REVIEWED DATABASE OF THE TSUNAMI RUN-UP DATA ON THE DOCUMENTATION IN JAPAN

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ABSTRACT :

The purpose of research is to develop the "Tsunami runup and trace database system" collecting historical materials and documents concerning tsunamis that have hit Japan and of which the reliability of tsunami runup and related data is taken into account. This study defined criteria for determining the reliability of runup and trace data and those for rearranging historical materials. The system was designed after analyzing of requirements for functions necessary to use the database system as a platform for the collection and delivery of trace data.

KEYWORDS: nuclear power stations, tsunami runup and trace, historical documents, database, Web-GIS

1. BACKGROUND

In the tsunami assessment on nuclear power stations, the tsunami having the largest influence on the site is assumed for assessment in consideration of the runup and wave heights of past tsunamis recorded and/or simulated. The reproducibility of results from the tsunami numerical analysis should be verified with geometric mean K and geometric standard deviation κ (Aida, 1978), which are obtained by comparison of the calculated tsunami height with the recorded tsunami runup height. On the other hand, tsunami runup and trace data includes uncertain data and is not clarify the reliability of data itself. It is unresolved task that 'decreasing the reliability of the analysis because uncertain data is used, when verifying it.' For these reasons, a trace database for which the reliability of the data itself is quantitatively taken into account is required.

2. OBJECTIVE

The followings are objects of the research project ;

(1) Understand the current state of the tsunami assessment on nuclear power stations and identify tasks.
(2) Develop the "Tsunami runup and trace database system" for which the reliability of tsunami trace data is taken into account.

In order to do so:

(3) Establish an expert committee entrusted by *Japan Nuclear Energy Safety Organization* to discuss and define the reliability of trace data quantitatively and to study criteria for rearranging historical materials.
(4) After analyzing requirements for functions, like user-friendly, design the database system.

3. UNDERSTAND THE CURRENT STATE OF TSUNAMI ASSESMENT TECHNOLOGY AND REARRANGEMENT OF TASKS

3.1. Understanding of the current state concerning the use of runup and trace data

(1) Method of verifying tsunami assessment results

In the tsunami assessment on nuclear power stations, the tsunamis having the largest influence on the site are evaluated for assessment in consideration of the runup and trace height of past tsunami. In most cases, the reproducibility of the tsunami numerical analysis results is verified by comparison of the analysis results with the trace height. The reproducibility of the tsunami analysis results depends on the reliability of the trace data of past tsunami.

(2) Tsunami source estimating techniques
Although it would be ideal if earthquake motion and tsunami could be explained with the same fault model, but in many cases the reality is that the earthquake source fault model, which explains earthquake motion is not always consistent with the tsunami source model, which explains the trace height of tsunami. In recent years, the inversion method using tsunami runup and trace height and wave form records has been widely used instead of just tide records, allowing the tsunami source (location of a tsunami source and variation of the sea-bottom) to be estimated. The reliability of estimation of a tsunami source depends on tsunami trace and tide records.

3.2. Issues and measures concerning the use of runup and trace data
As described in Section 3.1, tsunami runup and trace data is used as important verification data. The data, however, includes uncertain data (data without reliability and data with uncertain criteria for measured height) (Takeuchi, et al., 2005). Therefore, we establish the tsunami runup and trace database, for which the reliability of trace data is quantitatively taken into consideration.

4. HISTORICAL MATERIALS TARGETED FOR DATABASE REGISTRATION
4.1. Targeted tsunamis
Tsunamis that hit Japan in the past, will be included as targets for database registration. Table 1 shows a list of tsunamis eligible for database registration. The names of tsunamis will be indicated by their "Christian Era years + Japanese calendar era names + tsunami source regions" according to the designation by Watanabe (1998) in principle to differentiate between tsunamis with similar names.
Target tsunamis will be selected so that considerable tsunami sources shown at nuclear site areas in Figure 1 will be included without omission. In particular, although the number of past tsunami sources is fewer in the Chugoku, Kyushu, Setonaikai, and Nihonkai areas compared with other areas, tsunamis even with small to medium damage level will be included in the target for those generated in those regions, given the possible damage caused by them due to their traveling at high velocity. As a matter of fact, tsunamis damaged the sides of islands away from the Pacific in the Setonaikai area far away from tsunami sources. In addition, there is concern that secondary damage may be generated by sediment deposition at a sea water intake facility of a nuclear site even if the tsunami wave height is low.

