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Paper:

Evacuation Behavior of Facilities for the Elderly in the Heavy Rain of July 2018

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The heavy rain disaster in July 2018 caused significant damages such as leaks and inundation above floor level at many facilities for the elderly. In the present study, we surveyed facilities for the elderly near Oda River, Okayama Prefecture, and those near Hiji River, Ehime Prefecture, to study the necessity of a facility-specific criterion to start evacuation on the basis of the characteristics of the facilities used by people who need care. The results of the survey indicated that evaluation information released by the local government might not ensure sufficient evacuation time. An example of a criterion to start evacuation based on the water level of a nearby river or the amount of dam discharge was shown as one of the ways that each facility voluntarily makes decisions on fast evacuation.

Keywords: facility for the elderly, criterion to start evacuation behavior

1. Introduction

Typhoon No. 10 in August 2016 hit a group home for elderly dementia patients in Iwaizumi-cho, Iwate Prefecture, and caused the deaths of all nine residents. The manager of the home received evacuation preparation information but did not think that it actually called for the evacuation of people who needed care. Therefore, the residents could not take appropriate evacuation action. After this experience, "evacuation preparation information" was renamed as "evacuation preparation and evacuation start of elderly people and others," and the Flood Prevention Law was partially amended in May 2017 so that "facilities used by people who need care built in areas with a high risk of flood or landslide disaster" had to create an evacuation plan and perform an evacuation drill. However, according to a survey by the Ministry of Land, Infrastructure, Transport and Tourism [1] (as of the end of March 2016), only 2% of facilities (716 out of 31,208) used by people who need care had created an evacuation plan and performed an evacuation drill as designated in the local disaster management plans of the municipalities.

After Typhoon No. 10 in August 2016, the Association of Group Homes for Dementia Elderly in Iwate Prefecture conducted a hearing survey at 12 group homes in Iwaizumi-cho, Miyako-shi, Kuji-shi, Noda-mura, and Tanohata-mura from August 31, 2016 to September 1, 2016. The first report [2] showed that deciding when to evacuate was difficult for many facilities. It also showed that information for determining evacuation timing was more effective if it was provided not as audible information but as visible information that would give people a more direct feeling of danger.

There are preceding studies on flood control measures for facilities used by people who need care. Yoshii analyzed evacuation behavior at a facility for the elderly during heavy rain in Amami [3]. Kitadaga and Miyamoto analyzed how a facility's disaster experience would affect and contribute to its disaster prevention activities [4]. Nagaie et al. [5] proposed a way of creating an evacuation support plan against flood damage with a focus on site characteristics. In a preceding study on a criterion to start evacuation, Katada and Kanai [6] proposed that residents should determine a criterion for evacuation by detecting indications of a landslide disaster. As part of an inundation analysis of mid-size and small rivers, Harada et al. [7] proposed a way of setting a criterion to decide voluntary evacuation according to surrounding conditions.

On the other hand, there have been almost no detailed analyses on a criterion for starting evacuation of facilities for the elderly, except the ones by the authors [8–12].

Because of the heavy rain in July 2018, 276 facilities for the elderly in the Chugoku and Shikoku Regions and other areas had leaks and flooding over floor level [13] (**Table 1**). In the present study, we performed an inundation trace survey and a hearing survey at two facilities near Oda River in Okayama Prefecture and at three facilities near Hiji River in Ehime Prefecture during the period from July 2018 to February 2019 in order to study the necessity of a facility-specific criterion to start evacuation on the basis of the characteristics of the facilities used by people who need care. In addition, as an example of a safer criterion for the facilities, we chose a facility near Hiji River and performed an inundation analysis to study the correlation among the inundation conditions, temporal changes in discharge from a dam, and evacuation behaviors.

Table 1. Damages to facilities for the elderly.

Prefectures	Facility type	Number of damaged facilities
Gifu	Long term care health facilities	2
Shiga	Nursing home for the elderly	2
Kyoto	Nursing home for the elderly	10
Osaka	Nursing home for the elderly	6
Hyogo	Nursing home for the elderly	10
Okayama	Nursing home for the elderly	69
Shimane	Group home for the dementia elderly	1
Hiroshima	Nursing home for the elderly	84
Ehime	Nursing home for the elderly	38
Yamaguchi	Nursing home for the elderly	1
Fukuoka	Private residential home for the elderly	41
Nagasaki	Low-cost social welfare facilities for the elderly	2
Okinawa	Nursing home for the elderly	10
Total		276

2. Overview of the Heavy Rain in July 2018

Typhoon No. 7 arose in the southern Sea of Japan at 9AM on June 29, 2018, went through the Tsushima Channel on the night of July 3, and changed into an extratropical storm in the middle of the Sea of Japan at 3PM on July 4. A seasonal rain front extending from a depression stayed over western Japan from July 5 to 8. Then, wet air continuously flew from the south sea into the rain front and formed a local linear rainband in various places in western Japan, which caused a record-breaking heavy rain in a vast area from the Chubu to Kyushu Regions.

As a result, Okayama Prefecture had record-breaking heavy rain until July 8 and a special heavy rain warning was issued to 24 cities and villages in the prefecture on the night of July 6. The total precipitation during the period from 0AM on July 3 to 12PM on July 8 was 497.0 mm in Onbara, Kagamino-cho, and 490.0 mm in Tomi, Kagamino-cho (**Fig. 1**) [14]. The heavy rain caused not only human damages including 61 deaths and 3 missing persons, but also property damages including 4,822 completely destroyed houses, 3,081 partly destroyed houses, 2,921 inundated houses over the floor level, and 6,035 inundated houses below the floor level in Okayama Prefecture [15]. In Mabi-cho, Kurashiki-shi, which we surveyed for the present study, a levee on the left bank of Oda River was destroyed; about 12 km^2, covering 27% of the area, and about 4,600 houses were inundated. Since the water level increased in a short period of time, many people could not evacuate from their houses. About 2,350 people were rescued by Self-Defense Forces personnel and fire fighters, and 51 people died [16].

In Ehime Prefecture, the precipitation during the period from 0AM on July 5 to 12PM on July 8 was 571.0 mm in Chikanaga, Kihoku-cho, and 539.5 mm in Uwa, Seiyo-shi (**Fig. 2**) [17]. The heavy rain caused 27 deaths, 625 completely destroyed houses, 3,018 partly destroyed houses, 187 inundated houses over the floor level, and 2,492 inundated houses below the floor level in Ehime Prefecture [18]. In Nomura-cho, Seiyo-shi, which we surveyed for the present study, Nomura Dam began discharging water of the same amount as the inflow to the dam at 6:20AM on July 7 and the discharge rate reached 1,797 m^3/s. The sudden increase in the discharge caused an overflow of Hiji River, resulting in the death of five people who failed to evacuate. In addition, the discharge rate of Kano River Dam, located on the downstream side of Nomura Dam, reached 3,742 m^3/s at 7:35AM, about six times higher than the safety standard rate, and Ozu-shi in the downstream area experienced significant damage [19].

