

WARNING SYSTEM IN THE PHILIPPINES FOR SHALLOW TRANSLATIONAL AND DEEP SEATED-LANDSLIDES



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Department of Science and Technology (DOST)



Web-based Landslide Warning System for shallow translational Landslides

Operational Landslide Warning System in Japan

Prefectural government and meteorological observatory (JMA) cooperated to **issue early warning information in 2006** using Ground Radar and RBFN methodology.

Prefectural government

- Surveying landslide hazard area
- Setting rainfall criteria for giving an early warning

Local meteorological observatory

- Rainfall observation
- Providing meteorological information through medias

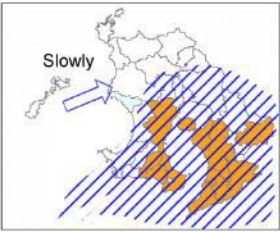
Sediment disaster warning Information report

No. O
Time Date/Month/Year

【Warning area(s)】
A city, B city, C town, D village

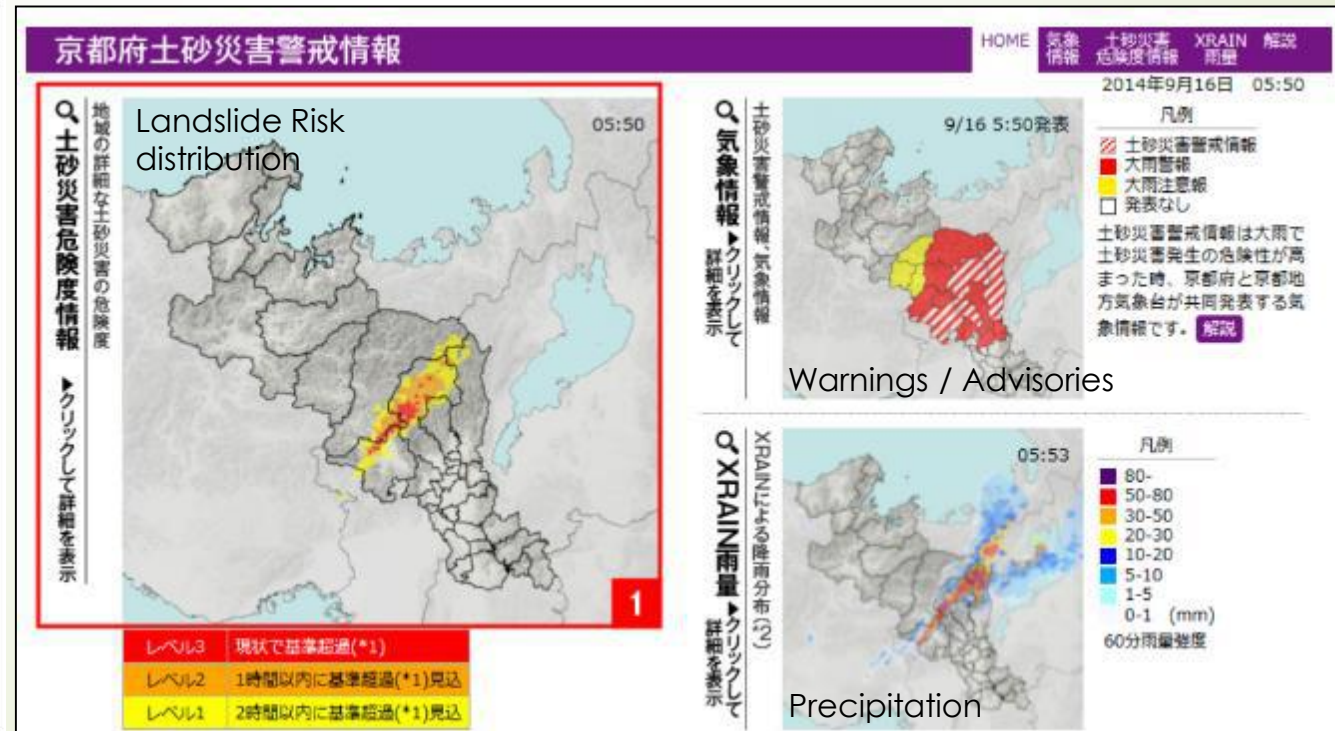
【Release of warning area(s)】
E village

【Warning message】
.....
.....



Legend:

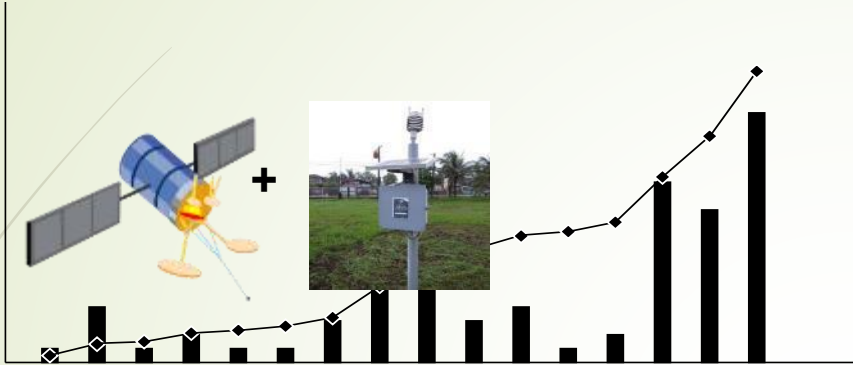
- Warning area(s)
- Release of warning area(s)
- High precipitation area (over 30mm/h)
- Movement direction High precipitation area



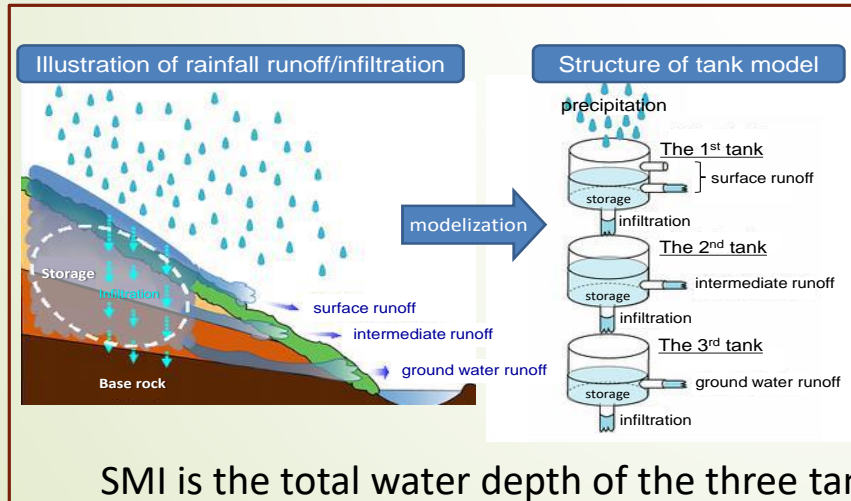
Methodology in the Philippines

Hourly Rainfall (Locally calibrated GSMaP)

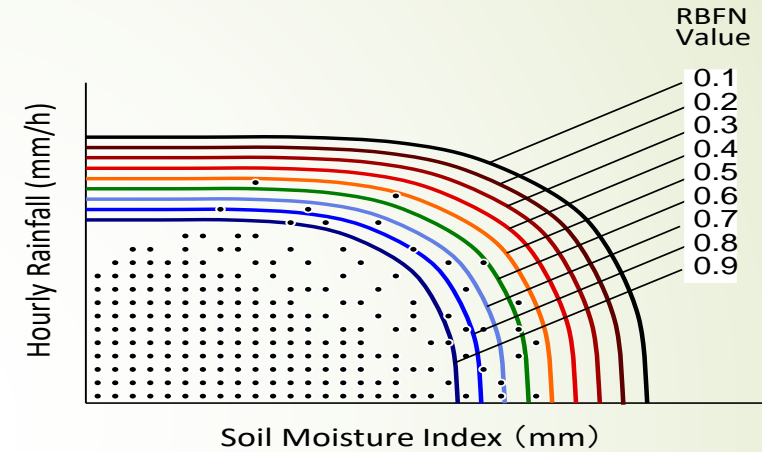
Hourly rainfall (mm/h)