4.2. Target historical materials and how to handle
Registration targets are documentation (academic papers, historical documents, municipal histories, antique maps, folklore, memorial monument, etc.) and trace survey results with a variety of authors of different literature types, ages, and expertise level as shown in Figure 2. Most historical materials for tsunamis are based on several cited documents, some of which trace back as far as historical documents or letters engraved in stone monuments. In other words, a single piece of trace data may consist of multilayered cited documents because such cited documents include documents written as a remake in later ages and folklore. There also exist descriptions indicating tsunami heights beyond expectations in scientific or engineering terms as a result of the interpretation or judgment of authors, or later revisions. In consideration of such characteristics, historical materials will be registered according to the following policies.
(1) For documents written as a remake, the original documents will be handled as the most important data (an original first policy). On the other hand, documents written as a remake will also be included as targets for database registration. (Traces revealed by later age on-the-spot investigation; traces revealed by analysis/interpretation of historical documents)
(2) A high priority in registration will be given to survey reports examined by historical tsunami researchers over descriptions in tsunami runup and traces conserved in municipal histories anywhere in Japan.
(3) Suspicious documents (part of documents classified as historical materials written as a remake or folklore). Such traces will be ranked as Confidence Level D and registered in the database along with the basis on which they were determined to be false.

Table 1 List of Tsunamis Targeted for Database Registration

Reference No. (Watanabe,1998)	Target Tsunami (tsunamis to hit Japan since 1600, provisional target)	Quantity of documentation	Document page containing the tsunami
	Tokai-Shikoku		
012	1605 Keicho Tokai Earthquake Tsunami	10	
020	1703 Genroku Earthquake Tsunami	27	72 articles
021	1707 Hoei Earthquake Tsunami	32	3881 pages
044	1854 Ansei Tokai Earthquake Tsunami	27	
045	1854 Ansei Nankai Earthquake Tsunami	25	
067	1923 (Great) Kanto Earthquake Tsunami	10	233
096	1944 Showa Eastern Nankai Earthquake Tsunami	18	221
099	1946 Showa Nankai Earthquake Tsunami	24	882
	Hokkaido		
025	1741 Kanpo (Oshima-Ohshima) Volcanic Earthquake Tsunami	7	51
043	1843 Tenpo Nemuro-oki Earthquake Tsunami	14	226
053	1894 Off the Southeast Coast of Nemuro Peninsula Earthquake Tsunami	8	60
102	1952 Tokachi-oki Earthquake Tsunami	2	25
148	1973 Off Nemuro Peninsula Earthquake Tsunami	5+2	62
182	1993 Off the Southwest Coast of Hokkaido Earthquake Tsunami	14	1562
186	1994 Off the East Coast of Hokkaido Earthquake Tsunami	4	61
—	2003 Tokachi-oki Earthquake Tsunami	2	234
	Pacific coast of Tohoku		
013	1611 Keicho Sanriku Earthquake Tsunami	4	52
018	1677 Enpo Sanriku Earthquake Tsunami	4	20
019	1677 Enpo Boso Earthquake Tsunami	3	19
039	1793 Kansei Sanriku Earthquake Tsunami	6	89
048	1856 Ansei Sanriku (Off Hachinohe) Earthquake Tsunami	3	44
055	1896 Meiji Sanriku Earthquake Tsunami	11	134
075	1933 Showa Sanriku Earthquake Tsunami	10	358
137	1968 Tokachi-oki Earthquake Tsunami	8	492
158	1978 Off Miyagi Prefecture Earthquake Tsunami	1	2
	Nihonkai Coast of Tohoku		
038	1793 Kansei Nishi-Tsugaru Earthquake Tsunami	8	202
040	1804 Kisakata Earthquake Tsunami	6	163
041	1833 Tenpo Off Yamagata Prefecture Earthquake Tsunami	6	173
131	1964 Niigata Earthquake Tsunami	10	2378
167	1983 Nihonkai-Chubu Earthquake Tsunami	25	3645
	Far-field tsunamis		
—	1960 Chilean Earthquake Tsunami	40	4883

* The quantity of documentation is based on research result by Disaster Control Research Center of Tohoku University

