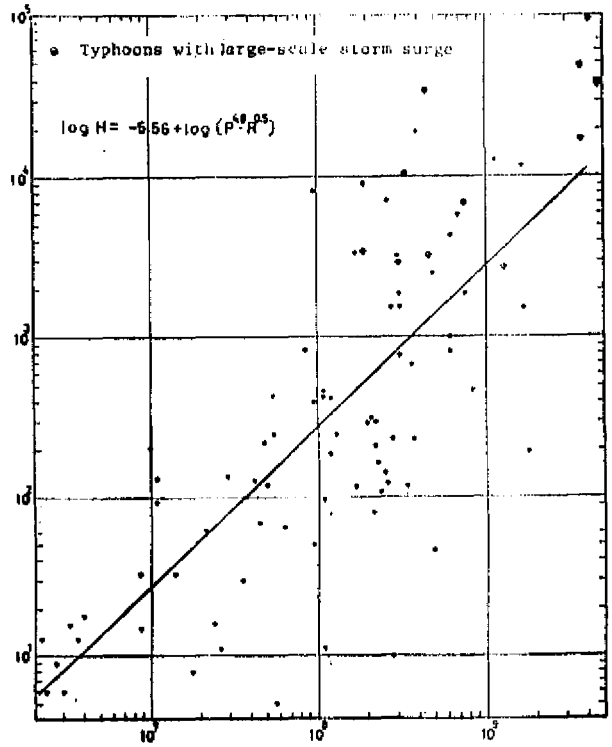
The humber of the injured



The intensity of typhoon at landing time

Figure 10. The relation between the intensity of typhoon at landing time and the number of the injured

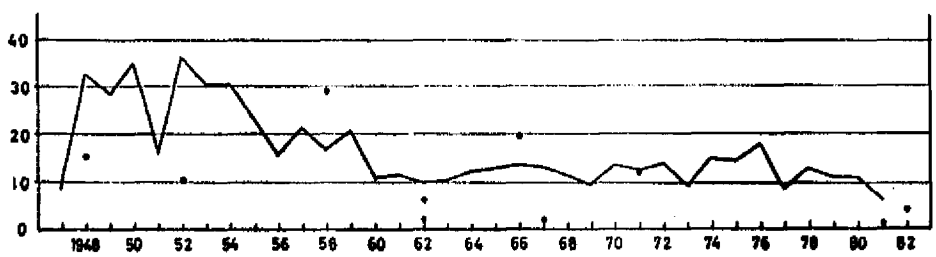
The number of damaged houses (H)



The intensity of typhoon at landing time

Figure 11. The relation between the intensity of typhoon at landing time and the number of damaged houses (the completely destroyed + the half-destroyed x 0.5)

The human casualty ratio



<u>Figure 12.</u> Changes over time in the human casualty ratio due to typhoon hazards. The solid line is the 3 year moving average for typhoons which landed during the hours of morning-10p.m. Dark dots are those which landed during midnight hours (the human casualty ratio is 10 times larger).

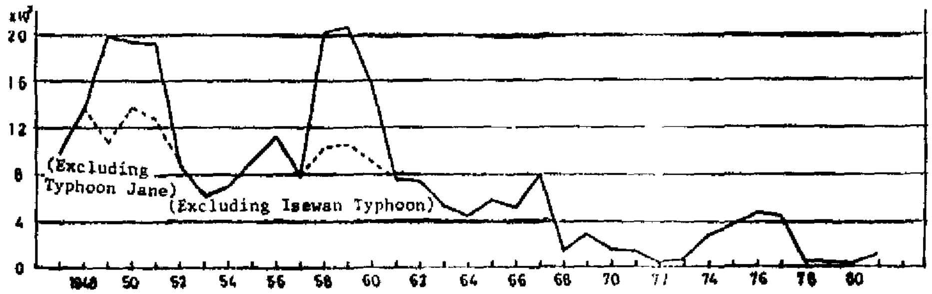


Figure 13. Changes over time in the ratio of housing damage $(H/P^{4.8}R^{a.5})$ due to typhoon hazards. The 3 year moving average of all typhoons

