



The 2013 International Training Workshop on Earth Sciences

Debris Flow Disaster Management in Taiwan

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1 November, 2013



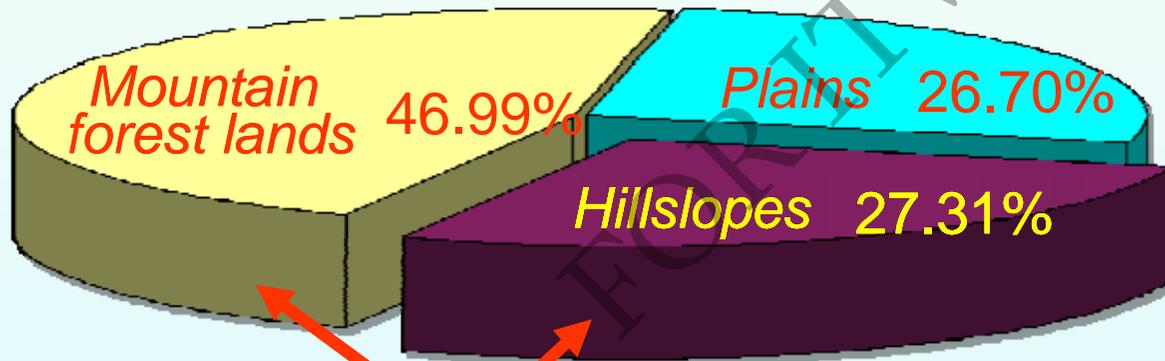
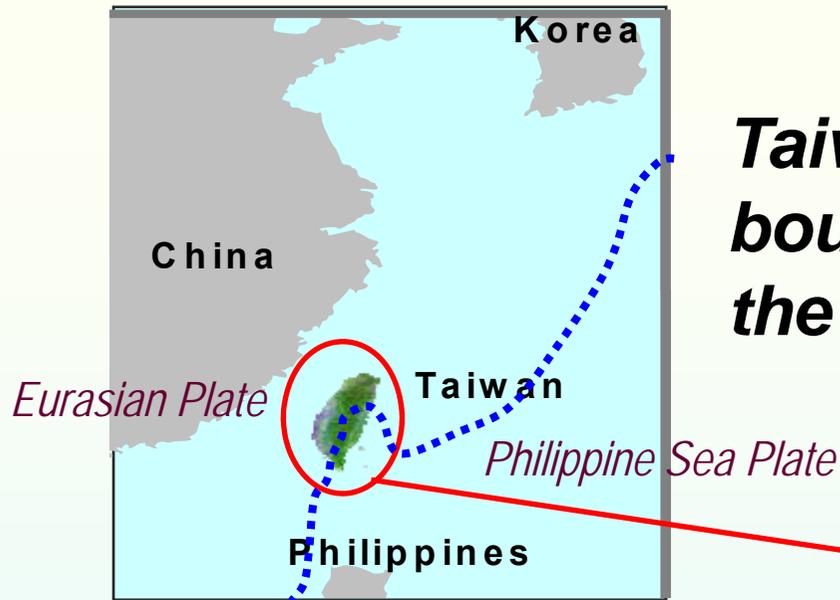
Outline

1. *Background Introduction*
2. *Debris Flow Disaster Management — Preparedness, Emergency response and Recovery*
3. *Challenges of Typhoon Morakot (2009) and Future Perspective*



Introduction

Taiwan is located at the convergent boundary of the Eurasian Plate and the Philippine Sea Plate.



Slopelands 73.30%

Land Resources Distribution





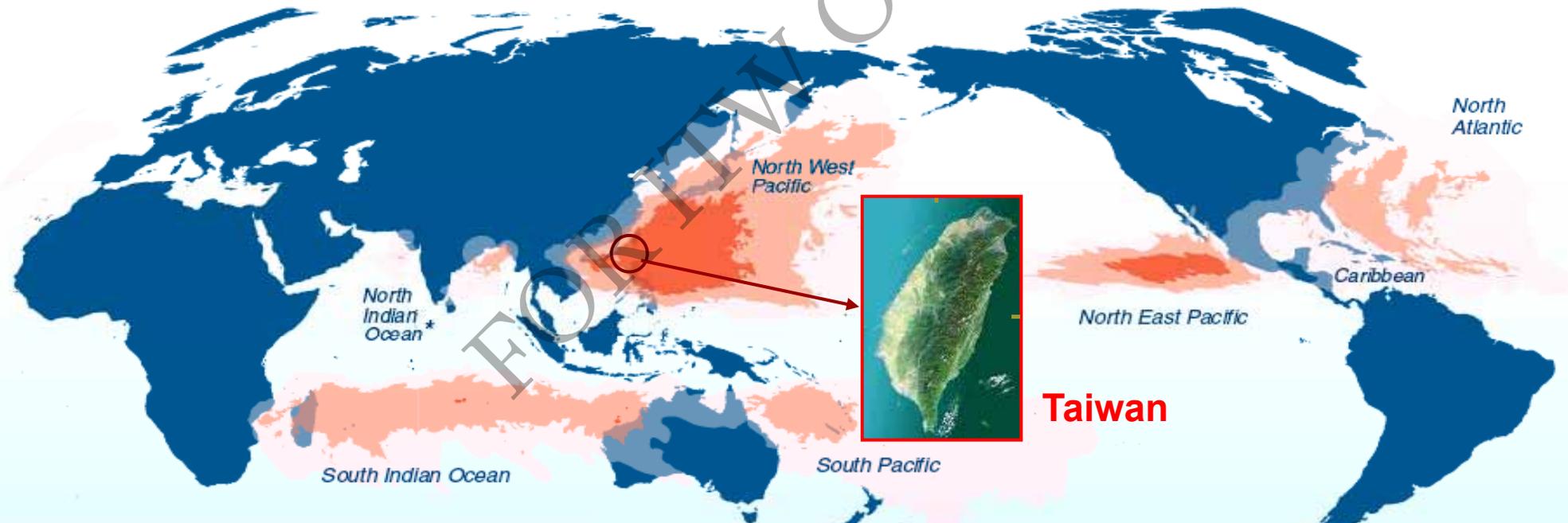
Climate Change Impact

- ◆ Temperature increases about **1.4** in the last 100 years (1901-2006).
- ◆ Number of typhoons per year increased dramatically after 2000.
From **N=3.2**(1951-2000) to **N=6.8** (2001-2009)

Tropical cyclone frequency

Average number of cyclones:
(1980-2000)

low moderate high



'Low' refers to less than one cyclone every three years per 0.002 dd², 'moderate' between one every three years to one every year per 0.002 dd² and 'high' to one to three cyclones per year per 0.002 dd². The unit '0.002 square decimal degree (dd²)' is equivalent to 25 km² on the equator, diminishing as latitude gets higher.

* average based on eight years only.

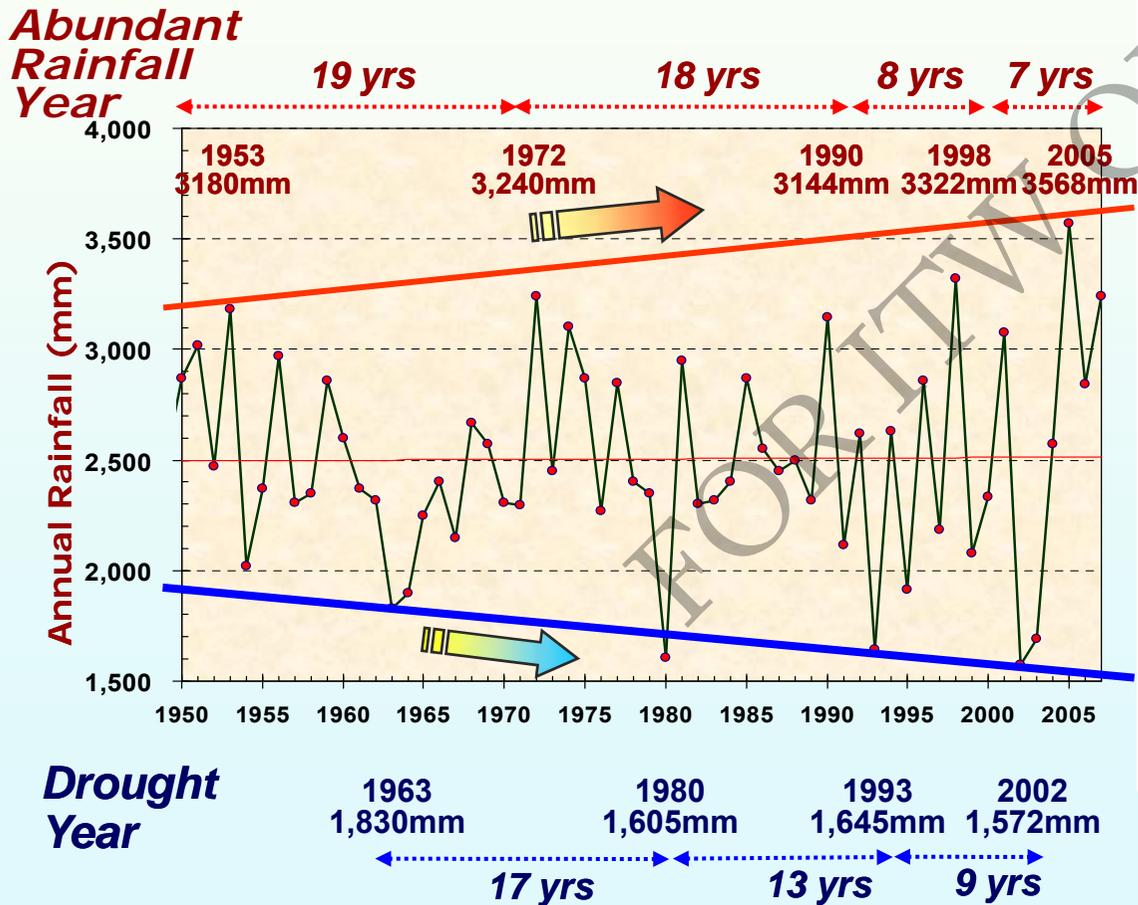
One of the regions suffered from typhoons

Sources: PREVIEW Global Cyclone Asymmetric Windspeed Profile, UNEP/GRID-Europe.

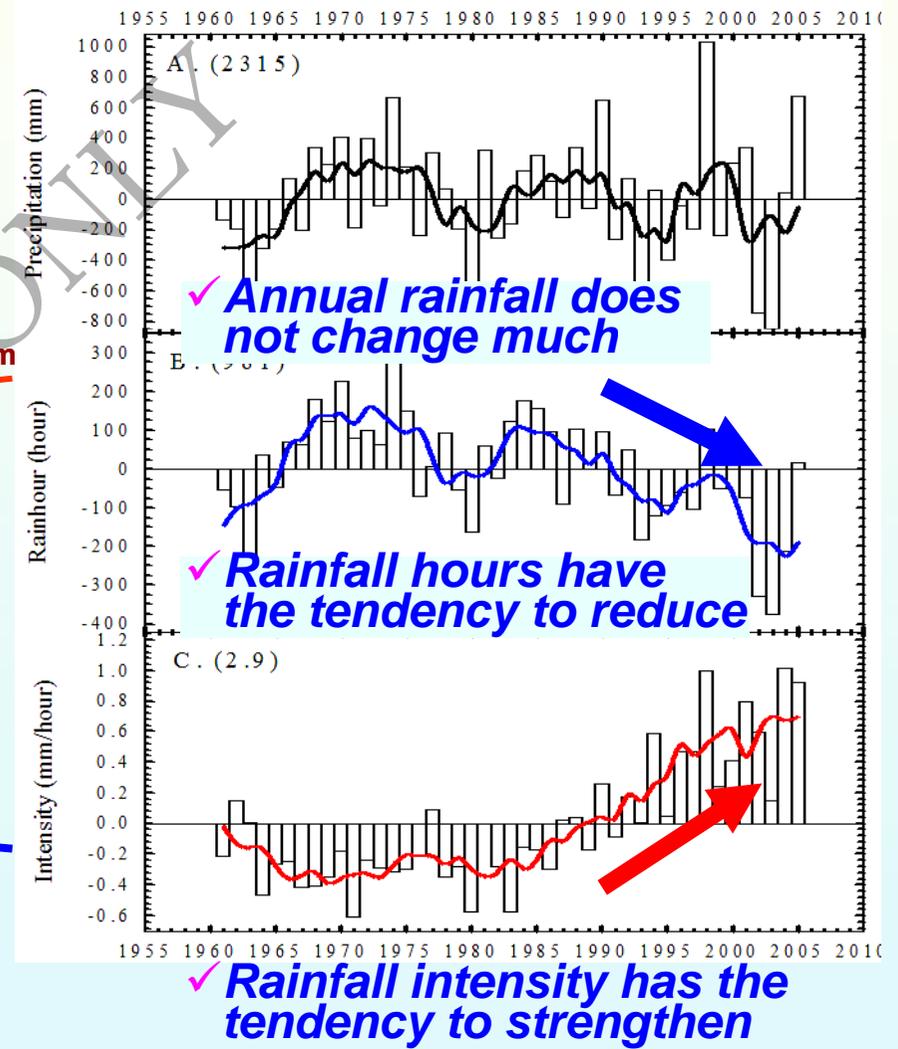


Variation of rainfall pattern of Taiwan in last 50 years

Significant change of rainfall and dry-rainy seasons increases the risk of watershed hazards.