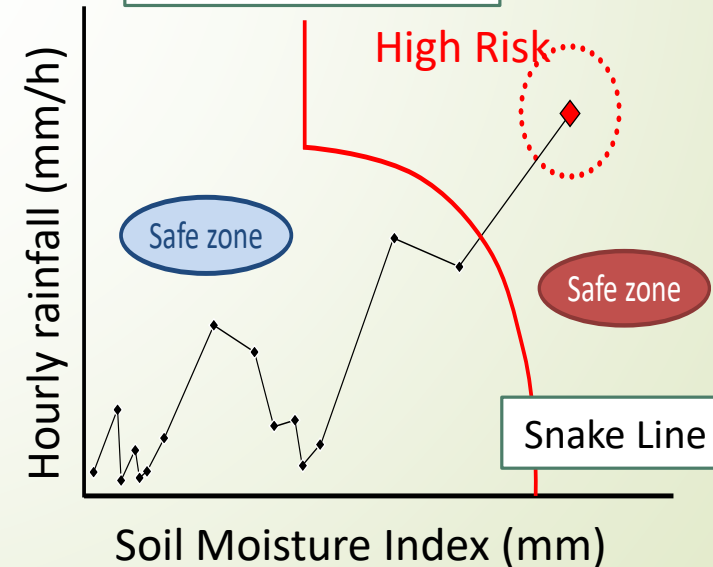
Soil Moisture Index (estimated from tank model)



Risk Level based on Critical Lines



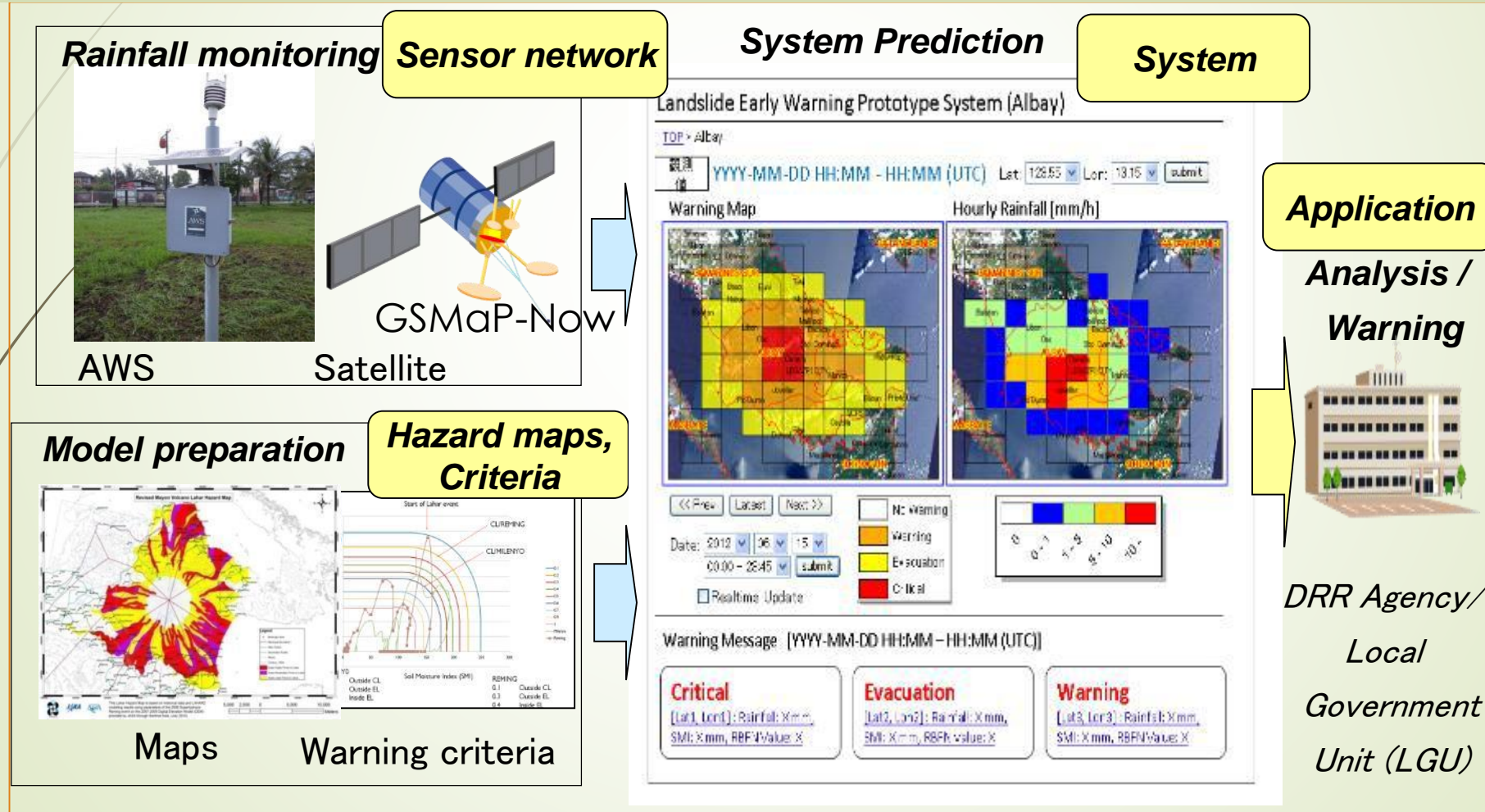
Critical Line (CL)



GSMaP Application to Landslide Warning System (GLAWS)

GSMaP rainfall archives are analyzed by a machine learning method (RBFN), and critical lines (CLs) of hourly rainfall and soil moisture index (SMI) are selected.

The system monitors rainfall in real-time and determines the landslide warning level.



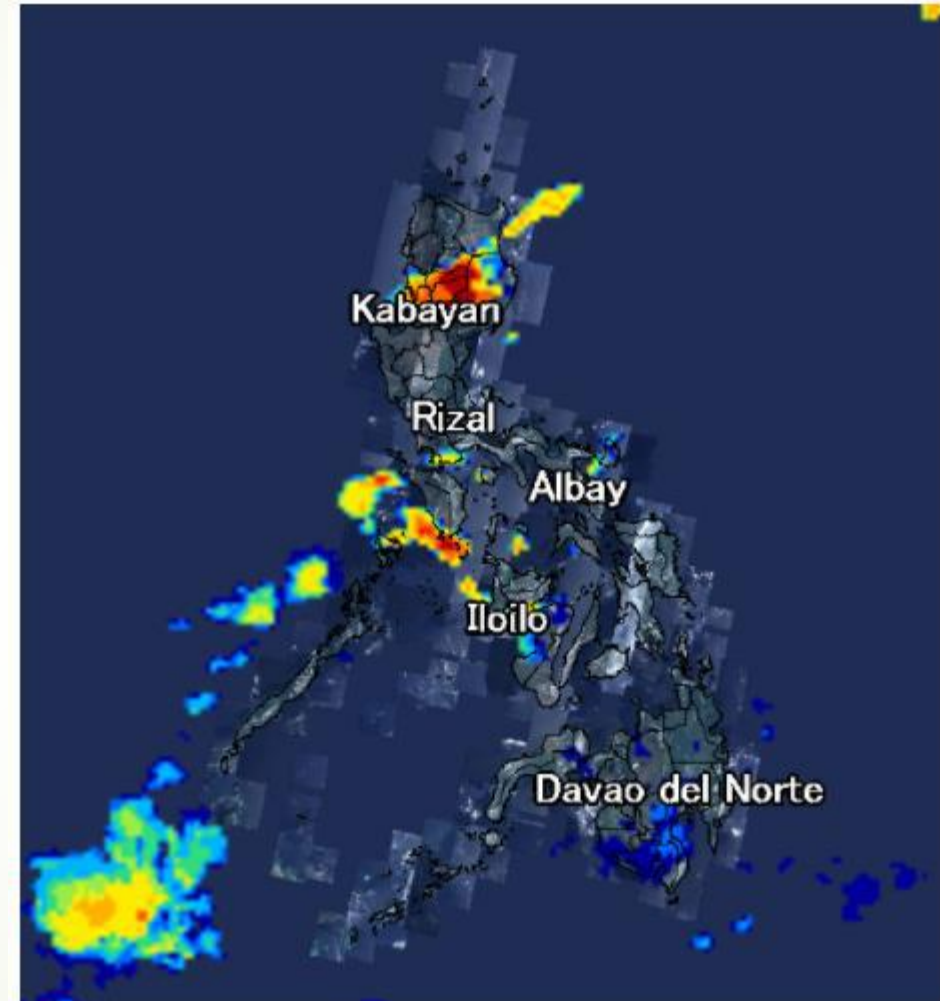
Landslide Warning System
<http://153.231.215.240/lsWarning/>