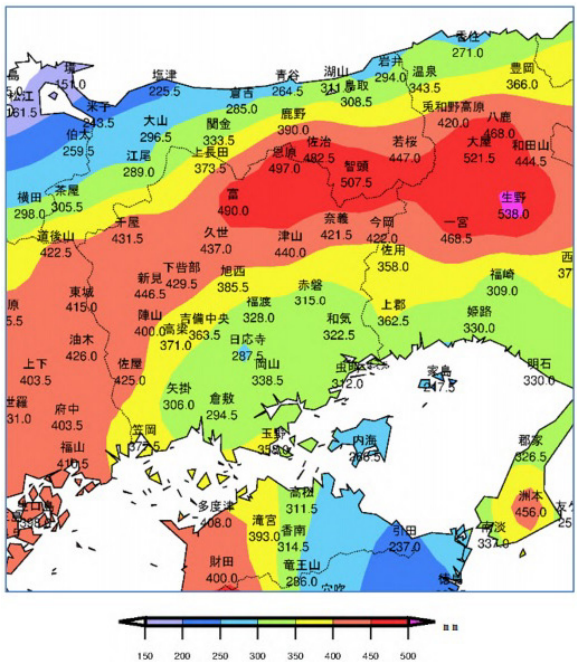

Fig. 1. Precipitation distribution from July 3 to 8 (Okayama Local Meteorological Observatory).

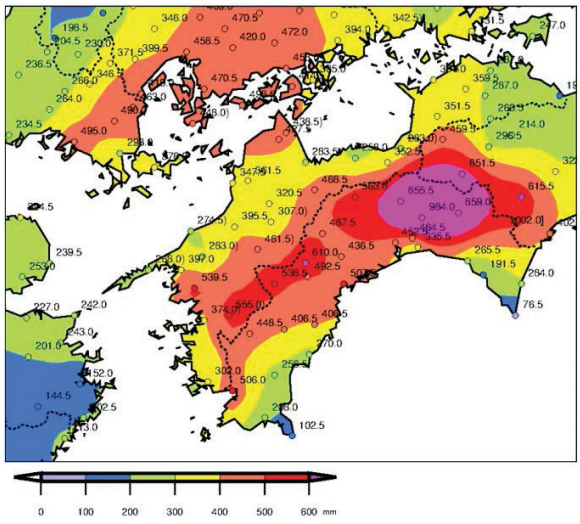

Fig. 2. Precipitation distribution from July 5 to 8 (Matsuyama Local Meteorological Observatory).

Table 2. Classification of safety ensuring behaviors.

Viewpoint on actions	Safety ensuring actions	Specific actions
Emergency action	Staying	Staying at home or another place where safety can be ensured.
	Vertical migration	Moving to an indoor place on the second or higher floor where safety can be ensured.
	Horizontal migration (temporary)	Leaving the current place and moving to a neighboring place temporarily where safety can be ensured.
Action to live a temporary life	Horizontal migration (long term)	Living a temporary evacuation life at an evacuate site or another place different from home for a certain period of time.

3. Evacuation Behavior of Facilities for the Elderly

The Central Disaster Management Council's "Expert Examination Committee for Evacuation in Disasters" [20] defines "evacuation" as "safety ensuring behaviors." Furthermore, the committee classifies safety ensuring behaviors in four typical classes from two viewpoints of "emergency actions" and "actions to live a temporary life for a certain period" (**Table 2**).

In the present study, we surveyed "emergency actions." The behaviors of the people from the facilities for the elderly, A to E, found through the hearing survey were classified into (1) timing to start evacuation and (2) evacuation behaviors. We examined the relations among the issuance of an evacuation warning from local governments, the release of a climate alert, evacuation behaviors, and inundation conditions around each facility in chronological order to calculate how much time each facility would have to evacuate.

3.1. Evacuation Behavior of Facility A (Mabi-Cho, Kurashiki-Shi, Okayama Prefecture)

Figure 3 shows the locations of the inundated area and the facility for the elderly, A (hereinafter referred to as facility A), in Mabi-cho. **Fig. 4** is a magnified map of the area enclosed by the red frame in **Fig. 3**, showing the locations of facility A and Oda River. **Table 3** shows the evacuation behaviors of the people from facility A. A warning about evacuation preparation and the start of the evacuation of elderly people and others was issued for people in mountain areas in Kurashiki-shi at 11:30AM on July 6. It was for areas at risk of landslide disaster and was irrelevant to facility A.

Facility A is a one-story building and the flood water reached 5.0 m in height. The manager received a flood hazard map provided by the municipal government but did not make a manual for evacuation from flooding or conduct an evacuation drill. There were 29 long-term residents and 7 short-stay residents in the facility on the day of the disaster.

(1) Timing of the start of the evacuation

On the day before the heavy rain, the manager had decided to start the evacuation to an associated facility if an

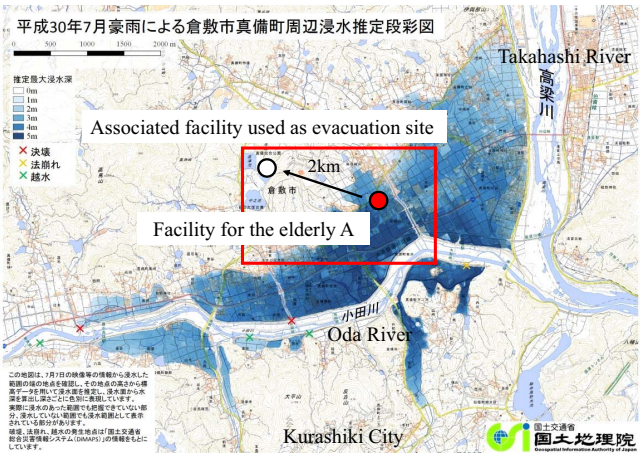

Fig. 3. Locations of inundated area and facility A in Mabi-cho (created by modifying a gradient tints diagram of inundation around Mabi-cho, Kurashiki-shi due to the heavy rain in July 2018 created by the Geospatial Information Authority of Japan).

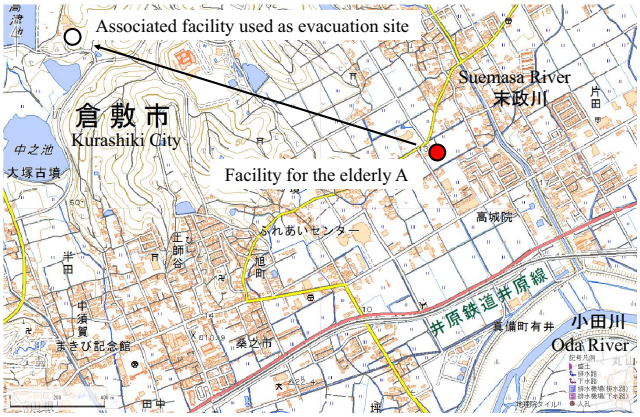

Fig. 4. Locations of facility A and Oda River.

