Flood and Inundation Maps in Taiwan

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Outline

- Principal types of flood
- Hydrological Characteristics in Taiwan
- Flood Characteristics in Taiwan
- Flood/Inundation Maps
- Application of Flood/Inundation Maps
- Flood in Taipei and its lesson

Principal types of flood

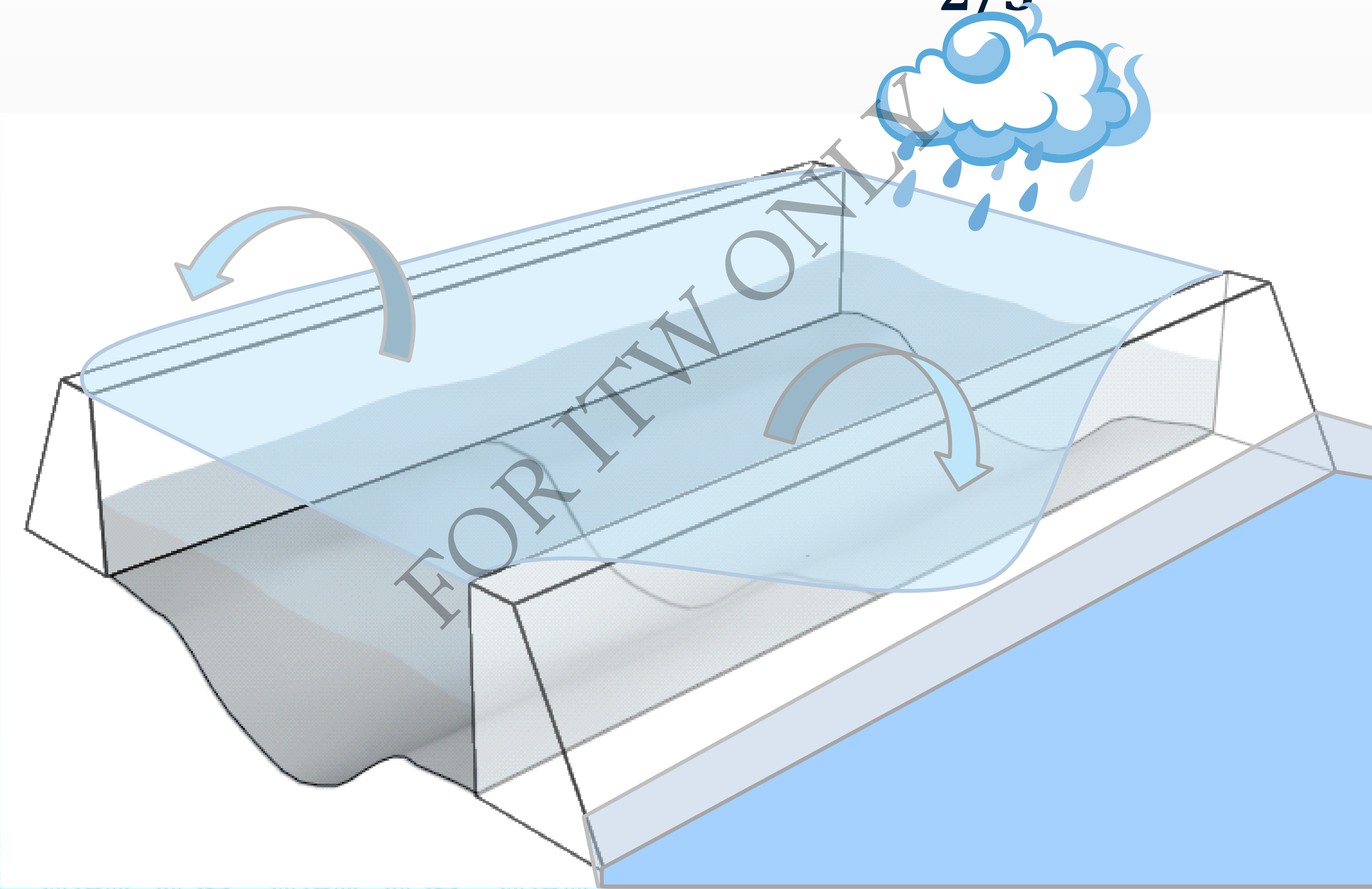
Principal types of flood

- **Riverine floods**
- **Estuarine floods**
- **Coastal floods**
- **Catastrophic floods**
- **Other**

Riverine floods 1/5

- **Riverine flooding**
  - is a function of precipitation levels and water runoff volumes within the watershed of the stream or river.

Riverine floods 2/5



Riverine floods 3/5

Riverine floods 4/5

- **Slow kinds:** Runoff from sustained rainfall or rapid snow melt exceeding the capacity of a river's channel. Causes include heavy rains from monsoons, hurricanes and tropical depressions, foreign winds and warm rain affecting snow pack.
- Unexpected drainage obstructions such as landslides, ice, or debris can cause slow flooding upstream of the obstruction.

Riverine floods 5/5

- **Fast kinds:** include flash floods resulting from convective precipitation (intense thunderstorms) or sudden release from an upstream impoundment created behind a dam, landslide, or glacier.

Estuarine floods 1/3

- Commonly caused by a combination of sea tidal surges and river runoff.

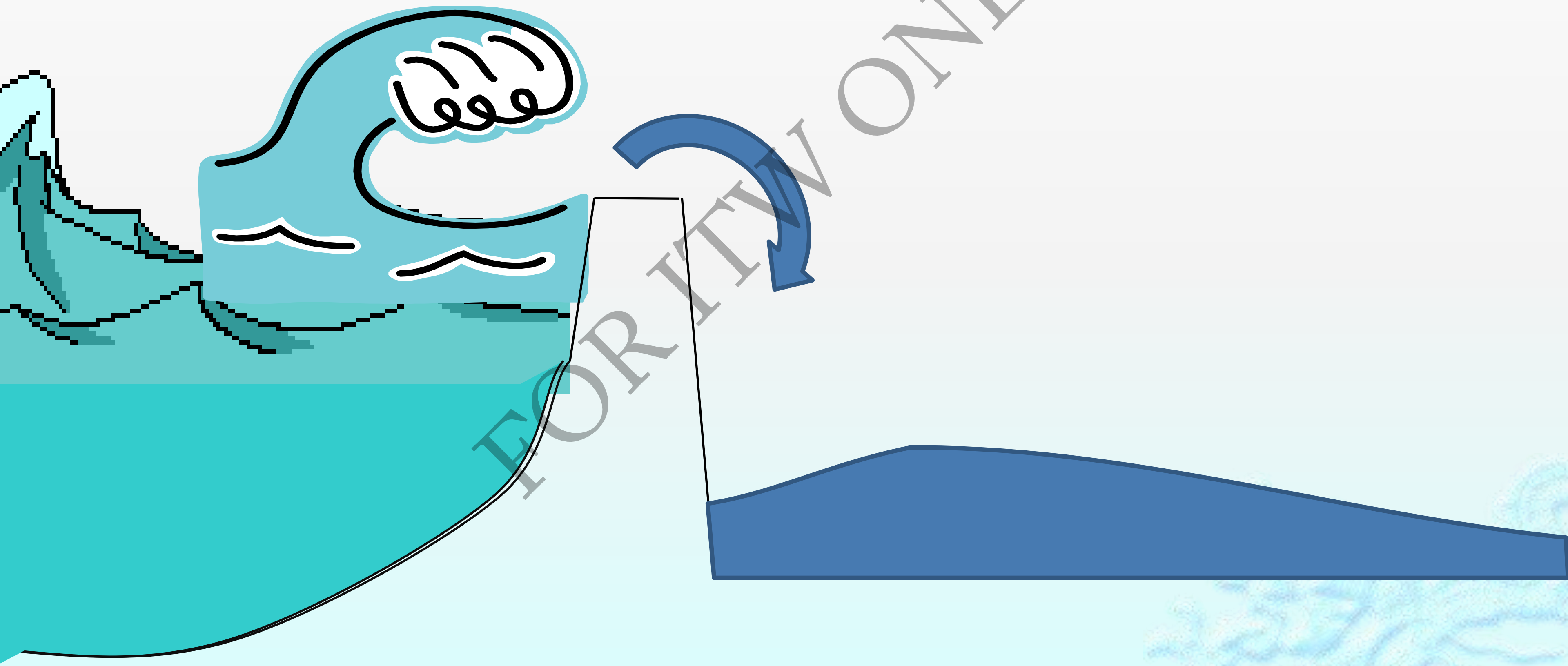
Estuarine floods $_{2/3}$

Estuarine floods $_{3/3}$

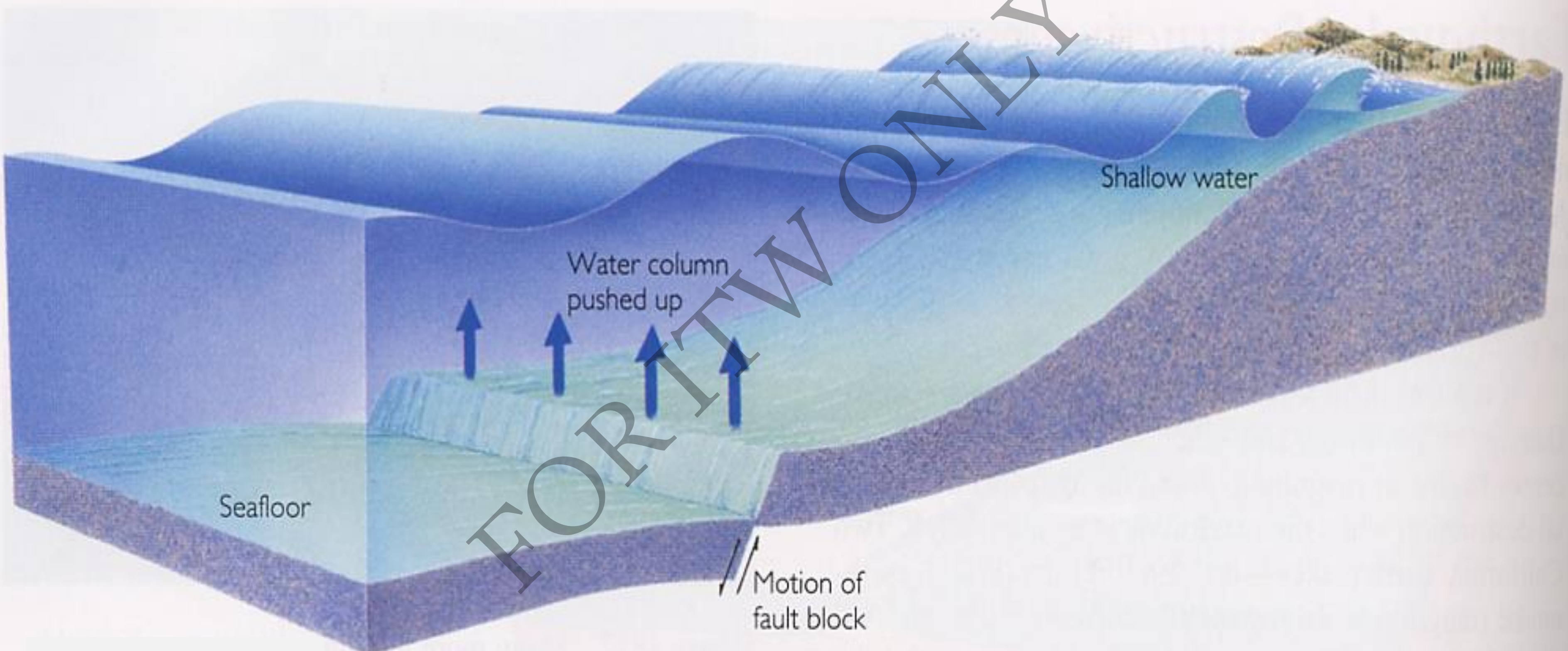
Coastal floods 1/4

- Caused by severe sea storms, or as a result of another hazard (e.g. tsunami or hurricane). A storm surge, from either a tropical cyclone or an extratropical cyclone, falls within this category.