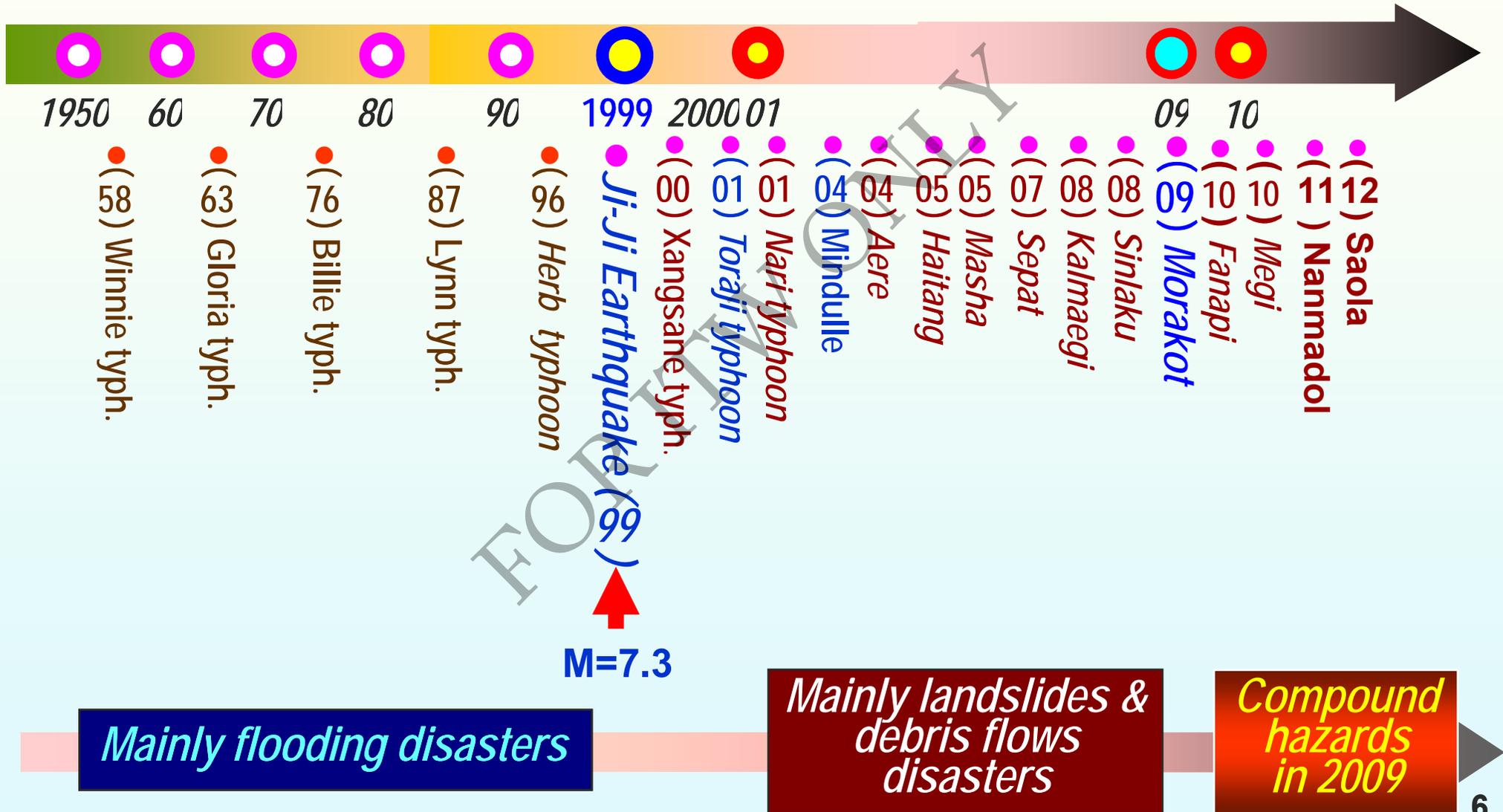


Annual rainfall of Taiwan in the past 50 years





Historic Typhoon Disasters in Taiwan





Soil and Water Conservation Bureau (SWCB)

1996-Herb

Debris Flow Disasters in Taiwan





2. Debris Flow Disaster Management — Preparedness, Emergency Response and Recovery

FOR ITIN ONLY



Source area
Landslides

Transportation part
Erosion effect

Deposition(fan) zone
Affected area

2011南瑪都颱風屏東
縣滿州鄉土石流災害



Hazard Assessment Procedures (NOAA-USGS)

Where?

(hazard mapping)

When?

(rainfall intensity-duration thresholds)

How big?

(volume or peak discharge)

How far?

(runout and inundation-area mapping)



Debris Flow Disaster Prevention Framework

1,664
Torrents

Potential debris flow torrents

Where?

Delineation of affected areas

How big (far)?

48,496
People

Inventory of protected targets

Feedback

Hardware

Software

Assessment

Engineering

Land use restrictions

Residential Relocation

Evacuation

When?

Disaster analysis

Zoning

Rainfall warning threshold

Feedback

Rainfall > Threshold

1. Prevent vulnerability factors
2. Mass energy transformation
3. Diversion
4. Suppression works
5. Restrain works

Delimitation
↓
Announcement
↓
Restriction

Location
↓
Coordination
↓
Relocation

Planning
Drill
Promotion

Warning

Evacuation

Disaster Info.



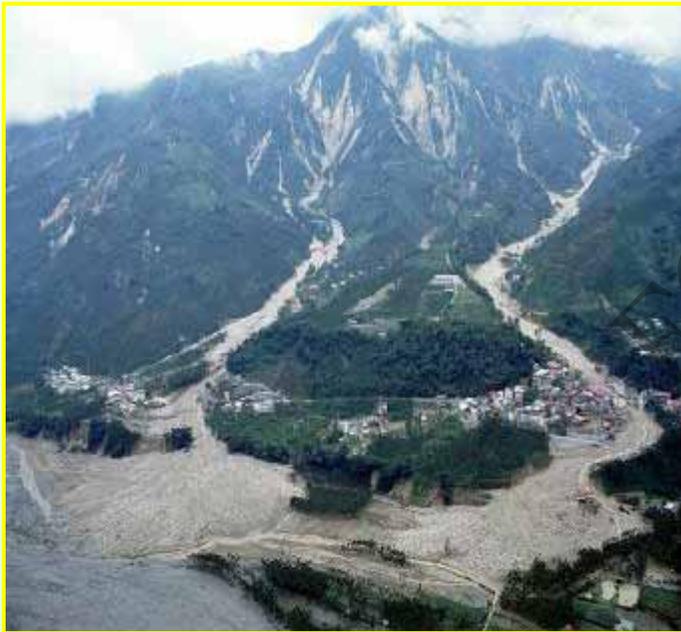
Investigation of Potential Debris Flow Torrents & Landslides

■ Potential Debris Flow Torrents

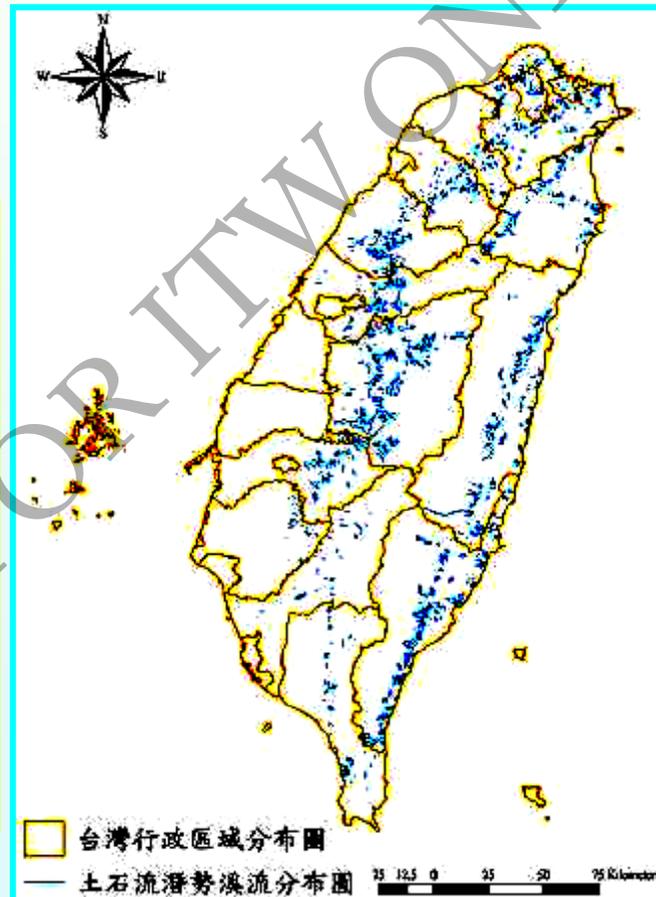
1,664 Torrents

■ Landslide Areas

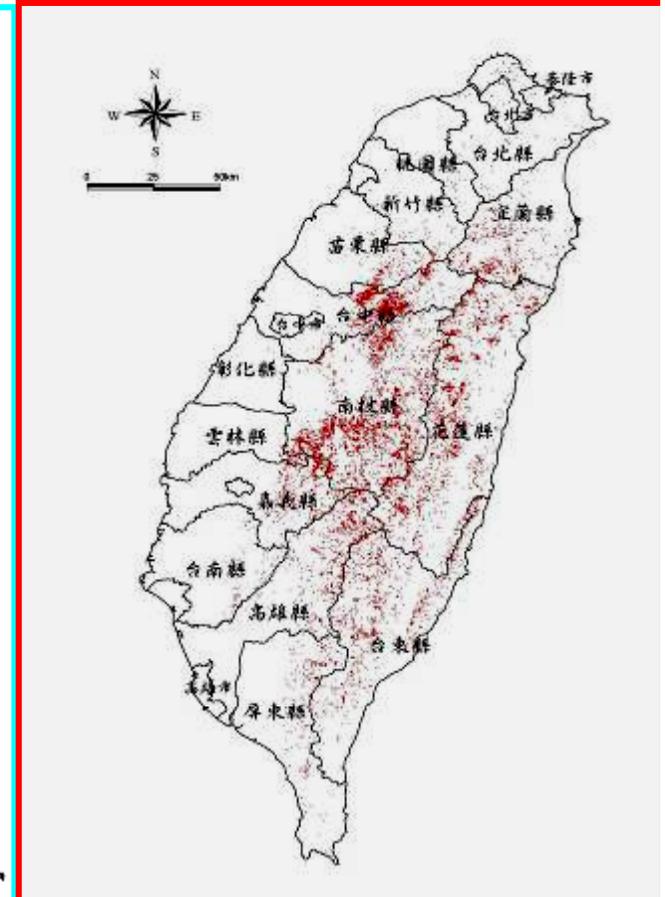
46,950 ha



Potential Debris Flow Torrents

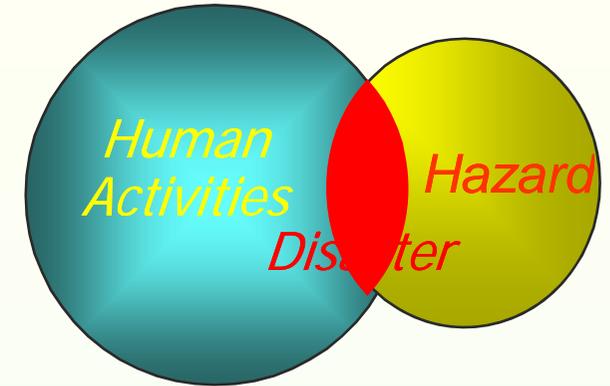


Historic Landslides Distribution





Investigation of Potential Debris Flow Torrents



Risk Degree=Probability X Assured Safety

Factors of Probability

- Valid watershed area : 3 ha before 921 earthquake(1999) adopted 10 ha
- Rock broken extent
- Length of fault, slope...
- Upstream collapse area

Assured Safety

- Protected Targets: houses, school, roads, publics, farms.....etc.
- Including 10° slope deposit range