"evacuation advisory" was issued. On July 6, after collecting the climate information, water level information on the river, and images of the river from a live camera, the manager decided to start the evacuation as planned when an "evacuation advisory" was issued for the entire Mabi area at 10PM.

Table 3. Evacuation behavior of facility A.

Day	Time	Climate alert / evacuation information / discharge from dam	Countermeasure of facilities against disaster
July 5	19:40	Flood warning	
July 6	11:30	Preparation for evacuation and start of evacuation of the elderly (mountainous areas in all of Kurashiki-shi)	
	21:40	Water level of Oda River for evacuation reached (at Yakage)	
	22:50	Overflow warning of Oda River (at Yakage)	
	22:00	Evacuation advisory (for entire Mabi area)	Decision made on evacuation
	22:10	Water level of overflow of Oda River reached (at Yakage)	
	22:40	Special warning of heavy rain (Kurashiki-shi)	
	22:45		Start of evacuation (transporting the residents to the associated facility)
	23:45	Evacuation order (for Mabi district and south of Oda River)	
July 7	0:00		Completion of evacuation, returning of some staff to the facility
	0:30	Information of overflow of Oda River (near Maeda)	Start of inundation and evacuation and isolation of the staff to the roof top
	1:30	Evacuation order (for Mabi district and north of Oda River)	
	4:00		Water level increase and power failure
	6:00		Inundation peak (5 m)
	19:00		Rescue by helicopter and boat

Fig. 5. View from the roof top at 5:01AM on July 7 (provided by the facility).

(2) Evacuation behavior: "horizontal migration (temporary)"

The facility staff were immediately assembled and began to transport the residents to an associated facility about 2 km away at around 10:45PM. The evacuation finished at 0:00AM. The staff then returned to the facility to take waterproofing measures for the equipment. Flooding began at around 0:30AM, and 25 of them were left on the roof top. **Fig. 5** was taken by a person left on the roof top at around 5AM on July 7 when the inundation height reached its peak; the photo shows the inundation around the facility. The staff were all rescued by a boat and helicopter 14 hours later.

3.2. Evacuation Behavior of Facility B (Mabi-Cho, Kurashiki-Shi, Okayama Prefecture)

Figure 6 shows the locations of the inundated area and the facility for the elderly B (hereinafter referred to as facility B) in Mabi-cho. **Fig. 7** is a magnified map of the area enclosed by the red frame in **Fig. 6**, showing the locations of facility B, Oda River, and Takahashi River. **Table 4** shows the evacuation behaviors of the people of facility B. As mentioned above, a warning about evacuation preparation and starting the evacuation of elderly people and others was issued for people in mountain areas in Kurashiki-shi at 11:30AM on July 6. It was irrelevant to facility B, which is located on flat land.

Facility B is a three-story building and the flood water reached 3.5 m in height. There were 30 residents in the facility on the day of the disaster.

(1) Timing of the start of the evacuation

On July 6, evacuation information was released by the local government, and river images from a live camera were collected. When an "evacuation advisory" was issued for the entire Mabi area at 10PM, the evacuation began, as at facility A.

(2) Evacuation behavior: "horizontal migration (temporary) + vertical migration"

The staff were assembled immediately and began to transport the 36 residents to an associated facility (a three-story building) nearby, facility B (a one-story building), at around 11PM. Experiences of past transport drills were taken advantage of. Since the elevators could not be used because of a power failure, the staff moved the residents to

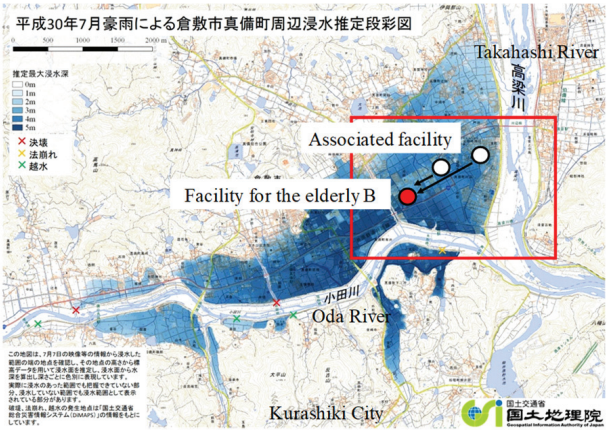

Fig. 6. Locations of inundated area and facility B in Mabi-cho (created by modifying a gradient tints diagram of inundation around Mabi-cho, Kurashiki-shi, due to the heavy rain in July 2018, developed by the Geospatial Information Authority of Japan).

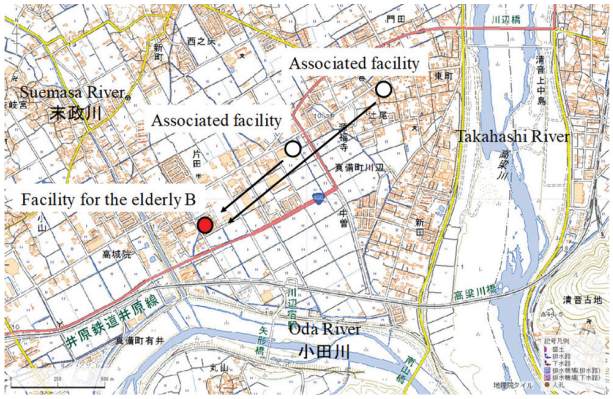

Fig. 7. Locations of facility B and Oda River.

Table 4. Evacuation behaviors of facility B and related facilities.

Day	Time	Climate alert / evacuation information / discharge from dam	Countermeasure of facilities against disaster
July 5	19:40	Flood warning	
July 6	11:30	Preparation for evacuation and start of evacuation of the elderly (mountainous areas in all of Kurashiki-shi)	
	21:40	Water level of Oda River for evacuation reached (at Yakage)	
	21:50	Overflow warning of Oda River (at Yakage)	
	22:00	Evacuation advisory (for entire Mabi area)	Decision made on evacuation
	22:10	Water level of overflow of Oda River reached (at Yakage)	
	22:30		Call for staff through an emergency contact network
	22:40	Special warning of heavy rain (Kusashiki-shi)	
	23:00		Start of evacuation (transporting the residents to the associated facility)
	23:45	Evacuation order to the southern area of Oda River in Mabi-cho	Transportation of the residents to the third floor by the staff
July 7	0:00		Completion of evacuation
	0:30	Information of overflow of Oda River (near Maeda)	Start of inundation and isolation
	1:30	Evacuation order (for Mabi district and north of Oda River)	

the third floor on their own. About 70 neighbors also evacuated to the facility. Therefore, a total of about 150 people (residents, staff, and neighbors) were left in the facility building, waiting for rescue.