Coastal floods $_{2/4}$



Coastal floods 3/4



Tsunami

Generation of a tsunami by fault movements caused by an earthquake on the seafloor. Movement of the seafloor due to an earthquake produces a surge of water, which oscillates and flows out as a long sea wave, or tsunami. Such a wave is only a few meters high on the deep sea but can increase in height manyfold when it enters shallow coastal waters.

Coastal floods 4/4

Catastrophic floods 1/3

- Caused by a significant and unexpected event e.g. dam breakage, or as a result of another hazard (e.g. earthquake or volcanic eruption).

Catastrophic floods 2/3

South Asia Disaster

Other 1/6

- Floods can occur if water accumulates across an impermeable surface (e.g. from rainfall) and cannot rapidly dissipate (i.e. gentle orientation or low evaporation).

Other 2/6

Other 3/6

- A series of storms moving over the same area.

Other 4/6

Other 5/6

- Dam-building beavers can flood low-lying urban and rural areas, often causing significant damage.

Other 6/6

Hydrological Characteristics in Taiwan

Hydrological Characteristics in Taiwan

- **Rainfall Distribution**
- **Runoff Distribution**
- **Typhoons and Storms**
- **Specific Peak Discharge**

Hydrological Characteristics in Taiwan

Rainfall Distribution $_{1/3}$

- Taiwan is located at subtropical zone with high temperatures and rich rainfall. The average annual precipitation is 2,500 mm, it reaches 3,000 to 5,000 mm in the mountainous regions.
- Most of the precipitation concentrates in the summer season (June, July and August). There also are typhoons in the summer season, they often bring together with storms.

Rainfall Distribution 2/3

- The maximum one hour precipitation reaches 300 mm, the maximum one day precipitation reaches l,748 mm which is 93.4% of the world record (1 ,870mm).
- In comparison with the records in the world, the one-hour to 3-day maximum precipitations in Taiwan are approximately 85 to 93% of the world records, and are approximately 1.6 times the magnitude in Japan.

Rainfall Distribution 3/3

2005/6/12
Peak Intensity
109.5mm/hr
At Yunlin

Hydrological Characteristics in Taiwan

- **Runoff Distribution**：

  Rivers are short and steep in Taiwan with large runoff differences in wet and dry seasons.

  Discharges respond rapidly with rainfall intensity and flood flows：usually carry large amount of sediment.

Hydrological Characteristics in Taiwan

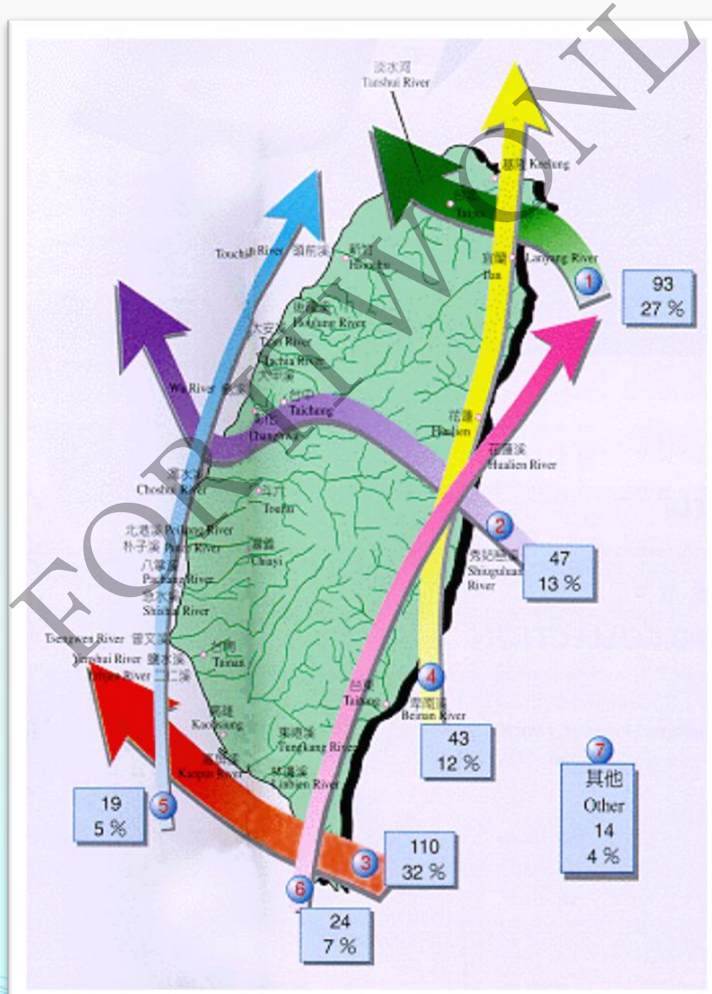
- **Typhoons and Storms** $_{1/8}$ ：

  There were 350 typhoons and over one thousand storms occurred in Taiwan from 1897 to 1997.

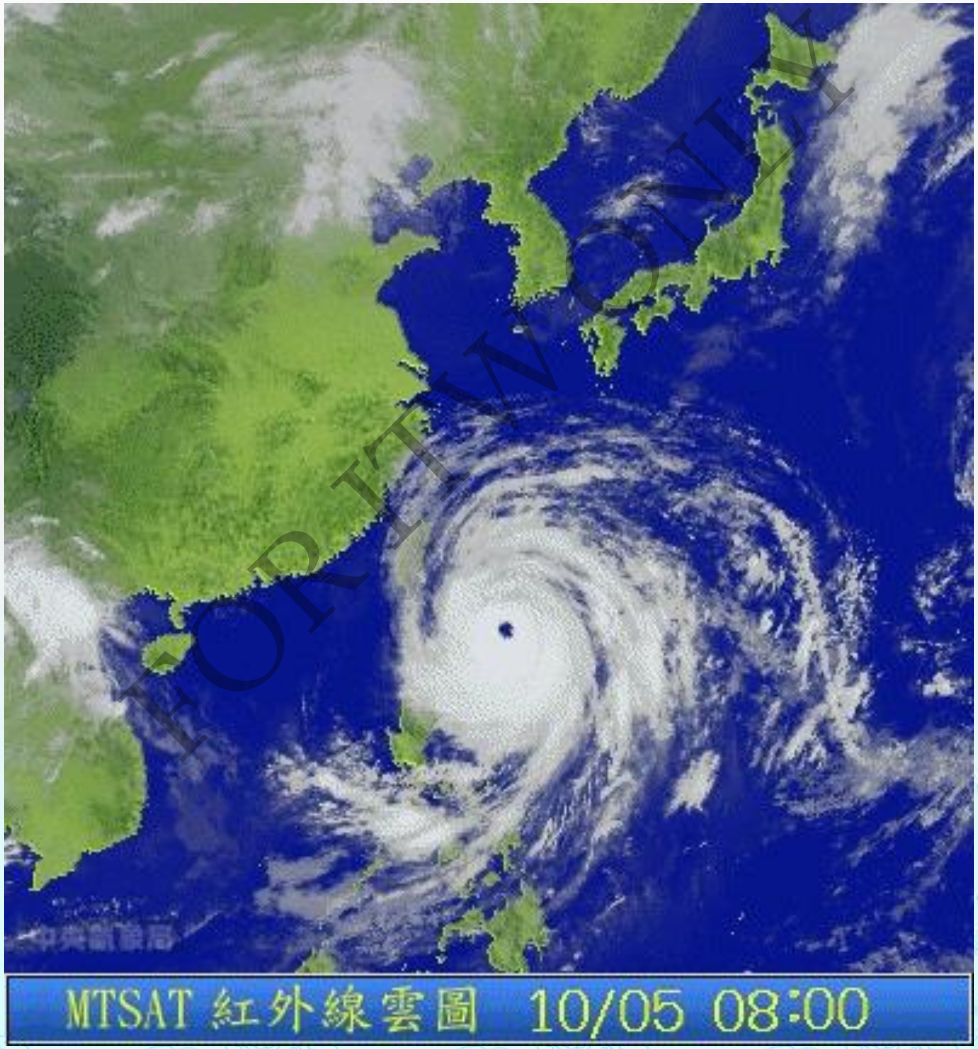
  Losses due to natural disasters reached 12.8 billion NTD from 1983 to 1995. The amount is approximately 4.6 times the fire damages in the same periods.

Typhoons and Storms 2/8

Typhoon Routes and No. of Occurrence (1897 to 1997)



Typhoons and Storms 3/8



Typhoons and Storms 4/8

By 1970~2006

Rank	Year	Typhoon	Date	Station	Rainfall (mm)
1	1996	賀伯	07/29～08/01	阿里山	1987.0
2	1987	琳恩	10/22～10/27	竹子湖	1941.4
3	1978	婀拉	10/11～10/14	竹子湖	1434.1
4	2001	納莉	09/08～09/19	竹子湖	1315.0
5	2005	海棠	07/16～07/20	阿里山	1215.5
6	2004	敏督利	06/28～07/03	阿里山	1181.5
7	1973	娜拉	10/07～10/10	新竹	1073.7
8	1974	貝絲	10/10～10/12	阿里山	1044.3
9	2000	象神	10/30～11/01	鞍部	1022.1
10	1990	楊希	08/17～08/20	阿里山	985.6

Rainfall events exceeding 1000 mm/day

排名	雨量站	年分	日期	雨量	降雨事件
1	宜蘭新寮_水利局	1967	10月18日	1672.6mm	解拉颱風和東北季風共伴
2	宜蘭天埤_台電	1974	10月11日	1385.0mm	貝絲颱風和東北季風共伴
3	宜蘭圓山_台電	1974	10月11日	1368.0mm	貝絲颱風和東北季風共伴
4	花蓮大觀_水利局	1973	10月9日	1361.2mm	娜拉颱風和東北季風共伴
5	宜蘭山腳_台電	1969	10月2日	1350.0mm	芙勞西颱風和東北季風共伴
6	花蓮綠水_台電	1994	7月10日	1256.0mm	提姆颱風
7	宜蘭天埤_台電	1973	10月8日	1250.0mm	娜拉颱風和東北季風共伴
8	花蓮溪畔進水口_台電	1997	8月29日	1137.0mm	安珀颱風
9	台北竹子湖_氣象局	1987	10月24日	1135.5mm	琳恩颱風和東北季風共伴
10	屏東泰武_水利局	1934	7月19日	1127.0mm	低氣壓or西南氣流
11	花蓮綠水_台電	1997	8月29日	1126.0mm	安珀颱風
12	宜蘭山腳(高地)_台電	1969	10月2日	1125.7mm	芙勞西颱風和東北季風共伴
13	屏東新瑪家_水利署	2007	8月13日	1119.0mm	熱帶低氣壓北上引發強烈西南氣流
14	屏東泰武_水利署	2005	7月18日	1096.0mm	海棠颱風
15	花蓮達美多_台電	1973	10月9日	1095.0mm	娜拉颱風和東北季風共伴
16	嘉義阿里山_氣象局	1996	7月31日	1094.5mm	賀伯颱風
17	屏東阿禮_水利署	2005	7月18日	1084.0mm	海棠颱風
18	花蓮天祥_氣象局	1997	8月29日	1051.0mm	安珀颱風
19	嘉義竹崎_嘉南水利會	1945	9月3日	1050.0mm	海倫颱風
20	桃園巴峻_石門水庫	1963	9月10日	1044.0mm	葛樂禮颱風
21	宜蘭土場_氣象局	2001	9月17日	1042.0mm	納莉颱風
22	花蓮布洛灣_氣象局	1997	8月29日	1036.5mm	安珀颱風
23	屏東新瑪家_水利署	2005	7月18日	1030.0mm	海棠颱風
24	宜蘭土場_水利署	2001	9月17日	1011.0mm	納莉颱風
25	屏東尾寮山_氣象局	2005	7月18日	1010.0mm	海棠颱風
26	屏東瑪家_氣象局	2007	8月13日	1007.0mm	熱帶低氣壓北上引發強烈西南氣流
27	宜蘭大元山_台電	1977	9月22日	1002.0mm	黛納颱風和東北季風共伴
28	雲林梅林_雲林水利會	1959	8月7日	1001.1mm	熱帶低氣壓_87水災

Typhoons and Storms 5/8

Typhoon Herb, a Severe Damage and Lesson

- Time：July 31,1996 to August l, 1996. Typhoon eye landed Ilan on 8：44pm, July 31，1996.
- Path：Formed at 800km NE of Guam on July 24, 1996 and became a tropical depression in Fuchian on August 2, 1996.
- Maximum Wind Speed：59.5 m/s.
- Precipitation : Maximum daily precipitation of 1,094.5mm on July 31, 1996 at Alishan.

