

## Characteristics of Heavy Rainfall and Flood Damage in Aichi Prefecture from September 11th to 12th 2000

Haruhiko YAMAMOTO

Faculty of Agriculture, Yamaguchi University

Kiyoshi IWAYA

United Department of Agricultural Science, Graduate School of Tottori University

(Received for 4. Apr., 2002)

### ABSTRACT

Record heavy rainfall occurred in Aichi Prefecture from September 11 to 12 2000. We collected about 250 samples of precipitation data observed by various organizations, and analyzed the characteristics of the heavy rainfall that occurred in Aichi Prefecture. The Midori Ward Engineering-Works Office, Nagoya City recorded a daily precipitation of 499.5mm on September 11th and 147.5mm on the 12th. The total precipitation was 647.0mm. In the area from Midori Ward, Nagoya City to Agui Town in Chita district, in the NNE to SSW direction and area 6km wide by 20km long, total precipitation exceeded 600mm. Heavy rainfall of more than 80mm in the area running north and south from Moriyama Ward, Nagoya City to Agui Town appeared at 19:00, and strong rainfall occurred in the surrounding region. Flood damage was severe in 3km north-south and 1km east-west areas bounded by the Shin River, JR Tokaido, Nagoya Railroad Inuyama, and Johoku lines. In the southwest part of Ashihara-cho, Nishi Ward where the bank of the Shin River collapsed and in Nishibiwajima Town, flood depth exceeded 200cm in buildings.

### 1. INTRODUCTION

The Akisame-front which had been stagnated near Honshu was activated from September 11 to 12, 2000 (Tokyo District Meteorological Observatory, 2000). Because of this record heavy rainfall was recorded from the evening of the 11th through the early morning of the 12th in the Tokai District (Ushiyama *et al.*, 2000). Water levels of the Shonai, Shin and Tenpaku Rivers which flow through and around Nagoya City greatly exceeded the safe level, breaking past water level records. In Aichi Prefecture, river banks collapsed in 18 places, flooding occurred in 256 places, rain water remained undrained due to prolonged heavy rainfall, and flood damage occurred in almost all the cities, towns, and villages in the prefecture (Aichi Prefecture, 2000).

In recent years, we have collected precipitation data from rain gauges installed by various organizations in order to observe heavy rainfall precipitation that occurs in connection with typhoons and fronts in Japan, and to analyze the time and spatial features of that rainfall (Yamamoto *et al.*, 1999abc, 2000). We now have collected precipitation data recorded by various organizations in addition to AMeDAS (Automated Meteorological Data Acquisition System) data, for the purpose of analyzing in detail the features of the extremely heavy rain generated in the Tokai district. Furthermore, we investigated severe flood damage in Nishibiwajima Town and Nishi Ward, Nagoya City.

### 2. OBSERVATIONS PRECIPITATION

The position of Aichi Prefecture in Japan, the zone with its cities, towns, and villages, the city names, etc. are shown in Fig. 1.

Aichi Prefecture is located in the center of Japan and faces the Pacific Ocean to the south. The Nobi Plain spreads over the western part of the prefecture and the Minamialps mountain range over the northeast. The Kiso River flows into Ise Bay in the west of the prefecture. The Shonai and Shin rivers flow through the Owari district, and the Yahagi and Toyo rivers through the Mikawa district into Mikawa Bay.

In order to clarify the time and spatial characteristics of this heavy rainfall, information from organization's recording precipitation was investigated, and data about this rainfall were collected. The numbers of rain gauges installed at facilities to record precipitation in Aichi Prefecture are shown in Table 1, and the positions in Fig. 2. At the Nagoya Local Meteorological Observatory of the Meteorological Agency, AMeDAS points are installed in 19 places within the prefecture. The Nagoya Aviation Meteorological Station is located at the Nagoya airport, and ground weather surveys are carried out there.

In addition to the meteorological observatories of the Meteorological Agency, the Toyohashi Construction Office that manages the Yahagi and the Toyo rivers, and the 1st class rivers are managed by the Chubu Regional Construction Bureau of the Ministry of Construction (presently the Ministry of Land, Infrastructure and Transport Chubu District Maintenance Office). Precipitation is recorded in 33 places in the basin. Shonai River Construction Office, which manages the Shonai and Shin rivers has rain gauges installed in five places in the basin (eight places in Gifu Prefecture). Moreover, the Nagoya National Highway Construction Office, which maintains and manages national highways has observatories for precipitation installed in 11 places, e.g. along national highway No.1. Each office carries out intensive

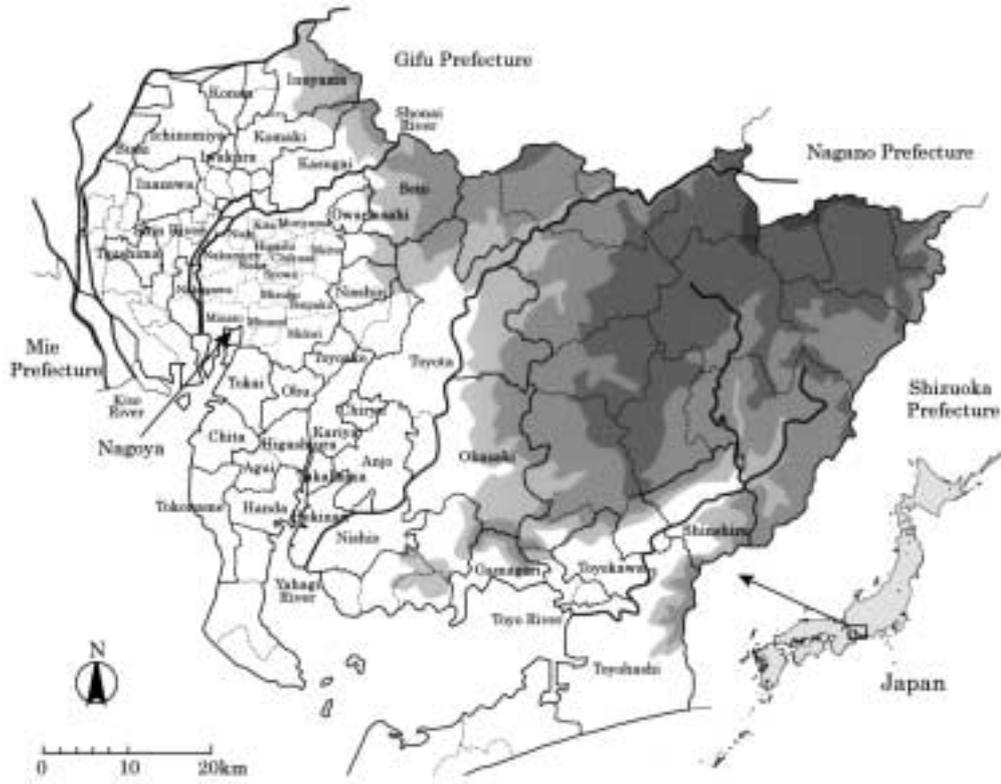


Fig. 1 Geographical position of Aichi Prefecture in Japan, the zone of cities, towns and villages in Prefecture, and city names, altitudes (100, 200, 500, 1000m) and river names.