3.3. Evacuation Behavior of Facility C (Shiba, Ozu-Shi, Ehime Prefecture)

Figure 8 shows the locations of the inundated area and the facility for the elderly C (hereinafter referred to as facility C) around Hiji River. **Fig. 9** is a magnified map of the area enclosed by the red frame in **Fig. 8**, showing the locations of facility C, Hiji River, and Yoke River. **Table 5** shows the evacuation behaviors of the people of facility C.

Facility C is a two-story building and the flood water reached 1.3 m in height. The manager received a flood hazard map provided by the municipal government and a flood record of the region. They did not have a manual for evacuation from flooding but had conducted an evacuation drill. There were 16 residents in the facility on the day of the disaster.

(1) Timing of the start of the evacuation

On July 7, information on the amount of water discharged from Kano River Dam and information from water level observatories (at Ohkawa and Ozu 2nd) were collected, and the water level of Yoke River behind the facility was visually checked. Six private vehicles belonging

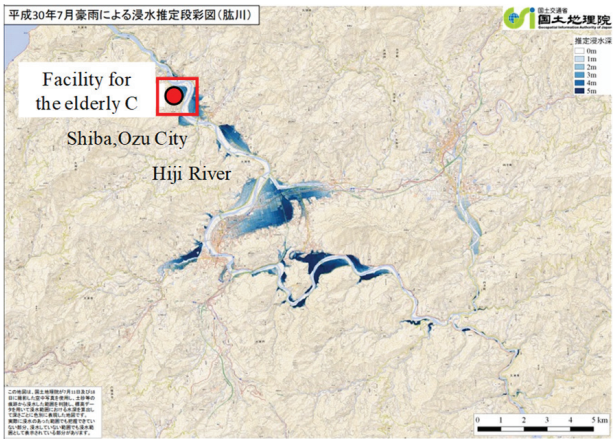

Fig. 8. Locations of inundated area and facility C around Hiji River (created by modifying a gradient tints diagram of inundation around Hiji River due to the heavy rain in July 2018 created by the Geospatial Information Authority of Japan).

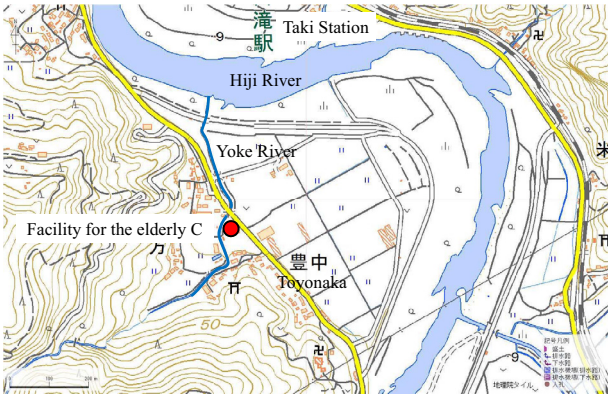

Fig. 9. Locations of facility C and Hiji River.

Table 5. Evacuation behavior of facility C.

Day	Time	Climate alert / evacuation information / discharge from dam	Countermeasure of facilities against disaster
July 7	2:32	Flood warning	
	5:20	Overflow warning of Hiji River and Yaochi River	
	5:50	Preparation for evacuation and start of evacuation of the elderly (Toyonaka and Shirataki)	
	6:20	Start of disaster prevention operation for abnormal flooding of Nomura Dam	
	6:30		Six private vehicles belonging to the staff were moved to a hill.
	7:00		Entrance of the facility was sandbagged.
	7:10	Evacuation advisory (Toyonaka and Shirataki)	
	7:30	Evacuation order (entire city)	Evacuation was decided.
	7:35	Start of disaster prevention operation for abnormal flooding of Kano River Dam	
	8:00		Start of evacuation (the residents were moved to the second floor by elevator.)
	8:30		Completion of the evacuation
	8:50		Notification to the municipal countermeasure headquarters. Receipt of data on the water discharge.
	9:00		Evacuation to an associated facility failed because of inundation of the road. Start of the inundation
	12:30		Inundation at a height of about 20 cm around the facility
	13:20		About 1 m (flowing into the facility)
	13:30		About 1.2 m (peak height)

to the staff were moved to a hill at 6:30AM, and the entrance to the facility was sandbagged at 7AM.

On the other hand, a warning about evacuation preparation and starting the evacuation of elderly people and others was issued at 5:50AM by the local government. An evacuation advisory was issued at 7:10AM and an evacuation order was issued for the entire city at 7:30AM, five minutes before the start of the disaster prevention operation because of the abnormal flooding of Kano River Dam.

People at the facility began evacuating when the evacuation order was issued.

Fig. 10. View from a veranda on the second floor at 1:35PM on July 7 (provided by the facility).

Fig. 11. Locations of flooded area near Hiji River and facility D (Created by modifying a gradient tints diagram of inundation around Hiji River due to the heavy rain in July 2018 created by the Geospatial Information Authority of Japan).

(2) Evacuation behavior: "vertical migration (failure of horizontal migration)"

The residents were moved to the second floor at 8AM. At 8:50AM, the staff heard from the municipal headquarters for disaster control that the discharge from Kano River Dam reached 3,700 m^3/s. Therefore, the staff tried to transport the residents to an associated facility at 9AM but failed because of the inundation of the road. At 12:30PM, the inundation height around the facility was 20 cm and was increasing rapidly. It reached its peak at around 2PM. **Fig. 10** shows the surrounding situation of the facility; it was taken from a veranda on the second floor at 1:35PM, when the inundation height was reaching its peak.

3.4. Evacuation Behavior of Facility D (Tokumori, Ozu-Shi, Ehime Prefecture)

Figure 11 shows the locations of the inundated area and the facility for the elderly, D (hereinafter referred to as facility D), around Hiji River. **Fig. 12** is a magnified map of the area enclosed by the red frame in **Fig. 11**, showing the locations of facility D and Hiji River. **Table 6** shows the evacuation behaviors of the people of facility D.

Facility D is a five-story building, and the flood water reached 2.4 m in height. On the basis of the experiences of floods in 1991, 1995, and 2004, countermeasures against flood disaster had been taken. For example, water prevention panels and sewage backflow preventive valves were installed, a stockpile was stored on the fifth floor of an associated facility next door, and the residential rooms were all on the third or higher floors. In addition, a countermeasure manual against flood disasters contained a specific criterion for taking an emergency action (precipitation of 160 mm in 3 hours, 3.5 m water level at Ohkawa water level observatory, and discharge of 600 m^3/s from Kano River Dam). On the day of the disaster, there were 60 residents. However, since their rooms were on the upper floors, there was no need for evacuation.