Typhoons and Storms 6/8

Typhoons and Storms 7/8

Typhoon Sinlaku

- **Formed** :September 7, 2008
- **Dissipated:** September 21, 2008
- **Maximum Wind Speed :** 51.0 m/sec
- **Precipitation :** Maximum precipitation 1,457.7mm/day at Alishan.

Typhoons and Storms 8/8

Hydrological Characteristics in Taiwan

- **Specific Peak Discharge：**

  The peak discharge per unit drainage area in Taiwan is the largest in the world.

  For instance, the specific peak discharge of Choshui River is 450 times that of Yangtze River in China and 25 times that of Sinno River in Japan.

Flood Characteristics in Taiwan

Flood Characteristics in Taiwan

- **Wild and Uncontrollable Rivers**
- **Excessive Specific Flood Peak Discharge**
- **Land Subsidence and Inundation**
- **Uneven Distribution of Water Resources**

Wild and Uncontrollable Rivers 1/3

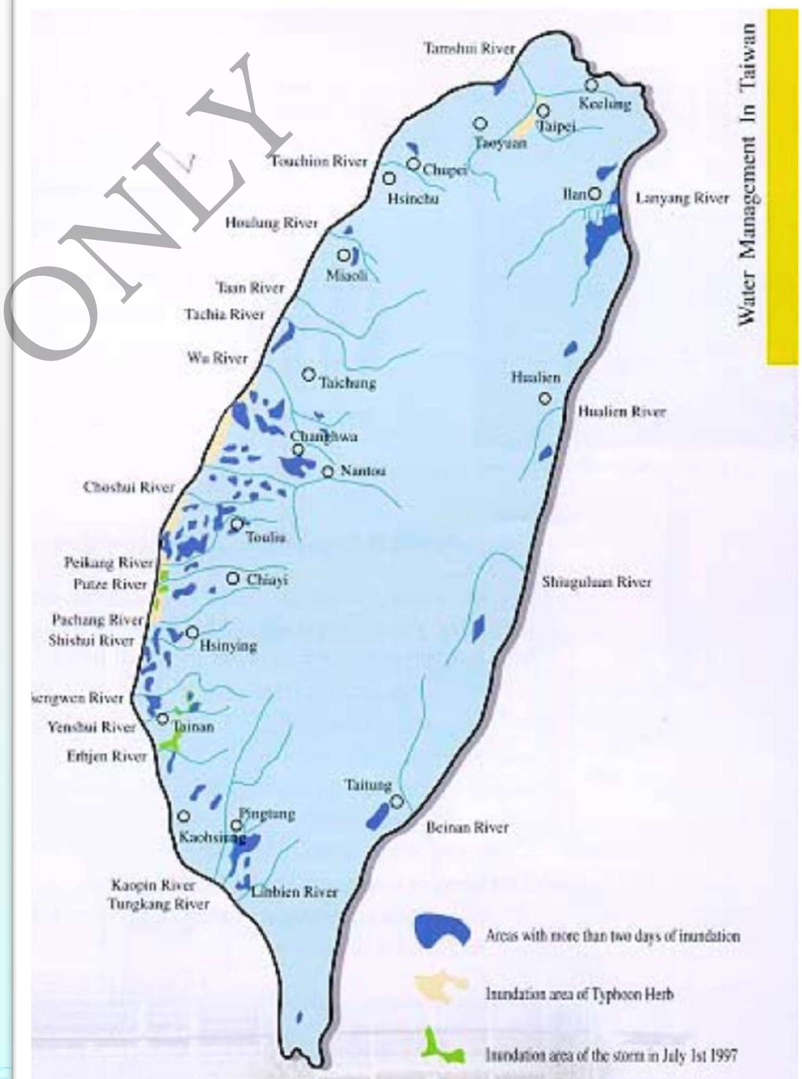
- 21 major rivers, 29 secondary rivers and 79 minor rivers.
- Relatively small drainage area, only 9 rivers exceed 100km^2.
- Relatively short length, only 6 rivers exceed 100km.
- Relatively steep slope, upstream reaches exceed 1/100, downstream reaches 1/200~1/500, only 5 rives having slope milder than 1/1000.

Wild and Uncontrollable Rivers 2/3

- Poor watershed geologic conditions, most of them are sandstone and shale with easy-to-collapse feature, sediment concentrations are huge, there also exists some special geologic structures such as mudstone and conglomerate which can easily become mudflow.

- Concentrated rainfall, short rivers and rapid flows, poor flow conditions, uneven time distribution of flows, rapid rise of flow peak.

Wild and Uncontrollable Rivers 3/3



Excessive Specific Flood Peak Discharge

- Due to extreme rainfall intensity, steep river slope, rapid flow conditions and high runoff coefficient of watersheds in Taiwan, peak discharges per unit drainage area are the largest in the world.

Excessive Specific Flood Peak Discharge

- For example, the peak discharge per unit area of Choshui River is 7.7 cms/km2 which is approximately 450 times that of Yangtze River in China and 25 times that of Sinno River in Japan.

Land Subsidence and Inundation 1/3

- Most of subsidence areas in Taiwan are located in SW coastal area south of Wu River, Lanyang Plain and Taipei Basin.
- In February 1971, groundwater control zones were delineated with associated control regulations published to manage groundwater utilization and to prevent subsidence and seawater intrusion in Taiwan.

Land Subsidence and Inundation 2/3

- Among those subsidence areas, groundwater pumping in Taipei Basin has been controlled since 1978, and thus subsidence in the basin has been stabilized.
- However, the other areas with excessive use of groundwater are still not controlled, and therefore subsidence in those areas have not yet been improved.

Land Subsidence and Inundation 3/3

- The total subsidence area in Taiwan reaches 1,747km2 which is approximately 6.4 times the area of Taipei City and is approximately 16% of the plain area in Taiwan.

Uneven Distribution of Water Resources 1/3

- **Uneven Space Distribution：**

✓ The average annual precipitation is 2,500mm, however, in Hualien River and upstream reach of Keelung River, the annual precipitation reaches 7,500 to 8,000mm

✓ In some part of the western coastal plain region, the annual precipitation is less than 1 ,200mm, and is even less than 1,000mm in Penghu area.

Uneven Distribution of Water Resources 2/3

- **Uneven Time Distribution：**

✓ Uneven seasonal Distribution Precipitation concentrates in the period from May to October which accounts for 78% of the annual precipitation.

Uneven Distribution of Water Resources 2/3

- **Uneven Time Distribution：**

✓ Uneven Annual Distribution

- The annual precipitations in 1980 and 1993 were only l,600mm.
- The annual precipitations in 1953, 1972 and 1990 were more than 3,100 mm.
- The ratio of Wet to dry season in northern region is 6：4 and in southern region is 9：1 which causes the difficulty of water resource utilization in the southern region.

Flood/Inundation Maps

Inundation Maps

- Inundation Mapping is a basic tool for flood preparedness and mitigation activities, including flood insurance programs.
- Planners want to know inundation:
  - Spatial extent
  - Depth
  - Flow velocity
  - Probability of occurrence
- Format should facilitate integration with information on population and infrastructure

Inundation Maps

Production

- Potential inundation analysis is to estimate possible flood hazard situation .
- Land surface model and specific rainfall conditions are needed for production of inundation maps.

Inundation Maps

- Purpose/Intended Use - Flood Inundation Maps will show the extent of flooding expected spatially over a given area.
- Audience - The initial target audience is the state and local agencies that must make emergency operational decisions during flooding events. However, since the graphics are easy to view, anyone with an interest during these events can make use of the maps.

Inundation Maps

Applications

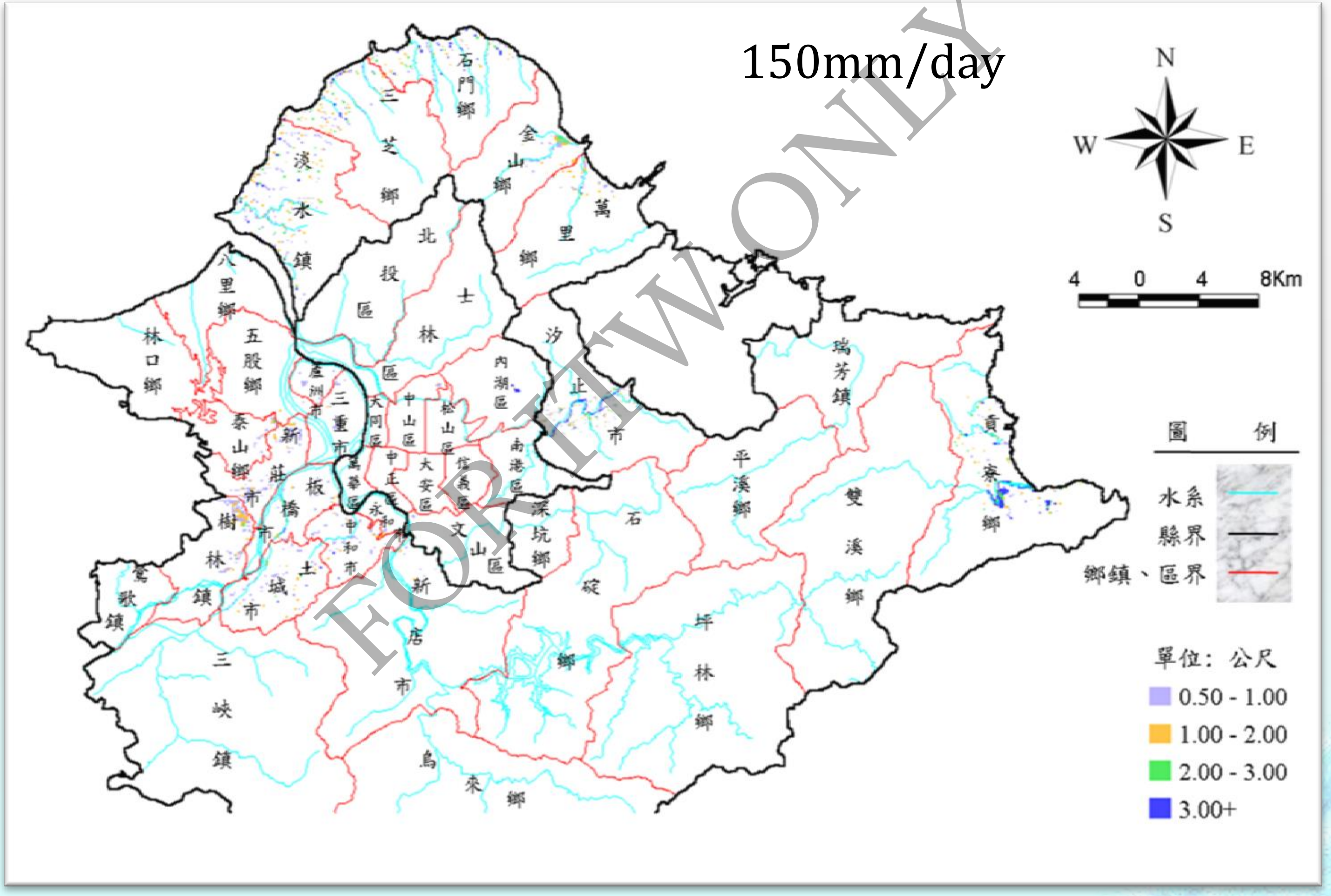
- Calculating pecuniary loss by combination of potential inundation data and local economic development.
- Examine efficiency of drainage engineering.
- Restrict land use in high flooding potential area in order to minimize flood loss.
- Consultation for instituting flood insurance rate.