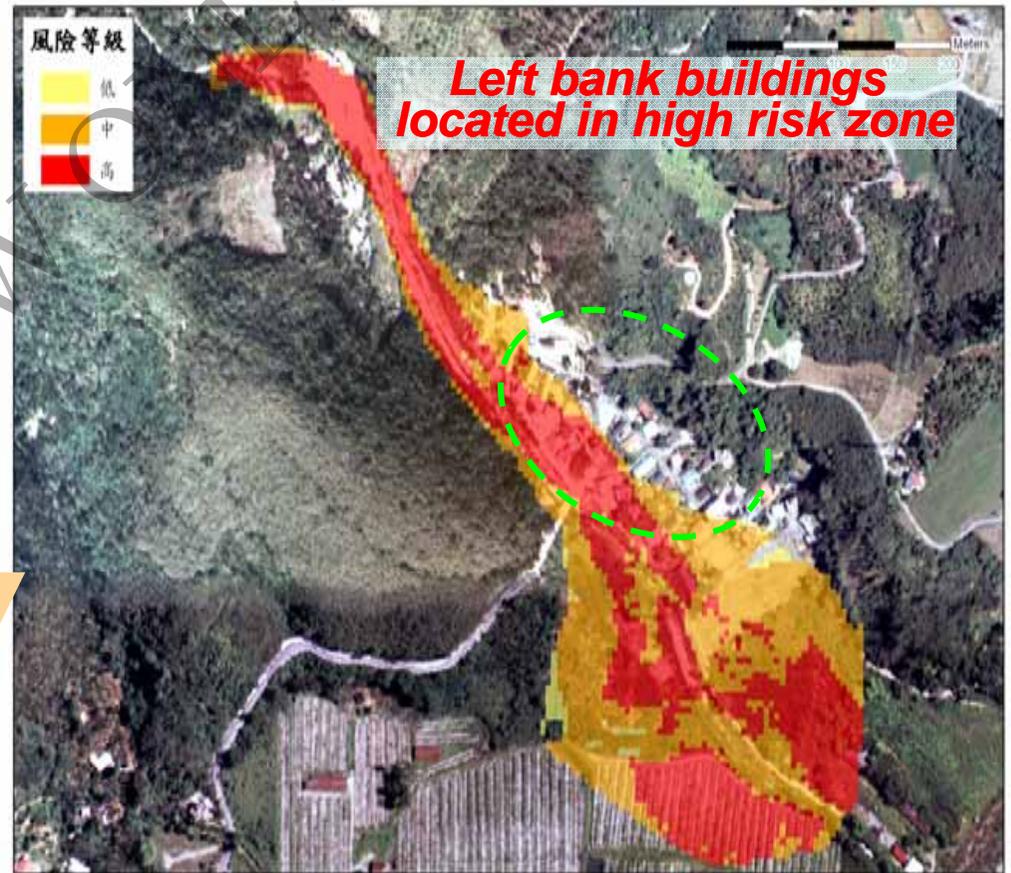
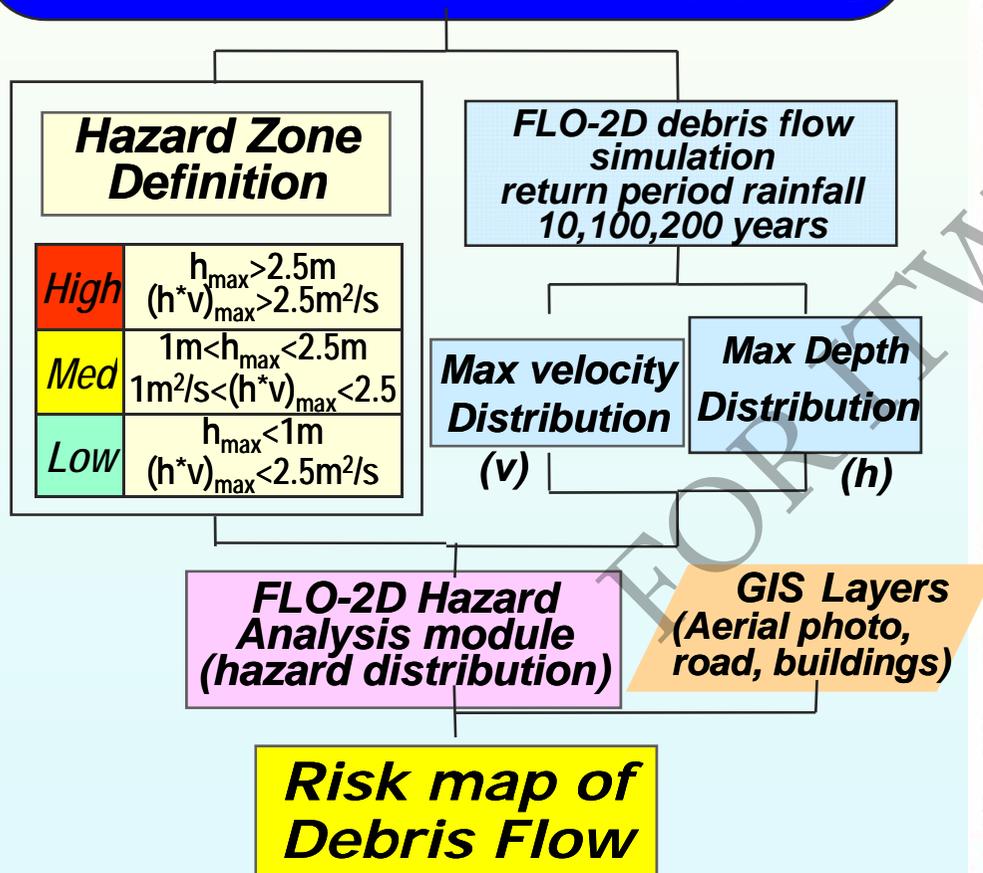
Risk		Probability		
		Low	Mid	High
Assured Safety	Low	Low	Low	High
	Mid	Low	Mid	High
	High	Mid	High	High



Risk Mapping

Warning Simulation of Debris Flow Disaster Condition

Debris Flow Risk Mapping





Localized Rainfall-based Debris-flow Warning Model

- **Rainfall Triggering Index (RTI)**
= Rainfall intensity \times Effective accumulative rainfall

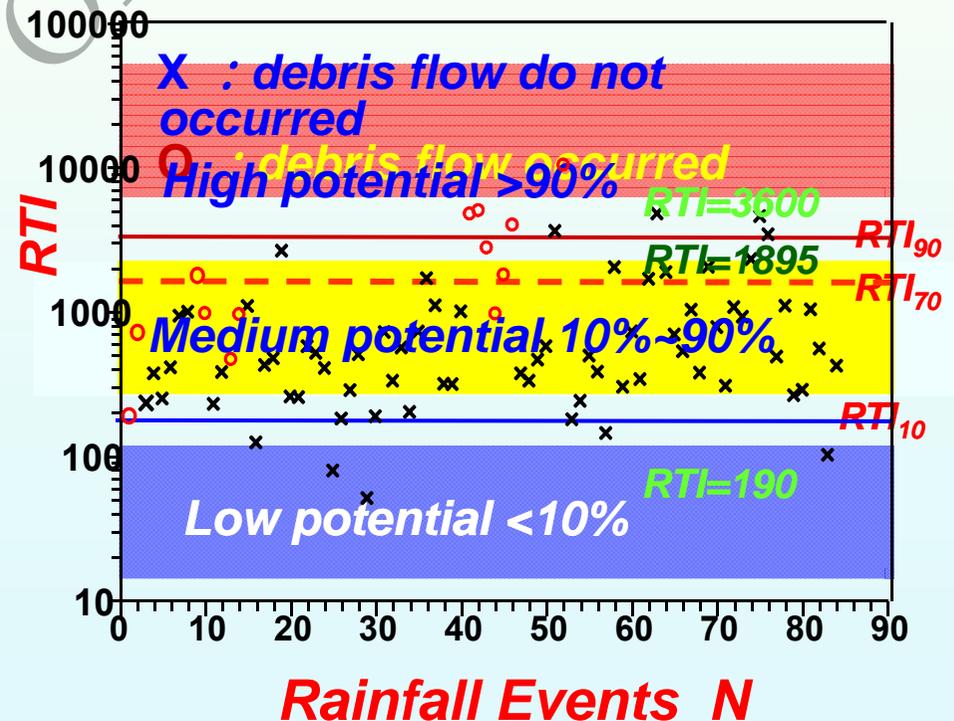
$$RTI = I \times R_t$$

R_t : Effective accumulative rainfall
= Accumulative rainfall
+ Preceding rainfall for 7 days

I : Rainfall intensity (mm/hr)

RTI_{70} : RTI at 70% of probability that debris flow occurred

- The critical accumulative rainfall for evacuation (R_c) is set for easier public understanding and local application





Does the public understand the warning model?

- ❖ *The answer is **NO**.*
- ❖ *People can understand the accumulated rainfall, but **do not** (do not want to) understand the rainfall intensity.*
- ❖ *Weather Bureau reports only the accumulated rainfall also.*
- ❖ ***More simplified model for the public is needed.***

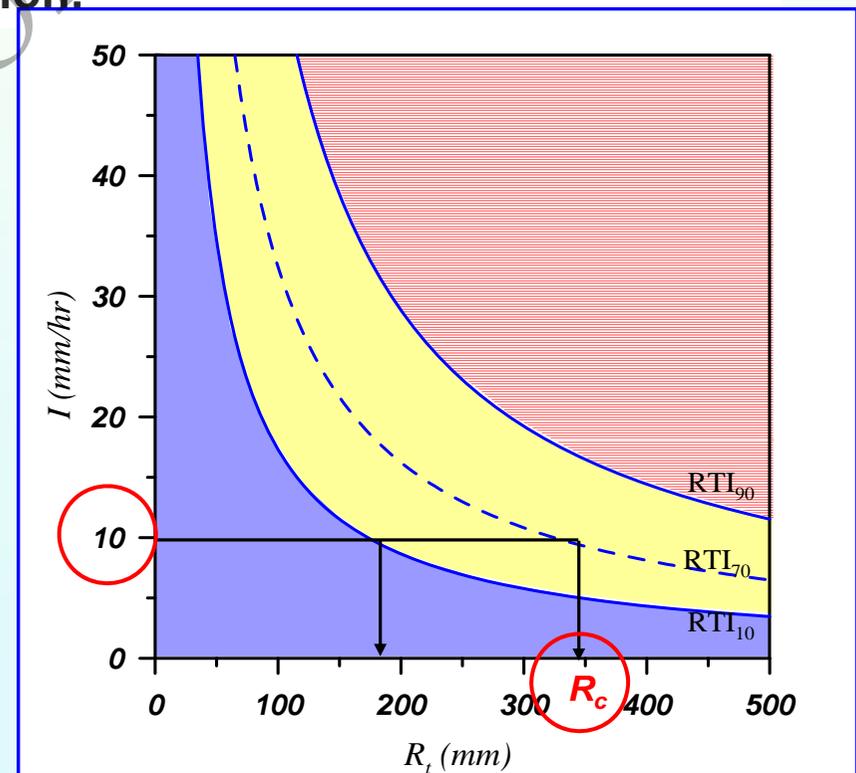


Simplified RTI model

The critical RTI-value involves two parameters (I and R) is too academic and not easy to understand for people living in mountainous areas.

The **critical accumulated rainfall (R_c)** is set for easier public understanding and application for evacuation.

R_c is estimated from the critical RTI-value with a consideration of **rainfall intensity of 10 mm/hr**, and rounded with 50mm as an interval of the critical accumulated rainfall. That is to say for different counties, R_c could be 200, 250, 300, 350, 400, 450, 500, 550, or 600 mm.





Warning criteria Table

Village and (N) : the numbers of debris flow torrents in the village

Rainfall station 2

Rainfall station 1

101年土石流警戒基準值明細表

101.02修訂

縣市	鄉鎮	警戒區範圍		土石流警戒基準值 (mm)	參考雨量站	
		警戒區座落村里 (土石流潛勢溪流總數)	土石流潛勢溪流數(條)		代表站1	代表站2
蘇澳鎮	新塢里(4)		4	500	南澳	東澳
	高建里(1)、永春里(2)、長安里(1)、永樂里(7)、蘇北里(1)、聖湖里(4)		16		蘇澳	冬山
三星鄉	集慶村(1)、拱照村(3)、天山村(1)		5	600	三星	寒溪

Township

Warning Criteria

Numbers of debris flow torrents in township



Announcement of Debris Flow Warning in Taiwan

■ **Rainfall Threshold for Debris Flow Warning : 200 600mm**

Predict Rainfall > Threshold

Real Rainfall > Threshold

-30hr.

