APPLICATIONS BY NARA PREFECTURE FOR UTILIZING LESSONS LEARNED FROM THE GREAT FLOODS ON KII PENINSULA

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In 2011, Typhoon Talas brought record-breaking heavy rain and the Great Floods on Kii Peninsula, and caused extensive sediment-related disasters such as deep-seated landslides, especially in the south of Nara Prefecture with 24 casualties and where 184 homes were damaged. In April 2012, in light of this disaster, Nara Prefecture formed the Deep-Seated Landslide Control Office and the "Deep-Seated Landslide Study Group ('Study Group')" to identify the mechanism of deep-seated landslides and to establish countermeasures, in addition to the "Investigative Panel on Monitoring, Warning, and Evacuation Systems for Large-Scale Sediment Disasters ('Panel')" to establish an evacuation system that withstands large-scale sediment disasters. This report describes the outcomes of our efforts and countermeasures against disasters.

Key words: large-scale sediment disasters, monitoring, warning, evacuation

1. OUTLINE OF THE GREAT FLOODS ON KII PENINSULA

1.1 Outline of Typhoon Talas and the Characteristics of the rainfall in 2011

The large-scale, powerful, and slow-moving Typhoon Talas was formed in the vicinity of the Mariana Islands at 9:00 on August 25, 2011, moved northward, cut across the landmass of Japan by passing over the Shikoku and Chugoku areas, and exited onto the Japan Sea on September 4. Since Typhoon Talas was large and moved slowly, rainfall continued for a long time, bringing a record heavy rain to a wide range of areas mainly in the mountains.

The total rainfall from August 30 exceeded 1,000 mm in a wide range of the area mainly on Kii Peninsula, and it had reached 1,808.5 mm in Kamikitayama of Kamikitayama Village in Nara Prefecture where the total precipitation marked 60 % of the annual average rainfall (Fig. 1). A maximum of 72 hours of rainfall in Kamikitayama of Kamikitayama Village in Nara Prefecture had reached 1,652.5 mm, which greatly exceeded the observation record in Japan of 1,322 mm (Mikado, Misato-cho, Miyazaki Prefecture) since 1976 (**Fig. 1** and **Fig. 2**).

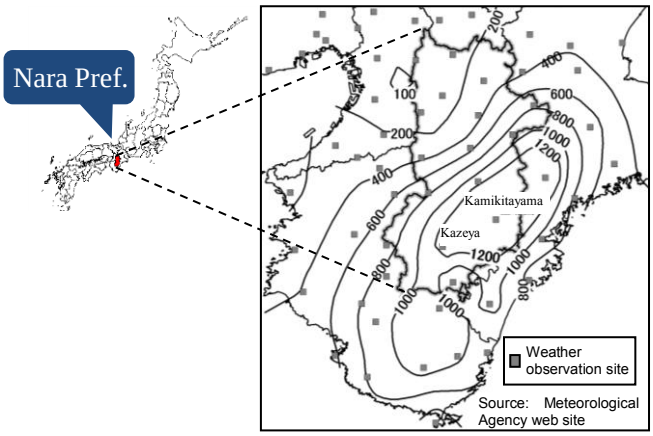

Fig. 1 Total rainfall contour map
(From 18:00, 8/30 to 24:00, 9/4 in 2011)

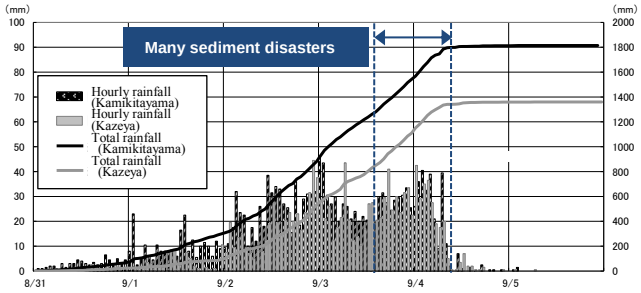

Fig. 2 Time series variation of rainfall at Kamikitayama, Kamikitayama Village and Kazeya, Totsukawa Village in Yoshino Dist.

1.2 Outline of sediment disasters that have occurred

"Deep-seated landslide" in which the breaking up of bedrock on the sides of the mountains was seen in 54 locations in the 2011 Floods (**Fig. 3**).

16 of 54 locations were accompanied by "River course blockage" in which collapsed sediment blocked river courses.