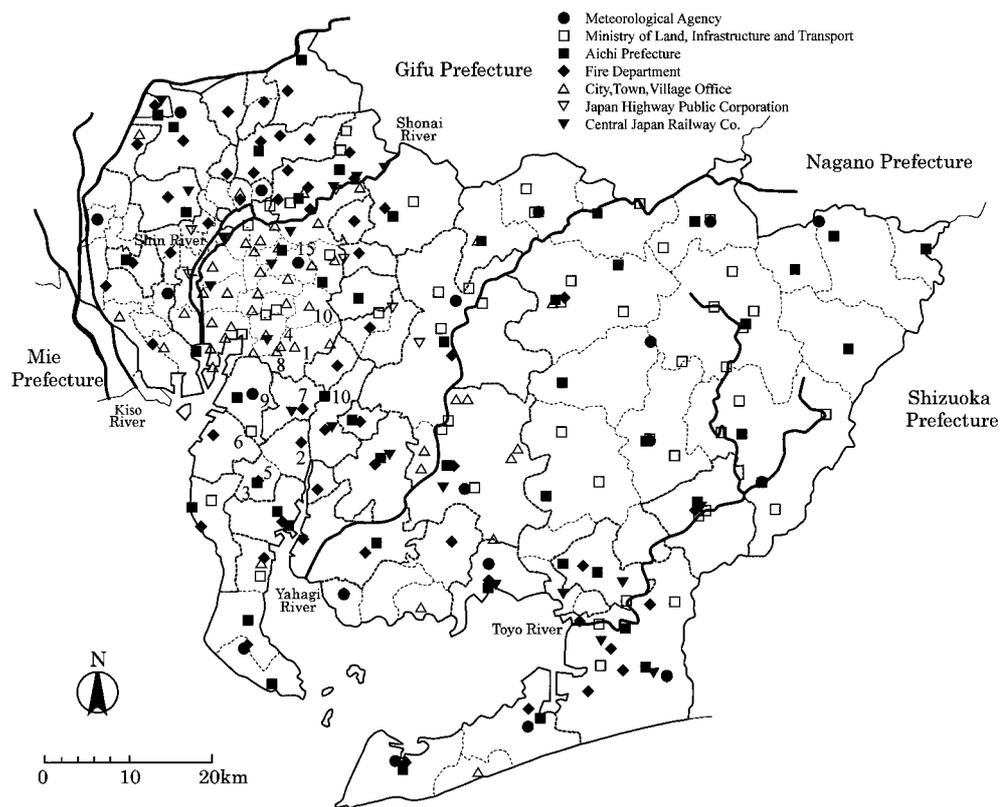


Fig. 2 Positions of rain gauges installed by various organizations to record precipitation in Aichi Prefecture. The symbols in the figure are the same as in Table 1. The numbers in the figure are the same as in Table 2.

management of precipitation data in real time by a telemeter system. Furthermore, the Water Resources Development Public Corporation has rain gauges installed in four places for the water management of the Aichi Canal. The River Division of the Construction Department, Aichi Prefecture observes precipitation at 50 places in the prefecture for the purpose of basin management of 2nd class rivers.

Fire departments have a fire-fighting weather survey system in 58 places within the prefecture, which provide unique information about the main meteorological elements. City office and each engineering-work offices in Nagoya City, rain gauges are installed in 30 places. Observations also are made in other cities, towns,

and villages. In the Nagoya Management Office (Japan Highway Public Corporation, Chubu branch), meteorological survey systems are made on the Tomei Express Way (in six places) which the office manages meteorological elements being managed as data at 5 minutes intervals. Central Japan Railway Company (JR Central) has installed rain gauges at 20 stations for the safety of rail traffic.

As stated in Aichi Prefecture observations of precipitation made in about 250 places, which number is about 13 times the number of AMeDAS observation points. Moreover, precipitation is recorded at the Waterworks Bureau, water purification plants and purification centers, in order to manage waterworks and sewers. Because, we are not conducting investigations about the existence of installed the rain gauges. The number of precipitation observation points may be even more in Aichi Prefecture. By collecting precipitation data from the observatories of various organizations, we could analyze local heavy rainfall.

Table 1. Numbers of rain gauges installed by various organizations to record precipitation in Aichi Prefecture.

Organization	Number of observatories	Symbol
Meteorological Agency	20	●
Ministry of Land, Infrastructure and Transport	49	□
River Construction Office*	38	
Highway Construction Office	11	
Aichi Prefecture	50	■
Fire Department	58	◆
Nagoya City	30	△
Cities, towns, and villages other than Nagoya City	17	△
Japan Highway Public Corporation	6	▽
Central Japan Railway Company (JR Central)	20	▼
<b>Total</b>	<b>250</b>	

The symbols in the table are the same as in Fig.2.

\*The Water Resources Development Public Corporation is included in the number of observatories.

### 3. CHARACTERISTICS OF HEAVY RAINFALL

#### 3.1 Heavy Rainfall Analysis using AMeDAS data

Local heavy rainfall occurred in Nagoya City and the surrounding region. Changes in the 1-hour, 10-minute, and accumulated precipitations observed in Nagoya (Local Meteorological Observatory) and Tokai (Local Meteorological Observing Station) of the Meteorological Agency from September 11 to 12, 2000 are shown in Fig.3. In Nagoya, weak rainfall began in the predawn of the 11th reached a maximum 20 mm/h then stopped during the morning. Rainfall began again around noon and increased in