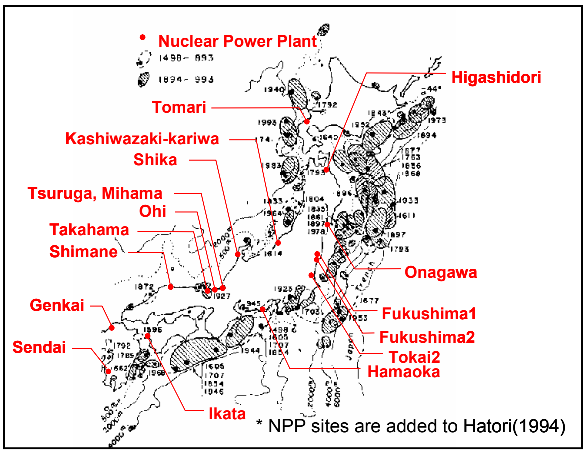

Figure 1 Distribution of Nuclear Power stations and Major Tsunami Sources in Japan

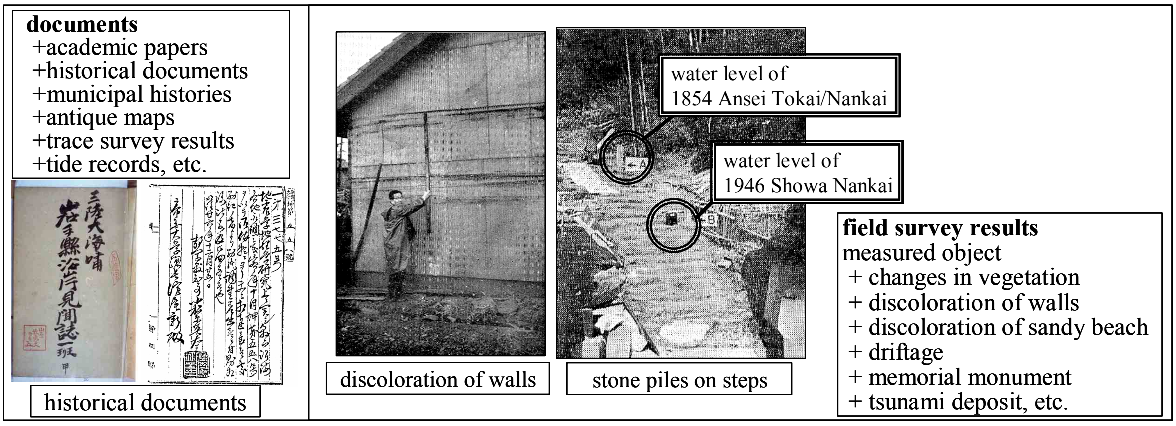

Figure 2 Registration targets (documents and tsunami traces)

5. WORK PROGRAM

5.1.Establishment of the Tsunami Runup and Trace Database Review Committee

Data will be prepared gradually with tsunami sources divided into (1) Tokai/Kinki area, (2) Hokkaido/Tohoku area, and (3) Kyushu/Okinawa for three years from the fiscal 2007. The Tsunami Runup and Trace Database Review Committee consisting of four members including experts in tsunami engineering and historical earthquake/tsunami and field survey and collectors of tsunami historical materials was established. This committee will be engaged in quantitative definition of confidence levels, determination of confidence levels of runup and trace data, and proposal of database functions. The results of studies and results of proposals performed by the committee will be discussed from Section 5.2 on.

5.2.Quantitative definition on confidence levels of runup and trace data

The immense tsunami runup and trace data archived in various patterns need to be sorted out in consideration of the quality and accuracy of the data and provided to users according to the purpose of use. This section defines the uniform criteria for determination of confidence levels required to that end.

The confidence level as shown in Table 2, which was developed by Chilean Tsunami Joint Survey Team (1961) and has been conventionally used to sort out tsunami traces, will be continued to be used in principle. However, a new definition will be proposed in the future for Confidence Level C as shown in Table 2 given the dependence on the performance of survey instruments. While the results of surveys performed at long ranges until the 1968 Tokachi-oki Earthquake Tsunami contain large errors because the survey had been carried out repeatedly with a hand level, the survey results after 1968 contain negligible errors because the equipment of survey on the field are rapidly improved.