Landslide Early Warning Prototype System

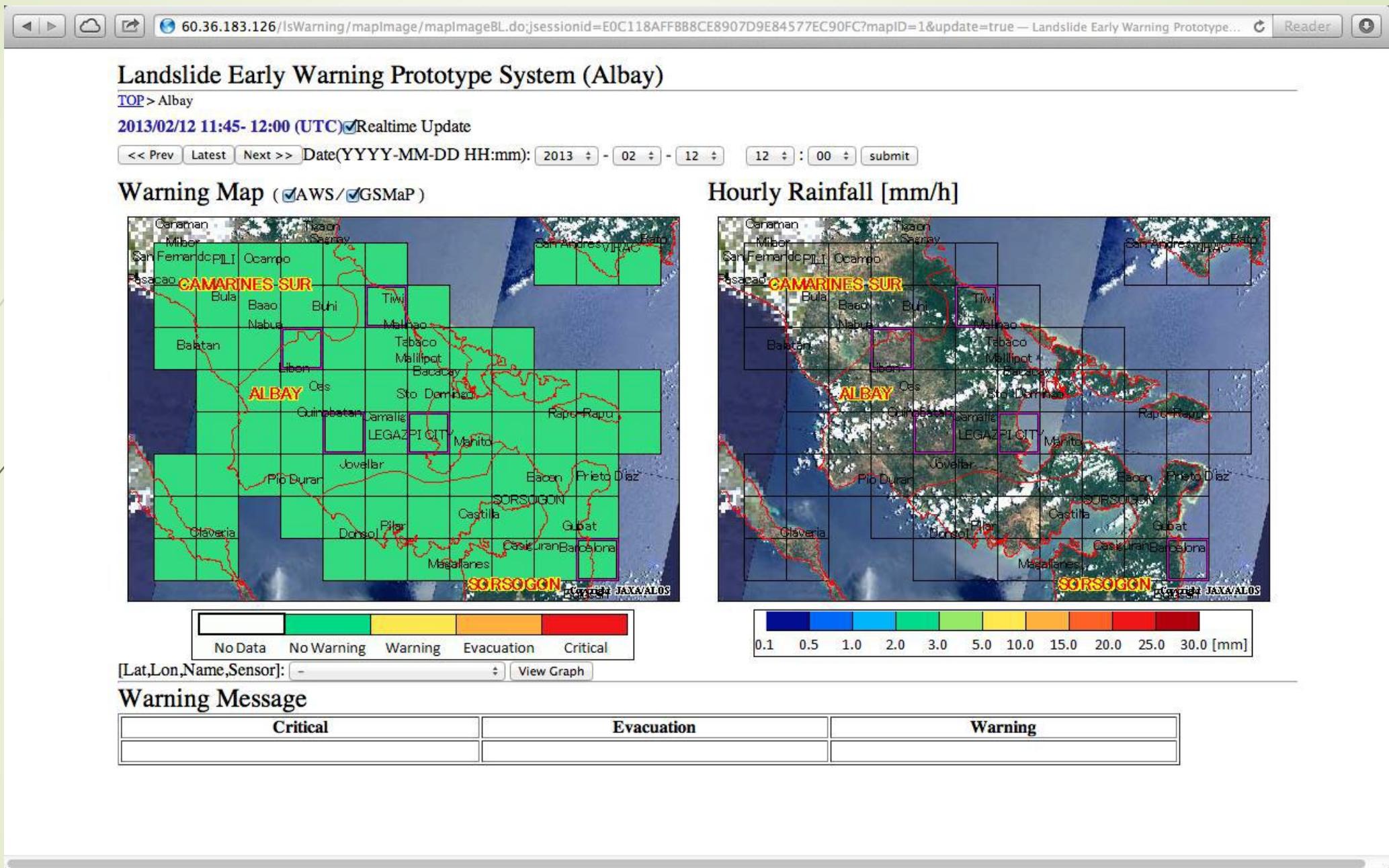
TOP

Hourly Rainfall [mm/h] - 2017-06-01 23:00 (PHT)

<< Prev Latest Next >> Date(YYYY-MM-DD HH:mm): 2017 - 06 - 01 23 :00 Submit



Rain 0.1 0.5 1.0 2.0 3.0 5.0 10.0 15.0 20.0 25.0 30.0[mm/hr]



Landslide Early Warning Prototype System (Rizal)

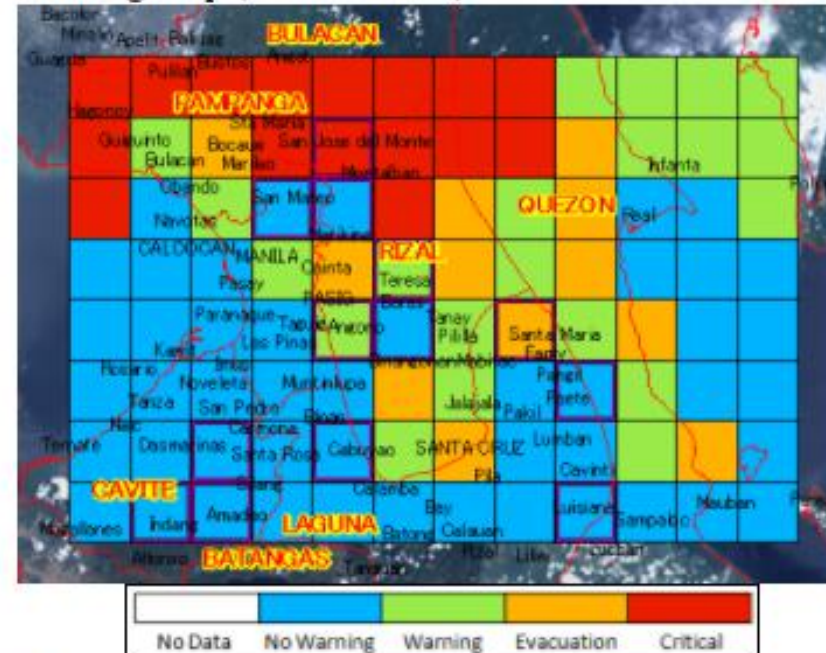
[TOP](#) > Rizal

[Text Mode](#)