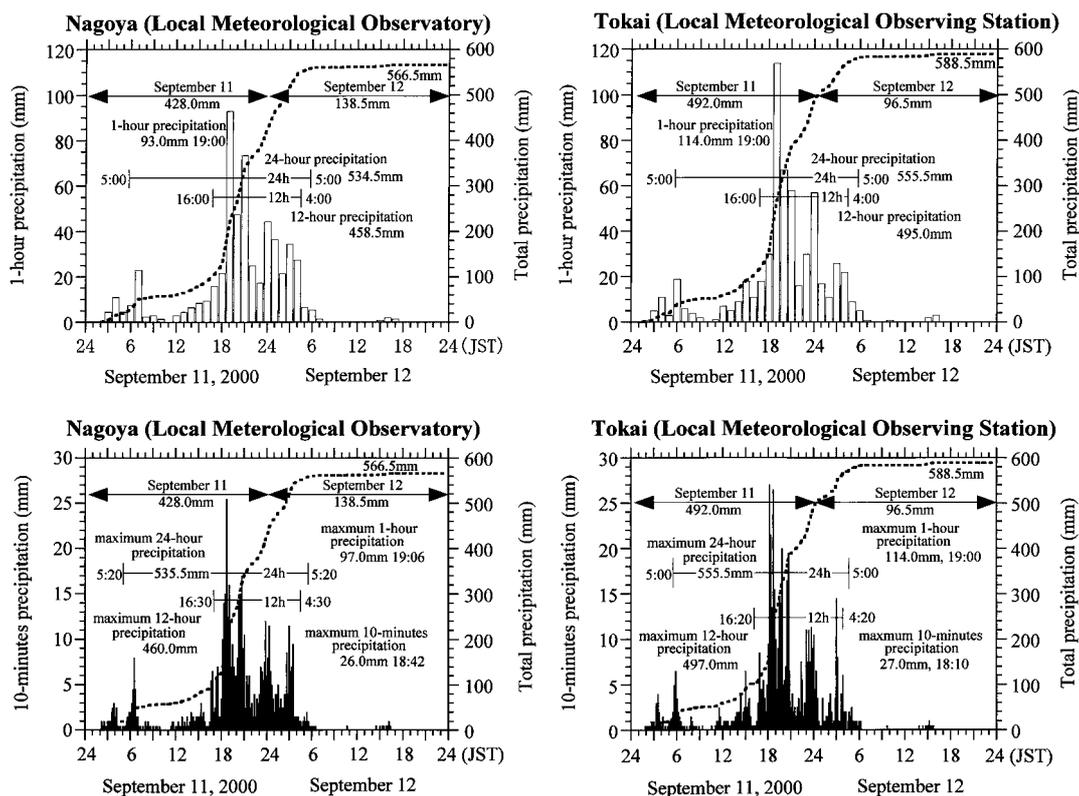


Fig. 3 Changes in 1-hour and 10-minute precipitation and the accumulated precipitation recorded at the Nagoya (Local Meteorological Observatory) and the Tokai (Local Meteorological Observing Station) facilities of the Meteorological Agency.

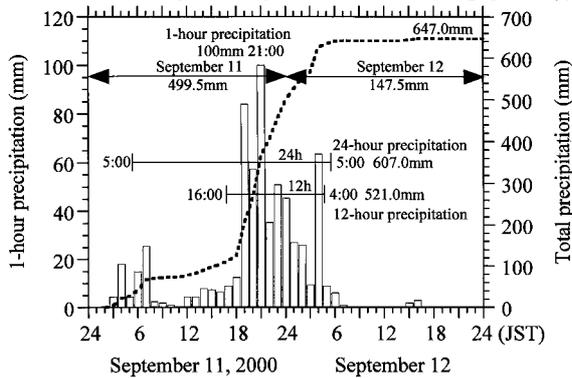
Table 2. Rainfall conditions 12 at observation points at which the total precipitation on September 11 and 12, 2000.

Ranking of precipitation <sup>1)</sup>	Observatory	Organization	Place	Symbol	Total <sup>2)</sup>	daily precipitation		1-hour maximum precipitation	12-hour maximum precipitation
						August	September		
1	Midori EWO <sup>3)</sup>	Nagoya City	Midori Ward	△	647.0	499.5	147.5	100.0	521.0
2	Higasiura	Fire Department	Higashiura City	◆	622.5	490.0	132.5	84.5	506.0
3	Agui	Aichi Prefecture	Agui Town	■	622	498	124	80	514
4	Narumi	Nagoya City	Midori Ward	△	618.5	492.5	72.0	103.5	496.5
5	Agui	Fire Department	Agui Town	◆	608.5	487.0	121.5	90.5	509.0
6	Tokai branch	WRDPC <sup>4)</sup>	Tokai City	□	608.0	479.0	129.0	114.0	495.5
7	Obu	Fire Department	Obu City	◆	605.5	467.5	138.0	0.0	479.5
8	Shimoshiota	Nagoya City	Midori Ward	△	590.0	471.0	119.0	101.5	469.5
9	Tokai	Meteorological Agency	Tokai City	●	588.5	492.0	96.5	114.0	495.0
10	Tenpaku EWO <sup>3)</sup>	Nagoya City	Tenpaku Ward	△	585.0	448.0	137.0	77.5	469.0
10	Izumida	Aichi Prefecture	Kariya City	■	585	460	125	81	459
15	Nagoya	Meteorological Agency	Chigusa Ward	●	566.5	428.0	138.5	93.0	458.5

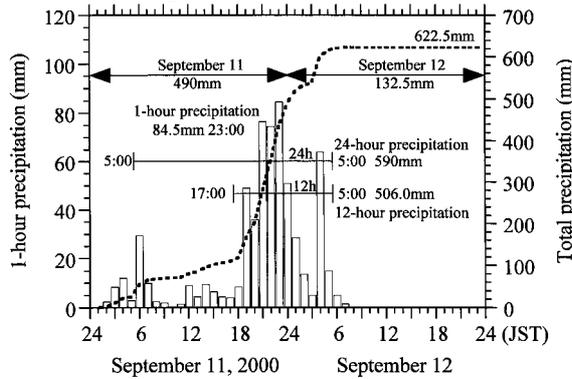
<sup>1)</sup> The number (precipitation ranking) and symbols are the same as Fig. 2. <sup>2)</sup> Total precipitation: September 11 to 12, 2000.

<sup>3)</sup> EWO : Enginnering-Works Office. <sup>4)</sup> WRDPC : Water Resources Development Public Corporation.

### Midori Ward Engineering-Works Office (Nagoya City)



### Higashiura (Fire Department)



### Agui (Aichi Prefecture)

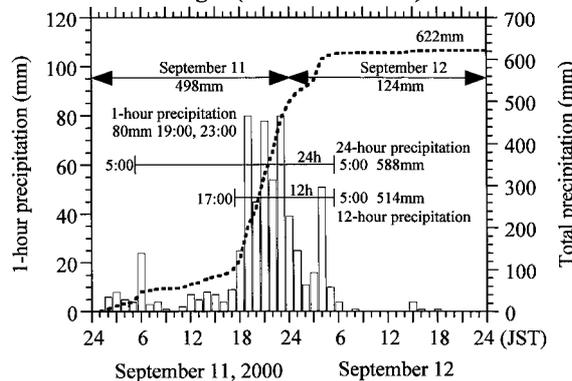


Fig. 4 Changes in 1-hour precipitation and the accumulated precipitations recorded from September 11 to 12 at the Midori Ward Engineering-Works Office, the Handa Fire Department, Higashiura branch and Agui Rainfall Observatory.

intensity from evening, becoming a record heavy rainfall with a total precipitation of 566.5mm from 18:00 to early morning of the next day.