-18hr.

-12hr.

Accumulative rainfall



Rainfall forecast

Advise Evacuation

Enforce Evacuation

Local government should Advise the inhabitant to evacuate.

Local government should Enforce the evacuation of inhabitants.



Soil and Water Conservation Bureau (SWCB)

Debris Flow Emergency Operation Task Force of SWCB

Toll-free Hotline



0800-246-246

Emergency Response during Typhoon

- Typhoon: Real-time weather condition
 - Rainfall monitoring: Every 10 min
 - Announce: **Debris flow warning**
- Debris flow information system**

<http://246.swcb.gov.tw/>

<http://246eng.swcb.gov.tw/> (English version)



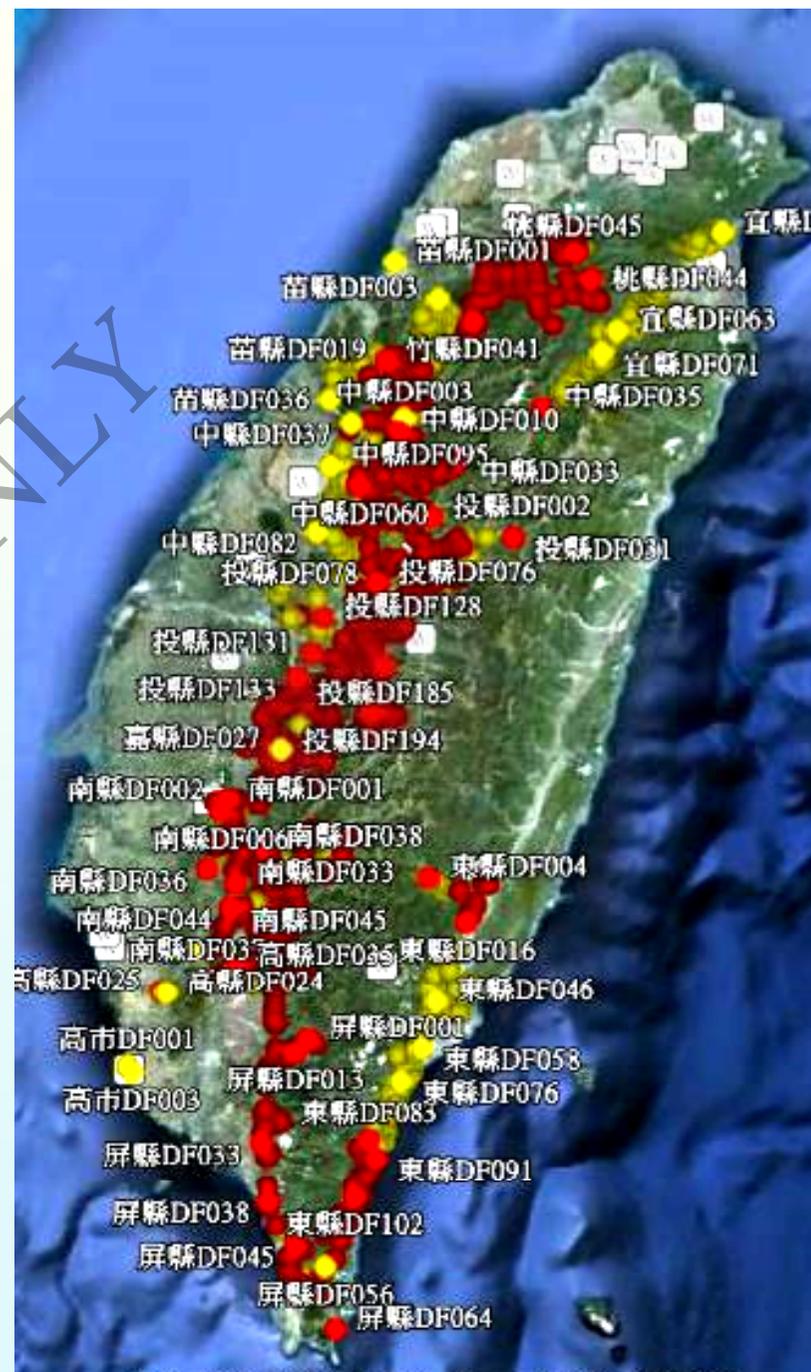


Debris Flow Warning and Evacuation

- ◆ During the typhoon Morakot period, the SWCB had issued **21 debris flow warnings** to the public and local governments based on the real-time weather information from CWB.

Debris flow warning	Warning ravines	County (City)	Town	Village
Red alarm	519	12	61	230
Yellow alarm	338	14	58	163

9,100 people were evacuated by local governments according to the warning. Among them, **1,046 people** escaped from the possible casualties.





Soil and Water Conservation Bureau (SWCB)

17 On-site and 3 mobile debris flow monitoring station

Monitoring Sensors



Rain gauge



CCD camera
Spotlight



Ultrasonic water
level meter



Wire sensor



Geophone

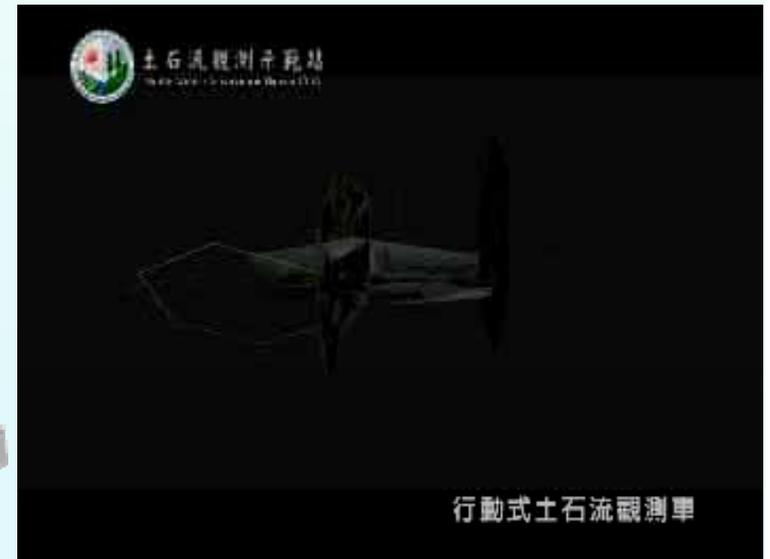
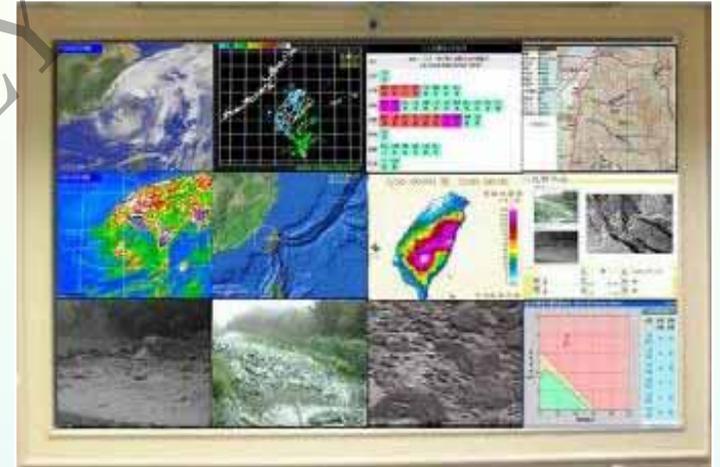
Satellite Transmission



Instrumental cabin

Information Display

<http://246.swcb.gov.tw>



行動式土石流觀測車



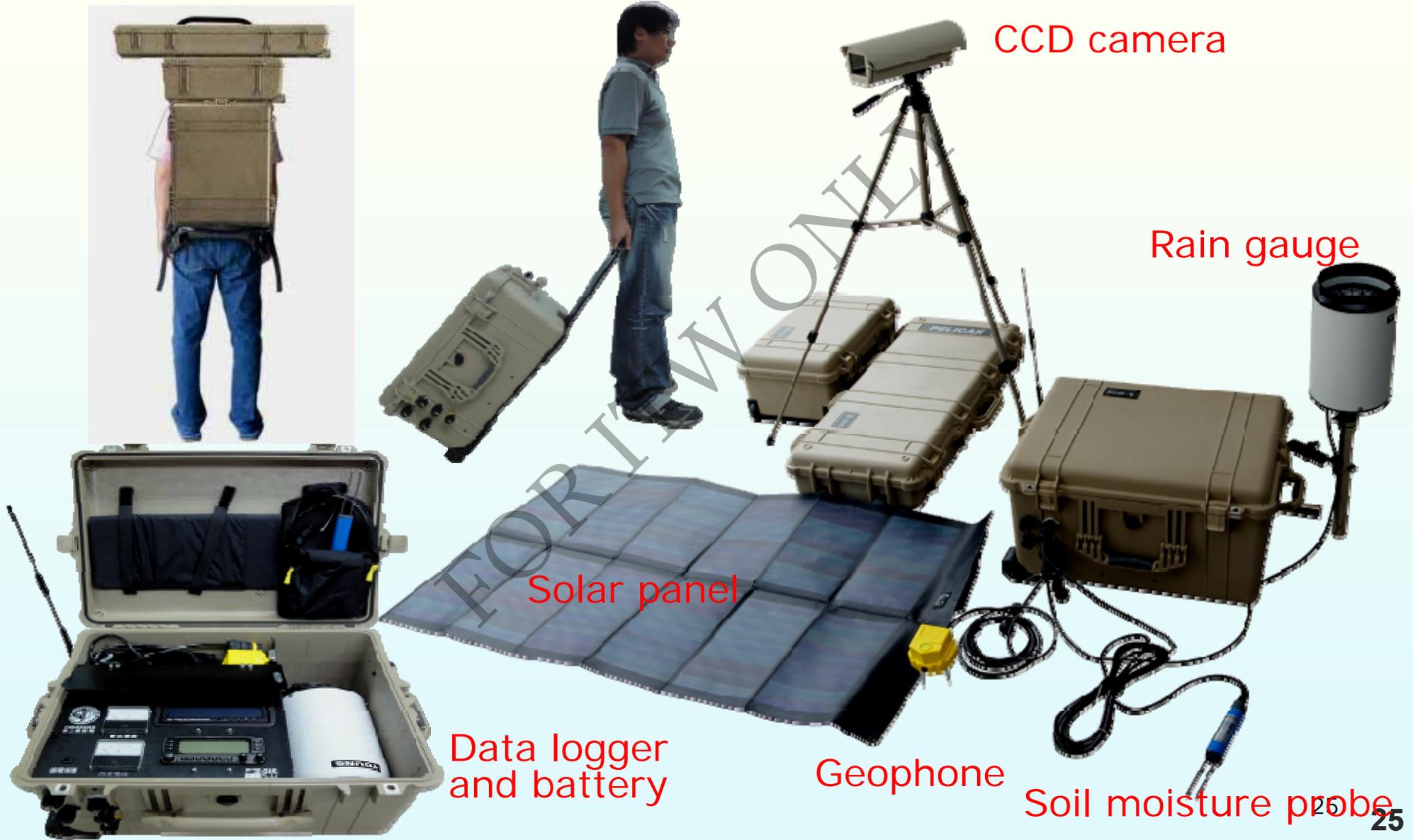
Soil and Water Conservation Bureau (SWCB)