Examples of historical materials, to which confidence levels were assigned based on the confidence level as shown in Table 2 include Tsuji et al. (2006). Takeuchi et al. (2005) reviewed the confidence levels of tsunami traces based on numerical analysis. The confidence levels of tsunami traces depend on "identification accuracy for positional information" and "confidence levels of height information accuracy." The Tsunami Runup and Trace Database Review Committee defined new criteria for "confidence levels of positional information" and "confidence levels of height information" as shown in Table 3. Given the wide variety of positional information described in documents such as longitude/latitude and place names at the time of tsunamis (name of municipalities, aza names, lot numbers, names of residences/houses, etc.), we classified detailed positional information including longitude/latitude or lot numbers as "⦿Reliable" confidence level of positional information. The actual determination of "the reliability of positional information" will be performed at high precision by identifying trace positions with the actual trace location superimposed with antique maps and so on using the Web-GIS as discussed in chapter 6. The "confidence levels of height information" will be classified according to whether the "height measurement standard" and the "definition of tsunami height" are described in the documentation.

5.3.Sorting-out criteria for historical materials

For historical materials prior to 1800 listed in Table 1, "confidence levels of documents" will be determined before determining the confidence levels of the respective trace data given the existence of several documents indicated to be false. For such false documents, the reasons for which they are determined to be false, will be registered in the database. Such false documents include (1) groundless information faked by document authors and (2) survey results impossible for the technology at the time the documents were made (such as a detailed wide area survey in 40 days). Overseas there is an example of classification of document confidence levels into 10 ranks (Liu, P. L.-F., 2007). The committee is expected to deliberate and propose sorting criteria in the future in consideration of the characteristics of the historical materials of Japan.

Table 2 Classification of Confidence Levels of Tsunami Traces

	Judgment criteria
Confidence Level A	High confidence level. Clear traces with small survey errors.
	Cases, which are highly confident, but are difficult to reproduce by normal mathematical calculations for tsunamis due to significant local topographical effects and so on, shall be classified in this category with such indication (A).
Confidence Level B	Moderate confidence level. Traces are obscure, but the surrounding conditions and witnesses indicate a reliable water level. Survey errors are small.
Confidence Level C	Low confidence level. Traces indicating waves having abnormally landed a sand beach, etc. or traces with significant survey errors due to survey points located away from the seashore.
Confidence Level D	Extremely low confidence level. Obscure traces overlapped by the effect of a tidal wave, a typhoon, etc., or folklore or other ungrounded information.

*Chilean Tsunami Joint Survey Team(1961) and The Tsunami Evaluation Subcommittee(2002)

Table 3 Information of Tsunami Trace Data and Newly-Proposed Confidence Levels
(Reliability: ⊙Reliable, ○Confirmation required, ΔTo be used for reference only)

Information item	Described information	Details of information	System display	Judgment
Positional information	Address, lot number information	Detailed information such as latitude/longitude, block number, etc. is included.	Reliable latitude/longitude information provided	⊙
		Information is detailed, but specific to a region or locality (such as Mr. ○○'s residence).	Latitude/longitude information provided if estimated at the moment.	⊙
			With the latitude/longitude unestimated at the moment, the location is set at a representative point (town office, station, port, etc.).	○
		No detailed information included.	Under review	○
	Maps, photos, sketches	Information serving to identify the point is included.	Reliable latitude/longitude information provided	⊙
		No information serving to identify the point is included.	Under review	○
		No		Δ
Height information	Information concerning the height measurement standard	Such information as the sea surface during the tsunami assault, the mean sea surface, and T.P. is included.	(To be put down with the standard)	⊙
		No		Δ
	Information concerning the definition of tsunami height	Definitions of run-up height, inundation height, wave height, and so on are included.	(To be put down with the height)	⊙
		No		Δ
	Influence of ground displacement	Described	(To be entered in the remarks column)	
		No		

5.4.Registration items

Table 4 shows a list of information to be extracted from documentation. In principle, the place names and tsunami height information described in the documents will be registered as designated in the documentation. Changes of place names due to mergers of cities, towns, villages, and so on further complicate the identification of positional information of traces. However, management and search functions for positional information capable of flexibly responding to past and future changes of names will be proposed in Chapter 6.