The daily precipitation (September 11: 428.0mm, records started 1891), the maximum 1-hour precipitation (97.0mm, records started 1891), and the maximum 24-hour precipitation (534.5mm, records started 1971) in Nagoya were observed the 1st highest record. The maximum 10-minute precipitation (26.0mm) was the 2nd highest record, furthermore, the maximum 12-hour precipitation from 16:30 to 4:30 of the next day was 460.0mm. This precipitation is equivalent to 30% of the normal yearly precipitation (1,535mm).

In the Tokai (Local Meteorological Observing Station), located in Tokai City adjacent to the southern part of Nagoya City, the daily precipitation (September 11: 492.0mm), the maximum 1-hour precipitation (114.0mm), and the maximum 24-hour precipitation (555.5mm) recorded on the 1st. Furthermore, the maximum 12-hour precipitation from 16:20 to 4:20 of the next day was 497.0mm. Because of this heavy rainfall, at the 19 AMeDAS observation points in Aichi, nine points (the daily precipitation) and seven points (the 1-hour precipitation) recorded on the 1st.

### 3.2 Analysis of Heavy Rainfall Based on Precipitation Data Recorded by Various Organizations

As described in Section 2, rain gauges have been installed in about 250 places in Aichi Prefecture by various organizations. Using these collected precipitation data, we analyzed the characteristics of the heavy rainfall in Aichi Prefecture.

Rainfall conditions at 12 observation points at which the total precipitation on September 11th and 12th are shown in Table 2. Changes in the 1-hour, and accumulated precipitations from September 11th to 12th recorded at the Midori Ward Engineering-Works Office, Nagoya City, the Handa Fire Department, Higashiura Office, and the Agui Rainfall Observatory (Aichi Prefecture management) are shown in Fig. 4. At the Midori Ward Engineering-Works Office, first there was a weak rain peak from predawn to early morning on the 11th, then heavy rainfall with a 1-hour precipitation of 100mm, which continued into the early morning of the 12th. Daily precipitation on the 11th therefore was 499.5mm, on the 12th, 147.5mm, and the total precipitation 647.0mm. The 24-hour precipitation was 607.0mm (from 5:00 on the 11th to 5:00 on the 12th), and 12-hour precipitation 521.0mm (from 16:00 on the 11th to 4:00 on the 12th).

At the Handa Fire Department, Higashiura Office, about

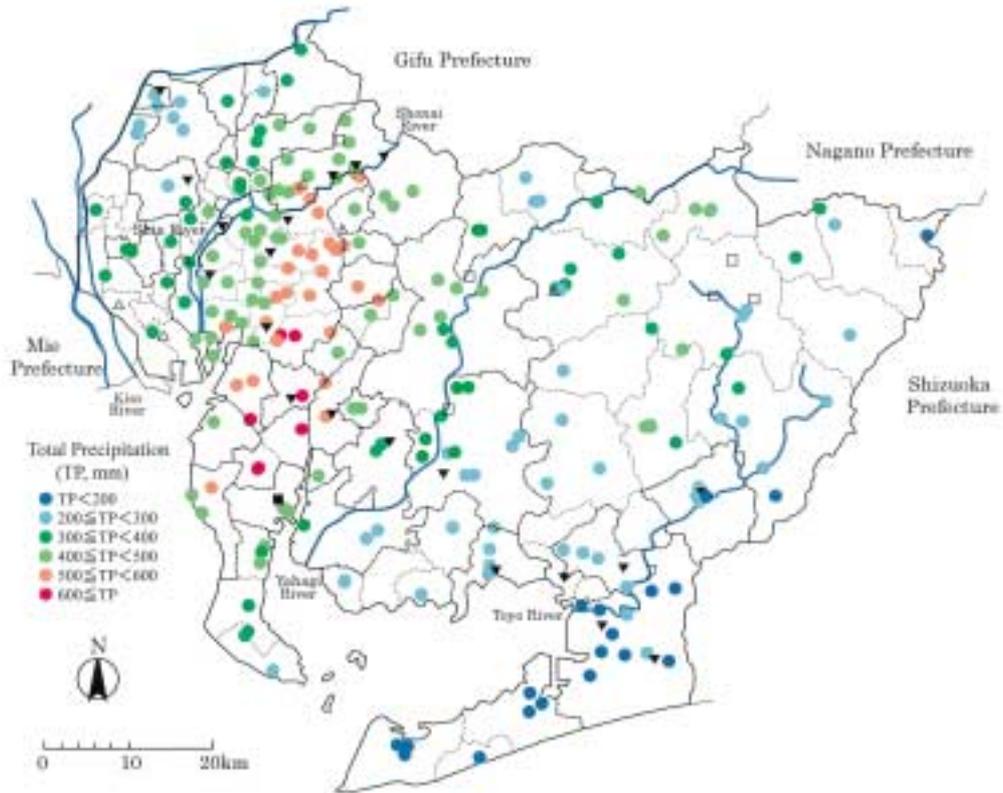
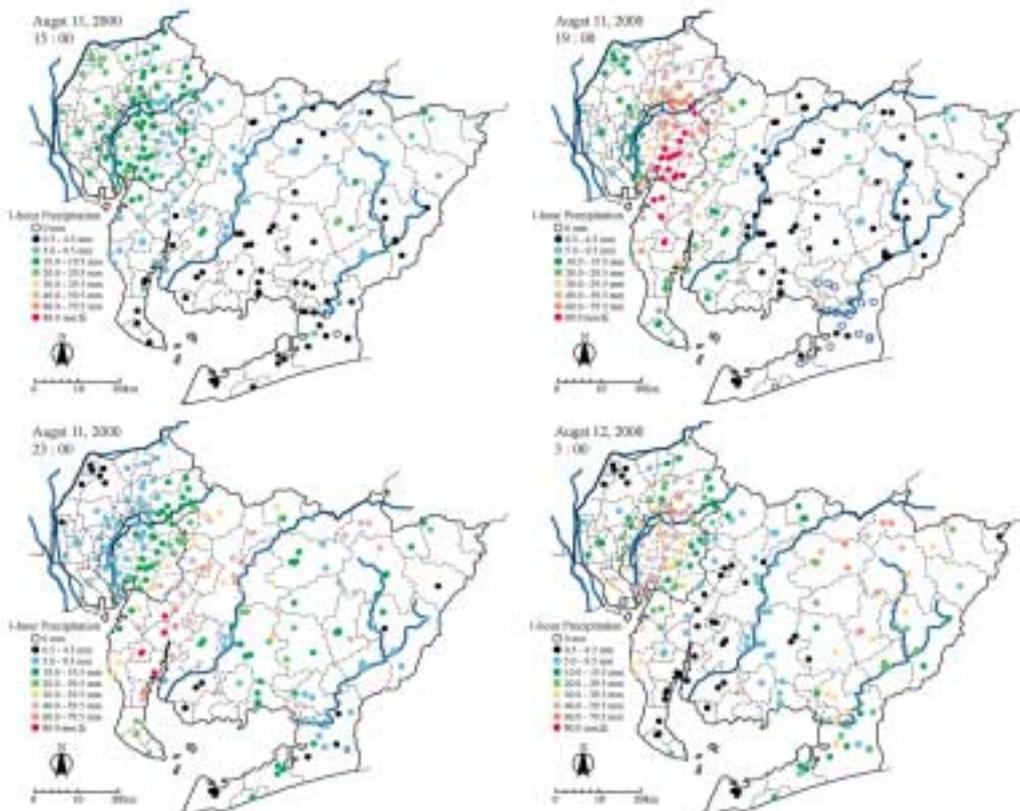