Evolution of mobile station





14 Grid debris flow monitoring station (since 2010)



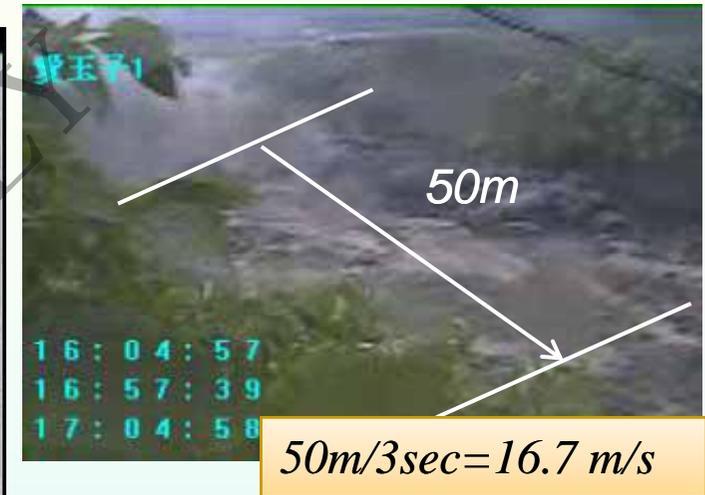


Typhoon Morakot, Aug. 8, 2009

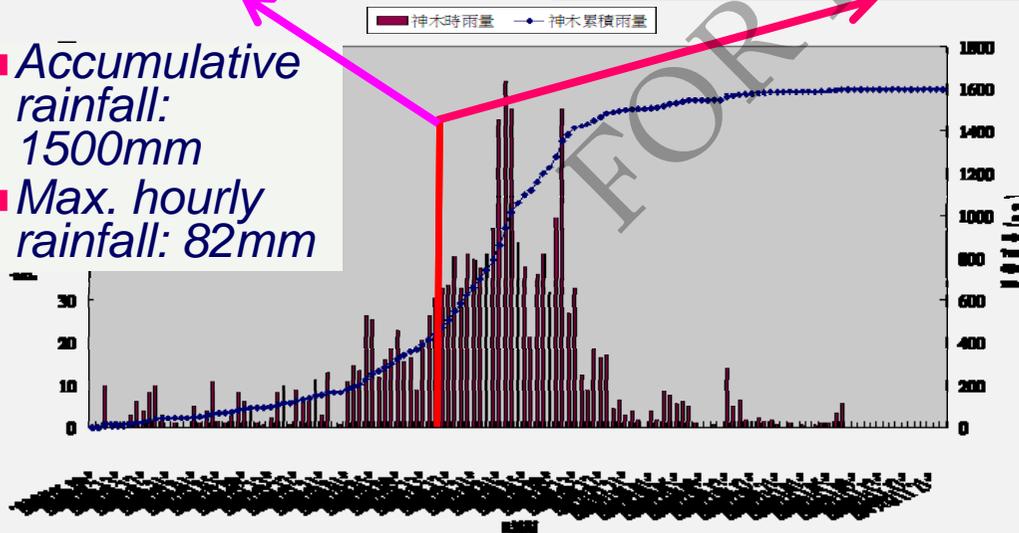
CCD image (front view)
downstream

CCD image (side view)
upper stream

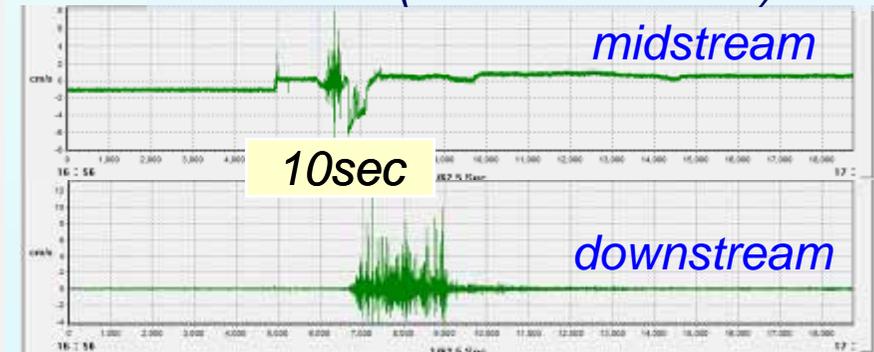
Velocity



- Accumulative rainfall: 1500mm
- Max. hourly rainfall: 82mm



- Geophone signal after wavelet transform (8/8 16:56~17:00)



$173m / 10sec = 17m/s$



Debris flows disasters after typhoon Morakot, 2009

Vertical incision



Lateral (bank) erosion



Aiyuzih creek

Deposition of debris



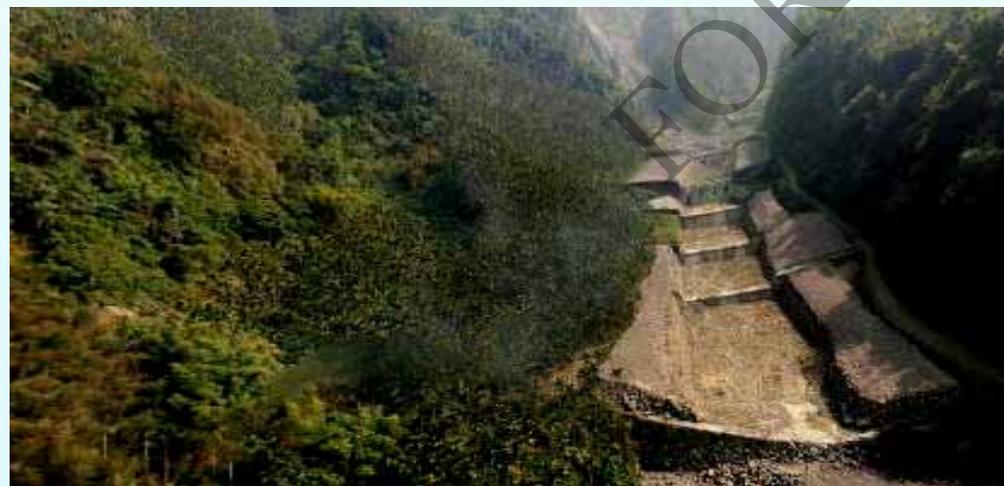


Unmanned Aerial Vehicle (UAV) to Collect and Analyze Disaster Information

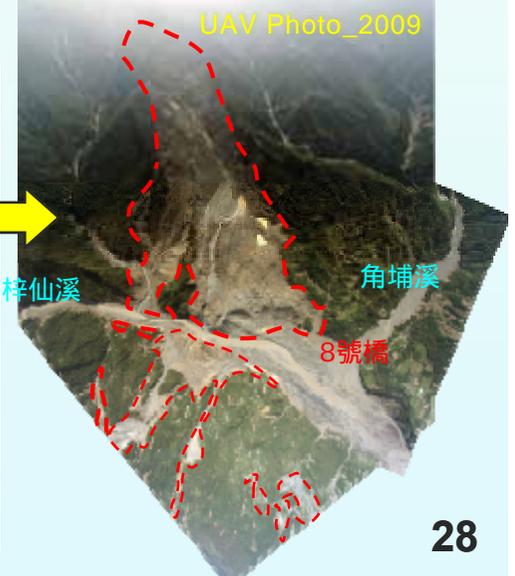
UAV	Photo System	Monitor System	Wave System



UAV Video Data



Aerial Photo_2001



UAV Photo_2009



Landslide Changing from UAV Images **(Upstream area of Aiyuzih creek)**

1996



2009



Debris Flow Disaster in Taitung County

Landslide area : 8 ha

Accumulative rainfall
1,383 mm

Rainfall threshold of
warning 350 mm

Maximum rainfall
intensity 100 mm/hr

Sediments 300,000 m³

15 houses buried

Engineering Construction Design



Artificial Vegetation Recovery

Debris Flow Monitoring station

Slit dam

Check dam

Sedimentation pond

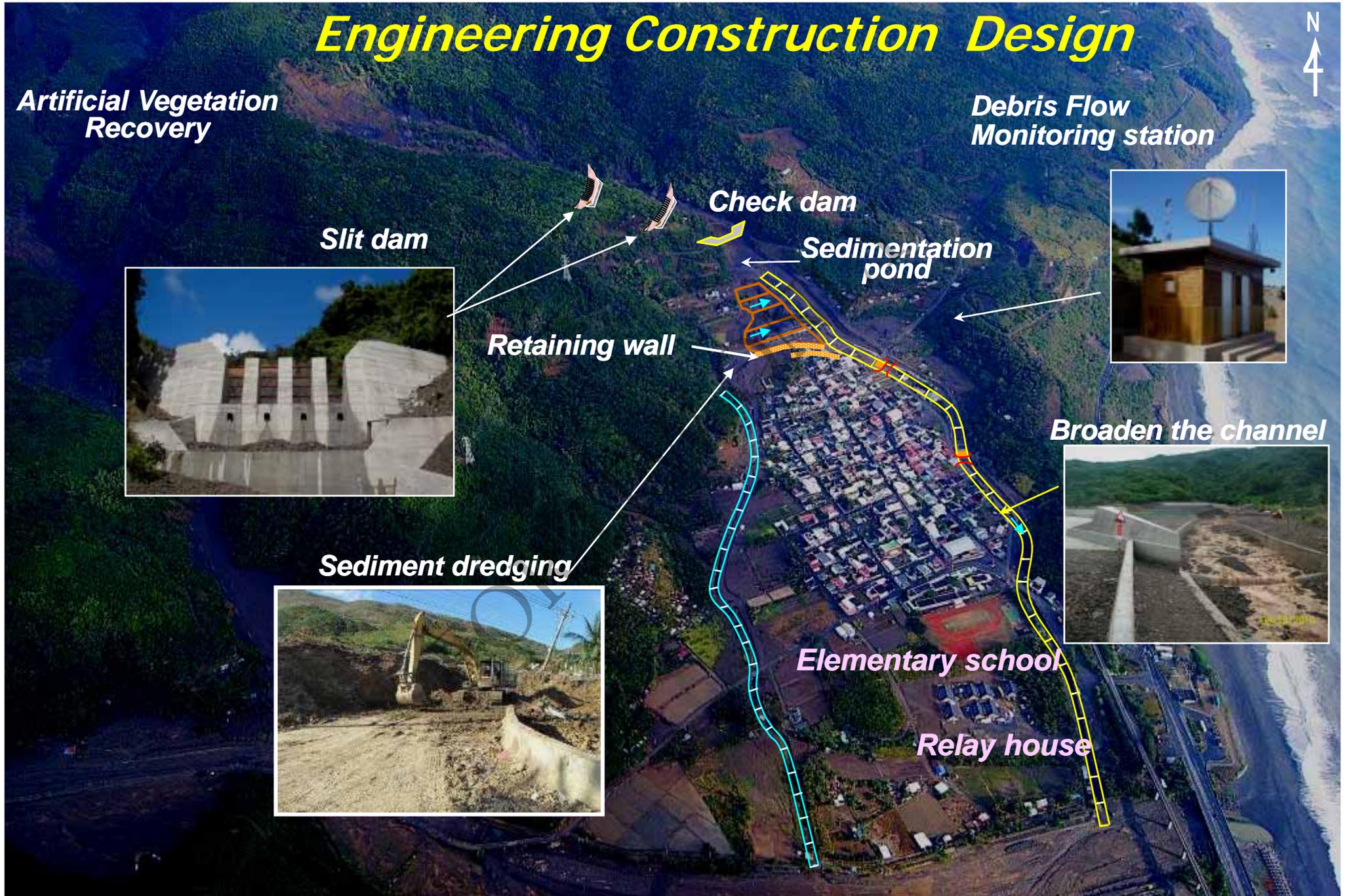
Retaining wall

Broaden the channel

Sediment dredging

Elementary school

Relay house





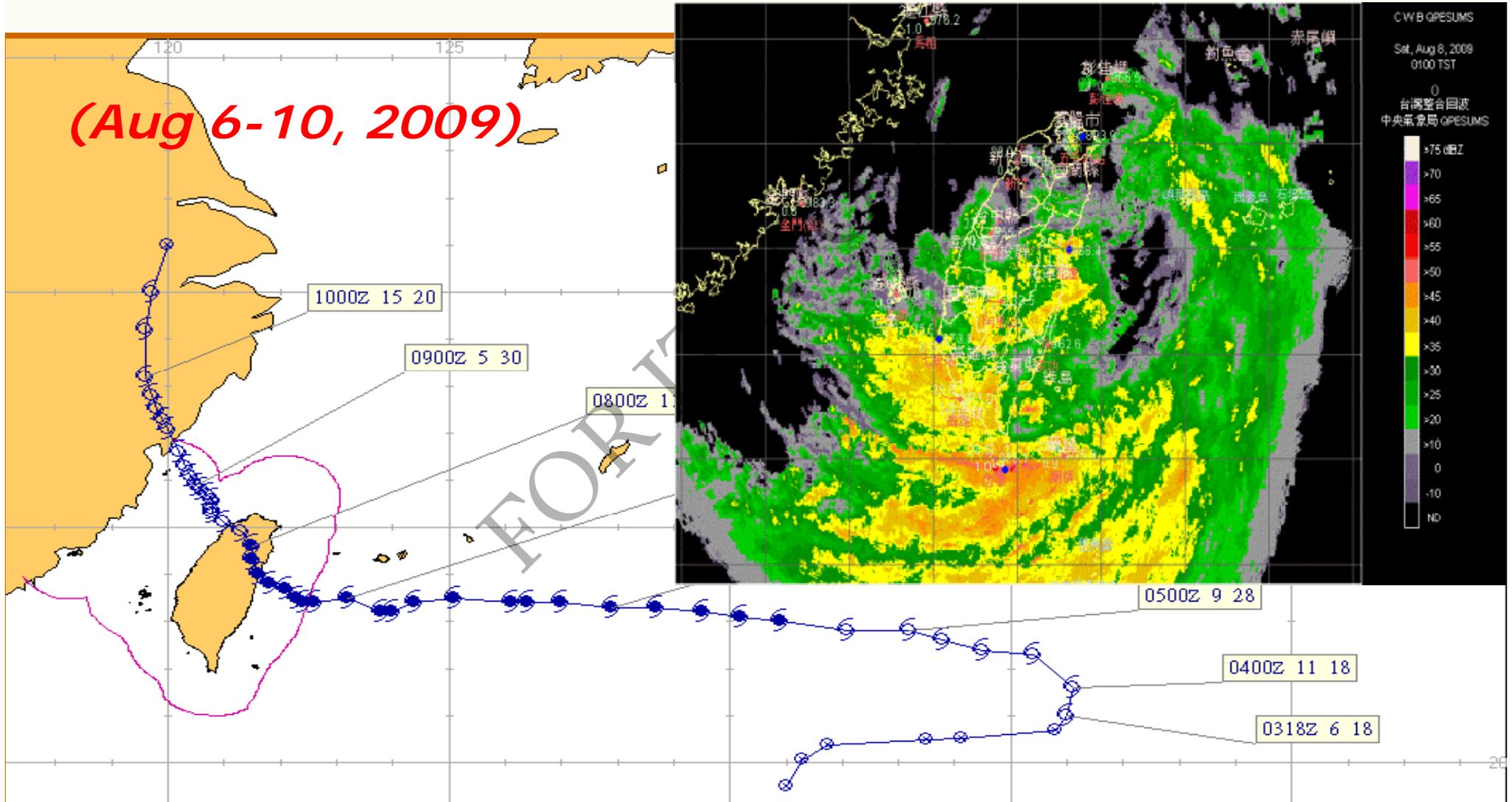
3. Challenges of Typhoon Morakot (2009) and Future Perspective