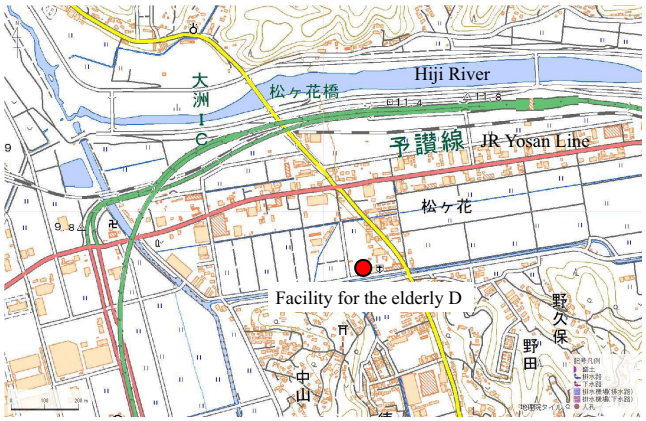

Fig. 12. Locations of facility D and Hiji River.

(1) Timing of the start of the evacuation

The manager had stayed at the facility overnight since July 5, collecting data on the water discharge from Kano River Dam, data on the water level of the river (at Ohkawa and Ozu 2nd), and information from fire fighters. The disaster countermeasure headquarters were organized at the facility around noon on July 6. In the evening, 80 people who used the facility's day service were moved to their homes, and about 40 assistive vehicles were transported to a hill park. At 4AM on July 7, the vehicles were transported to a higher hill. At that time, the parking lot of the facility was inundated by 20–30 cm, but the building was not. At 8AM, the building began to be inundated, with the inundation height reaching 25 cm above floor level at 9AM; it reached the ceiling of the first floor at 4PM.

(2) Evacuation behavior: "no need for migration of residents"

As mentioned above, since the residential rooms were on the upper floors, there was no need for evacuation.

Table 6. Evacuation behavior of facility D.

Day	Time	Climate alert / evacuation information / discharge from dam	Countermeasure of facilities against disaster
July 6	4:49	Heavy rain warning	The chief official stayed overnight at the facility.
	6:20	Landslide disaster warning information	
	Around noon		Start of countermeasures against disaster (establishment of disaster management headquarters)
	Evening		Moving of 80 people who used the day service to their homes, moving of vehicles to a hill
July 7	2:32	Flood warning	
	4:00		More moving of vehicles, inundation of parking lot, water prevention panel installed at the entrance
	5:20	Overflow warning for Hiji River and Yaochi River	
	6:20	Preparation for evacuation and start of evacuation of the elderly (Taira and Higashi Ozu) and start of disaster prevention operation for abnormal flooding of Nomura Dam	No need for evacuation because the residential rooms were on the third and higher floors.
	6:30		
	7:00		
	7:30	Evacuation order	
	7:35	Start of disaster prevention operation for abnormal flooding of Kano River Dam	
	8:00		Start of inundation
	9:00		Inundation at a height of about 25 cm above the floor
	10:49		Information on the start of overflow was received from firefighters.
	16:00		Inundation at a height of about 2.4 m above the floor

3.5. Evacuation Behavior of Facility E (Seiyo-Shi, Ehime Prefecture)

Figure 13 shows the locations of Hiji River and the facility for the elderly E (hereinafter referred to as facility E). **Table 7** shows the evacuation behaviors of the people of facility E.

Facility E is a two-story building, and the flood water reached 3.8 m in height. On the day of the disaster, there were 18 residents (9 on the first floor and 9 on the second) and 2 staff members in the facility. They did not have a manual for evacuation from flooding, but they did conduct an evacuation drill every month to check the emergency contact network and guide the residents on the second floor to the first floor.

(1) Timing of the start of the evacuation

At 5:10AM on July 7, the head official noticed an evacuation order propagated through a wireless-activated disaster warning system and made a phone call immediately to the staff at the facility, ordering them to assemble all of the residents on the first floor. At 5:30AM, the head official and the staff who were assembled on an emergency basis arrived at the facility and decided to transport the residents to an associated hospital.

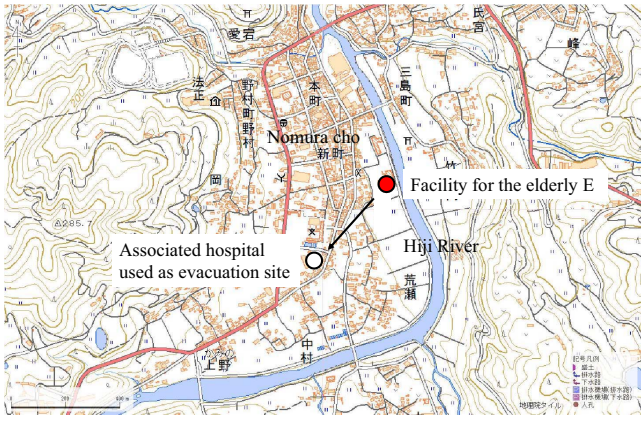

Fig. 13. Locations of facility E and Hiji River.

(2) Evacuation behavior: "horizontal migration (temporary)"

The first group of residents left the facility at 5:40AM in six vehicles, and the transport effort finished at 6:10AM. The head official and staff returned to the facility to transport breakfast from the facility. However, the inundation height increased at 6:30AM, and they gave up on transporting the breakfast and evacuated. The inundation

Table 7. Evacuation behavior of facility E.

Day	Time	Climate alert / evacuation information / discharge from dam	Countermeasure of facilities against disaster
July 7	There was no announcement on a "preparation for evacuation and start of evacuation of the elderly" or an evacuation advisory.		
	5:10	Evacuation order	Decision on evacuation (the residents sleeping on the second floor were guided to the first floor.)
	5:30		The facility head and staff were assembled, and vehicles from the associated hospital arrived.
	5:40		Start of evacuation (the residents were transported to the associated hospital.)
	6:10		Completion of evacuation
	6:20	Start of disaster prevention operation for abnormal flooding of Nomura Dam	The manager and staff returned to the facility to retrieve meals.
	6:30		Start of inundation (the water level increased suddenly and the staff evacuated because of the danger.)
	7:35		3.77 m
	10:30		End of inundation

height reached 6 cm above the second-floor level. **Fig. 14** of the facility was taken from a hill at around 7:10AM.

Fig. 14. View from a hill at around 7:10AM on July 7 (provided by the facility).