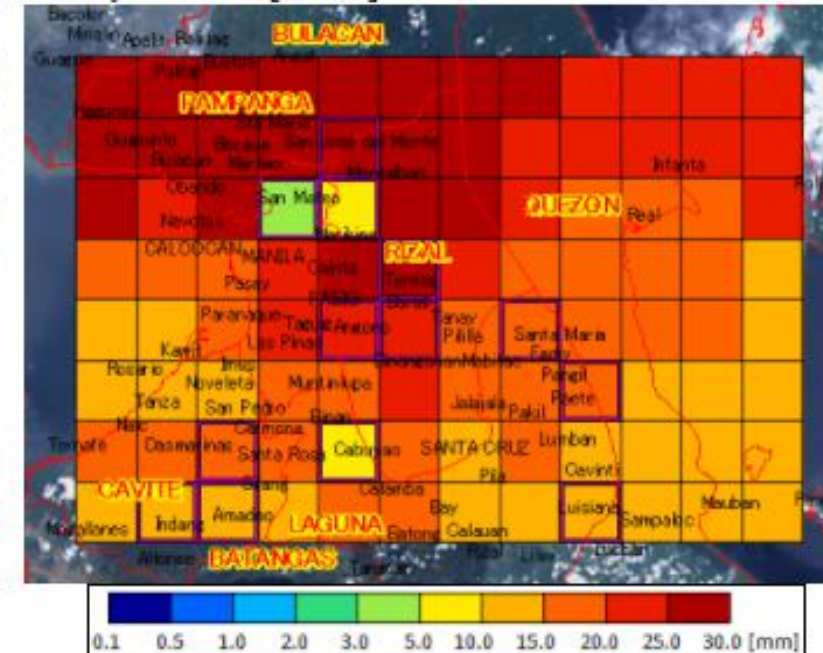
2016-10-16 05:30-05:45 (PHT) ☐ Realtime Update

<< Prev Latest Next >> Date(YYYY-MM-DD HH:mm): 2016 - 10 - 16 05 : 45 Submit

Warning Map (☒ AWS / ☒ GSMaP)



Hourly Rainfall [mm/h]



[Lat, Lon, AreaName, Sensor]: - View Graph View Warning

Warning Message

Warning	Evacuation	Critical
[N14.35,E121.25,Laguna Lake, Laguna lake, Laguna.GSMaP] Rainfall: 19.006670 mm. SMI: 192.813943 mm. RBFN value: 0.59	[N14.35,E121.35,Bagumbong, Jala-Jala, Rizal.GSMaP] Rainfall: 14.647260 mm. SMI: 194.904056 mm. RBFN value: 0.27	[N14.75,E120.75,Pugad, Hagonoy, Bulacan.GSMaP] Rainfall: 60.449330 mm. SMI: 211.468123 mm. RBFN value: 0.01
[N14.35,E121.65,Caesiav III, Mauban, Quezon.GSMaP] Rainfall: 13.956460 mm. SMI: 222.850888 mm. RBFN value: 0.51	[N14.35,E121.75,Caesiav III, Mauban, Quezon.GSMaP] Rainfall: 12.601570 mm. SMI: 250.459587 mm. RBFN value: 0.33	[N14.75,E121.15,Balite, Rodriguez, Rizal.GSMaP] Rainfall: 45.437690 mm. SMI: 208.872776 mm. RBFN value: 0.08
[N14.45,E121.35,Quisao, Pihilla, Rizal.GSMaP] Rainfall: 17.875730 mm. SMI: 209.947114 mm. RBFN value: 0.57	[N14.45,E121.25,Laguna Lake, Laguna lake, Laguna.GSMaP] Rainfall: 20.717430 mm. SMI: 194.779348 mm. RBFN value: 0.26	[N14.75,E121.25,San Rafael, Rodriguez, Rizal.GSMaP] Rainfall: 36.020550 mm. SMI: 238.563138 mm. RBFN value: 0.09
[N14.45,E121.65,Caesiav III, Mauban, Quezon.GSMaP] Rainfall: 14.977560 mm. SMI:	[N14.55,E121.45,Bagumbayan, Santa Maria, Laguna.GSMaP] Rainfall: 15.937780 mm. SMI:	[N14.85,E120.75,San Isidro, Hagonoy, Bulacan.GSMaP] Rainfall: 98.085370 mm. SMI:

Rizal Pilot Study – Training and Calibration

A local calibration and training on the use of WEB-based Landslide Warning System (GLAWS) was conducted in Antipolo City (Barrangay-Level) and Rizal Province (Municipal Level) together with National DRR agencies (MGB,PAGASA,PHIVOLCS).



Trial use of warning information through case study

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Landslide Early Warning Prototype System (Rizal)

[TOP](#) > Rizal

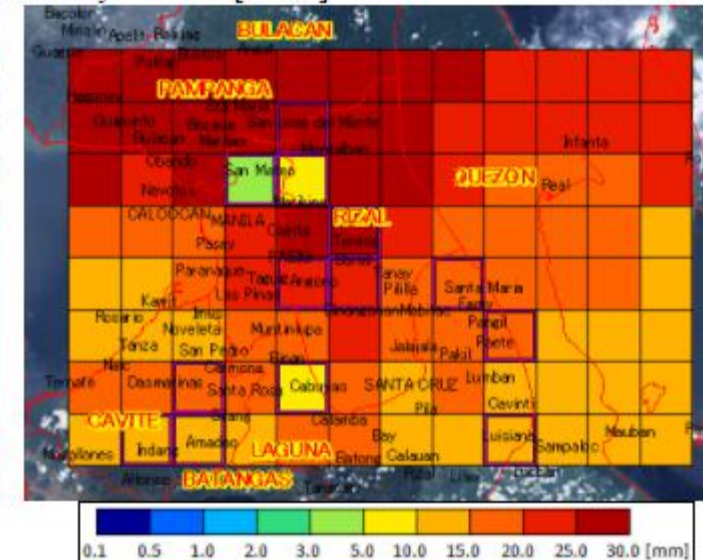
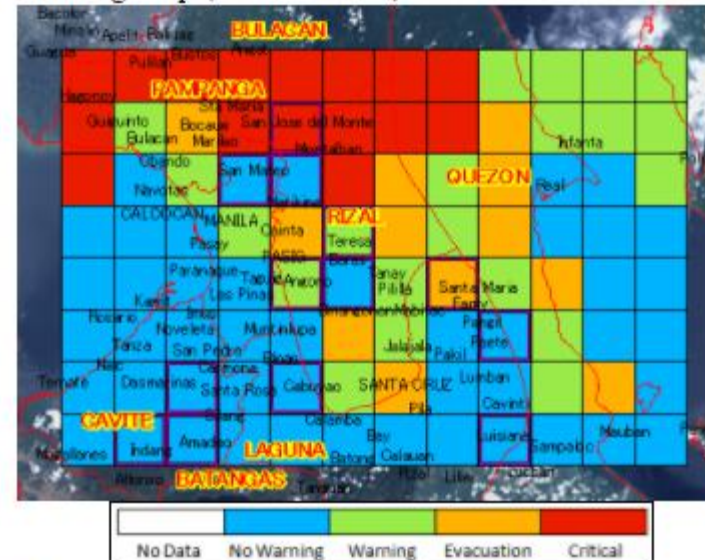
[Text Mode](#)

2016-10-16 05:30-05:45 (PHT) ☐ Realtime Update

<< Prev Latest Next >> Date(YYYY-MM-DD HH:mm): 2016 - 10 - 16 05 : 45 Submit

Warning Map (☒ AWS / ☒ GSMaP)

Hourly Rainfall [mm/h]