Inundation Maps

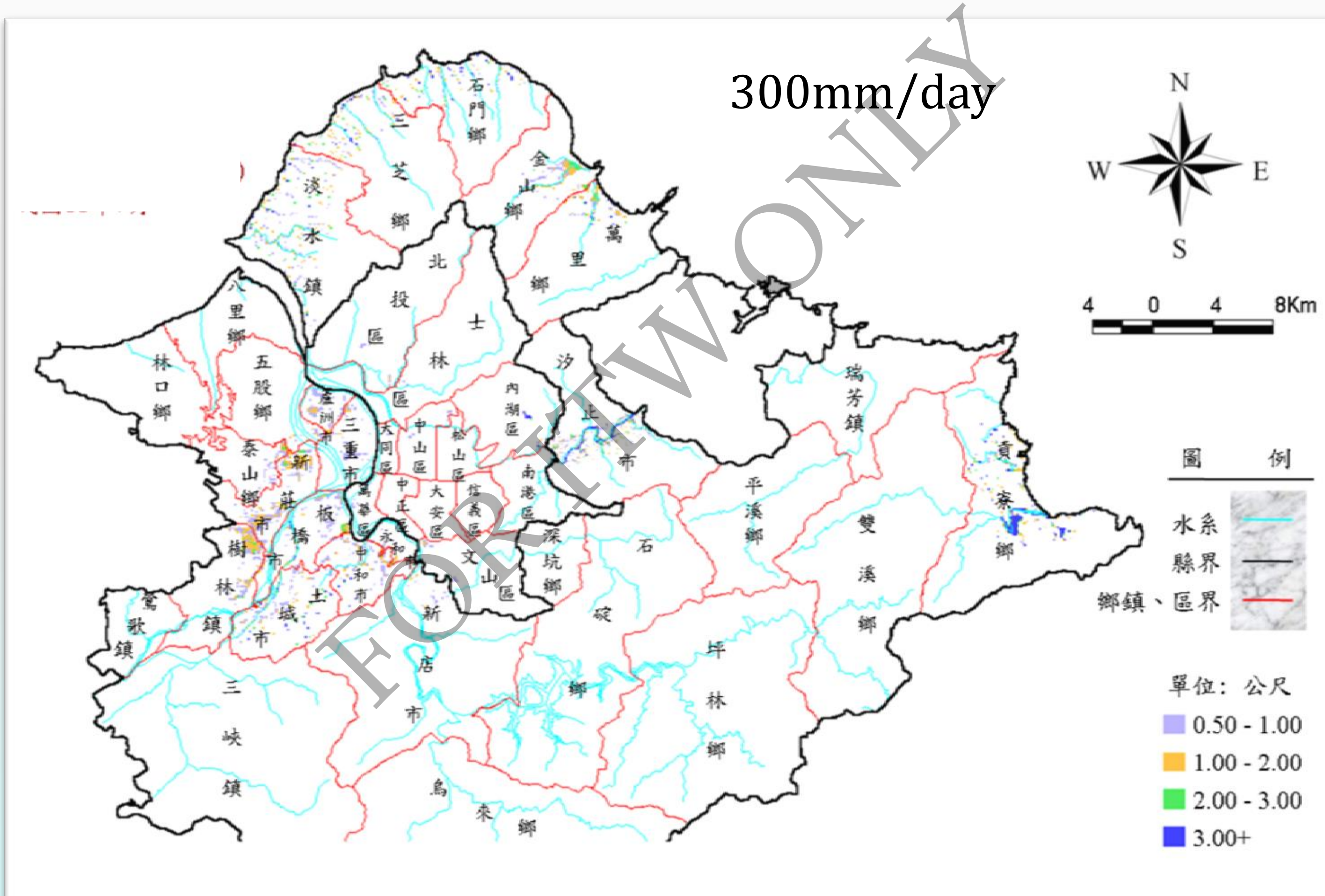
Applications

- Estimate possible inundation area with immediate rainfall records.
- Provide fast and detailed data to help making emergency operational decisions.

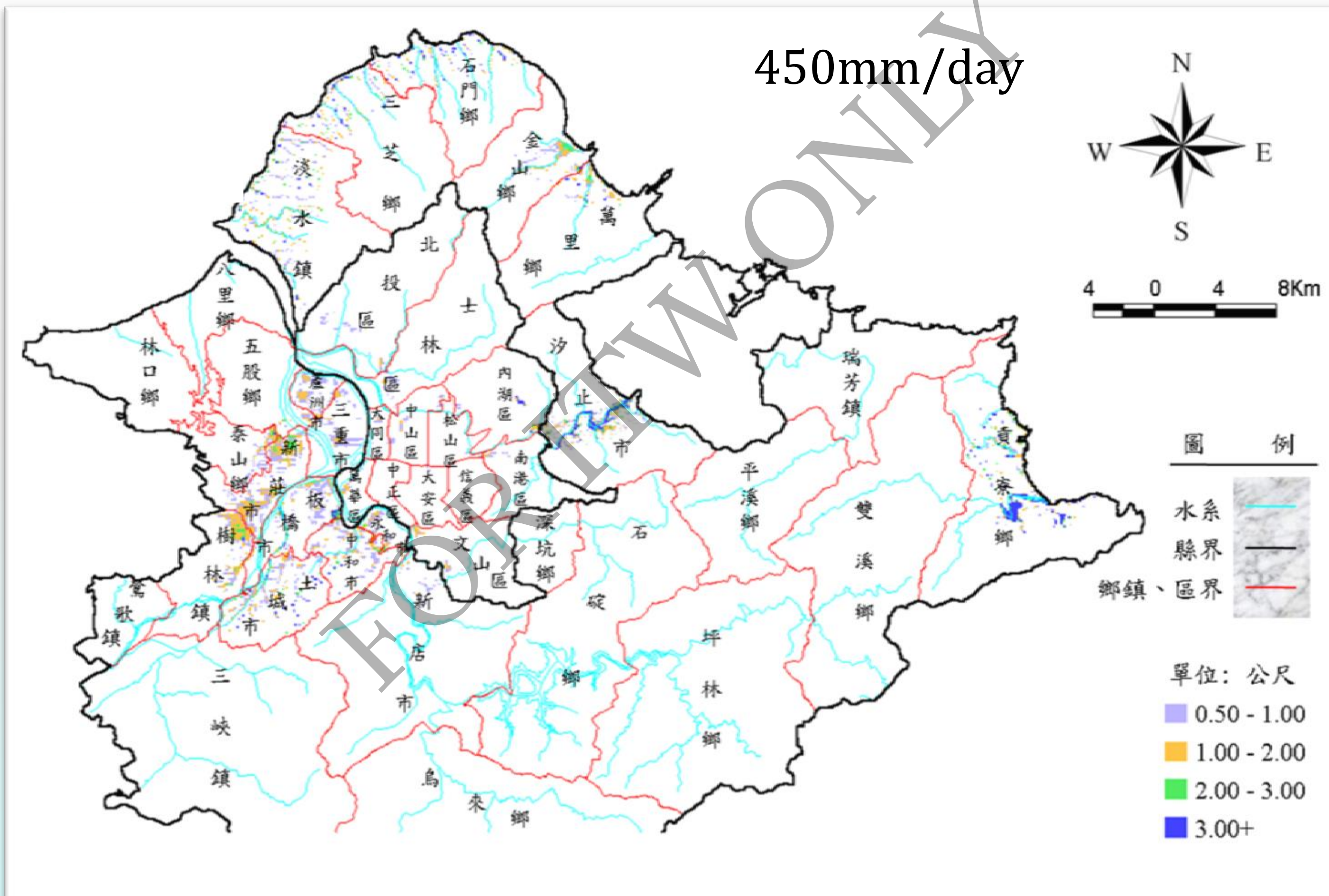
Inundation Maps



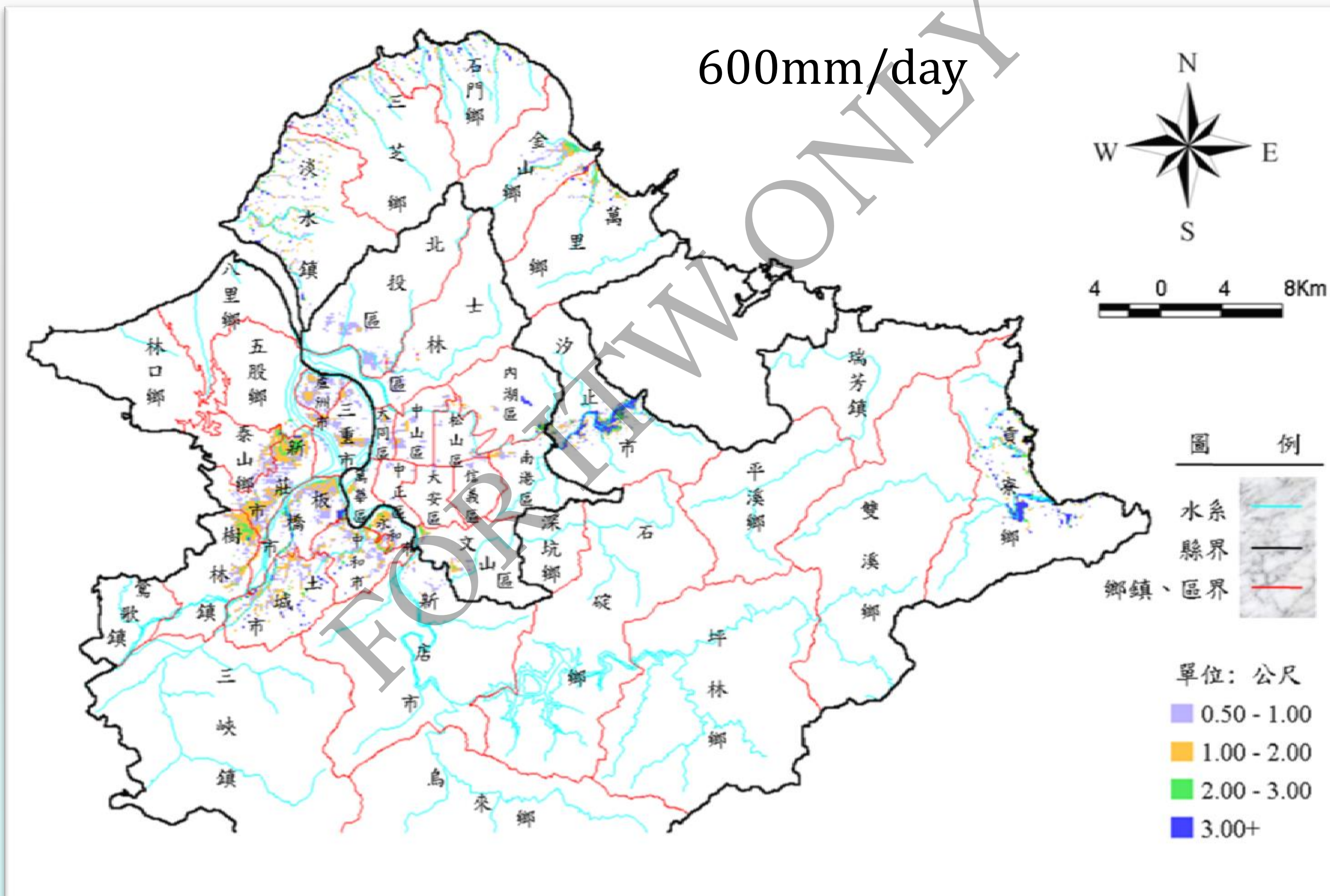
Inundation Maps



Inundation Maps



Inundation Maps



Application of Flood/Inundation Maps

Flood Design Criteria of the Taipei MRT System

- Flood Design Considerations
- Flood Prevention Facilities

Flood Design Considerations

- Taipei MRT adopted an estimated flood level in a return period of 200 years plus an additional 50cm.
- Based on this criterion, all entrances to stations, structural openings, and depots were designed to this level to prevent water intrusion.