FOR ITW ONLY



Typhoon Morakot, 2009

Typhoon Route and Radar Echo Image





Damage of Calamity Caused by Typhoon Morakot (Aug 6-10, 2009)

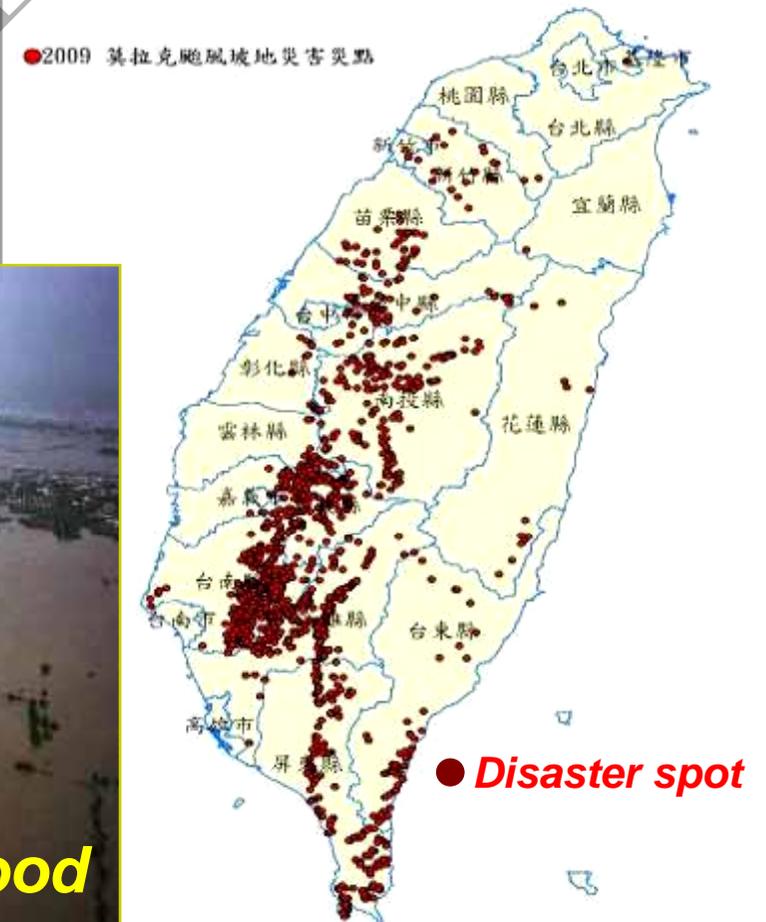
- Max. accumulative rainfall (Aug 6-10, 2009): **3059.5mm**.
- Coverage area of total rainfall 2000mm: **320,000km²**.
- Total new landslides: **39,492 ha**.
- Evacuate and withdraw: **24,950 people**.
- Casualty and missing: **757 people**.
- Total damage: **6.7 billion USD(1.6% GDP)**



Landslide



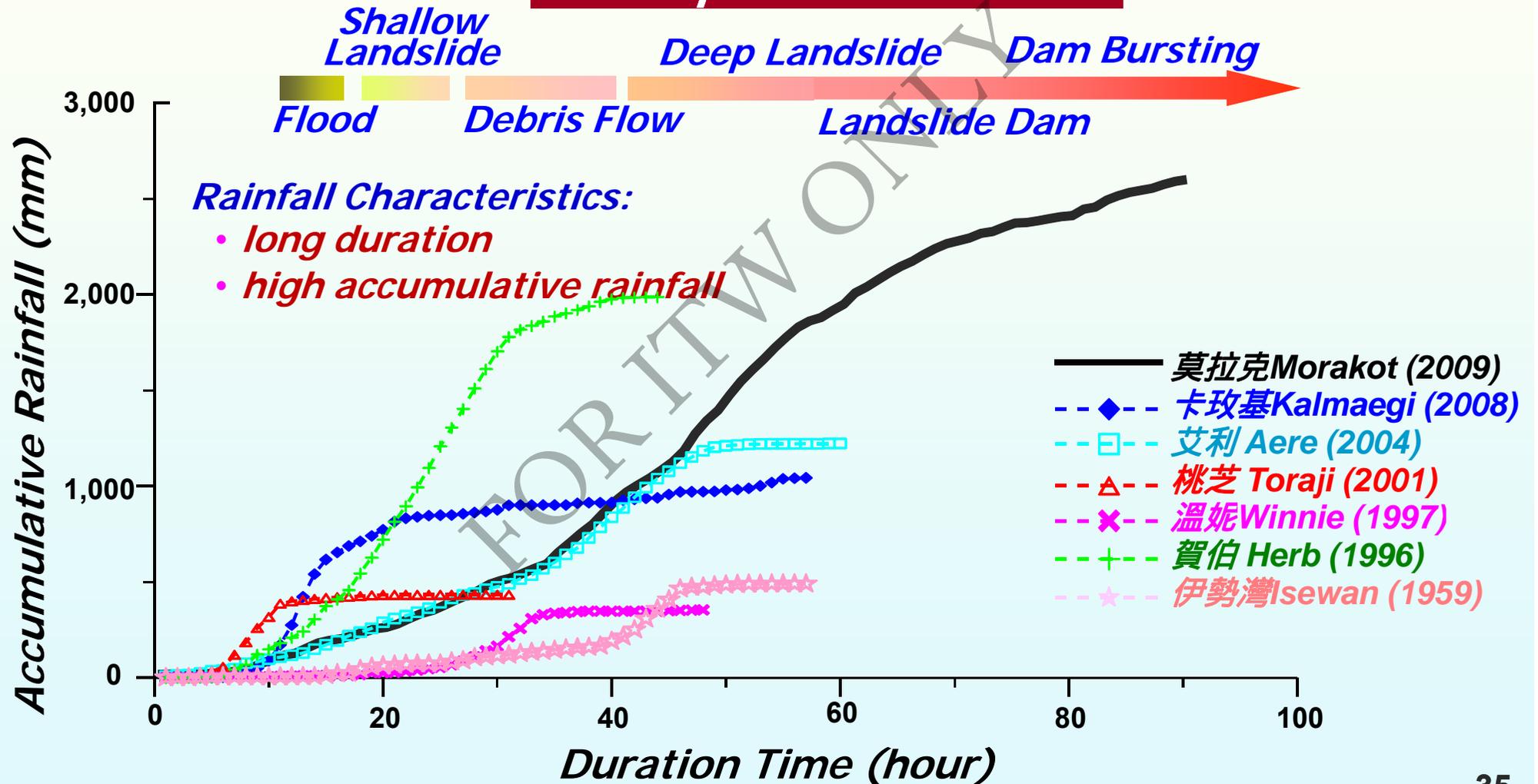
Flood





Rainfall-Duration Curve between the Morakot & Historic Typhoons

Compound Hazards





Soil and Water Conservation Bureau (SWCB)

Compound Hazards Occurred Simultaneously

✓ **Compound hazards**
at Hsiaolin Village, Chia-sien,
Kaohsiung County:

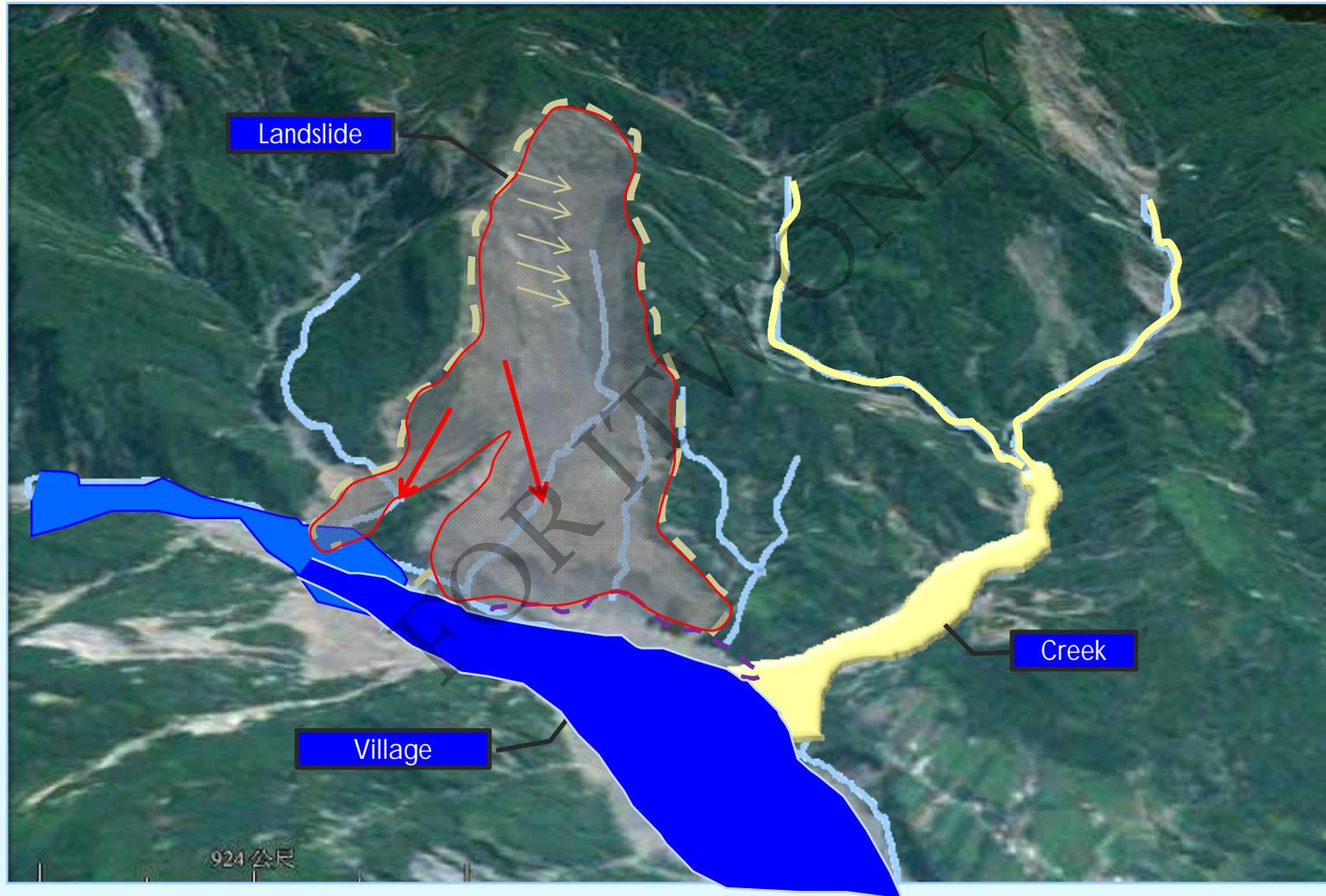
- ↪ **Flooding**
- ↪ **Shallow landslide**
- ↪ **Debris flow**
- ↪ **Deep-seated landslide**
- ↪ **Landslide barrier dam**
- ↪ **Dam breach**

- **Dead and missing: 457 people**
- **Accumulative rainfall: 2,076mm**
- **landslide coverage area: 350 ha**
- **Sediment yield of Landslide: $25 \times 10^6 \text{m}^3$**