[Lat,Lon,AreaName,Sensor]: - View Graph View Warning

Warning Message

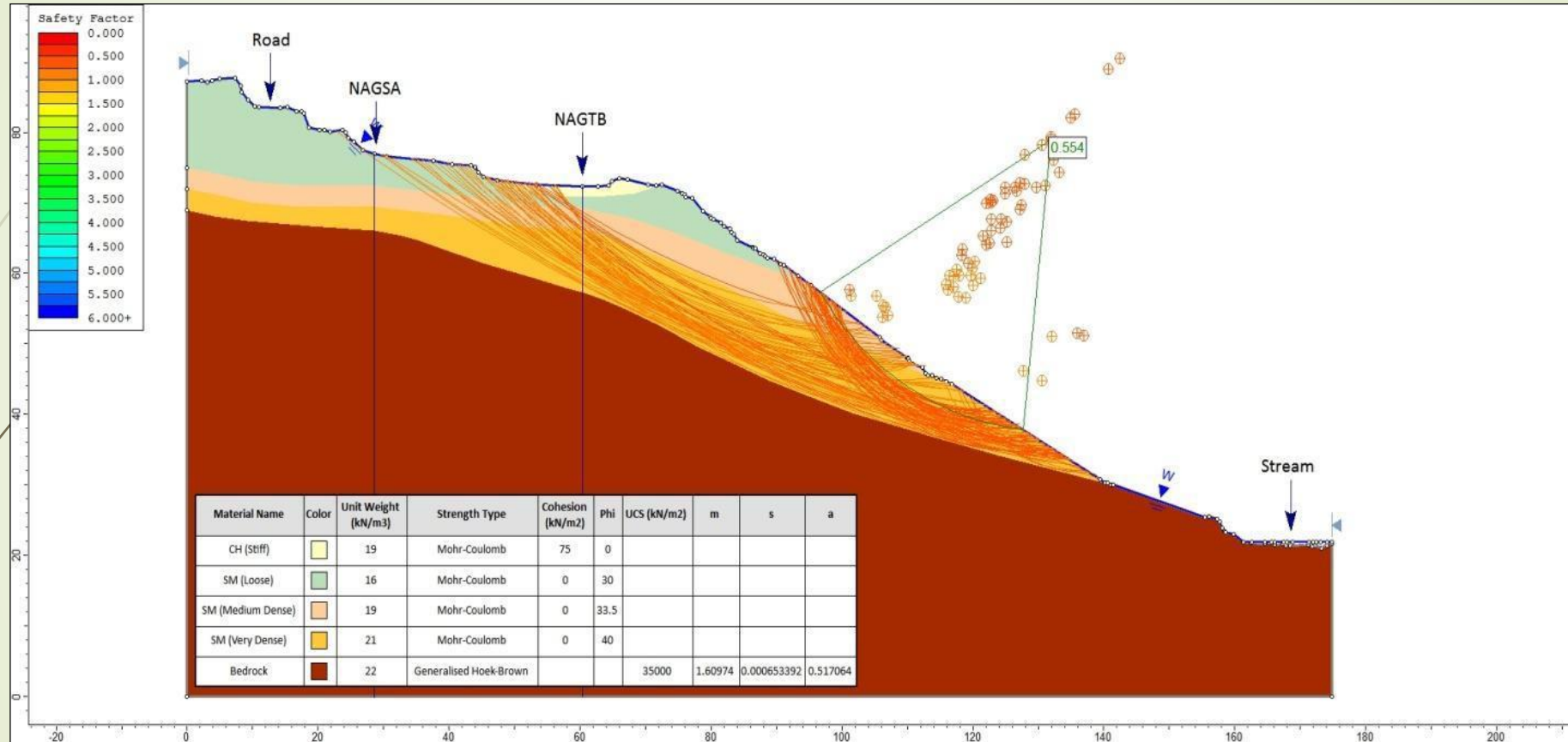
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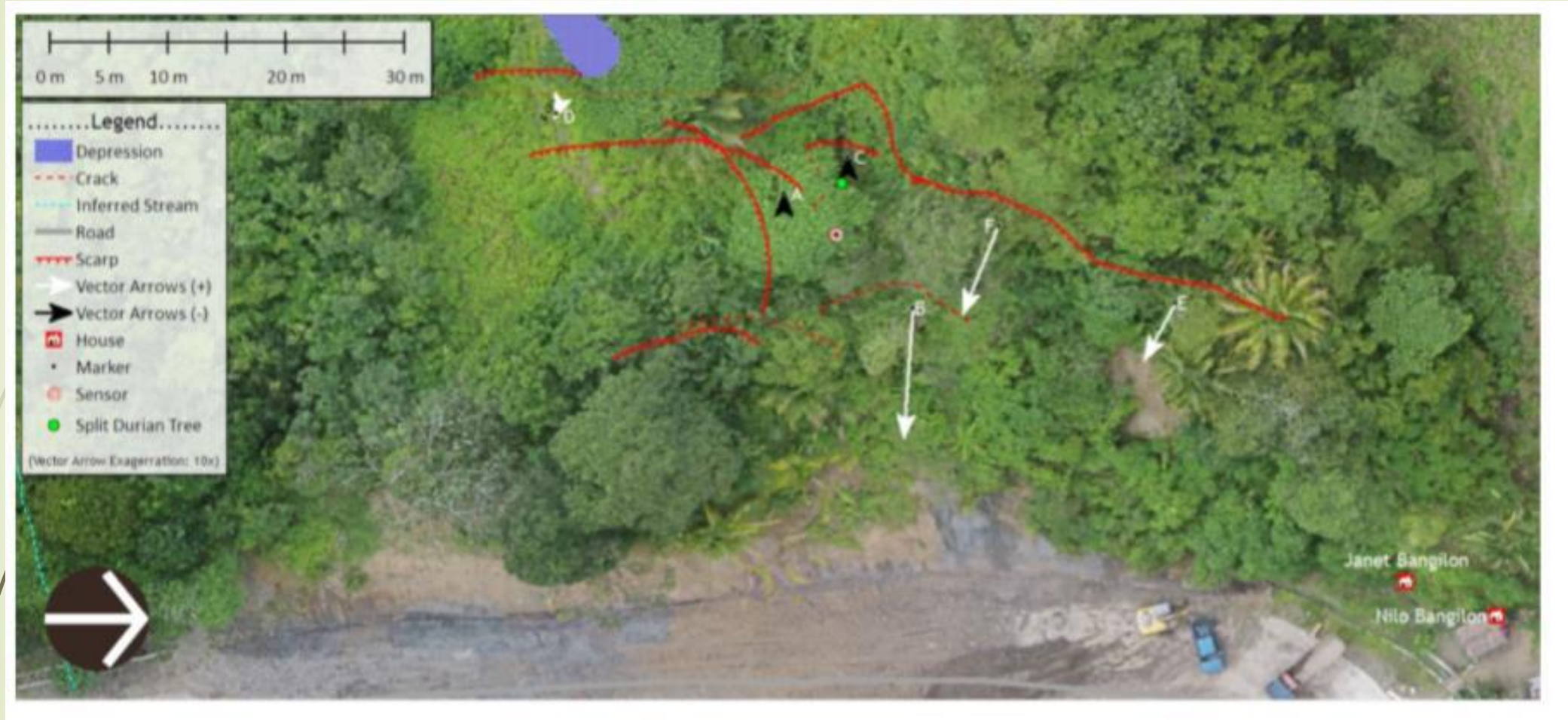
Landslide Warning System for Deep-seated Landslides

Modelling Failures for Deep-seated Landslides



Nagyubuyuban, San Fernando City, La Union. Slope stability analysis for the saturated condition showing all surfaces with factors of safety less than 1.0. Factor of safety is 0.554.