Flood Prevention Facilities

- Flood prevention facilities for entrances on the Taipei MRT can be summarized as follows:

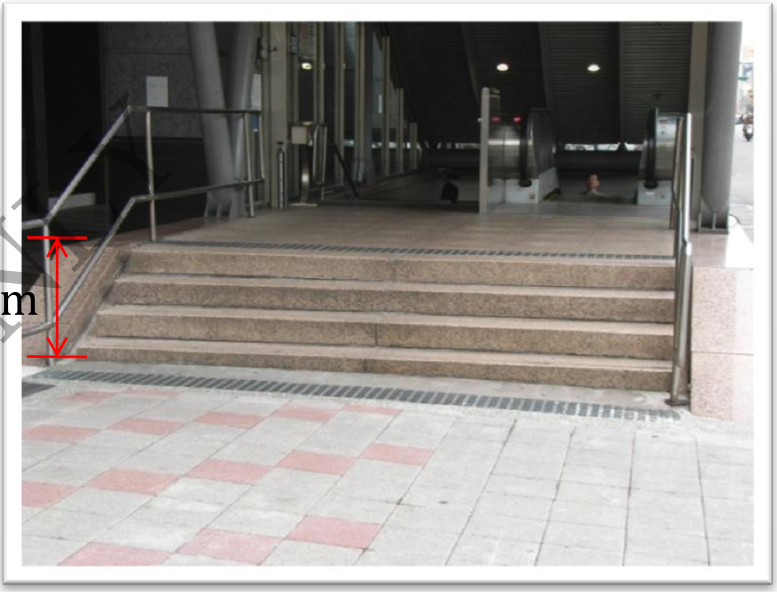
  1. All entrances shall be a minimum of 15cm above the flood level with a return period of 100 years, and also meet the requirement of a minimum 60-120cm above the adjacent ground level.

  2. All entrances shall be provided with floodgates 50cm above the flood level in a return period of 200 years.

The Taipei MRT System

Flood Prevention Facilities

45cm

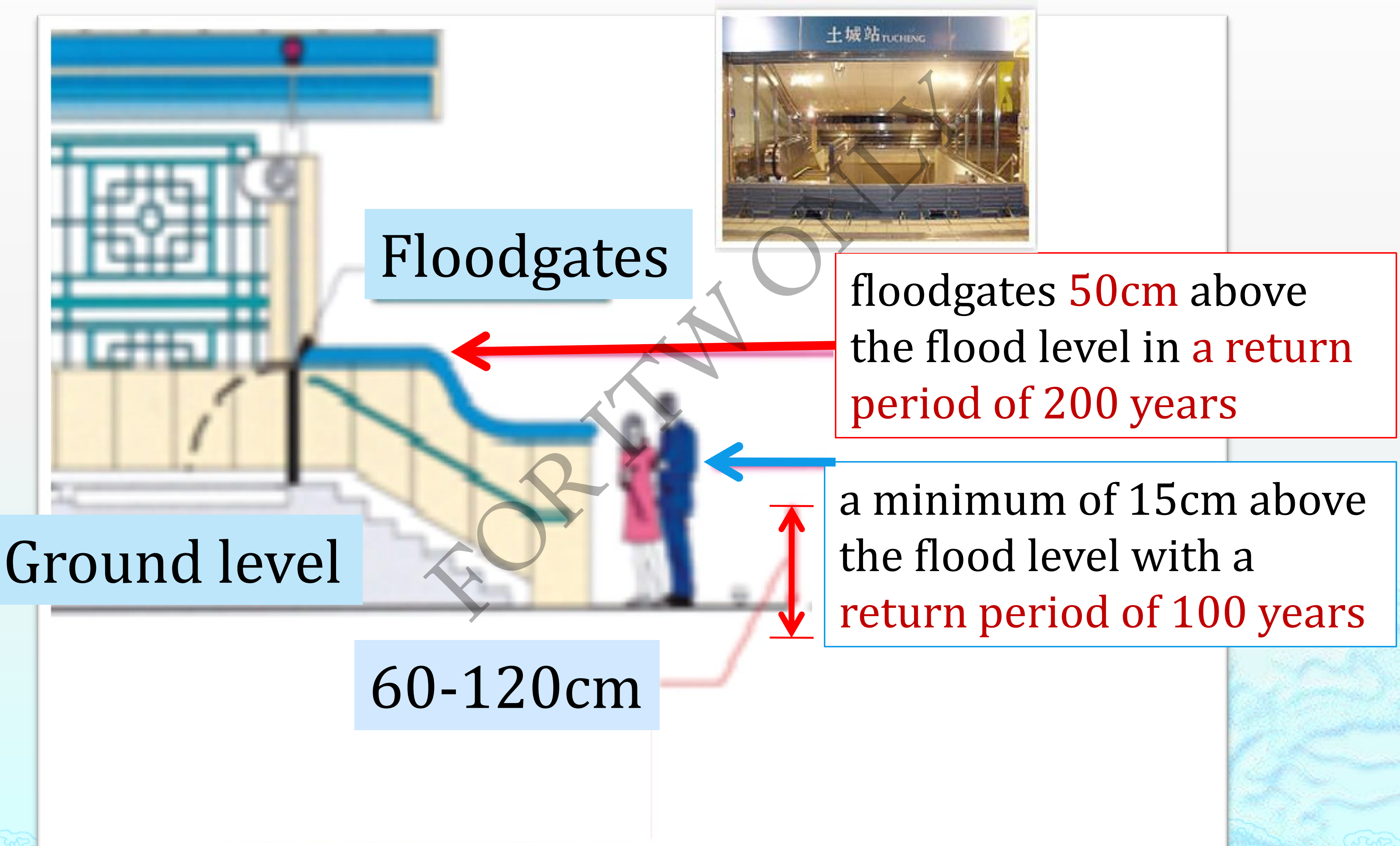


60cm

75cm

60cm

Flood Prevention Facilities



Flood in Taipei and its lesson

On Sep. 16 and 17 in 2001, the typhoon Nari swept through Taiwan with a historical-high rainfall record in northern Taiwan.

The typhoon Nari event in 2001

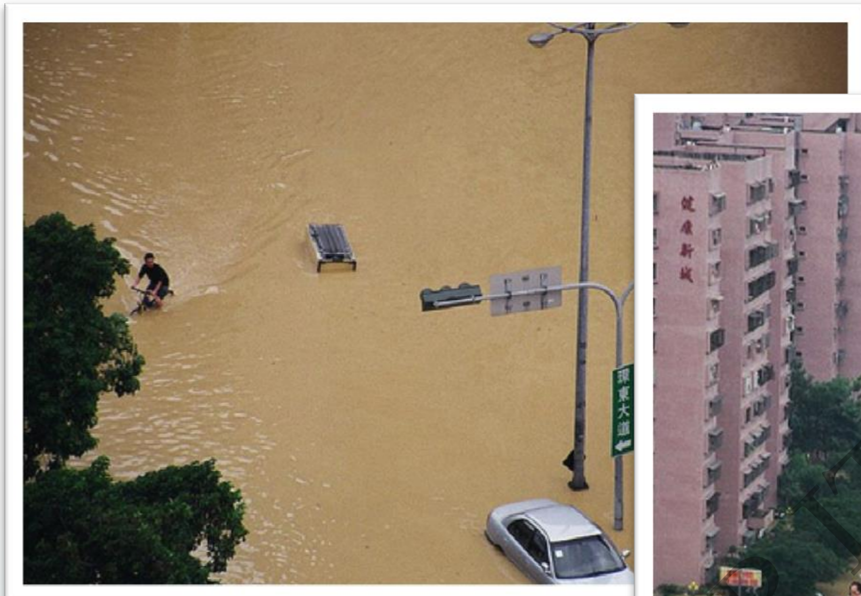
The total amount and peak intensity of rainfall in downtown Taipei during the typhoon Nari event.

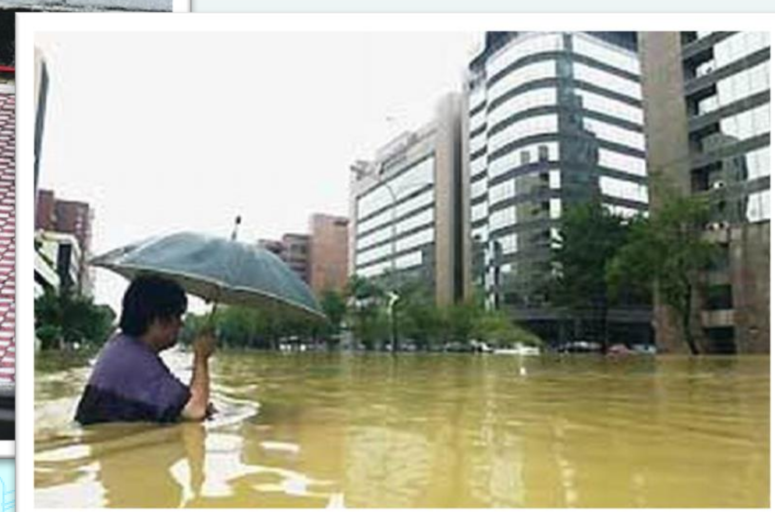
Total Rainfall (mm)	Peak Intensity (mm/hr)
732.0	109.5

The typhoon Nari event in 2001

Gauge Name	Total Rainfall (mm)	Peak Intensity (mm/hr)
Shihlin	576.0	94.0
Sunchun	554.0	68.0
Taipei	618.0	77.0
Chungcheng Bridge	630.0	95.0
Yunghon	565.0	93.5
Mucha	669.5	57.5
Shinyi	549.0	84.5
Nankang	787.0	105.0
Tachih	629.5	93.5
Neihu	732.0	109.5