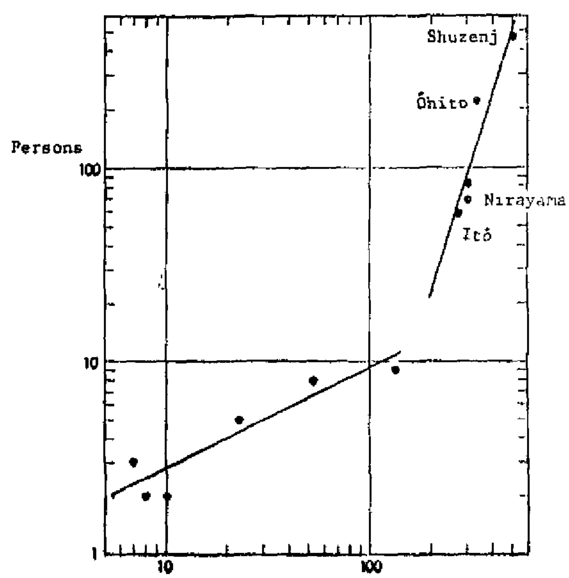
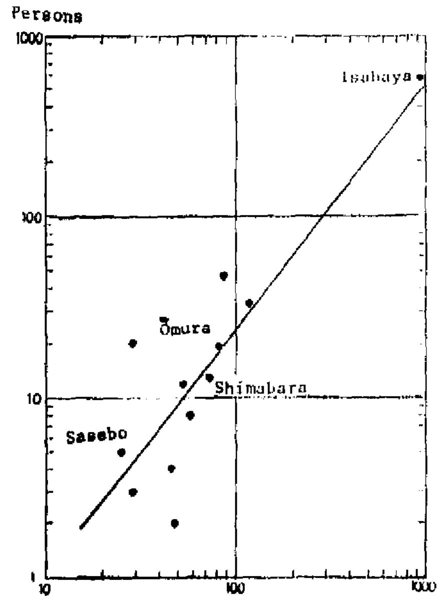


Figure 14. The relation between the number of damaged houses and the number of deaths due to Kanogawa Suigai (1958) (by the unit of cities, towns and villages)

The number of deaths



The number of damaged houses (the completely destroyed + the washed away x 2)

Figure 15. The relation between the number of damaged houses and the number of deaths due to Isahaya Suigai (1957) (by the unit of cities, towns and villages)

The number of completely destroyed and washed away houses (H)

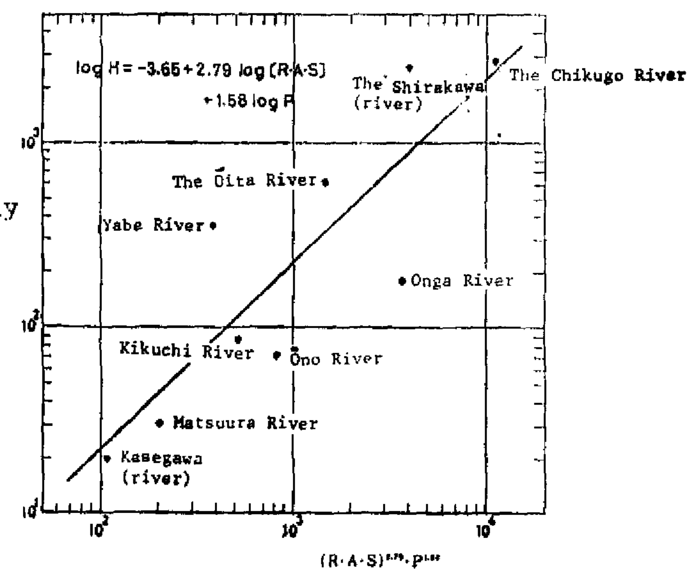


Figure 16. The relation between the number of damaged houses and factors of the intensity of flood and the damage potential in the case of Nishinippon Flood (1953) (1) (by the unit of basins)
R: Average annual total rainfall of the basin (mm),
A: Basin area (Km2), S: Inclination ratio, P: Household density (Km2)

The number of completely destroyed and washed away houses (H)

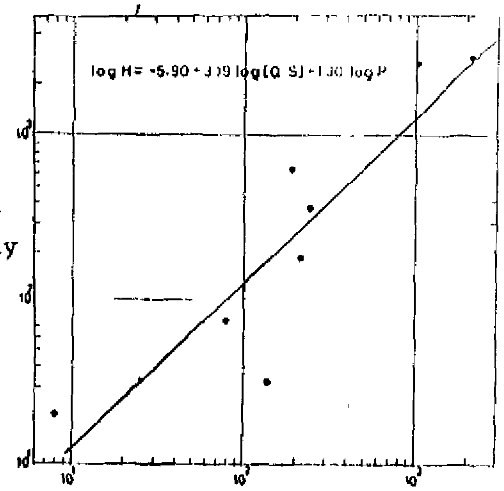
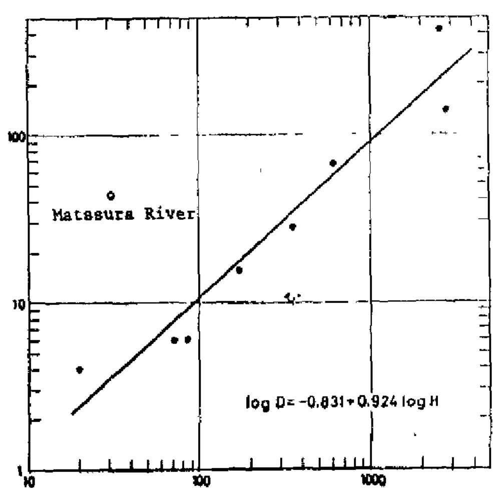