3.6. Problems with the Criterion to Start the Evacuation

In principle, an "evacuation preparation and evacuation start for elderly people and others" issued by a local government is used as a criterion to start evacuation from floods from facilities for the elderly and other facilities used by people who need care. This is because an "evacuation preparation and evacuation start for elderly people and others," which was named after the "evacuation preparation information" when residents of a facility for the elderly in Iwate Prefecture died in Typhoon No. 10 in August 2016, is now widely known as a guide for people who need care to evacuate and because the Ministry of Land, Infrastructure, Transport and Tourism made a manual for facilities used by people who need care to create an evacuation plan [21]. The ministry showed an example where an "evacuation preparation and evacuation start for elderly people and others" was used as timing to guide people who needed care in evacuating. In addition, the authors conducted a survey in 2017 for facilities for the elderly in four prefectures in Shikoku Region (answers were collected by mail and the numbers of sent questionnaire sheets and collected answers were 1,000 and 358, respectively) [10]. To the question "When do you decide to start evacuation?" 58% of the facilities answered "When the announcement of evacuation preparation and evacuation start for elderly people and others was issued," indicating that the facilities properly recognized the announcement to a certain degree.

Against this background, we analyzed each facility's criterion to start the evacuation.

Table 8 lists information about the evacuation behaviors of the facilities. The list items are the number of building stories, number of residents, evacuation site, classification of safety ensuring behaviors, height of inundation trace, existence of manual for countermeasures against flooding, execution of evacuation drills against flooding, check of river water level information and others, actual timing to decide on evacuation, time to prepare for evacuation (from decision on evacuation to start of evacuation), time of evacuation (from start of evacuation to completion of evacuation), time from completion of evacuation to start of inundation, and issuance of an "evacuation preparation and evacuation start for elderly people and others." Facility D is exempted from the analysis as there was no need for evacuation.

Facilities A and B decided to start evacuating when the evacuation advisory was issued and facilities C and E decided when the evacuation order was issued. Every facility had 20–30 minutes from when the evacuation fin-

Table 8. List of evacuation behaviors of facilities A to E.

Facility name	Facility A	Facility B	Facility C	Facility D	Facility E
Place	Mabi district, Kurashiki-shi, Okayama Prefecture	Mabi district, Kurashiki-shi, Okayama Prefecture	Shiba, Ozu-shi, Ehime Prefecture	Tokumori, Ozu-shi, Ehime Prefecture	Nomura-cho, Seiyo-shi, Ehime Prefecture
Number of building stories	One story	Three stories	Two stories	Five stories	Two stories
Number of residents	36	30	16	60	18
Evacuation site	Associated facility 1.5 km away	Third floor of the facility	Second floor of the facility	Third to fifth floors of the facility	Associated hospital about 600 m away
Classification of safety ensuring behaviors	Horizontal migration (temporary)	Horizontal migration (temporary) + vertical migration	Vertical migration (Horizontal migration failed.)	No need for migration	Horizontal migration (temporary)
Height of inundation trace	5.0 m	3.5 m	1.3 m	2.4 m	3.8 m
Existence of manual of countermeasures against flood	None	None	None	Available	None
Execution of evacuation drill against flood	No	Yes	Yes	-	Partly yes
Check of river water level information and others	Checked	Checked	Checked	Checked	Checked
Actual timing to decide evacuation	When the evacuation advisory was issued.	When the evacuation advisory was issued.	When the evacuation order was issued.		When the evacuation order was issued.
Time to prepare for evacuation (from decision on evacuation to start of evacuation)	45 min.	1 hour	30 min.		1 hour
Time of evacuation (from start of evacuation to completion of evacuation)	1 hour 15 min.	1 hour	30 min.		30 min.
Time from completion of evacuation to start of inundation	30 min.	30 min.	30 min.		20 min.
Issuing of "evacuation preparation and evacuation start for elderly people and others"	No	No	Yes		No

ished to when the inundation began. Therefore, starting the evacuation based on the timing of the evacuation advisory or evacuation order was not safe for the facilities for the elderly because preparation and evacuation of the elderly take a long time. However, in the areas where facilities A, B, and E were located, the "evacuation preparation and evacuation start for elderly people and others" was not issued before the evacuation advisory. As mentioned earlier, local governments basically issue an "evacuation preparation and evacuation start for elderly people and others" as a guide to start the evacuation of facilities used by people who need care in a flood disaster, but they do not always issue one. Therefore, every facility needs to have multiple criteria to start the evacuation.

Also, the issuance of an "evacuation preparation and evacuation start for elderly people and others" is not always the best timing for every facility. For example, if facility C begins to transport the residents to the associated facility based on the timing of the "evacuation preparation and evacuation start for elderly people and others" and the preparations for the evacuation and evacuation itself take an hour and 2 hours, respectively, then there is only 10 minutes left before the inundation begins. Namely, an "evacuation preparation and evacuation start for elderly people and others" does not take account of the evacuation period of each facility. Therefore, each facility needs to calculate the necessary time for the evacuation preparations and evacuation itself and determine its own criterion to start the evacuation.

To summarize, the "evacuation preparation and evacuation start for elderly people and others" is not sufficient as a criterion to start the evacuation of people at facilities for the elderly and it is necessary for each facility to determine its own criterion to start evacuating on the basis of, for example, the water level of a river or the discharge from a dam.

4. Attempt to Introduce a Criterion for Starting an Evacuation

To determine a safer criterion to start evacuation for facilities for the elderly where evacuation would take a longer time, we performed an inundation analysis of fa-

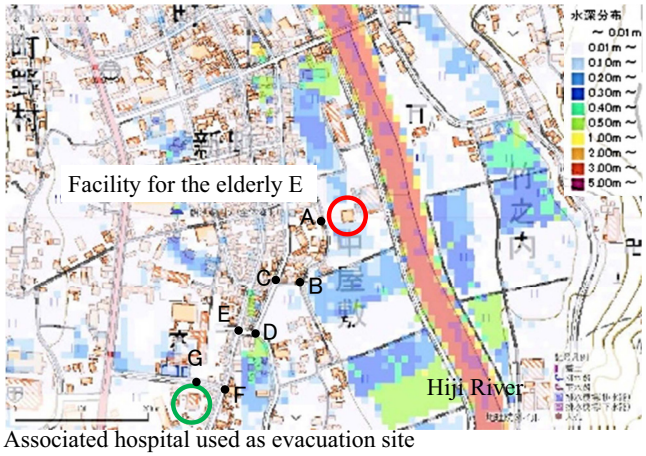

Fig. 15. Inundation at 6:10AM on July 7 (when the people of facility E finished evacuating).