The typhoon Nari event in 2001





The typhoon Nari event in 2001

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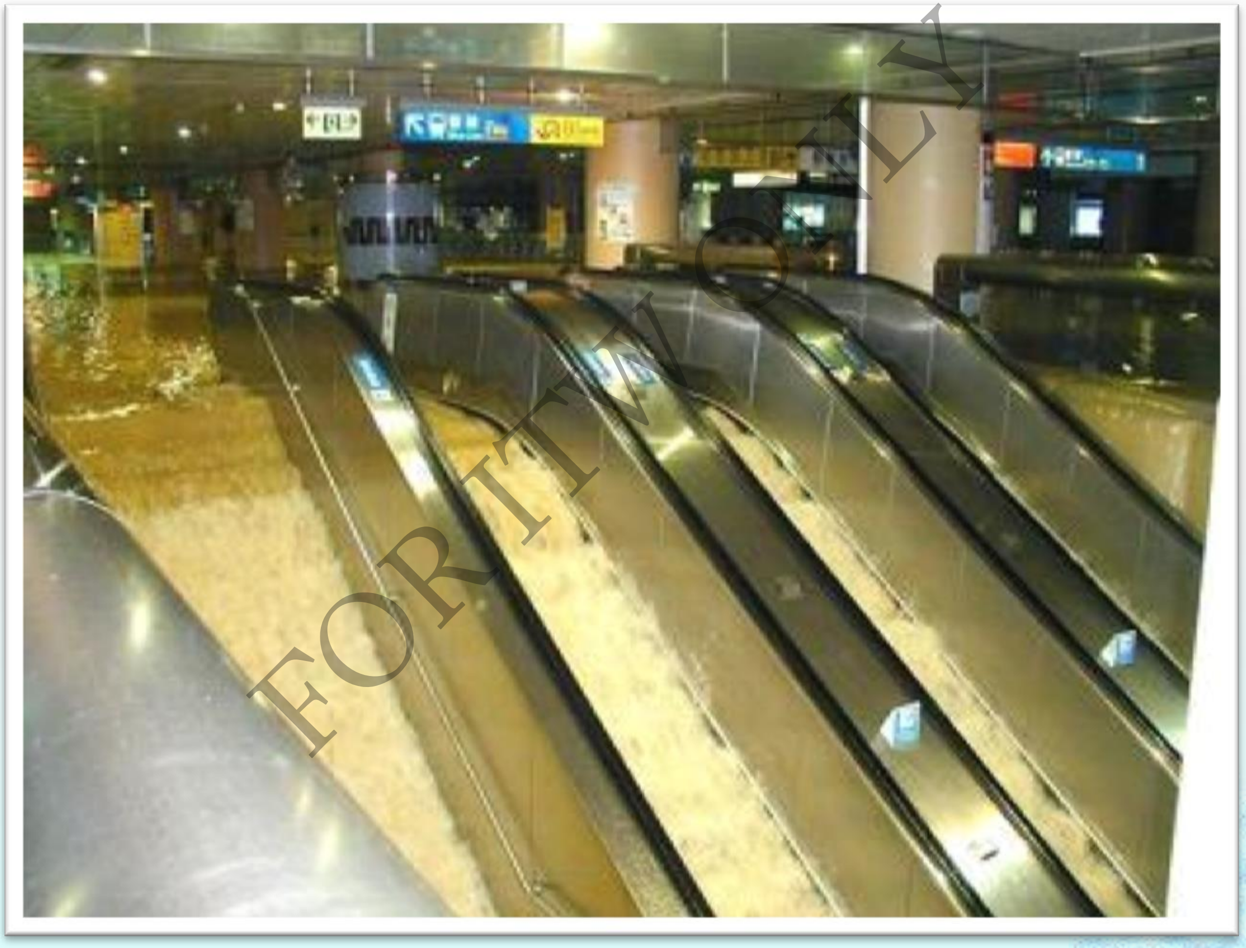


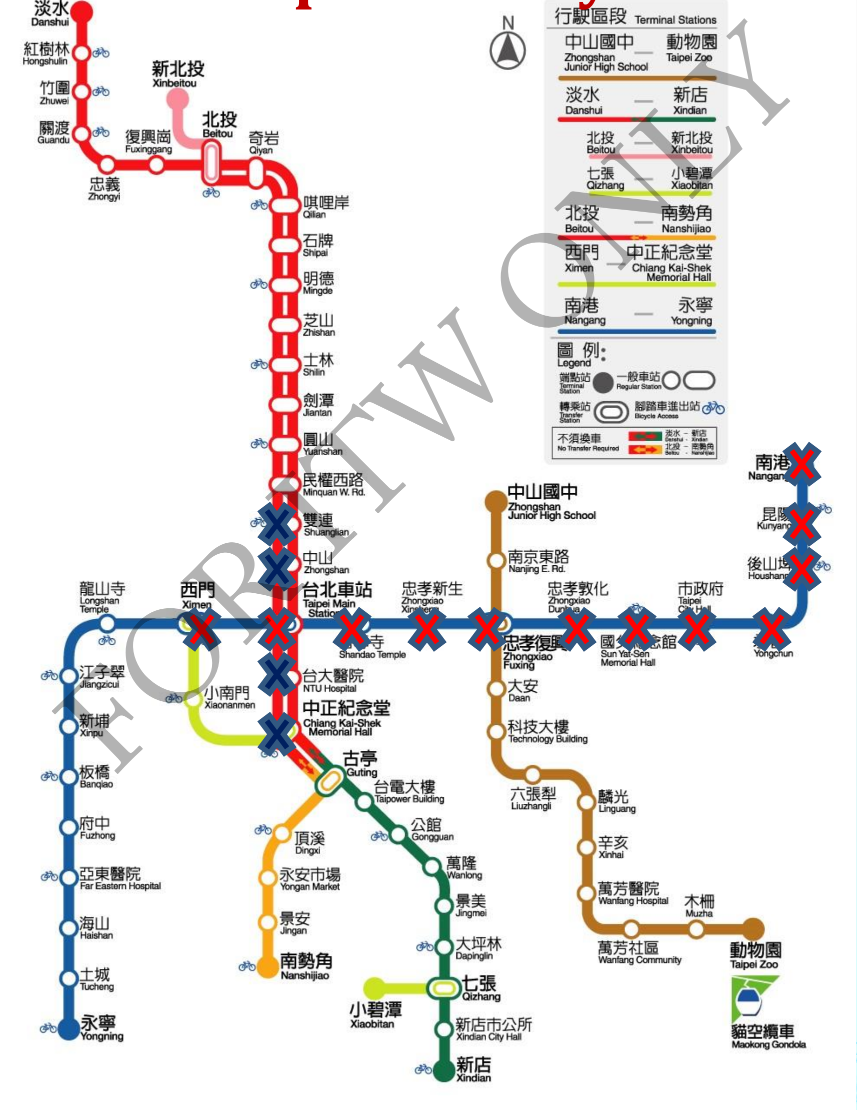
The typhoon Nari event in 2001

The typhoon Nari event in 2001

The typhoon Nari event in 2001

The typhoon Nari event in 2001

the Taipei MRT system



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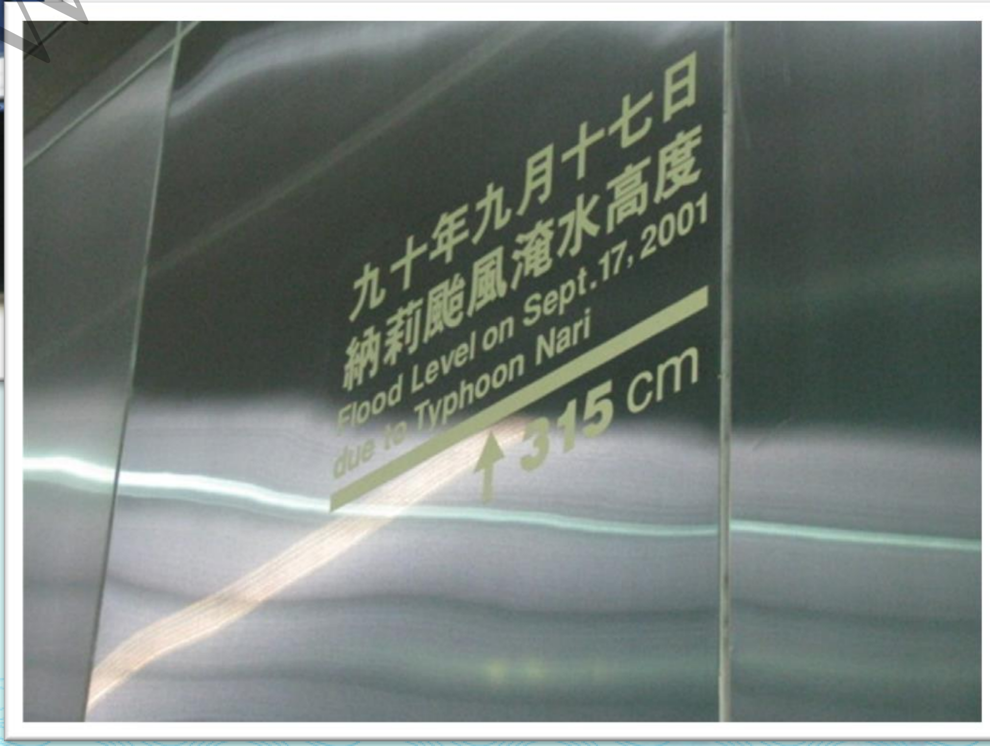
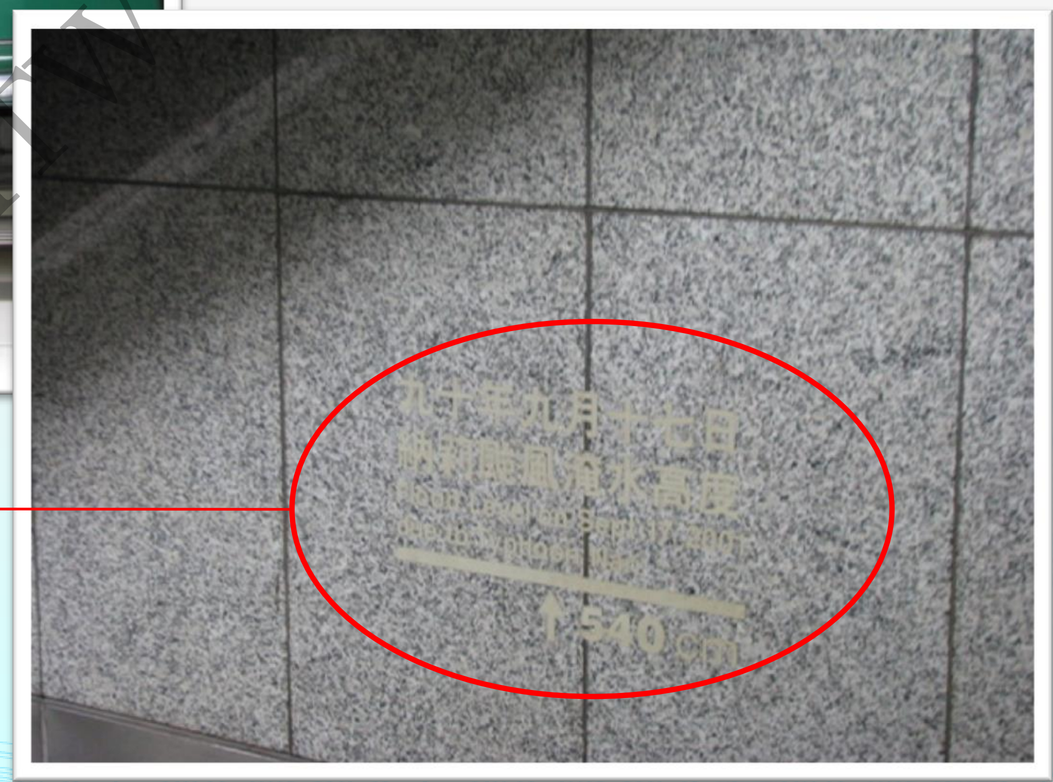