Figure 17. The relation between the number of deaths and factors of the intensity of flood and the damage potential in the case of Nishinipoon Flood (2) (by the unit of basins). Q: The Maximum flux (m^3/sec), S: Inclination ratio, P: Household density (Km^2)

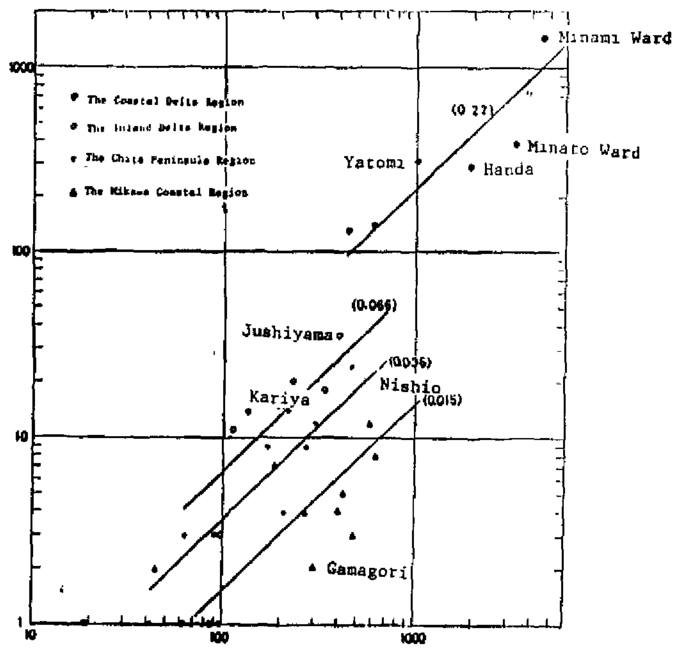
The number of deaths (D)



The number of completely destroyed and washed away houses

Figure 18. The relation between the damaged houses and the number of deaths due to Nishinippon Flood (by unit of basins)

The number of deaths



The number of damaged houses (the completely destroyed + the washed away x 2)

<u>Figure 19.</u> The relation between the number of damaged houses and the number of deaths due to Isewan Typhoon hazards (the storm surge struck region of Aichi Prefecture, by the unit of cities, wards, towns and villages)

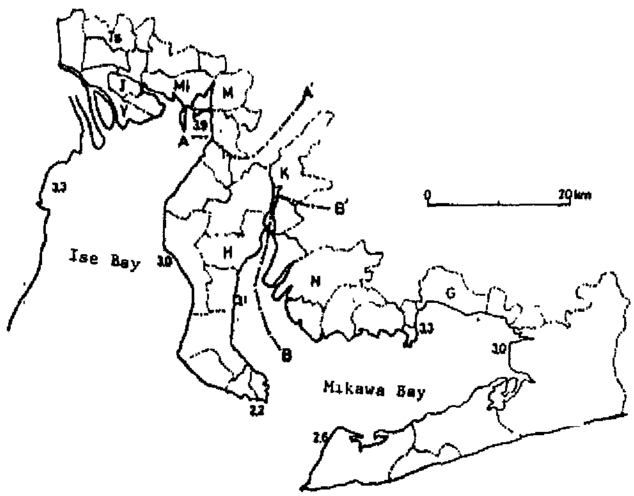
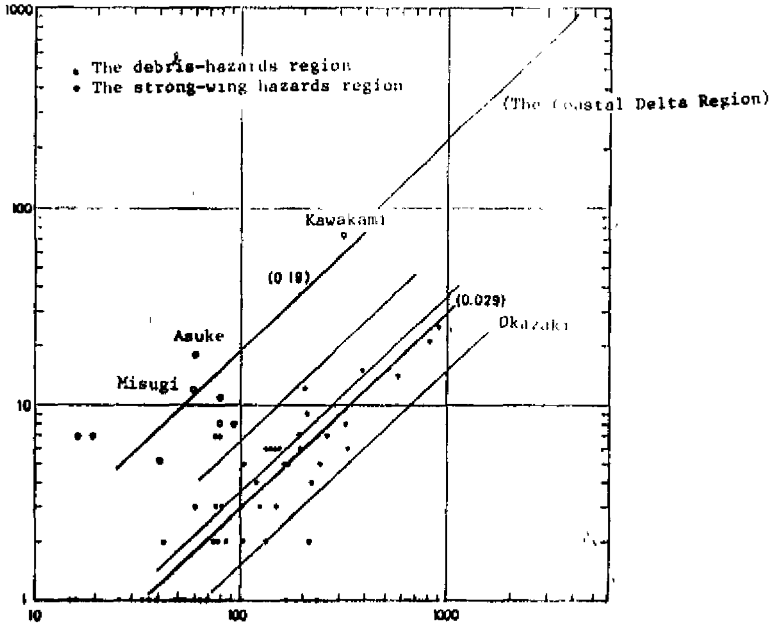