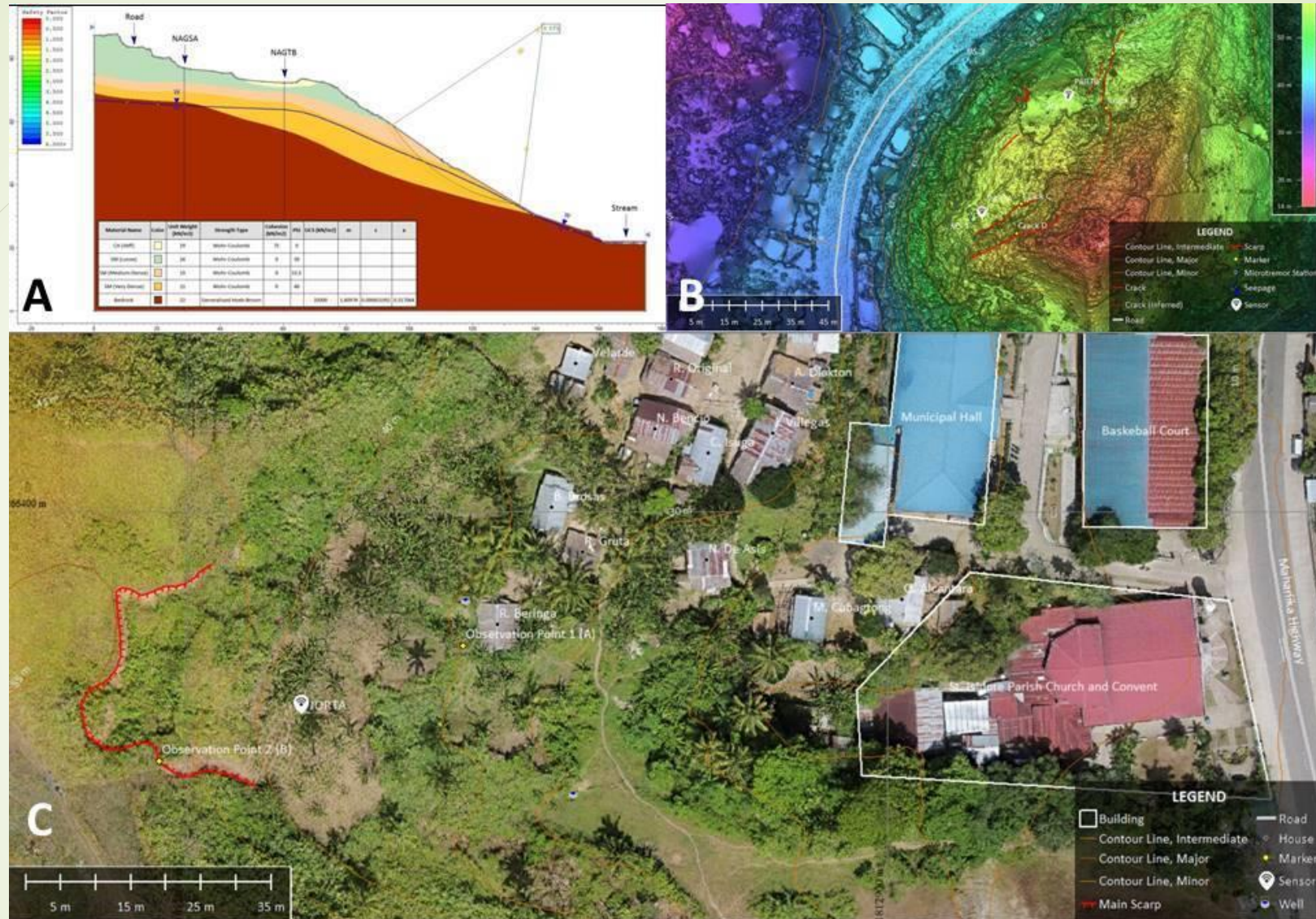
Mapping of active fissures for monitoring



Creeping evidence of fissures



Figure 6.9. Time series photo of tree split by ground displacements at Lower Mesolong, Talaingod. Left to right: June 11, July 28, and November 4, 2015.



- (A) Stability analysis of the slope in Nagyubuyuban, San Fernando.
- (B) Generated contours from the digital terrain model of the site in Brgy. Parasanon, Pinabacdao, Samar.
- (C) Features and exposure map of the site in Poblacion 1, San Jorge, Samar

Landslide features, and exposure map



Sitio Sambag, Brgy. Inabasan, Maasin, Iloilo

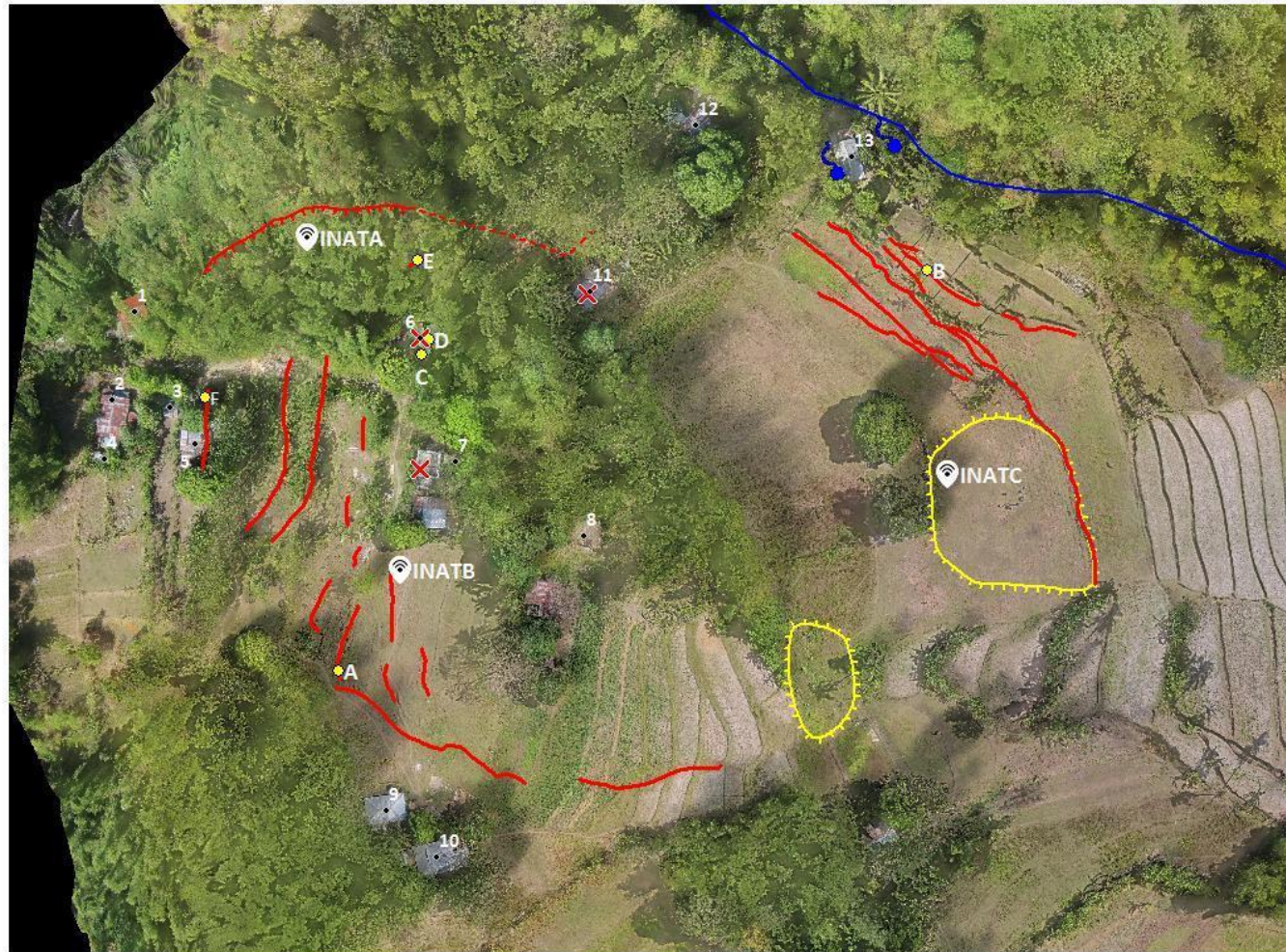
	Head of Household	Number of household members
1	A. Caldito	4
2	N. Dela Cruz	6
3	M.A. Eraldo	6
4	S. Arroyo	1
5	A. Monforte	1
6	O. Oresco	5
7	M. Oresco	8
8	S. Molina	1
9	Rod. Oresco	9
10	E. Molina	2
11	E. Perez	2
12	Rol. Oresco	9
13	E. Ibanez	6
Population		60