Fig. 5 Distribution of total precipitation over the two days, September 11th and the 12th 2000.



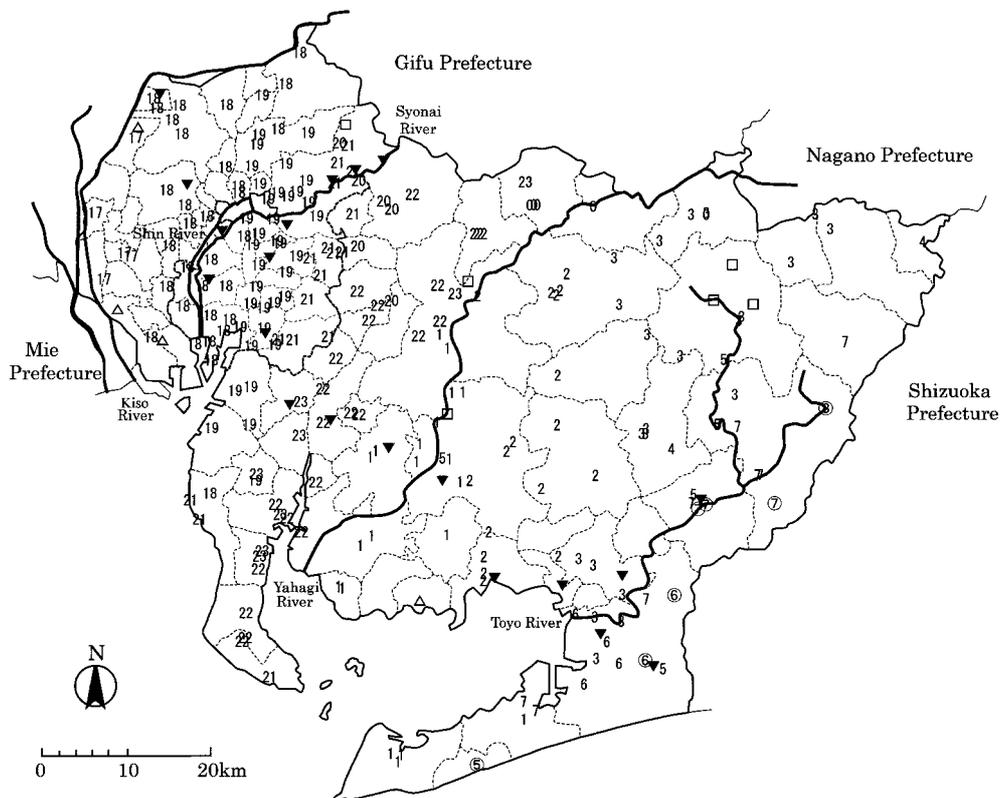


Fig. 7 Times of the recorded maximum 1-hour precipitation from the 11th to the 12th.

Table 3. The extent of damage caused by the heavy rainfall in Aichi Prefecture, September 2000.

<b>Human damage</b>		
	dead	Six persons
	missing persons	Zero persons
	serious injury	Seven persons
	slight illness	81 persons
<b>Building damage</b>		
<b>abode damage</b>		
	collapsed	15 buildings
	half collapsed	57 buildings
	part collapsed	167 buildings
	inundation above floor level	36,531 buildings
	flooding under floor level	38,897 buildings
<b>non-abode damage</b>		
	public facilities	45 buildings
	Other	814 buildings
<b>Damage to agriculture, forestry, and fisheries</b>		
	agricultural damage	— 1,506 million yen
	damage to farmland and agricultural institutions	1,842 places 4,334 million yen
	forestry damage	— 4,708 million yen
	fisheries damage	— 78 million yen
	<b>Total</b>	<b>10,626 million yen</b>
<b>Damage to public facilities</b>		
	rivers	713 places 12,059 million yen
	roads	459 places 4,018 million yen
	Other	258 places 2,388 million yen
	<b>Total</b>	<b>1,430 places 18,465 million yen</b>
<b>Damage to public education institutions</b>		
	public schools	121 places 2,479 million yen
	cultural properties	18 places 9 million yen
	public halls	15 places 67 million yen
	gymnastics institutions	37 places 1,146 million yen
	facilities for providing meals	6 places —*
	<b>Total</b>	<b>197 places 3,701 million yen</b>

\*Damage amount of money of facilities for providing meals is contained in a public schools.

Table 4. Main flood damage in Aichi Prefecture since 1959.