The "deep-seated landslides" were identified so as to meet all three criteria of "area greater than 10,000 m2", "depth greater than 10 m" and "new landslide" performing an aerial photo interpretation of aerial photos, etc. taken in September 2011, by pin-pointing the denuded land and conducting other measurements.

A long period of warnings and evacuation became necessary because there was a possibility that significant damage would occur in the neighborhood, etc. located downstream, if the river course was broken. In the large-scale river course blockage areas that occurred in the 2011 Floods, "warning zones" were announced as expected flood damage areas if the rivers were to break their courses, so that the residents of such specified zones were forced into long-term evacuation (**Fig. 6**).

"Warning zones" were lifted after 6 months of disaster when a certain level of safety was guaranteed by conducting emergency construction, etc.

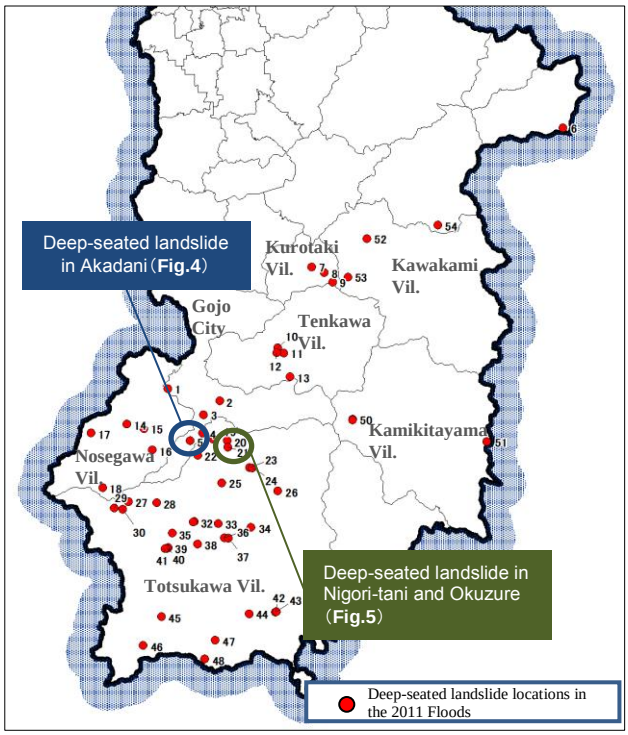

Fig. 3 Deep-seated landslide locations in the 2011 Floods

Fig. 4 Deep-seated landslide in Akadani (Gojo City)

Fig. 5 Deep-seated landslide in Nigori-tani and Okuzure (Totsukawa Village)

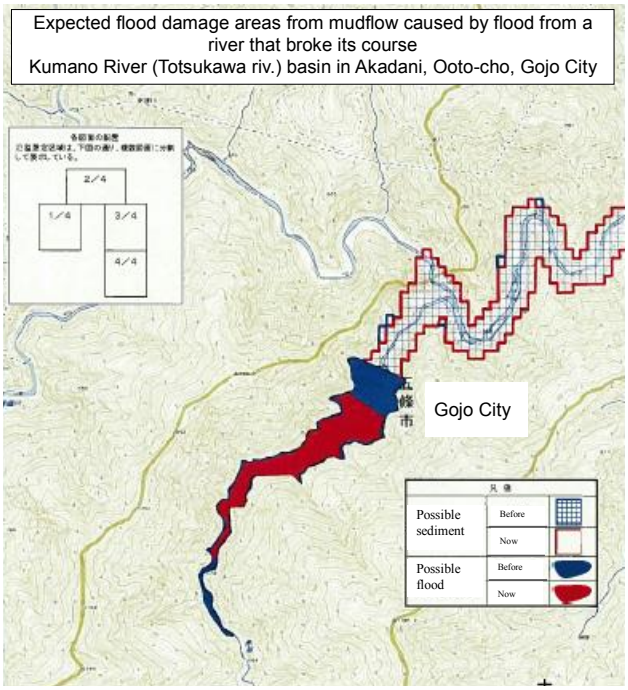

Fig. 6 Expected flood damage areas from a river that broke its course (Source: Ministry of Land, Infrastructure and Transport)

2. DAMAGE AND EVACUATION ASSESSMENT

Interviews were conducted with residents of the areas where extensive damage had occurred, to identify the damage and the evacuation situation (**Table 1**).