Sequence of compound disasters in Hsiaolin village



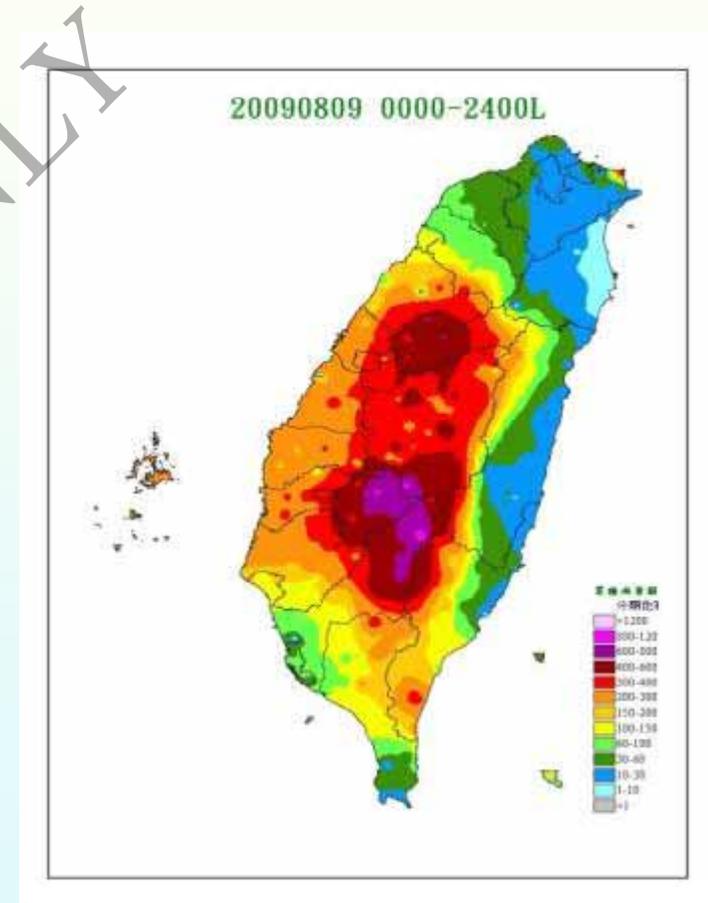


Should extreme rainfall of Morakot be considered as a normal or a extreme weather event ?

✓ *Extreme Rainfall Characteristics of Morakot*

- ◆ *Basin-wide coverage*
- ◆ *High intensity*
- ◆ *Long duration*

- *The max rainfall of Typhoon Morakot were Max 24-hr (1583mm) and 48-hr (2361mm). That rainfall approached to world records (48-hr 2467mm, 1958).*
- *The 24-hr rainfall in Kaoping River Basin was over the expectation of 200-yr return period.*



Total Rainfall Map of Typhoon Morakot, 8/6-8/9, 2009

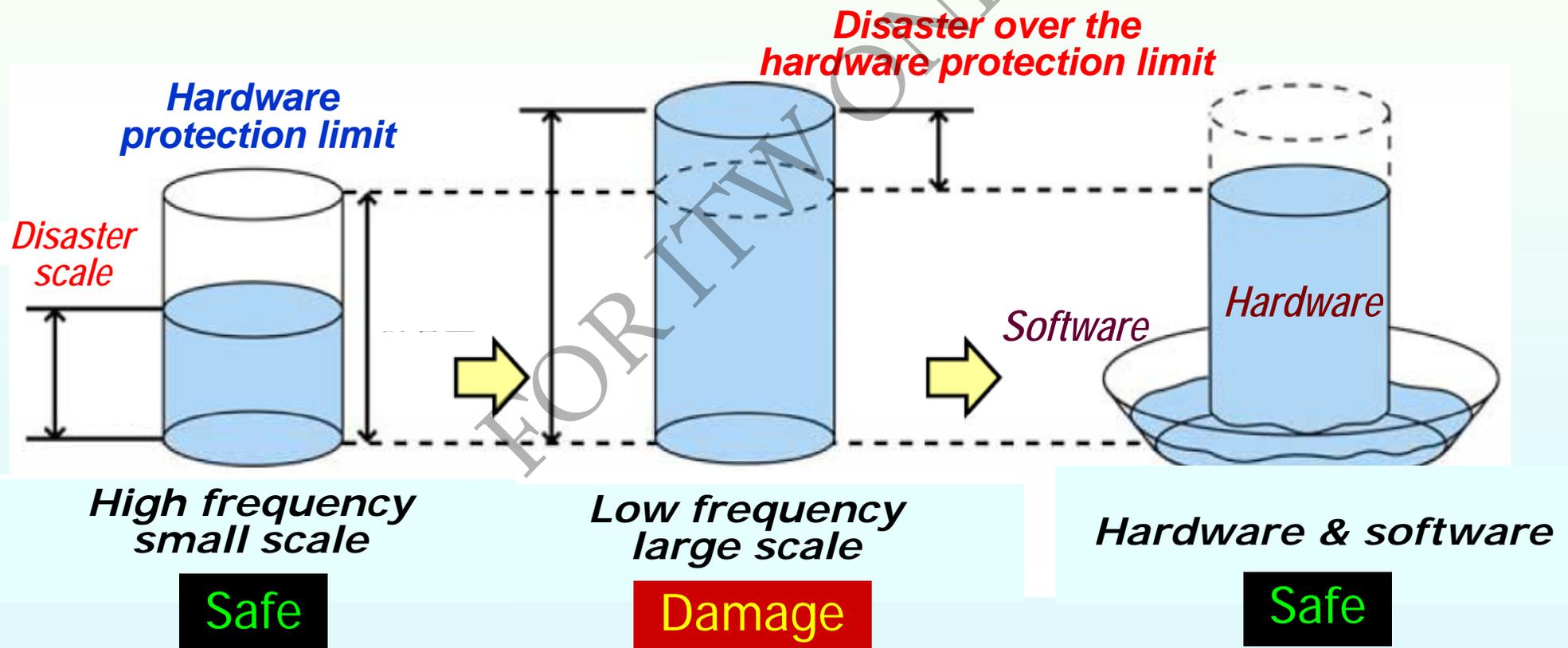
Does the slit dam work?





Integration of Software and Hardware

- Under climate change impact, strategy of disaster precaution should be considered from hardware to software.
- Non-engineering measures should combine with mitigation works.





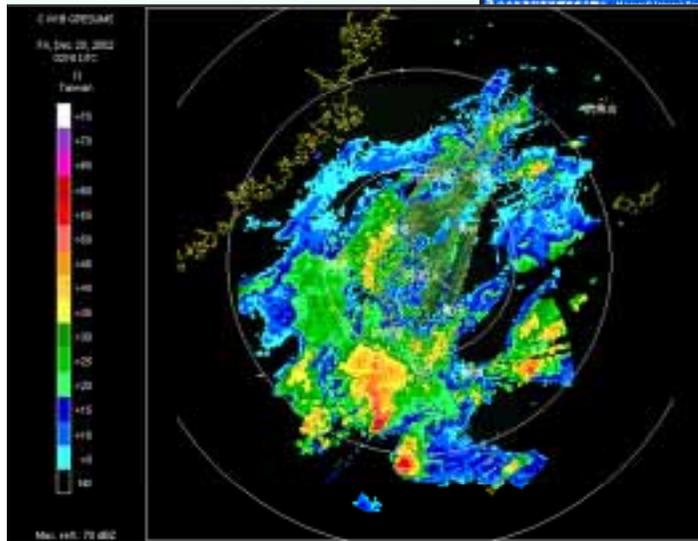
Apply QPESUMS for Rainfall Estimate

- ◆ Forecast 1 and 3 hour rainfall
- ◆ Data analysis: compute the rainfall value in the villages and rainfall stations
- ◆ Assess the timing of warning declaration

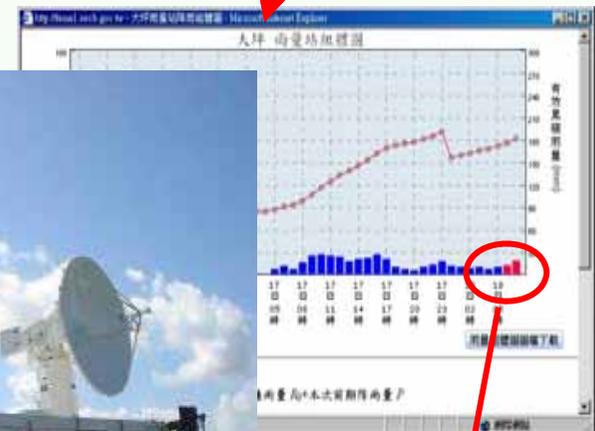
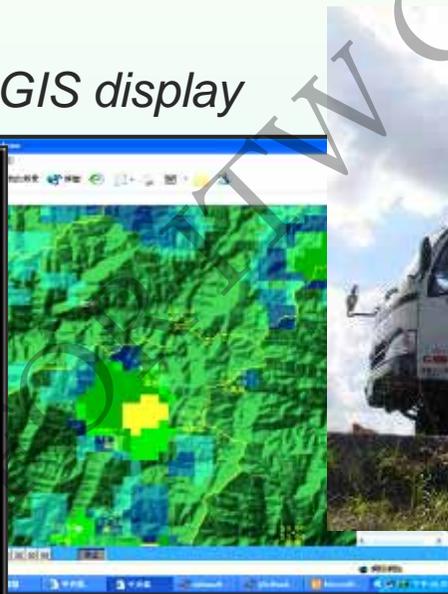
Enhance warning accuracy

Cooperation with NOAA, Water Resources Agency & Central Weather Bureau

GIS display



Spatial resolution : 1.3km
Time resolution : 10min



Forecast





App of Debris Flow Disaster Prevention Information

iOS
Android



雨量資訊

全部 10分鐘 單位:mm

1	台北市內湖區	碧湖國小	21.0
2	台北市信義區	信義	18.5
3	台北市內湖區	內湖	18.0
4	台北市南港區	南港	17.5
5	台北市中山區	大直	15.5
6	台北市中正區	中正橋	12.0
7	台北市士林區	士林	12.0
8	台北市大安區	公館	11.0
9	新北市汐止區	五指山	11.0

雨量

雨量資訊

彩色 - 台灣

累積雨量 - 大間距

6/28 00:00 ~ 6/28 15:00

累積雨量圖 (mm)

WSAT2 紅外線實圖 6/28 15:30

土石流警戒資訊

宜蘭縣	▲	無	▲	無	大粗坑	新北市	↑
基隆市	▲	無	▲	無	蘇澳	桃園縣	↑
台北市	▲	無	▲	無	下田埔	新竹縣	↑
新北市	▲	無	▲	無	玉峰	新竹縣	↑
桃園縣	▲	無	▲	無	白布帆	苗栗縣	↑
新竹市	▲	無	▲	無	松鶴	台中市	↑
新竹縣	▲	無	▲	無	豐丘	南投縣	↑
苗栗縣	▲	無	▲	無	郡坑	南投縣	↑

輪播全部觀測站影像

雷薩溪 CCD

10分鐘雨量: 0.0 mm
時雨量: 0.0 mm
6小時雨量: 9.0 mm
24小時雨量: 38.5 mm
單日累積雨量: 9.5 mm
土石流警戒基準值: 250 mm