Year	Month, date	Classification	Nagoya (mm) <sup>1)</sup>	Maximum		Human damage		Flood damage		Amount of damage <sup>5)</sup>
				precipitation (mm)		dead <sup>2)</sup>	injured	above <sup>3)</sup>	under <sup>4)</sup>	
1959	Sep, 26	Isewan typhoon	165.7	—	—	3,260	59,045	53,560	62,831	3,224
1961	June, 23-29	Baiu-front	398.0	682	Tatsuta	6	13	7,969	66,654	111
1962	June, 30 - July, 5	Baiu-front	238.6	447	Irako	2	1	1,605	15,501	—
1965	Aug, 17	T6524	188.6	—	—	1	18	1,729	49,623	93
1966	Oct, 12	Akisame-front	54.3	345	Tahara	10	14	4,349	20,747	42
1971	Aug, 30-31	T7123	321.5	465	Ohnuma	4	15	6,136	59,160	176
1971	Sep, 26	T7129	162.0	—	—	—	—	3,266	60,842	—
1972	July, 9-13	T7206	239.0	458	Sanage	50	12	20,075	12,077	302
1973	Aug, 4	Thunderstorm	53.5	—	—	—	—	3,428	47,701	—
1974	July, 7	T7408	65.0	323	Shinshiro	3	12	1,820	11,800	195
1974	July, 24-25	Baiu-front	130.0	333	Tsushima	1	7	7,248	74,035	92
1976	Sep, 8-14	T8617	422.5	682	Ichinomiya	1	37	13,050	102,677	378
1979	Sep, 24-25	Akisame-front	105.5	224	Minato-ward	2	—	1,665	33,351	26
1983	Sep, 27-28	T8310	234.0	305	Chausuyama	5	1	762	16,974	28
1991	Sep, 18-19	T9118	242.0	316.0	Minamichita	2	1	3,713	12,131	60
2000	Sep, 11-12	Akisame-front	566.5	588.5	Tokai	6	7	36,531	38,897	2,821

<sup>1)</sup>Total precipitation (Nagaya Local Meteorological Observatory).

<sup>2)</sup>Includes missing persons. <sup>3)</sup>Inundation above floor level. <sup>4)</sup>Flooding under the floor (>10,000 buildings). <sup>5)</sup>10<sup>8</sup> yen.

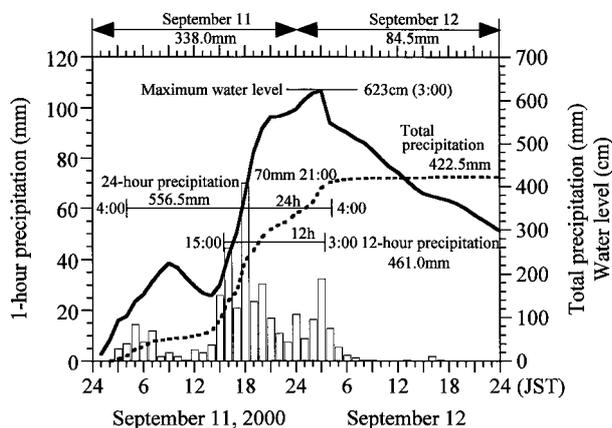


Fig. 8 Water level of the Shin River recorded at the Mizuba River Water Level Observatory, precipitation at the Nishikasugai Western Fire Department and accumulated precipitation value.

13km south of the Midori Ward Engineering-Works Office, precipitation was a little less than at the latter office, the total precipitation amounting to 622.5mm and the 12-hour precipitation to 506.0mm. Furthermore, the Agui rainfall observatory about 7km southwest of Higashiura had precipitation of 498mm on the 11th, 124mm on the 12th, and a 12-hour precipitation of 514mm. Total precipitation exceeded 600mm in seven places, and 12-hour precipitation exceeded 500mm in four places, making clear that record heavy rainfall had occurred over a wide area.

The total precipitation distribution for the two days from September 11th through 12th is shown in Fig. 5. From Midori Ward, Nagoya City to Agui Town, in the south-southwest direction from north-northeast, total precipitation exceeded 600mm over a large area 6km wide and 20km long. Total precipitation was recorded 500mm in southern Kasugai City, eastern Nagoya City, Nishin City, Kariya City, and northern Tokoname City, all in this area. As for the very large 50km x 25km area (Kasugai City, western Nagoya City, Seto City, western Toyota City, Chiryu City, Takahama City, Handa City, and Taketoyo Town extending eastern Komaki City), total precipitation was more than 400mm.

Distributions of 1-hour precipitation recorded every 4 hours

intervals from 15:00 on the 11th to 3:00 on the 12th, including 19:00 are shown in Fig. 6. Precipitation of 20-29.5 mm/h occurred in the western Owari district of western Nagoya City at 15:00 on the 11th. From the east of the Owari district to central Nagoya City, and Tokai City, 1-hour precipitation ranged from 10-19.5mm. In other areas, it was less than 10mm.

The 1-hour precipitation was more than 100mm at 19:00 in four places: the Tokai Local Meteorological Observation Station (114mm), the Mizuho Engineering-Works Office (100.5mm), and at Narumi (103.5mm) and Shimoshiota (101.5mm). The heavy rainfall region, which exceeded 80mm/h appeared in the belt area from Moriyama Ward, Nagoya City to Agui Town, and strong rainfall fell in the surrounding region. 1-hour precipitation of 100mm was recorded at the Midori Ward Engineering-Works Office (100.0mm) at 21:00, and more than 100mm at the Kariya (109.0mm) and the Takahama (102.5mm) fire departments at 22:00. The heavy rainfall region had moved southeast at 23:00, and the area with more than 80mm/h ranged from Higashiura Town to Taketoyo Town in eastern Chita peninsula. It moved into the Toyo River basin at 3:00 on the 12th, and it showed strong rainfall that exceeded 60 mm/h. Moreover, a strong rainfall area exceeding 40 mm/h again appeared from eastern Komaki City to Minato Ward, Nagoya City.

The time of the observed maximum 1-hour precipitation is shown in Fig. 7. The maximum value appeared at 17:00 in the cities, towns and villages adjacent to Gifu and Mie Prefectures. Furthermore, from Seto City abutting eastern Nagoya City to the Chita peninsula, the maximum 1-hour precipitation occurred between 20:00 and 22:00. Maximum 1-hour precipitation was observed about 1:00 on the 12th in the Yahagi River basin, and about 2:00 in the area between the Yahagi and Toyo rivers. In the Toyo River basin, the maximum was recorded between 3:00 and 8:00.