Many of the disaster locations near houses were the sediment disasters areas specified by Nara Prefecture, but casualties and damaged houses were found in other areas than such specified areas.Many of them were caused by landslide and debris flows which were large enough to damage the houses upstream as well as on the other side of Totsukawa River (first-class river).

Table 1 Damage and evacuation assessment

Village, etc.	Name of location	Results*1	Damage *2				Actual warnings and evacuation		
			Casualties	Houses	River course blockage	Details	Places in danger of sediment disaster*1	Evacuation (When disaster occurred)	Sediment warning information
Oto Cho, (Gojo City)	Yanagitani Riv. in Tsujido	La				Sediment from collapse stopped at the river.	Se & St	Voluntary	Issued at 11:50 on 9/2 Lifted at 15:25 on 9/6
	Kajiyadani in Tsujido	La, Se		✓		Houses were damaged by Sediment. No casualties because of voluntary evacuation.	Se & St & La	Voluntary	
	Ui	La	✓	✓	✓	Houses on the hill on the other side of the river were damaged. Flood damage from a river that broke its course. Some were killed or injured upon leaving the evacuation centers to go home.	St (on the other side of the river)	Voluntary	
	Akadani	La		✓	✓	Camp facility was damaged by Sediment.			
	Shimizu in Akadani	La		(✓)		Human harm and house damage downstream, but how is unknown.			
Nosegawa Village	Iwadani in Kitamata	La, Se		✓	✓	Houses were damaged by sediment. No casualties because of voluntary evacuation.	Se & St	Voluntary	Issued at 12:35 on 9/2 Lifted at 11:40 on 9/7
Totsukawa Village	Teradani in Nagatono	La, Se		✓		Houses were damaged by sediment. No casualties because of voluntary evacuation	Se & St Se & St	Voluntary	Issued at 12:35 on 9/2 Lifted at 11:40 on 9/7
	Nigori-tani Riv. in Nagatono	La	(✓)	(✓)	✓	Nagatono Power Plant, and some casualties and house damage upstream of the plant, but how is unknown.			
	Okuzure in Nagatono	La	(✓)	(✓)					
	Nagatono-tani in Nagatono	La			✓	Sediment blocked the river course.			
	Nojiri	La, Se	✓	✓		Sediment flowed into Totsukawa River destroying houses on the other side of the river.			
	Ohatadoro in Shigesato	Se			✓ in Meiji	Erosion at the locations of river course blockage from the Great Flood in Totsukawa Village (Meiji, 1889).			
	Kuridaira	La			✓	Sediment blocked the river course.			
Kawakami Village	Nishitani Riv. in Sako	La				Sediment buried a bridge on Route 169.	La		Issued at 14:15 on 9/2 Lifted at 15:25 on 9/6
Kurotaki Village	Kurotaki Riv. in Akataki A	La, Se		✓		Debris (mainly trees) damaged houses.			Issued at 17:55 on 9/2 Lifted at 20:10 on 9/4
	Kurotaki Riv. in Akataki C	La			✓	Sediment blocked the river course.		Evacuation advisory	
	Kashiharatani Riv. in Akataki	La			✓	Sediment blocked the river course.	Se	Evacuation order	
Tenkawa Village	Ashinose in Tsubonouchi	La	✓	✓	✓	Sediment blocked the river course temporarily. Houses on the other side of the river were washed away.		Voluntary	Issued at 11:50 on 9/2 Lifted at 11:40 on 9/7
	Hiyamizu in Tsubonouchi	La		✓	✓	Sediment blocked the river course temporarily. Damage by flood in the upstream area.			
	Tsubonouchidani in Tsubonouchi	La			✓	Sediment blocked the river course.			
Mitsue Village	Hataitani Riv.	La, Se				Sediment stopped near houses.	St & Se		Issued at 14:15 on 9/2 Lifted at 1:15 on 9/5
	Nagayamatani	La				Sediment blocked the river course.			
Hi-gashiyoshino Village	Mugitani Riv.	La, Se			✓	Sediment stopped at the breakwater.	La		Issued at 12:35 on 9/2 Lifted at 15:25 on 9/6

※1 Se: Sediment St: Steep slope La: Landslides *2 (✓) indicates the causes are not identified.