Table 4 (Provisional) List of Information to Be Extracted from Documentation

Tsunami	
	Tsunami name
	Earthquake magnitude/tsunami magnitude
Place name described in document	
	Name of municipality described in document
	Address described in document (lot number, village name, house name, factory)
Place name at the time of registration	
	Name of municipality/place/aza
Identified trace position	
	Latitude/longitude (world geodetic system, degree/minute/second)
	Presence/absence of address or lot number information (⦿, ○, Δ)
	Presence/absence of maps, photos, sketches (⦿, ○, Δ)
	Notes (information supporting the positional accuracy)
Object targeted for trace measurement	
	Measured object or witness (Changes in vegetation, walls of residential buildings, discoloration of sandy beaches, witness, earth and sand, tide records, driftage, stone monuments, stone piles, tsunami deposits, etc.)
Height measurement standard described in document	
	Height measurement datum plane
	Confidence levels regarding the height measurement standard (⦿, ○, Δ)
	Ground displacement Z (cm)
Tsunami height (m) described in document	
	Height of runup and trace (m)
	Inundation height or inundation depth (m)
	Confidence level regarding the definition of tsunami height(⦿, ○, Δ)
Tsunami height above T.P. (m)	
	Datum plane deviation correction method
	Height of trace(m)
	Inundation height or inundation depth (m)
	Measuring method (hand level, laser survey)
Confidence level	
	Confidence levels A, B, C, and D
	Confidence level determined by:
Documentation	
	Name of document, Reference pages, etc.
	Detailed drawings, etc.
	Remarks on original material
	Cited documents
Data registration	
	Registered by/registered on , Verified by/verified on

6. REQUIREMENT ANALYSIS AND DESIGNING OF FUNCTIONS OF THE RUNUP AND TRACE DATABASE SYSTEM

We performed a requirement analysis on the requirements for functions needed to use the Tsunami Runup and Trace Data System as a platform of the collection and delivery for trace information after holding a hearing at a meeting of the Tsunami Runup and Trace Database Review Committee as discussed in Section 5.1. Then we designed the infrastructure and functions for the database system based on the analytical results. Sections 6.1 to 6.3 will discuss the characteristics of the functions based on the requirement analysis.

6.1. Geographic/spatial information management function

A Web-GIS function will be mounted on the system to enable Internet browsing of trace information placed over a base of seamless map images and so on, capable of being quickly displayed and zoomed in or out. The positional information of traces will be managed in the form of degrees/minutes/seconds of the world geodetic system. In order to register and manage the trace information more accurately, original diagrams (antique maps, contour maps, inundated area maps, runup and trace data, wave-ray diagrams, etc.) in historical materials will be geometrically corrected according to the world geodetic system and will be overlaid on the Web-GIS. This function will be used to indicate overlapping areas such as (1) survey areas of several search groups for the 1960 Chilean Tsunami; and (2) inundated areas of the 1896 Meiji Sanriku Tsunami, 1933 Showa Sanriku Tsunami, and 1960 Chilean Tsunami; or (3) information about tsunami sources over the Web-GIS.
Changes of place names due to mergers of cities, towns, villages, and so on have further complicated the identification of positional information of traces. Accordingly, place names need to be associated with position

coordinates on the Web-GIS to register and manage positional information of places with changed names. In addition, a function needs to be added to indicate heights of traces with a bar chart on a seamless and dynamic map.

6.2. Trace information search function

Attribute information of approximately 50 items on traces associated with Table 4 will be registered and an attribute search function and frequently used summarizing functions (tabulation by tsunami names, tabulation of numbers of tsunamis by administrative districts, etc.) will be incorporated in advance to support statistical analysis. A function will be added to the system to provide researchers and designers with items necessary for the users to (1) calculate Aida's indicators K and κ (1978) to use to evaluate the tsunami analysis results or to (2) estimate tsunami source areas by an inversion method with heights of traces applied to evaluation functions, in the form of a table in csv format. The information items will be provided in a set of "point name, latitude/longitude, height of tsunami trace, confidence level of trace, confidence level of height information, and confidence levels of positional information" by extracting the data corresponding to the name of the tsunami and the confidence level of the tsunami arbitrarily designated by the user as shown in Figure 3. The magnitudes of earthquakes, which caused tsunamis, and their magnitudes will be compiled into a database separately in advance to add to the system an analyzing function associated with the tsunami runup and trace data.