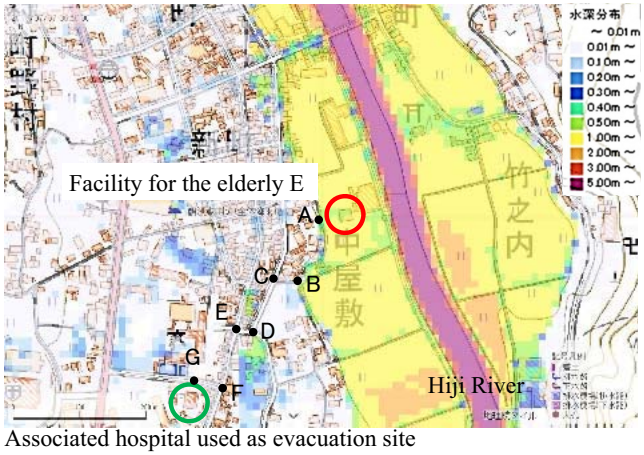

Fig. 16. Inundation at 6:50AM on July 7 (when the inundation of facility E began).

cility E in Nomura-cho, Seiyo-shi, Ehime Prefecture to find correlations among the inundation condition, water discharge from Nomura Dam, and other factors.

4.1. Reproduction of Inundation by Flood Analysis

The inundation analysis of Nomura Dam and the central area of Nomura-cho was performed by taking account of a temporal change in the water discharge from the dam in the upstream cross-section. The software "AFREL" (NITA Consultant), with an XOKABE engine developed by Takeshi Okabe, was used. The effectiveness of the XOKABE engine installed in AFREL was analyzed by Miyoshi et al. [22] in their analysis model of rainfall inundation in local cities or rural areas where sewer networks had not been well developed.

Figures 15 to **18** show the inundation conditions around facility E in chronological order. **Fig. 15** shows the inundation at 6:10AM when the evacuation of the people of facility E was finished. The road to the associated hospital to which they evacuated was not inundated and therefore they could evacuate by car.

Figure 16 shows the inundation at 6:50AM, 10 minutes after the start of the disaster prevention operation in response to the abnormal flooding of Nomura Dam. The water level of Hiji River increased quickly and there was inundation on the right bank. **Fig. 17** shows the inundation at 7AM, when the inundation height at facility E was 1.59 m. **Fig. 18** shows the inundation at 8AM, when the inundation height at facility E reached the maximum of 3.26 m. The inundation height decreased after 8AM.

The results indicated that the maximum inundation height was about 50 cm lower than the measured height, but the inundation condition almost agreed with what was obtained through the hearing survey.

Figure 19 indicates with a red line the evacuation route from facility E to the associated hospital to which the residents were evacuated. The distance between them was 605 m, and the difference in elevation was about 10 m.

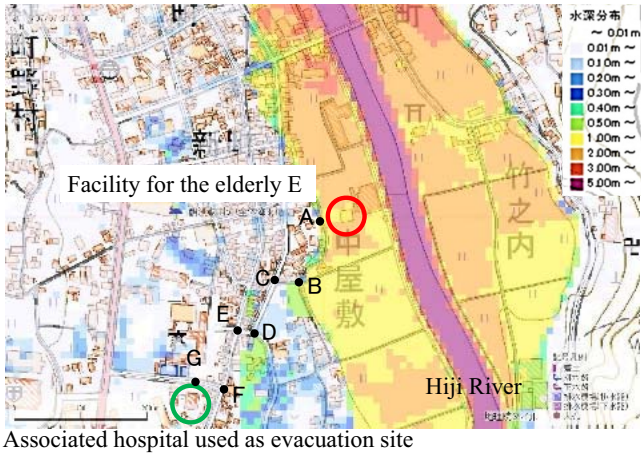

Fig. 17. Inundation at 7:00AM on July 7.

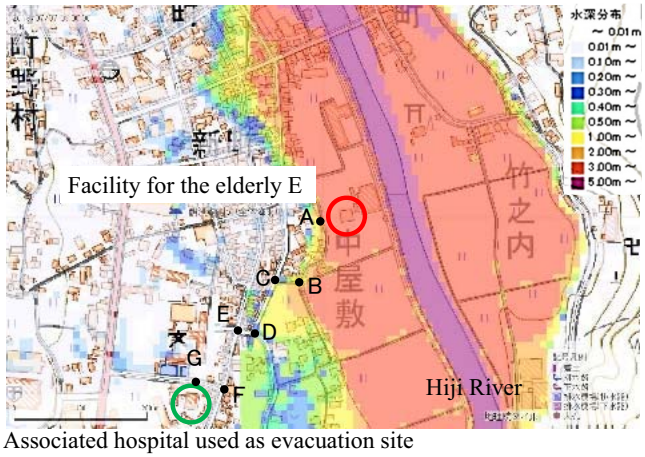

Fig. 18. Inundation at 8:00AM on July 7.

Figure 20 shows a temporal change in the inundation height along the evacuation route. The inundation height indicated by the blue line was determined by the inun-

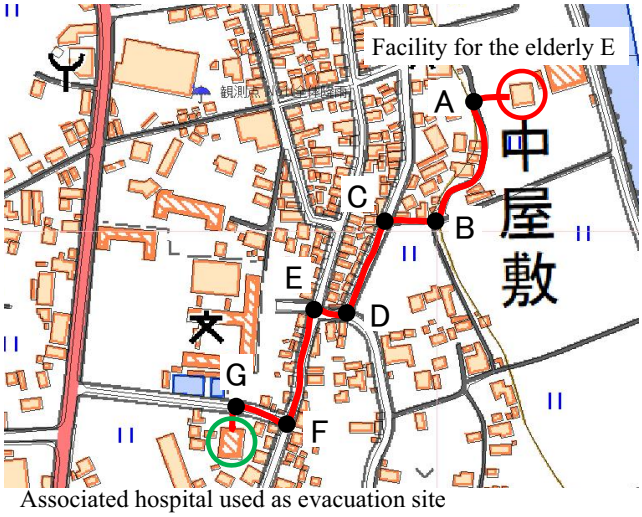

Fig. 19. Evacuation route from facility E.

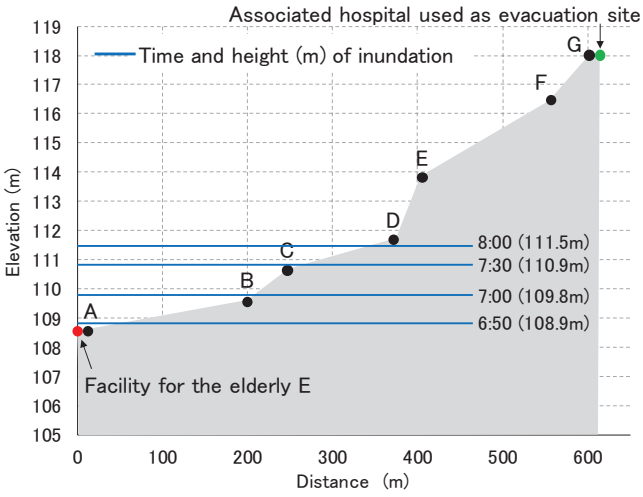

Fig. 20. Temporal change of inundation height along the evacuation route.