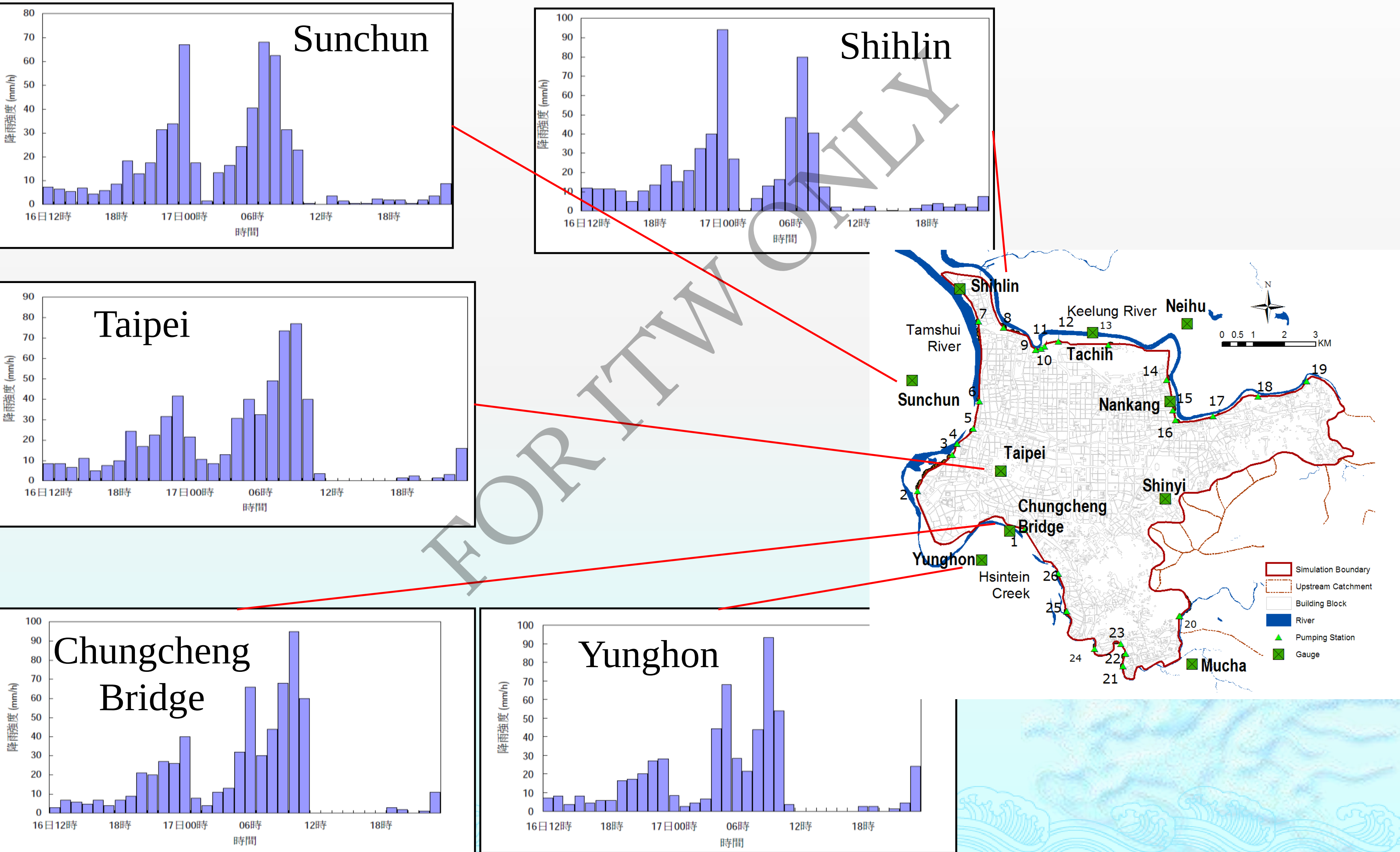
The typhoon Nari event in 2001



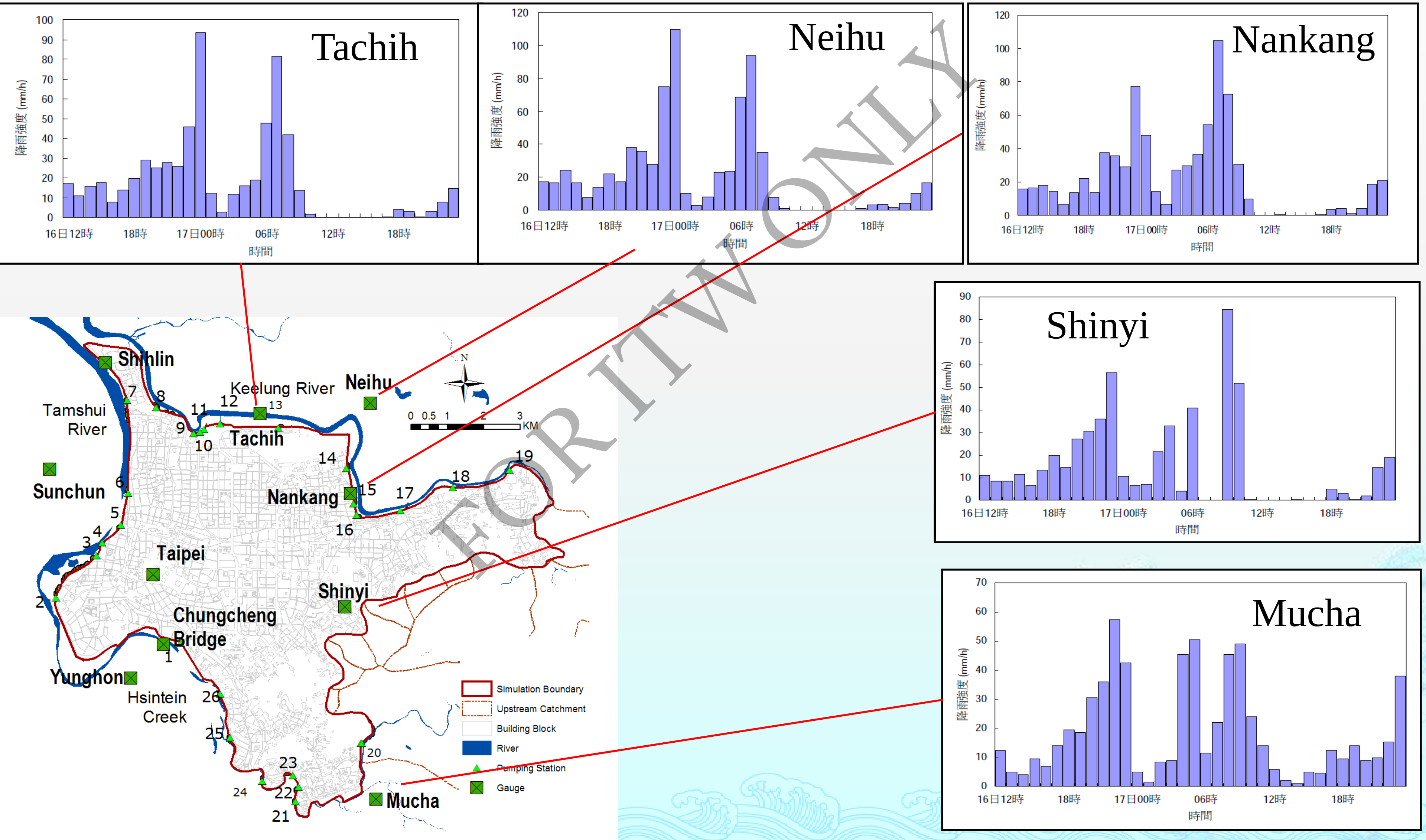
540 cm

The typhoon Nari event in 2001

The typhoon Nari event in 2001



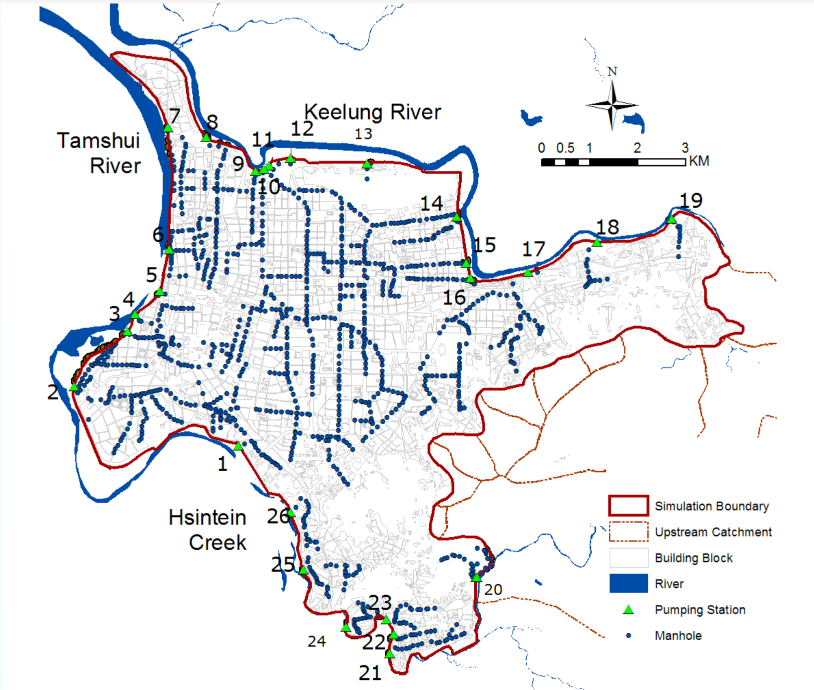
The typhoon Nari event in 2001



The typhoon Nari event in 2001

- The recorded and failing time pumping stations in downtown Taipei during the typhoon Nari event.

No.	design capacity (cms)	failing time	
		recorded	simulated
20	20.0	09/16 23:23	09/16 23:26
19	20.0	09/17 00:19	09/17 00:14
18	32.0	09/17 04:00	09/17 03:53
13	32.0	09/17 08:00	09/17 08:02
17	184.1	09/17 09:00	09/17 08:56

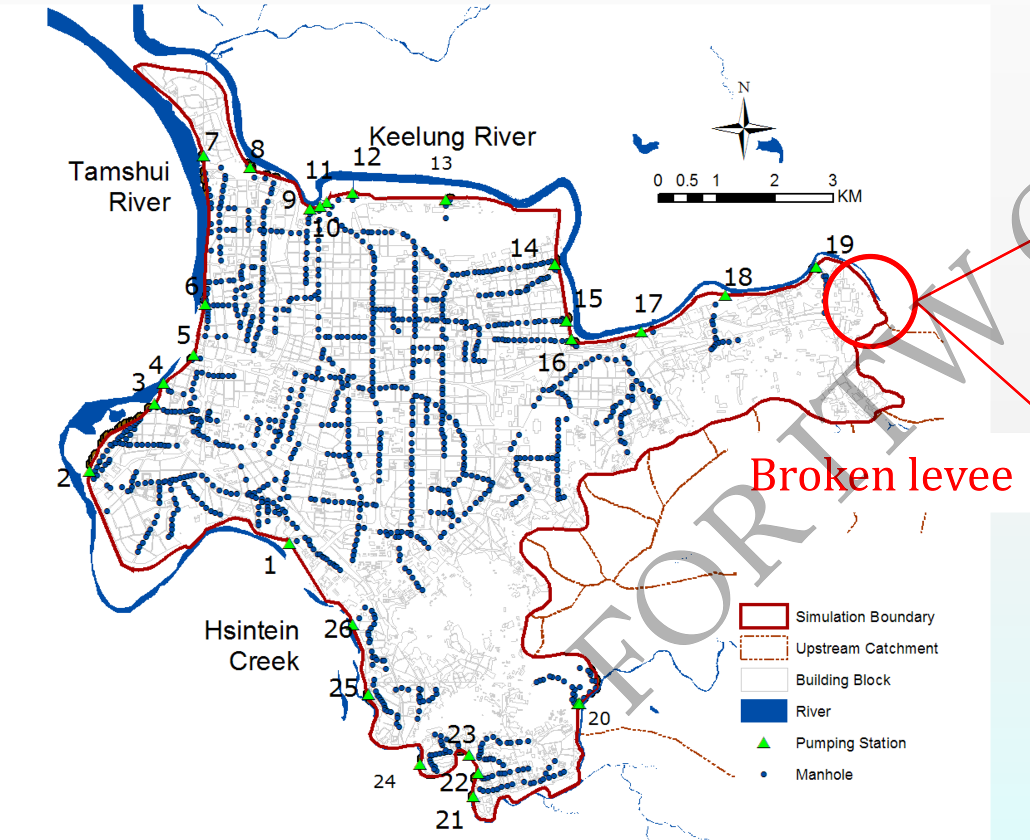


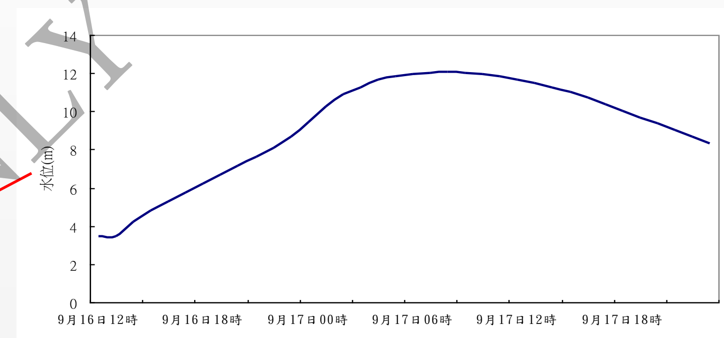
The typhoon Nari event in 2001

- The pumped and water volumes in subway systems in downtown Taipei during the typhoon Nari event.