Figure 20. A map indicating the locations of the cities, wards, towns and villages of Aichi Prefecture which suffered damages due to the storm surge accompanying Isewan Typhoon: A-A': The Southern Border of the Delta Region at the innermost part of Ise Bay, B-B': the border between the Chita Peninsula Region and the Mikawa Region. The numbers indicates the maximum level of the tide (m). Ts: The city of Tsushima, J: The Village of Jūshiyama, Y: The town of Yatomi, Mi: Minato Ward of the City of Nagoya, M: Minami Ward of the City of Nagoya, K: The City of Kariya, H: The City of Hauda, N: The city of Nishio, G: The City of Gamagōri, T: The City of Toyohashi

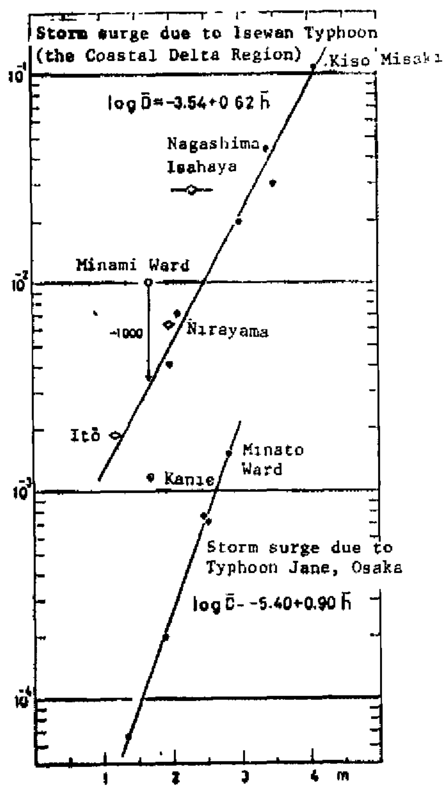
The number of deaths



The number of damaged houses (the completely destroyed + the washed away x 2)

Figure 21. The relation between the number of damaged houses and the number of deaths due to Isewan Typhoon hazards (the regions of strong wind and debris hazards, by the unit of cities wards, towns and villages)

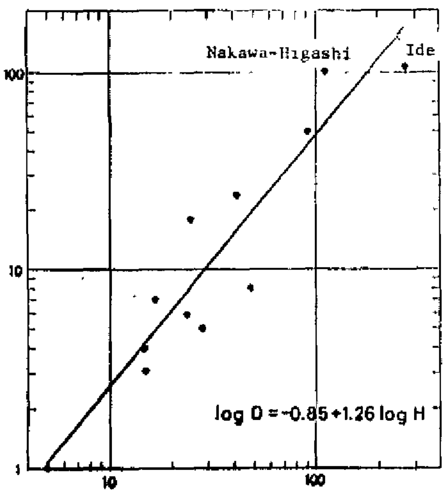
The death rate (D)



The average depth of inundation (h)

Figure 22. The relation between the average depth of inundation and the number of deaths due to storm surge and flood hazards (by the unit of cities, wards, towns and villages)

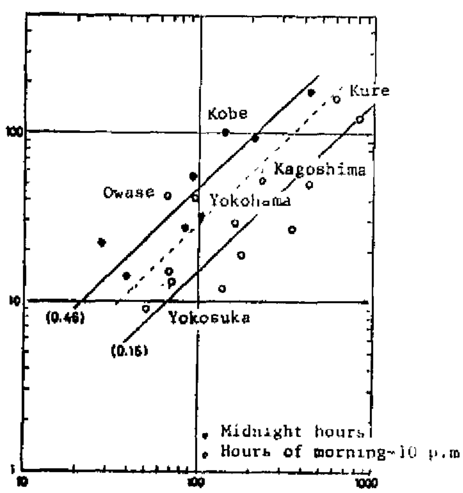
The number of deaths



The number of completely destroyed and washed away houses (H)