## 4. FLOOD DAMAGE

### 4.1 Outline of Flood Damage

The report of the Fire Defense Agency, compiled on October 2, 2000, states that damage by the heavy rainfall that lasted from September 10th to 12th affected 18 prefectures (Fire Defense Agency, 2000). That damage resulted in 10 people dead, 97

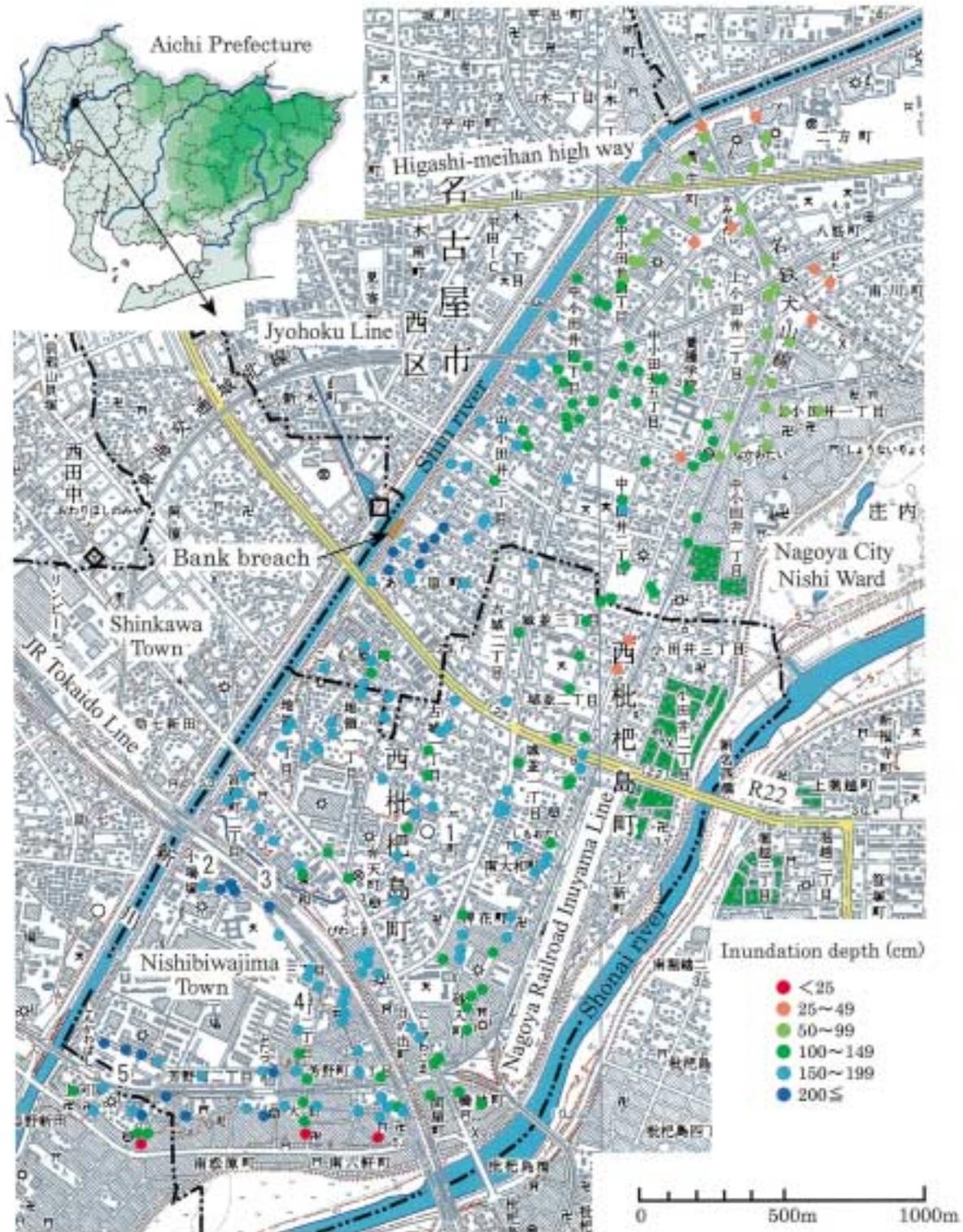


Fig. 9 Distribution of the depth (cm) of flooding of buildings in the area investigated, recorded by the fire department (◇) and water level observatory(□), and positions on photographs (1~5).

injured, 312 buildings destroyed, and 71,291 buildings flooded. Road destruction, bridge and river bank collapses, mountain landslides, and farmland damage subsequently occurred.

The type of damage caused by the heavy rainfall in Aichi Prefecture is shown in Table 3. The left-bank of the Shin River collapsed in Nishi Ward, Nagoya City causing severe flooding. Inundation above floor level occurred 4,000 buildings in

Nishibiwajima Town, and 5,000 buildings in Nishi Ward. Inundation above floor level was recorded for more than 2,000 buildings in Shikatsu Town and Shinkawa Town. Damage to public facilities amounted to 18,500 million yen, rivers (713 places, 12 billion yen) and roads (459 places, 4 billion yen). Farmland was flooded in various places and serious damage done to agricultural crops, particularly vegetables and paddy rice. In Aichi Prefecture,

agricultural damage caused by the heavy rainfall amounted to some 1.5 billion yen or more, and the total damage to 10 billion yen.

Main flood damages that occurred in Aichi Prefecture from the time of the Isewan Typhoon in 1959 to present is shown in Table 4. Damage in which flooding under the floor affected more than 10,000 buildings occurred 4 times in the 1960s, and 8 times in the 1970s. Although flood damage caused by heavy rain accompanying typhoons 8310 and 9118 has occurred recently, there was

comparatively little damage done by inundation above the ground floor level.

#### 4.2 Flood Damage in Nishibiwajima Town and Nishi Ward, Nagoya City

We made a field survey of the damage in these two places (Nishibiwajima Town and Nishi Ward of Nagoya City (Nakaotai area)), which suffered serious flood damage due to heavy. The water level of the Shin River recorded at the Mizuba River Water Level Observatory, the precipitation at the Nishikasugai Western Fire Department and the accumulated values are shown in Fig. 8. The rainfall, which began to lessen during the early morning of the 11th was recorded as 338.0mm on the 11th and 84.5mm on the 12th, total precipitation 422.5mm. Moreover, the 12-hour precipitation from 15:00 on the 11th was 461.0mm, and the 1-hour precipitation 70mm at 21:00. The water level of the Shin River rose rapidly from the afternoon of the 11th, the maximum of 623cm being recorded at 3:00 on the 12th. After the heavy rainfall ended, the water level of Shin River fell slowly.

The distribution of the depth (cm) of flooding of buildings in the area investigated, fire department, a water level observatory, and photographic positions are shown in Fig. 9. The depth of the flood is shown by the height of the flood mark from road surface. Flood damage was severe in the 3km north-south and the 1km



Photo 1. Flood mark on the glass of the door at the Nishibiwajima Town Office (Hanasaki-cho, Nishibiwajima Town).



Photo 2. Flood mark on the wall of the Meito dairy factory located northwest of the JR Biwajima Station (Kaechi, Nishibiwajima Town).