In Japan, the law called "Sediment Disasters Prevention Act" was enacted in recent years, with which Nara Prefecture was promoting the designation of damage potential zones, etc. However, because the law only applies to the surface failure of shallow slides of about 2 m depth, and the estimated maximum damage range is defined as 50 m up from the lower end of a sloped surface, the damage from the flood of large rivers such as Totsukawa River was not considered.

Many residents escaped disaster events through voluntary evacuation, before warnings were issued. Some, however, were killed or injured while at the evacuation centers (**Fig.8** Nagatono), or upon leaving the evacuation centers to go home when the rain ceased (**Fig.7** Ui).

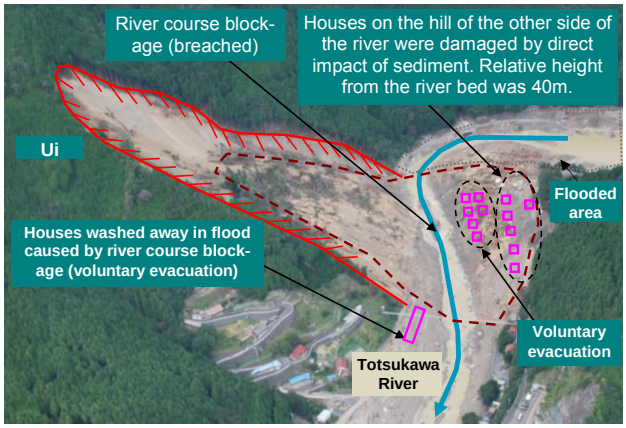

Fig. 7 Ui where the neighborhood on the other side of the river was damaged

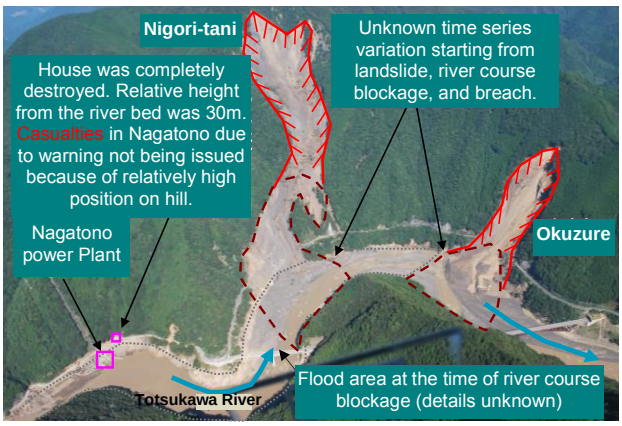

Fig. 8 Nagatono after damage from the overland flow

In addition, in Nagatono of Totsukawa Village, it became evident that the residents there were isolated due to the road cut-off caused by a small-scale landslide disaster, so that they were not able to evacuate when the Sediment-Related Disaster Warning was announced around 10 a.m. After 21 hours in isolation, electricity, telephone, etc., were also cut off, causing loss of communication. Casualties occurred which were thought have been caused by an abrupt wave from a deep-seated landslide 7 hours after that (28 hours after the small landslide) (**Table 2**).

Table 2 Damage in Nagatono

Date	Time	Detail	Results
9/2	2:20	Traffic restriction of Route 168 began	
	3:34	Heavy rain warning issued	
	⇓		
	12:35	Sediment disaster warning information issued	
	⇓		
	23:00	Sediment in Shiotsuru, Ogurusu	Shallow slide occurred. Route 168 is no longer available.
	⇓		
9/3	11:00	Sediment from Teradani began	
	12:00	Evacuation to the community centers or other locations	
	13:25	Calling for voluntary evacuation (wireless station for disaster prevention)	
	⇓		
	19:45	No communication through cell phones, and power failure	No communication, and power failure
	⇓		
9/4	2:00	Heliport flooded	
	3:00	Landslides in Nigoridani and Okuzure	Deep-seated landslide occurred
		→ Nagatono Power Plant completely destroyed	
		→ Damage to a house that people were evacuated to	3 casualties

3. LESSONS LEARNED FROM THE 2011 FLOODS

Lessons learned from the results of research on the 2011 Floods are as follows:

(1) Prevention of large-scale sediment disasters, including deep-seated landslides
- Large-scale sediment disasters significantly bigger than those that had been predicted may occur.
- Most of the large-scale sediment disaster events occurred after peak rainfall.