土石流防災資訊-民眾版

北屯區

大井港

田寮湖

番仔坑

半天嶺

羊箕湖

橫坑巷

北坑巷

三崎

太平區

雨量站站名: 大坑

地區: 台中市北屯區

十分鐘雨量: 0.0 mm

一小時雨量: 0.0 mm

三小時雨量: 0.0 mm

六小時雨量: 0.0 mm

12小時雨量: 0.0 mm

24小時雨量: 0.0 mm

本日雨量: 0.0 mm

預測一小時雨量: nm 1

預測二小時雨量: nm 0

預測三小時雨量: nm 0

座標: 24.1936,120.813

地址: 新社鄉協成村興義街219號

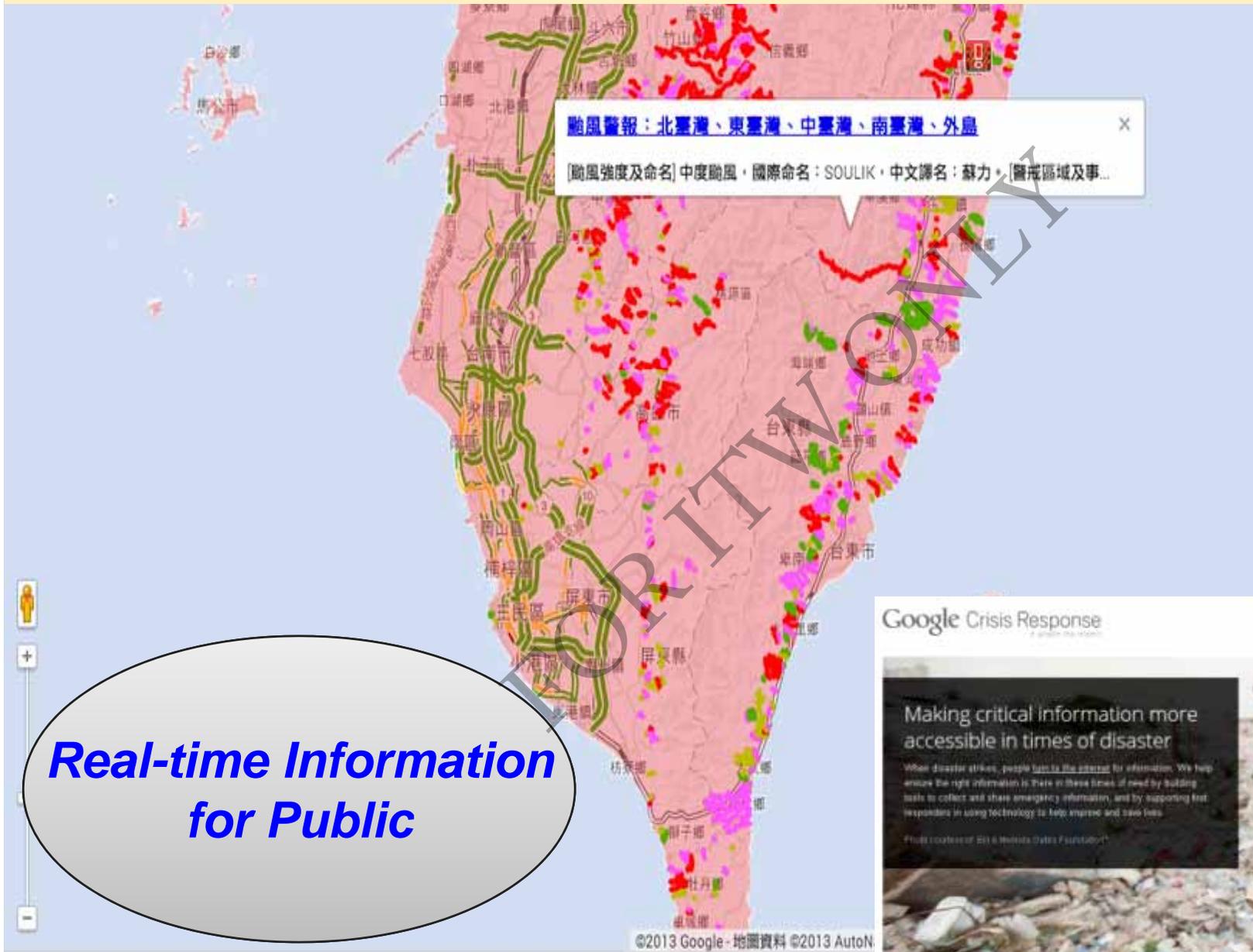
電話: 04-25813437

容納人數: 200

目前定位點: 24.181664,120.648541

直線距離: 約 16762 公尺

Application of Google Crisis Response

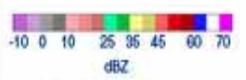


Real-time Information for Public

臺灣防災地圖

發佈者：Google Inc.

圖例



資料來源：中央氣象局 (CWB)
上次更新時間：下午4:05 (20分鐘前)

災害示警
資料來源：中央氣象局、水土保持局、及水利署，並透過Google.org的災害示警發佈

公路封閉
Highway closures
資料來源：公路總局 (DGH)

災害性封閉

預警性封閉
縮放至區域大小 · 下載 KML 檔

圖例

 道路預警性封閉

土石流警戒(含疏散避難路線圖&避難處所)

Google Crisis Response

HOME RESPONSE EFFORTS FOR RESPONDERS FAQ

Making critical information more accessible in times of disaster

When disaster strikes, people turn to the internet for information. We help ensure the right information is there in these times of need by building tools to collect and share emergency information, and by supporting first responders in using technology to help respond and save lives.

Photo courtesy of UN & Humanitarian Foundation





華山

Integration of Debris Flow Disaster Mitigation & Rural Regeneration in Hua-shan, Ku-keng, Yunlin

The name of **“Hometown of Taiwan Coffee”** spreads all over the whole country.

Typhoon Nari, 2001



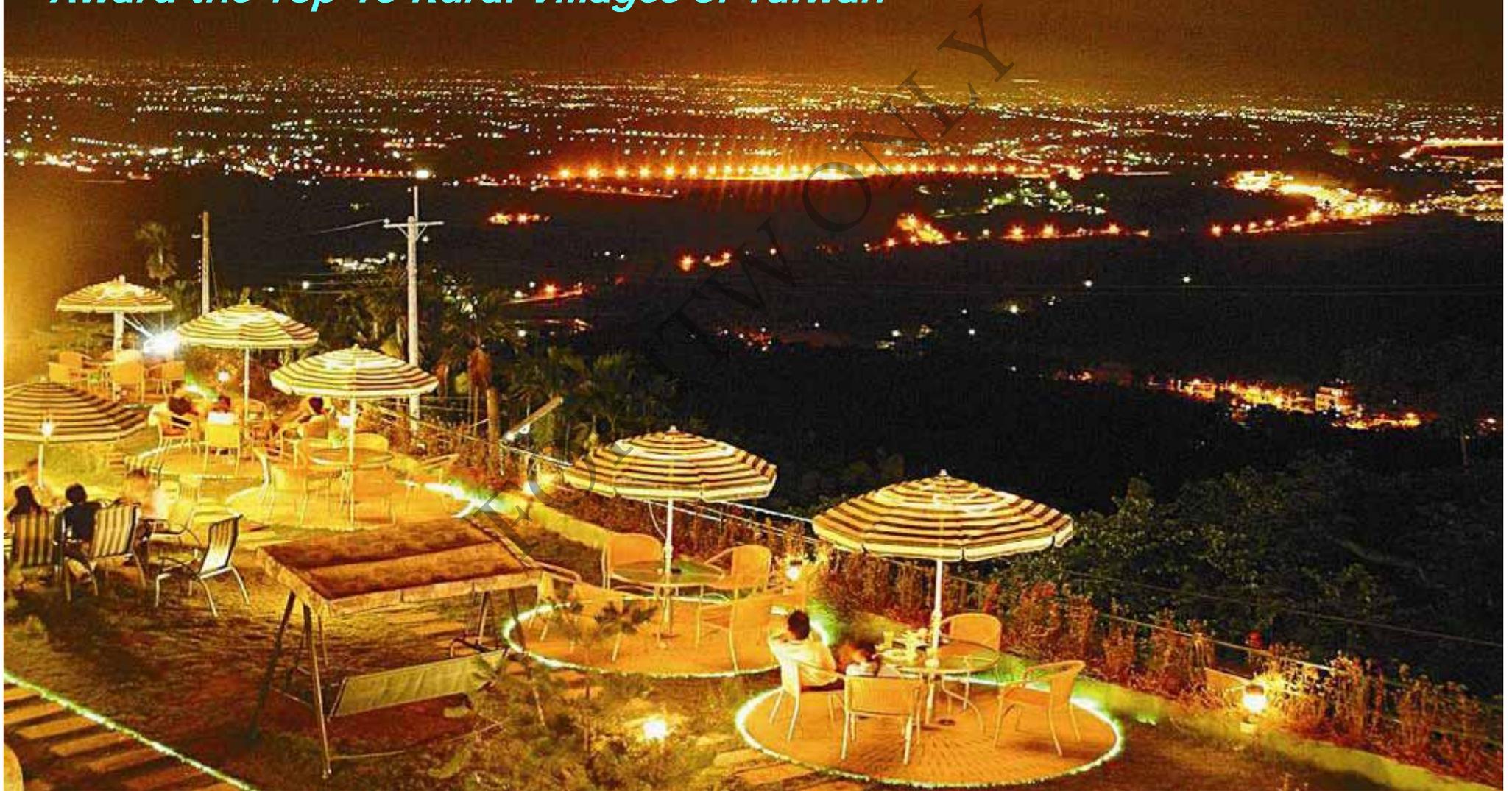
A news report about 2006 Coffee Festival in Hua-shan

Debris flow monitoring

After treatment

華山經典農村

Award the Top 10 Rural Villages of Taiwan

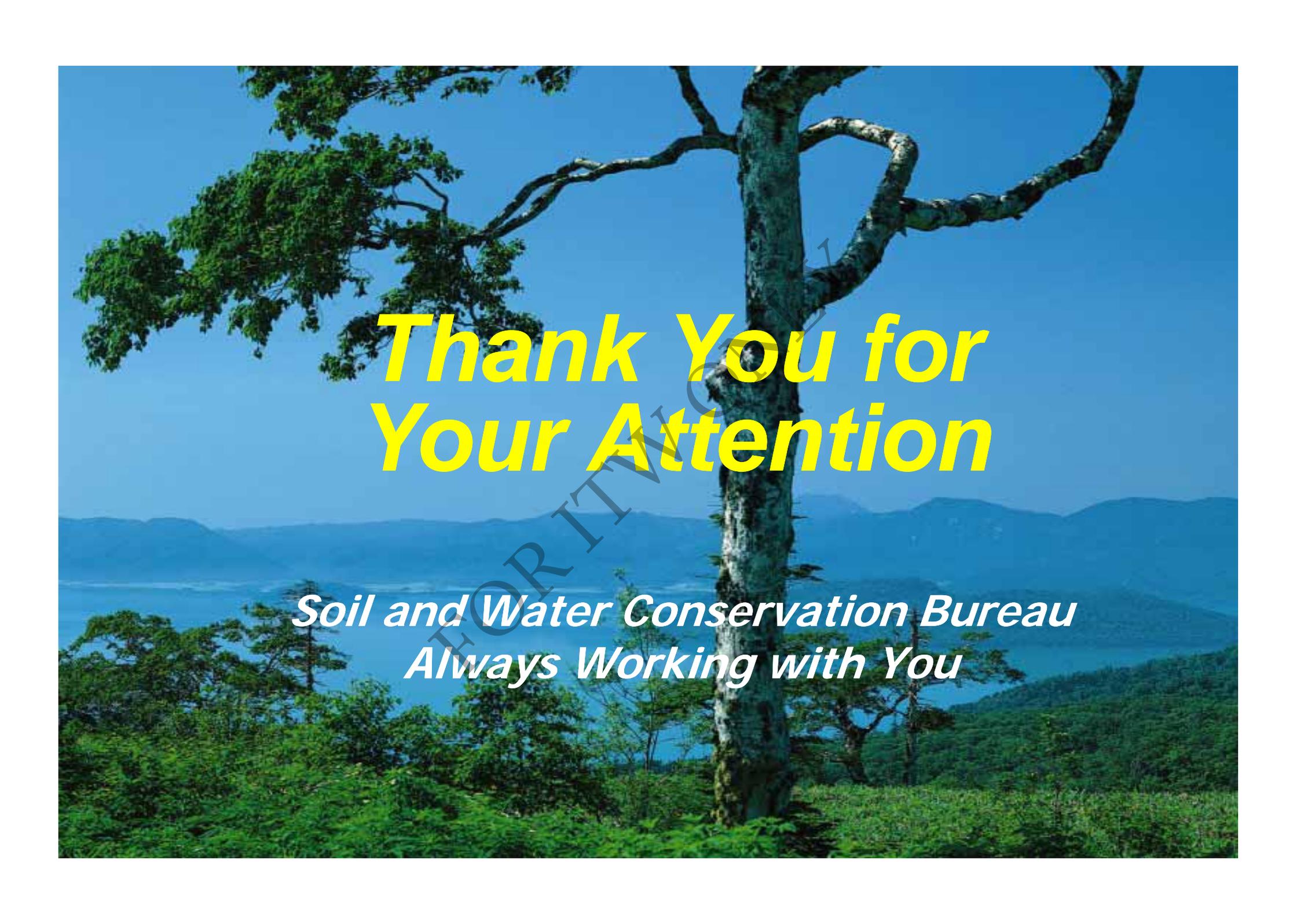




Future Perspective for Natural Disaster Management

- T.H.I.N.K -

- ❖ *Technology* : Research, development and practice.
- ❖ *Human management* : Improve people's awareness of precaution against disaster.
- ❖ *Investigation* : Investigate the potential locations to cope with disasters.
- ❖ *Notice* : Accurately control possible occurring time and give a declaration.
- ❖ *Knowledge* : Information and database as well as expert decision- making system.



***Thank You for
Your Attention***

***Soil and Water Conservation Bureau
Always Working with You***