Figure 23. The relation between the number of damaged houses and the number of deaths due to Minami-Yamashiro hazards (1953) (by the unit of towns and villages)

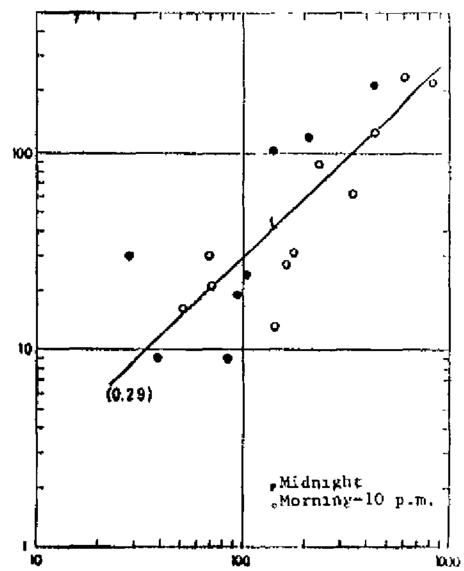
The number of deaths



The number of damaged houses (the completely-destroyed and washed-away + the half-destroyed x 0.5)

Figure 24. The relation between the number of damaged houses and the number of deaths due to landslide and debris-flow hazards (1965-82) (the scale of damages by the unit of prefectures based on the police investigation)

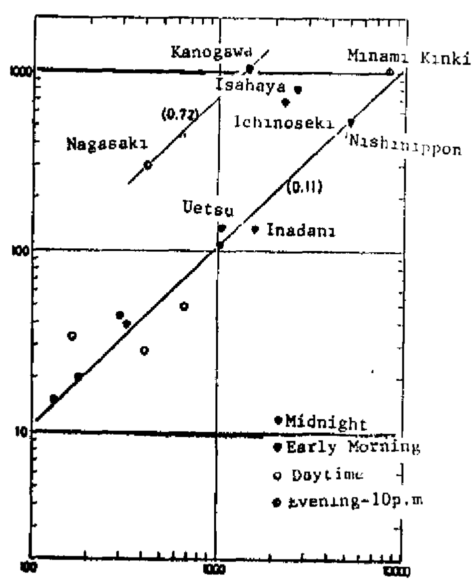
The number of injured



The number of damaged houses (the completely destroyed-washed-away + the half-destroyed x 2)

Figure 25. The relation between the number of damaged houses and the number of injured due to landslide and debris-flow hazards (1965-82) (the scale of damages by the unit of prefectures based on police investigation)

The number of deaths



The number of damaged houses (the completely-destroyed-washed-away + the half-destroyed x 2)

Figure 26. The relation between the number of damaged houses and the number of deaths due to combined hazards of flood and landslide-debris-flow (1948-82) (the scale of damages by the unit of prefectures based on the police investigation)

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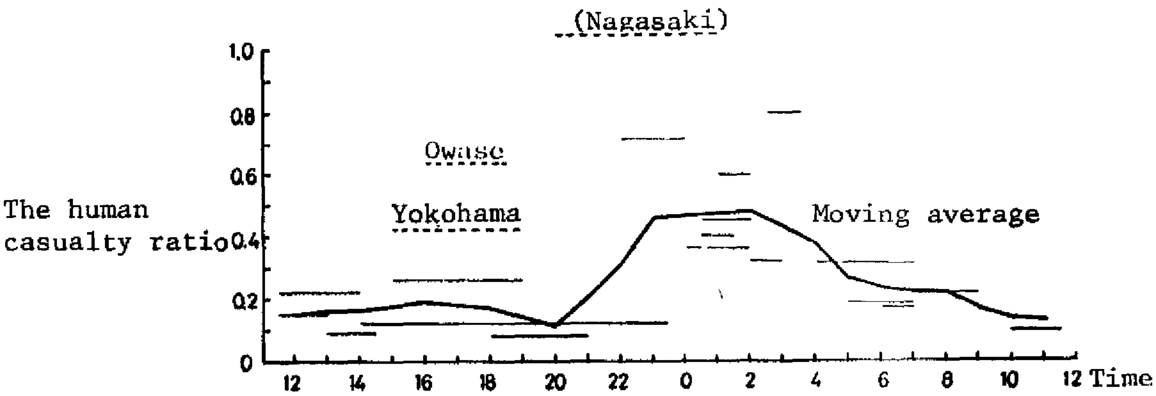

Figure 27. Hourly changes in the human casualty ratio (the number of deaths/the number of damaged houses) due to debris hazards