Photo 3. Flood mark under a bridge of the JR Tokaido Line (Yowa, Nishibiwajima Town).



Photo 4. Flood mark on the wall of an apartment building located south of the JR Biwajima Station (Asahi-machi, Nishibiwajima Town).



Photo 5. Flood mark on the wall of the building of Takaoka Electric Factory located about 500m west of Futatsuri Station on the Nagoya Railroad Nagoya line (Yoshino-cho, Nishibiwajima Town).

east-west areas bounded by the Shin River, and the JR Tokaido, the Nagoya Railroad Inuyama, and the Johoku lines. In Ashihara-cho, Nishi Ward, where the bank of the Shin River collapsed and in the southwest of Nishibiwajima Town, the depth of flooding in building exceeded 200cm. In the north-northeast area of Nishibiwajima Town, the depth of flooding was shallow, less than 50cm in the northern part of the Nakaotai area.

The flood damage situation is shown in Photos 1-5. Photo 1 shows the flood mark on a glass at the Nishibiwajima Town Office. The 140cm flood mark was reached at that public office. Photo 2 shows the flood mark on the wall of the Meito dairy factory located northwest of the JR Biwajima Station. Here, flood mark is at 180cm, and marks exceeding 200cm are present around the factory. Photo 3 shows the flood mark under a bridge of the JR Tokaido Line. It is at 350cm, and the road has completely subsided.

Photo 4 shows the flood mark on the wall of an apartment building located south of the JR Biwajima Station. Although the depth of flooding is 172cm, because the ground floor of the building is a parking lot, there was no flooding of the apartments above that level. Photo 5 shows the flood mark on the wall of the building belonging to Takaoka Electric Factory located about 500m west of Futatsui Station on the Nagoya Railroad Nagoya line. Flood exceeding 200cm was recorded nearby, the deepest flooding in the entire area investigated. Serious damage also was caused by flooding at the Nagoya factory of Mitsubishi Heavy Industries located north of Futatsui Station.

## 5. CONCLUSIONS

- 1) We collected a set of about 250 precipitation data recorded by various organizations and analyzed the characteristics of the heavy rainfall in Aichi Prefecture, September 11th to 12th 2000.
- 2) Daily precipitation at that time (428.0mm, records stated 1891), maximum 1-hour precipitation (97.0mm, records stated 1891), and maximum 24-hour precipitation (535.5mm, records stated 1971) in Nagoya (Local Meteorological Observatory) recorded the 1st highest record.
- 3) At the Midori Ward Engineering-Works Office, Nagoya City, there first was a weak rain peak from predawn to early morning on the 11th, then heavy rainfall with a 1-hour precipitation of 100mm. Daily precipitation was 499.5mm on September 11th and 147.5mm on the 12th, and the total precipitation was 647.0mm.
- 4) From Midori Ward to Agui Town in the Chita district, NNE to SSW direction the total precipitation exceeded 600mm over a large area 6km wide by 20km long.
- 5) In Aichi Prefecture, the heavy rainfall moved slowly from west to east from the evening of the 11th through the early morning of the 12th. Heavy rainfall that exceeded 80mm was prolonged from north and south in the area from Moriyama Ward, Nagoya City to Agui Town, at 19:00, and strong rainfall also occurred in the surrounding region.
- 6) Flood damage was severe over an area 3km north-south and

1km east-west bounded by the Shin River, and the JR Tokaido, the Nagoya Railroad Inuyama, and the Johoku lines. In southwest Ashihara-cho, Nishi Ward, where the bank of the Shin River collapsed, and in Nishibiwajima Town, flood depth exceeded 200cm in buildings.

## ACKNOWLEDGMENTS

We are grateful to the following organizations for precipitation and river water level data used in this study: the Meteorological Agency (Nagoya Local Meteorological Observatory), the Ministry of Land, Infrastructure and Transport (Chubu District Maintenance Office), the Aichi Construction Department, Nagoya City (engineering bureau and fire fighting office), Water Resources Development Public Corporation (Aichi Water Management Faculty), and various fire fighting organizations, cities, towns, and villages, and the Japan Highway Public Corporation (Nagoya Management Office).

## REFERENCES

- Aichi Prefecture, 2000. The damage situation due to heavy rainfall, <http://www.pref.aichi.jp/shobo/BOUSAI/index.html> (in Japanese).
- Fire Defense Agency, 2000. About the damage situation caused by heavy rainfall from September 10, Heisei 12 (the 15th news), <http://www.fdma.go.jp/html/infor/120910ooame.htm> (in Japanese).
- Tokyo District Meteorological Observatory, 2000. Meteorological disaster news flash (Heavy rainfall caused by typhoon 14 and the front in Heisei 12 from September 11 to 12), (in Japanese).
- Ushiyama M., T. Ishigaki, K.Toda and M.Chigira, 2000. Characteristics of heavy rainfall disasters in Tokai district on September 11 to 12, 2000, *Jour. Japan Soc. Natural Disaster Sci.*, 22 (1), 1-11 (in Japanese with English abstract).
- Yamamoto H., S.Hayakawa and K.Iwaya, 1998. Characteristics of heavy rainfall and agricultural disasters by typhoon 9709 in northern part of Yamaguchi Prefecture, *Jour. Japan Soc. Natural Disaster Sci.*, 17 (1), 3-16 (in Japanese with English abstract).
- Yamamoto H., K.Iwaya, K.Suzuki, S.Hayakawa and Y.Suzuki, 1999a. Heavy rainfall disaster in Miyazaki Prefecture by typhoon 9719, *Jour. Japan Soc. Natural Disaster Sci.*, 18 (1), 55-69 (in Japanese with English abstract).
- Yamamoto H., K.Iwaya, K.Suzuki and S.Hayakawa, 1999b. Heavy rainfall disaster in September of 1998 by akisame Front in Kochi Prefecture, *Jour. Japan Soc. Natural Disaster Sci.*, 18 (2), 213-226 (in Japanese with English abstract).
- Yamamoto H., K.Iwaya, K.Suzuki and S.Hayakawa, 1999c. Heavy rainfall characteristics and flood disaster by typhoon 9810 in Okayama Prefecture, *Jour. Japan Soc. Natural Disaster Sci.*, 18 (3), 301-313 (in Japanese with English abstract).
- Yamamoto H., K.Iwaya, K.Suzuki, S.Hayakawa and Y.Suzuki, 2001. Survey on meteorological observations in northern part of Yamaguchi Prefecture and using meteorological observation data, *Jour. Japan Soc. Natural Disaster Sci.*, 19 (4), 437-452 (in Japanese with English abstract).