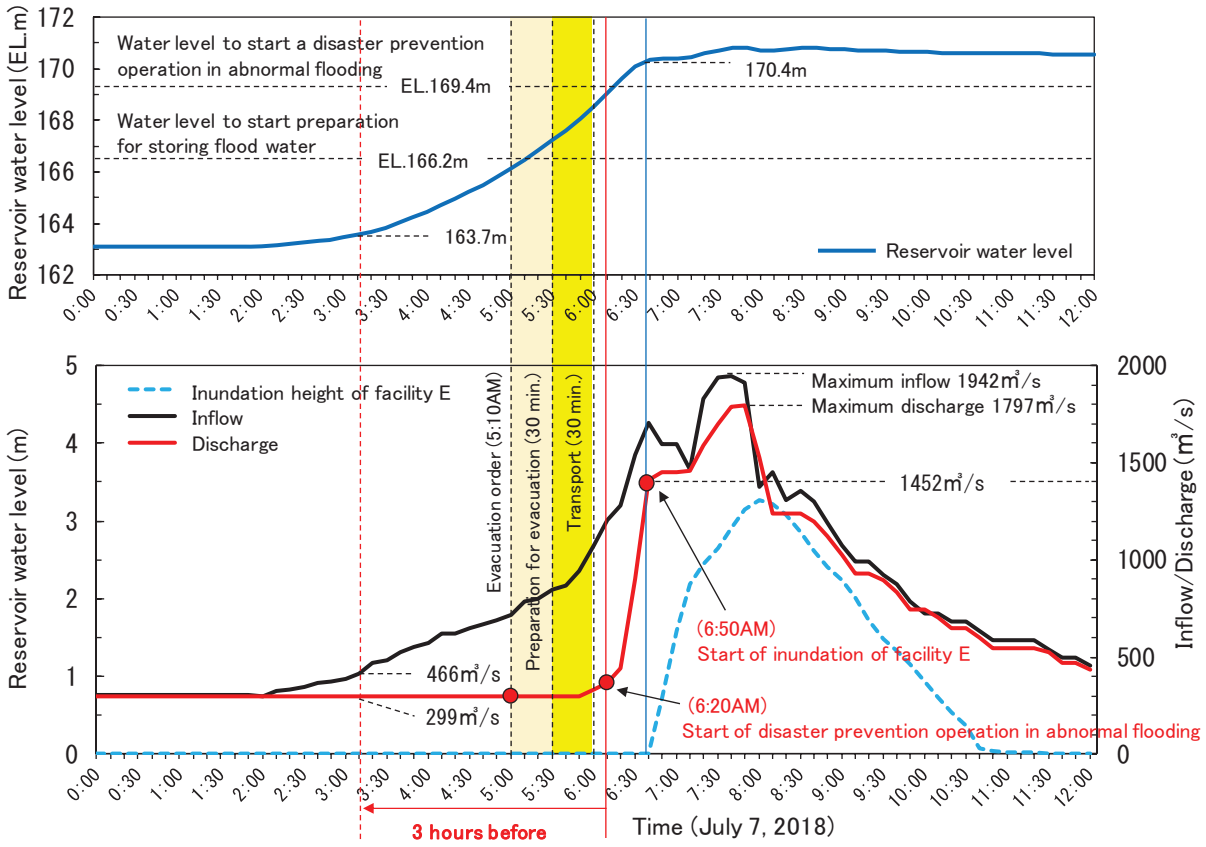

Fig. 21. Situation of Nomura Dam, evacuation behavior of facility E, and inundation condition.

dation height at facility E. At 6:50AM, 40 minutes after the people at facility E finished evacuating, the inundation began, and site A was inundated. Site B was inundated at 7AM and site C at 7:30AM. At 8AM, the flood water had almost reached site D.

4.2. Situation of Nomura Dam and the Evacuation Behavior of Facility E

Figure 21 shows the situation of Nomura Dam, the evacuation behavior of facility E, and the inundation condition from 0AM to 12AM on July 7.

The stormwater detention operation of Nomura Dam

began at 10PM on July 6, and the disaster prevention operation for abnormal flooding began at 6:20AM on July 7. The water discharge from the dam reached maximum at 7:50AM on July 7 and the disaster prevention operation for abnormal flooding finished at 1PM. According to an examination by the Ministry of Land, Infrastructure, Transport and Tourism, the ministry informed Seiyo-shi at 2:30AM on July 7 that the disaster prevention operation for abnormal flooding would begin at around 6:50AM. Information on the dam's operation was also provided subsequently, but no evacuation advisory was issued. At 5:10AM, an evacuation order was suddenly issued.

Under the evacuation order, facility E had to immediately prepare for the evacuation of its residents and began transporting them. The evacuation to the associated hospital finished 10 minutes before the start of the disaster prevention operation for abnormal flooding. After the start of the operation, the amount of water discharge rapidly increased in a short period of time. The amount of discharge reached 1,452 m^3/s and the water level of the reservoir was 170.4 m when the inundation of facility E began at 6:50AM.

4.3. Guide to the Start of the Evacuation of Facility E

The local government of Seiyo-shi made a trial calculation to determine a guide to release evacuation information taking account of dam water discharge information after the heavy rain in July 2018.

[Beneath Nomura Dam (Nomura district)]

- Information for preparations for evacuation: Storm warning
- Evacuation advisory: Notification of increase in water discharge (from 300 to 400 m^3/s)
- Evacuation order: Prior notification of a disaster prevention operation for abnormal flooding (three hours before start)

In the present case, if people began evacuation 3 hours before the start of the disaster prevention operation for abnormal flooding, the reservoir water level would be 163.7 m, the water inflow 466 m^3/s, and the discharge 299 m^3/s. These data could be used as a guide for future safe evacuations of the people of facility E.

5. Summary

The heavy rain in July 2018 caused leaks and inundation above floor level at many facilities for the elderly. In the present study, we surveyed two facilities near Oda River in Okayama Prefecture and three facilities near Hiji River in Ehime Prefecture to study the necessity of the facilities having their own criteria for starting an evacuation, taking account of the characteristics of the facilities used by people who need care. As a result, we found that the criteria for starting evacuation were extremely important for facilities for the elderly, where it would take time for the elderly to evacuate. We chose a facility near Hiji River and performed an inundation analysis to study correlations among the inundation condition, temporal change in discharge from a dam, and evacuation behaviors. We were able to obtain the reservoir water level of the dam, the water inflow, and the water discharge rate three hours before the start of the disaster prevention operation for abnormal flooding to use as a guide for starting an evacuation. However, this guide was derived from the results and cannot be used for the next disaster. Since disasters are always different from each other, it is necessary to find the characteristics of each disaster and thoroughly examine and evaluate them. At present, anyone can view the water level of a river and the water discharge rate from a dam on the Internet. However, since it is difficult for the staff of facilities for the elderly to determine a criterion to start an evacuation, advice from experts in river management is needed.

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