6.3. Function to display geographic features in three dimensions

A function displaying the land altitude data in three dimensions will be added to the system so that general users may easily understand the effects of terrain roughness on the wave height amplification associated with tsunami propagation. In order to display the land altitude of the whole of Japan in three dimensions, this system will be linked with Google Earth. In this case 3-D display will be realized based on satellite images with 50-m resolution in space mesh size and heights of the meshes. For points with unique trace heights and areas with wave heights likely to be amplified by a shallow water effect, a concentration effect, a resonance effect, or reflection/refraction, height data with 10-m resolution will be independently prepared for detailed 3-D display separately from the whole Japan version. The roughness of the submarine topography data will be expressed by overlapping depth contours on the map plane.

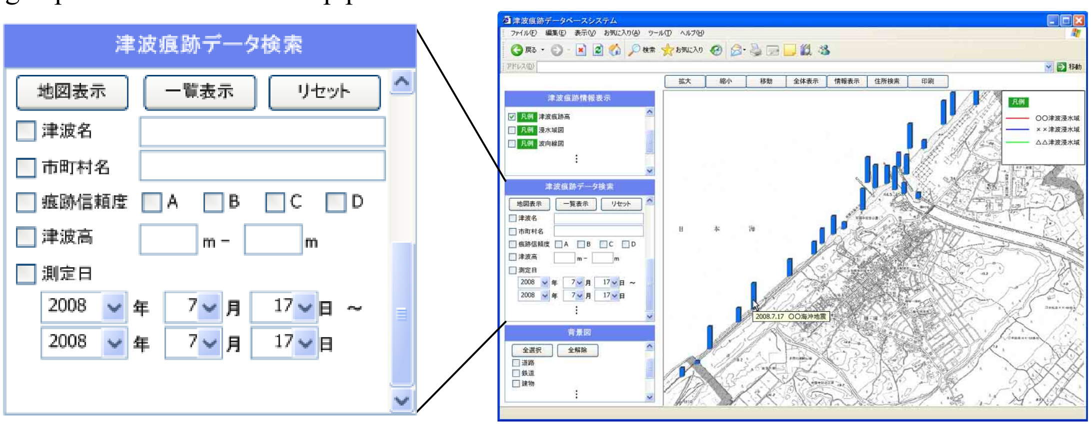

Figure 3 Example of Searching Display

7. SUMMARY AND FUTURE TASKS

The main conclusions of discussion are summarized below;

(1) Tsunami runup and trace data is used as important verification data in the tsunami assessment on nuclear power stations.

(2) To develop the "Tsunami runup and trace database system", for which the reliability of data is taken into consideration, an expert committee was established, criteria for determining the reliability of runup and trace data were defined, and those for rearranging historical materials were studied. We need to judge not

only the "reliability of trace data" but also the reliability of document, "identification accuracy for positional information" and "confidence levels of height information accuracy".

(3) The system was designed after requirements for functions necessary to use the tsunami runup and trace data system as a platform for the collection and delivery of data were analyzed. As a result, these are proposed that display function with Web-GIS, the function to display geographic features in 3-D, the management function for positional information capable of flexibly responding to past and future changes of names.

(4) The expert committee will review the reliability of trace data. As the ultimate achievement, a countrywide tsunami runup and trace database with high reliability from academic knowledge will be maintained.

(5) This database is expected to be used effectively in the tsunami assessment on nuclear power stations.

(6) This data will be important not only in the field of nuclear seismic safety, but also in the field of general tsunami disaster prevention.

In addition, future tasks are as follows;

(1) The registration of information about tsunami deposits in this database leads to other potential uses:
(a) Estimate the scale of prehistoric tsunami by superimposing the damage scale (death count, etc.) of historical tsunami. (b) Estimate the scale of past tsunami and tsunami source in consideration of sedimentation; erosion and deposition, by tsunami.

(2) Analyze requirements to register the distributional areas of tsunami deposits, occurrence eras of tsunami, the estimation results of recurrence periods of earthquakes and tsunami, which are obtained from tsunami deposits, in this database.

(3) To use this database for statistical processing using runup and trace data (for example, the preparation of hazard curves), express reliability A, B, C, and D as numerical values. (Define values for B to D with reliability A as 1.0) For this purpose, a questionnaire survey will be conducted for about 20 tsunami experts and trace survey engineers.

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