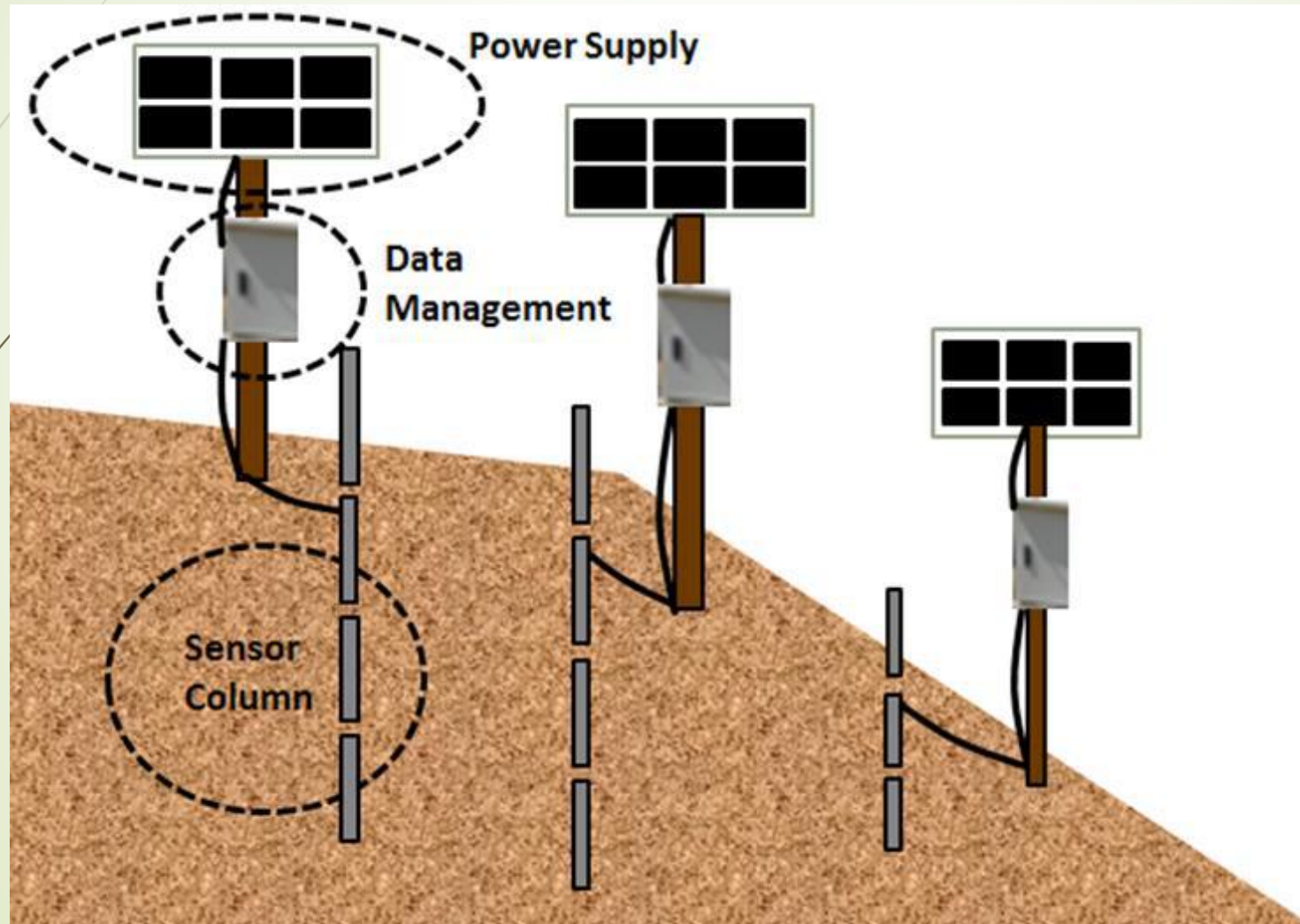
LEGEND	
Bulging	Damaged Structure
Crack	House
Crack (Inferred)	Marker
Scarp	Seepage
Stream	Sensor