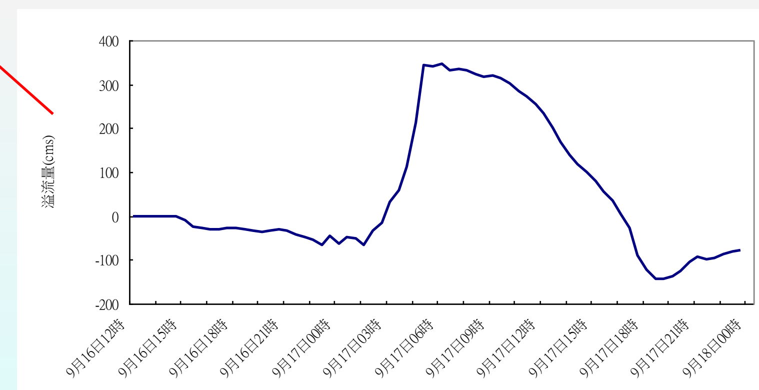
System	Pumped Water Vol. (x 10^3 m^3)	Simulated Flood Water Vol. (x 10^3 m^3)
TRTS & MRTS Red Line	1012	950
MRTS Blue Line	390	406

The typhoon Nari event in 2001



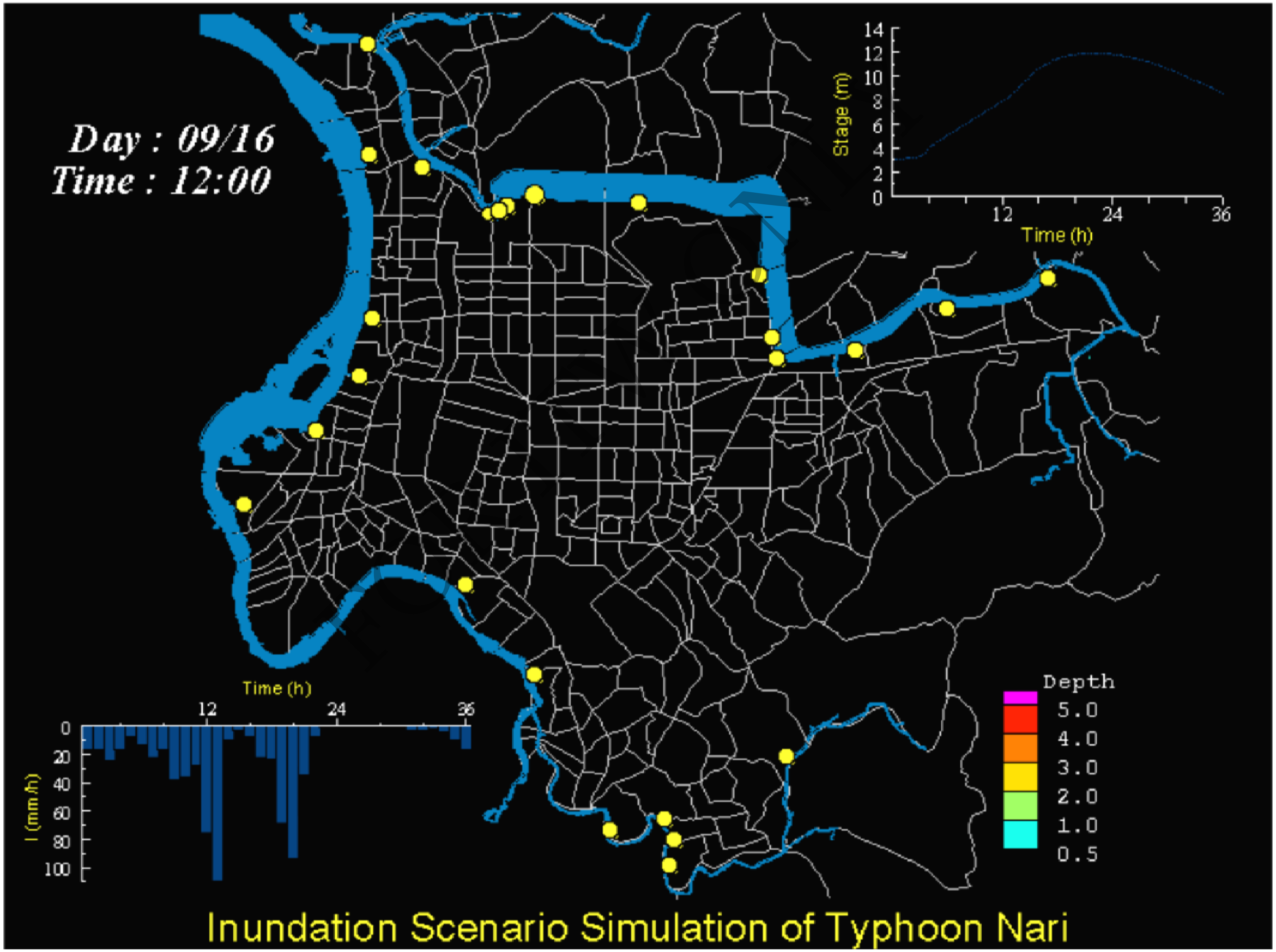


Discharge(cms)



Water level (m)

The typhoon Nari event in 2001



Upgrading Flood Protection Criteria

After the disaster of Typhoon Nari in 2001, an overall review of the flood prevention systems for the Taipei MRT was carried out, and enhancement measures were adopted as follows:

1. The flood prevention standard on the long-term Taipei MRT network is now set at a return period of 200 years plus an additional 110cm, or the level of flooding recorded during Typhoon Nari plus additional height.

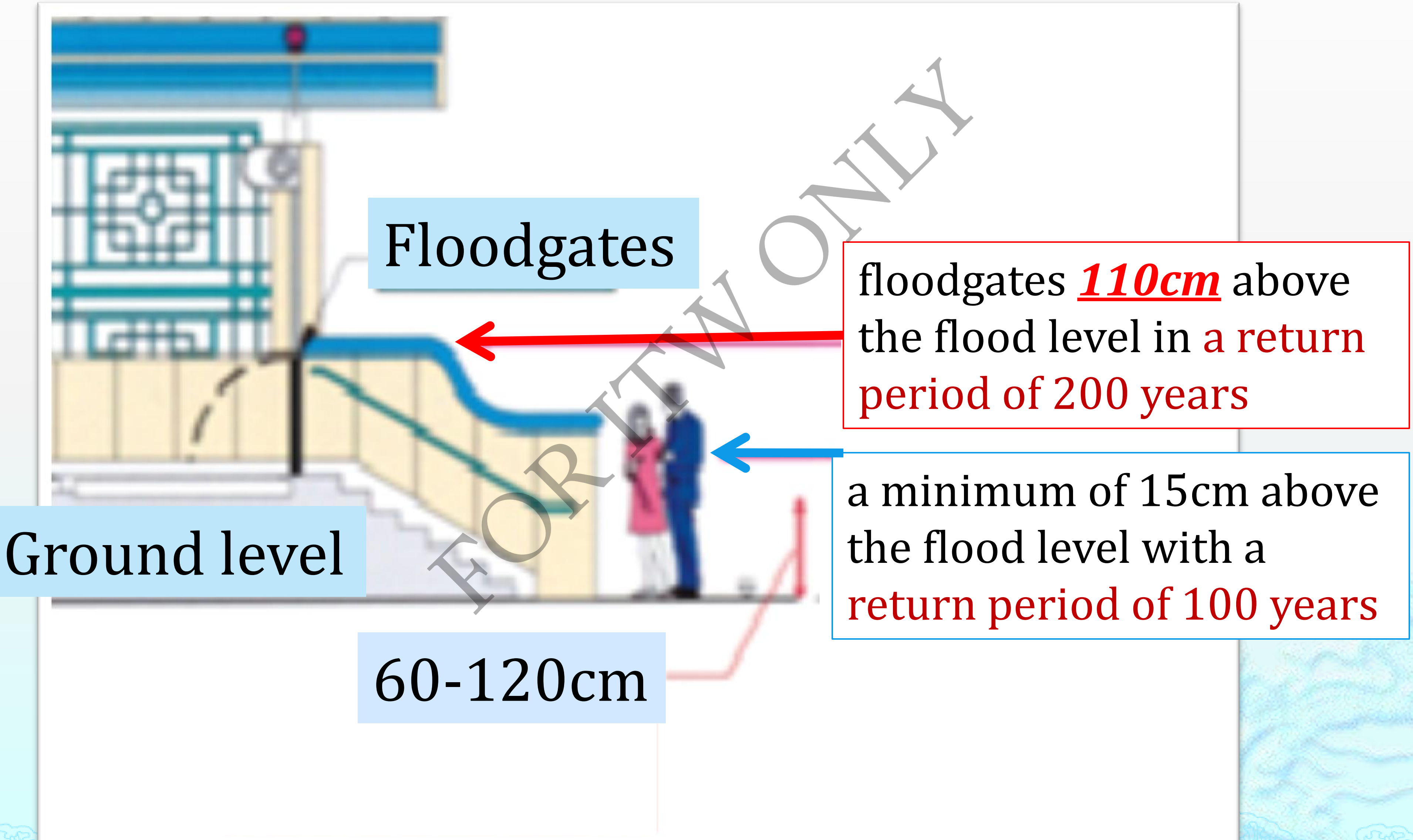
Upgrading Flood Protection Criteria

2. Watertight doors shall be considered for installation on sidewalks connecting to the Taipei MRT, in joint development buildings and at underground connections with other transportation facilities.
3. Gaps between vital mechanical & electrical facility rooms and conduits & pipes shall be filled with watertight materials.

Upgrading Flood Protection Criteria

4. Assessment of the installation of full dimension floodgates on the daylighting sections and interchange stations where interfaces with tunnels exist and on both sides where lines cross rivers and faults.
5. Existing flood prevention facilities shall be improved or floodgates shall be heightened at stations on the initial network, in accordance with the flooding height recorded during Typhoon Nari.

Upgrading Flood Protection Criteria



Thank You for your attention