(2)Timing and duration of the Sediment-Related Disaster Warning
- Nara Prefecture and the Metrological Observatory announced "Sediment-Related Disaster Warnings" on the basis of rainfall information prior to the occurrence of large-scale sediment disasters. This announcement is useful as a basis for warnings and evacuations.

(3) Limitation of long distance evacuation
- Many national and prefectural routes tend to be cut off by small-scale landslides before large-scale sediment disaster events in small neighborhood of mountains, thus causing disruptions to transportation and communication.
- There is a need to prepare for a relatively safe shelter within a community for when long distance evacuation is impossible.

(4) Actual evacuation
- Many residents escaped disaster events through voluntary evacuation, before warnings were issued. Such voluntary actions by residents should be encouraged.
- Some, however, were killed or injured while at the evacuation centers, or upon leaving the evacuation centers to go home when the rain ceased. It is necessary that it be known to everybody that large-scale sediment disasters can occur after rain, as well as the possibility of abrupt waves, etc. attacking a neighborhood which is located near a riverbed.

(5) Delivery of warnings and evacuation information
- Because both electric and data cables were down when roads were cut off, some municipalities experienced intermittent blackouts and disruption of cable TV, land and mobile phone services. It is important to prepare several means of communication in the event there is a black-out or break in communications.

4. INTEGRATED APPROACH TO ESTABLISHING A DISASTER MANAGEMENT SYSTEM

An integrated disaster management system, which accurately collects information, helps in the making of decisions, and disseminates disaster information, needs to be constructed. The system will need to be able to handle compound sediment disaster processes in which a normal-scale sediment-related disaster develops into a large-scale sediment-related disaster owing to changes in rainfall.

Nara Prefecture considers it important use the lessons learned from the 2011 Floods, and also, to reflect regional characteristics and local opinions in the process of establishing a feasible system of community disaster management. Thus, several study sites have been selected, and collaboration with local municipalities and community disaster prevention organizations are now underway (**Fig.9**).

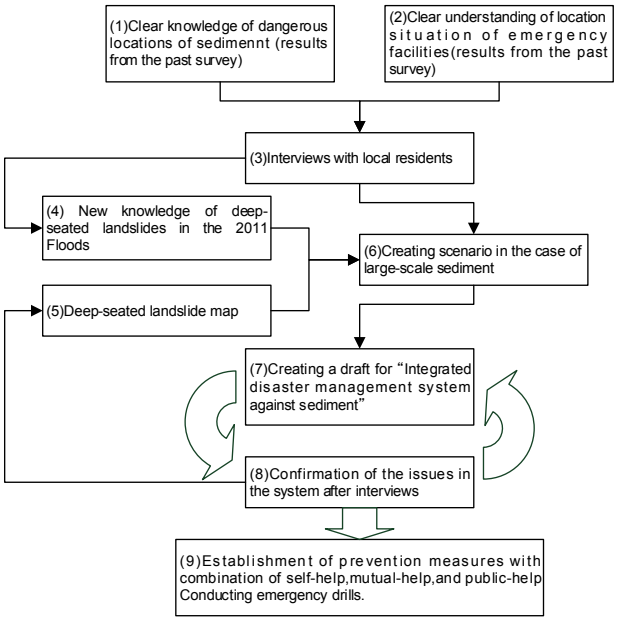

Fig. 9 Integrated approach to establishing a disaster management system

4.1 Basic Concept of control of large-scale sediment disasters

The damage from tsunami disasters caused by earthquakes including the Great East Japan Earthquake that occurred in the same year as the 2011 Floods, can be estimated to some degree from research on remnants of past tsunamis, and from analysis and simulation. Shelters may be built based on the information obtained. On the other hand, im-

plementing measures by building structures, etc. in anticipation of the locations and scale of slope collapses, and damage is difficult regardless of the studies that have been carried out on large-scale sediment disasters, such as deep-seated landslides that occurred in the 2011 Floods.

Establishment of an "integrated disaster management system" that can handle large-scale sediment disasters, is the goal for the time being, with a focus mainly on non-structural measures.

4.2 Topics for further discussion

(1) Evacuation
- When to evacuate and where to take refuge
- What information is necessary to trigger evacuation, and how to deliver the information
- Setting up an easy-to-understand evacuation index for each area

(2) Evacuation centers and routes
- Location of safer evacuation centers, areas, and routes

(3) Deep-seated landslide and river course blockage
- Understanding the mechanism of deep-seated landslides, predicting both the scale of damage and likely amount of time available left for evacuation

(4) Disaster prevention and disaster risk reduction with combination of self-help, mutual-help, and public-help
- Supporting community disaster prevention organizations
- Clarifying the roles of community disaster prevention organizations and municipalities

4.3 Study sites research outcomes

Study sites from the three districts which suffered from the most damage in the 2011 Floods, were selected for study, and the circumstances of such sites were reported following exchange of opinions with the communities. There have been opinion exchanges with the local communities about scenarios of large-scale sediment disasters by area, after "Conditions of the time of the Great Floods on Kii Peninsula", "Risk of small and medium-scale disaster", "Flood damage risk" and "Warning and evacuation system" have been studied. And then, the Panel would reflect the outcomes from the studies and the exchanges of opinions to future initiatives.

As a result of study, research and discussion, the members of the local communities concluded that the following considerations were of key importance:
- Safety guarantee of the evacuation centers
- Specific standards of evacuation
- Scope of activities of community disaster prevention organizations at the time of the disasters
- Knowing available routes when there is no other information available at the time of the disasters
- Evacuation to the other area is dangerous on the way
- Rainfall is different even within the village

Fig. 10 Exchange of opinions

Fig. 11 Interviews at sites

4.4 Establishment of an integrated disaster management system

Non-structural measures against sediment disasters before the 2011 Floods had been the delivering network for "Sediment disasters-related information", investigation and designation of the "Sediment disasters warning zones". Because many "deep-seated landslides" occurred in the 2011 Floods, establishment of an integrated disaster management system has been carried out in consideration of large-scale sediment disasters including deep-seated landslides.

Establishment of an integrated disaster management system should focus on "When", "Where" and "How" to improve the community disaster prevention force (**Fig. 12**).

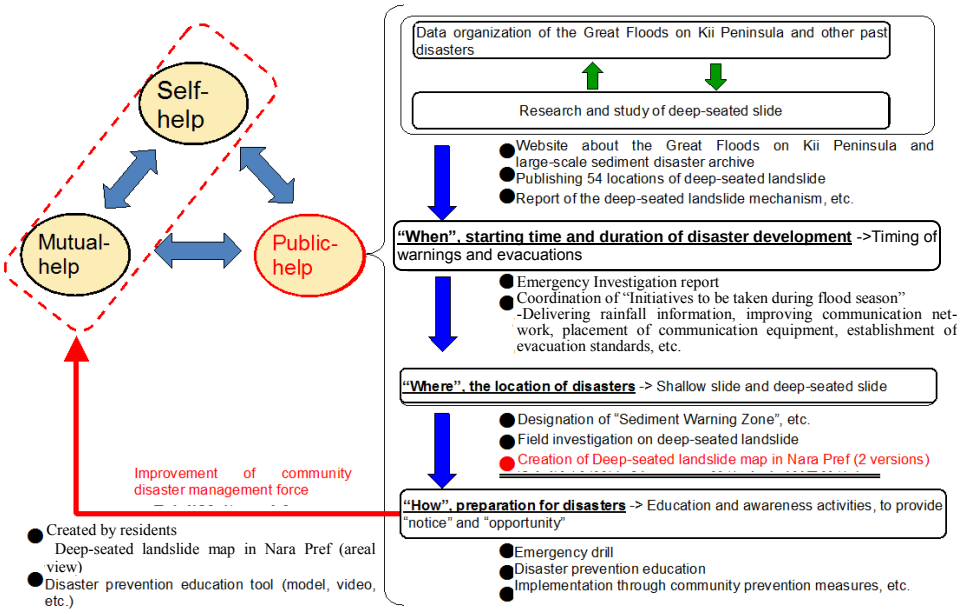

Fig. 12 Integrated disaster management system diagram

(1) "When", timing and duration of disaster development

- How to deliver warning information and trigger evacuation based on the condition of rainfall, has been the issue of activity.

Review of the standard amount of rainfall for warning and evacuation was carried out, whereas traffic regulations for sections of main roads which are used for evacuation were also overhauled to reflect the results from the 2011 Floods. Currently, strengthening of the information communication system is the focus.

(2) "Where", the location of disasters

A deep-seated landslide map in Nara Prefecture, which shows the locations of the most likely sediment disasters, is on the way as a major tool of an integrated disaster management system. The deep-seated landslide map will be prepared in the following two formats .

a) Deep-seated landslide map in Nara Prefecture (city view)

A "Deep-seated landslide map in Nara Prefecture (city view)" will be created for the purpose of relative risk assessment in a wide area, which is in accordance with "Draw-off manual of mountain streams likely to cause deep-seated landslides (draft), No. 4115 by Public Works Research Institute", with additional information from the results of deep-seated landslides that have occurred in the 2011 Floods, for the southern prefecture (**Fig. 13**).

The reference, "Instruction of Deep-seated landslide map (city view)", will be created in addition to the map, for active use.

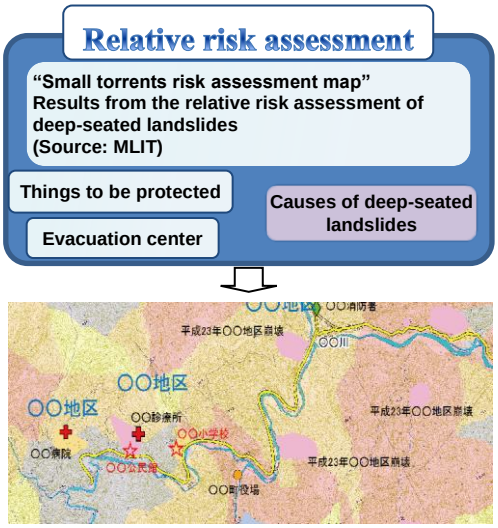

Fig. 13 Deep-seated landslides map in Nara Prefecture (city view)

b) Deep-seated landslide map in Nara Prefecture (areal view)

A "Deep-seated landslide map in Nara Prefecture (areal view)" will be created for use in disaster prevention on the local level, providing information about compound sediment disasters including shallow slides as well as deep-seated landslides (**Fig. 14**).

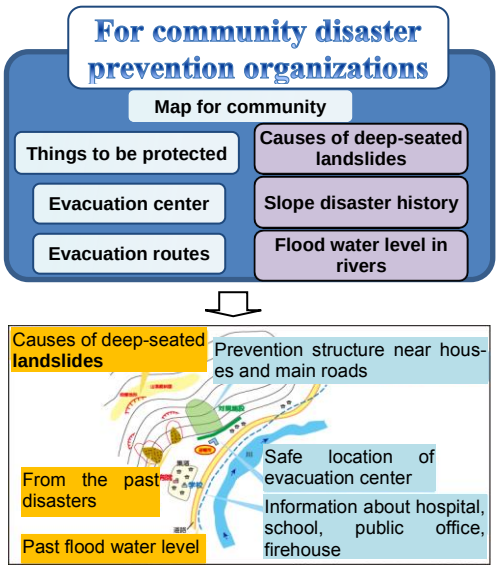

Fig. 14 Deep-seated landslides map in Nara Prefecture (areal view)

Improvement of the community disaster management force requires active involvement of the community disaster prevention organizations. "Deep-seated landslide map in Nara Prefecture (areal view)" will be designed so as to be created and used mainly by the community disaster prevention organizations, and the following has been prepared after analyzing the method for creating a map and its usage by the residents at the study sites:

- Reference manual - "Preparation and usage instruction for Deep-seated landslide map (areal view)"
- Case study of study sites

(3) "How", preparation for disasters

Preparations during normal times are important for disasters.

Hence, improvement of disaster prevention consciousness among residents and communities is required. Emergency drills and disaster prevention education have been conducted thus far as well as awareness activities, to provide "notice" and "opportunity".

Specifically, information on the 2011 Floods and the Great Flood in Totsukawa Village in Meiji has been used to create a disaster record as a reminder. Useful tools are prepared for disaster prevention education and emergency drills, to establish a "large-scale sediment disasters archive" for data and tools to be used on an ongoing basis.

5. CONCLUSIONS

Cities and villages that suffered from severe damage in the 2011 Floods, have been working independently on creating hazard maps and installing satellite-based mobile phones, etc. in cooperation with the residents. In Nara Prefecture, an integrated disaster management system for the study sites against sediment disasters has been studied in collaboration with the municipalities and the community disaster prevention organizations, etc. to develop wider use of the system in other areas of the prefecture.

Post-disaster recovery and reconstruction in Nara Prefecture continues till FY2014, which marks three years since the 2011 Floods. The approaches currently taken will be reviewed in the coming autumn, to improve safety of the communities.

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