Updated as of February 2016



Schematic diagram of sensor system and field deployment

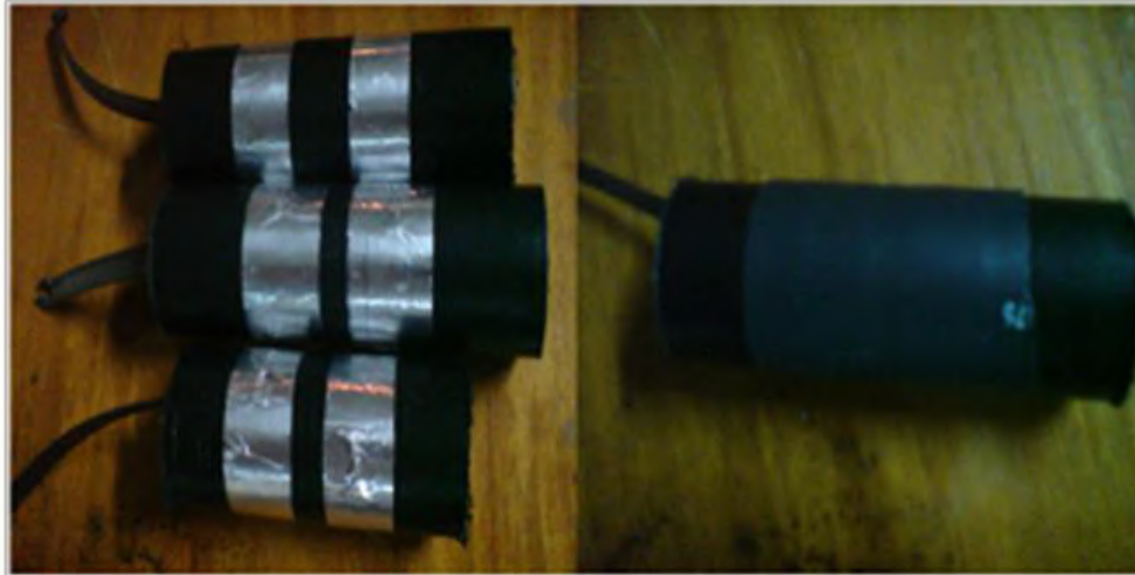


Manufacturing of Tilt and Moisture Sensor

1 set of sensors per meter

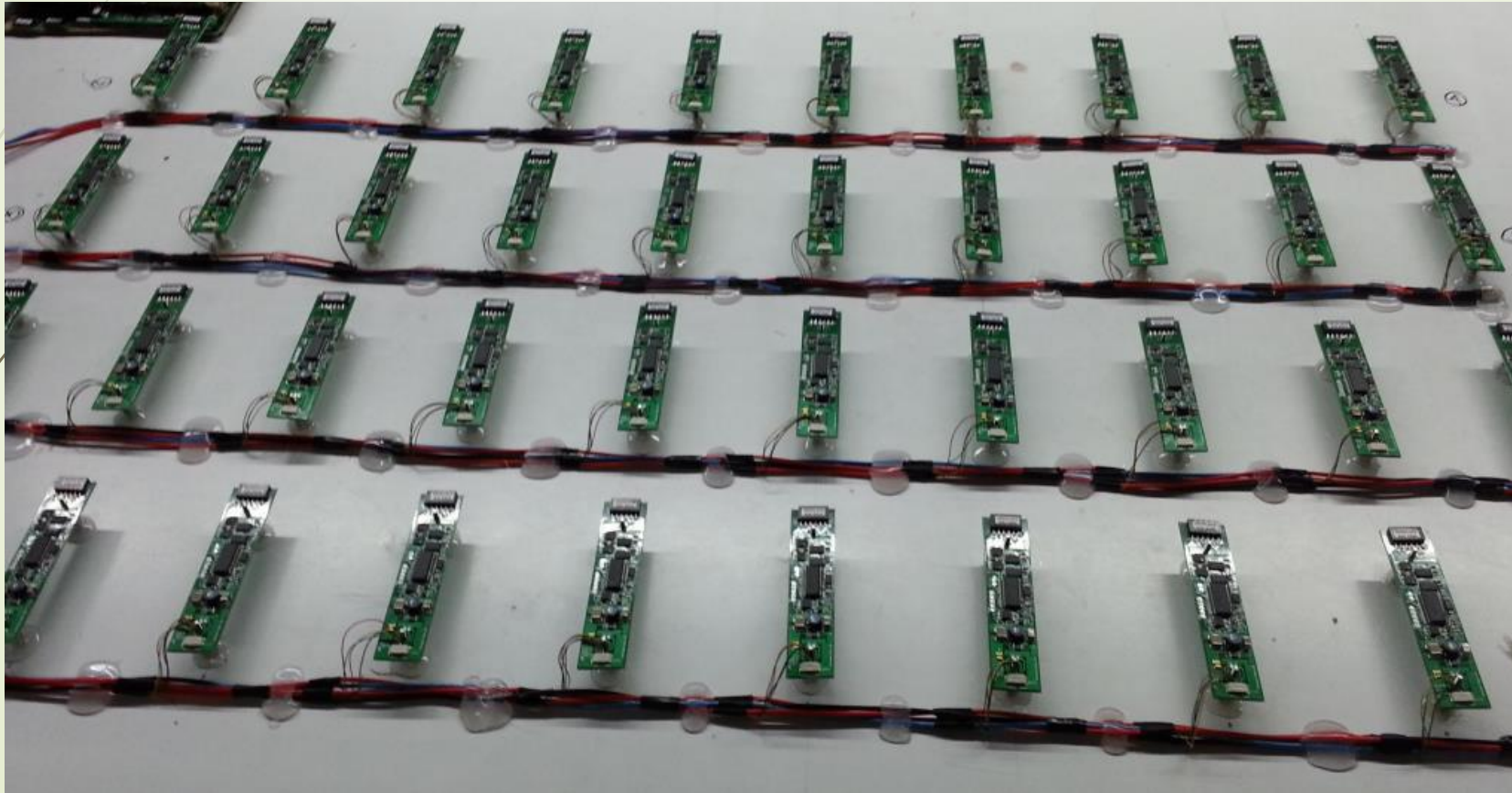


Tilt Sensor



Moisture Sensor

Manufacturing of refined landslide sensor system: Electronics



50 Sites with Landslide Sensors and Automatic Weather Stations



Brgy. Lipanto, AWS
Installation



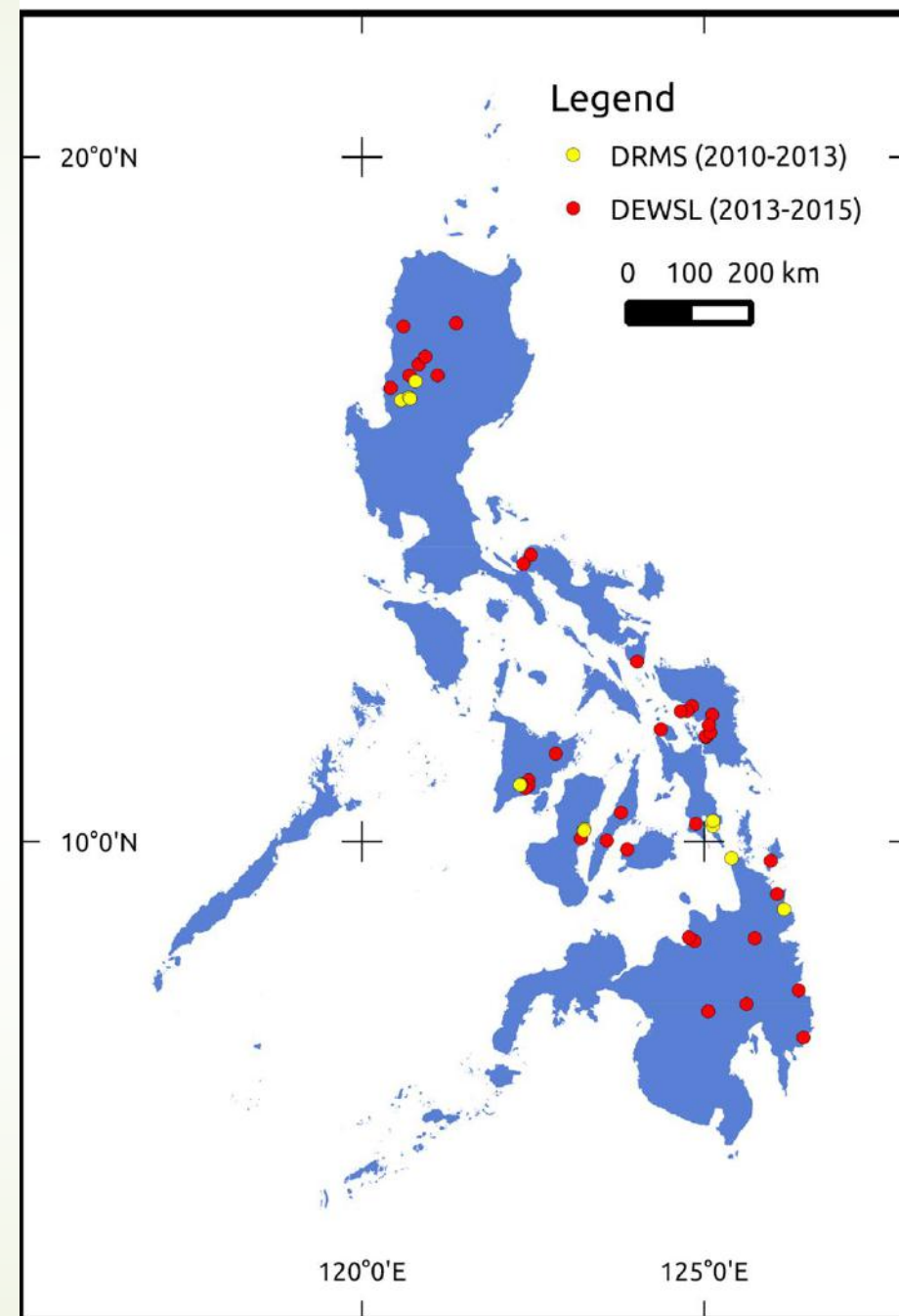
Brgy. Bolodbolod AWS
Installation



Brgy. Boloc Sensor
Maintenance

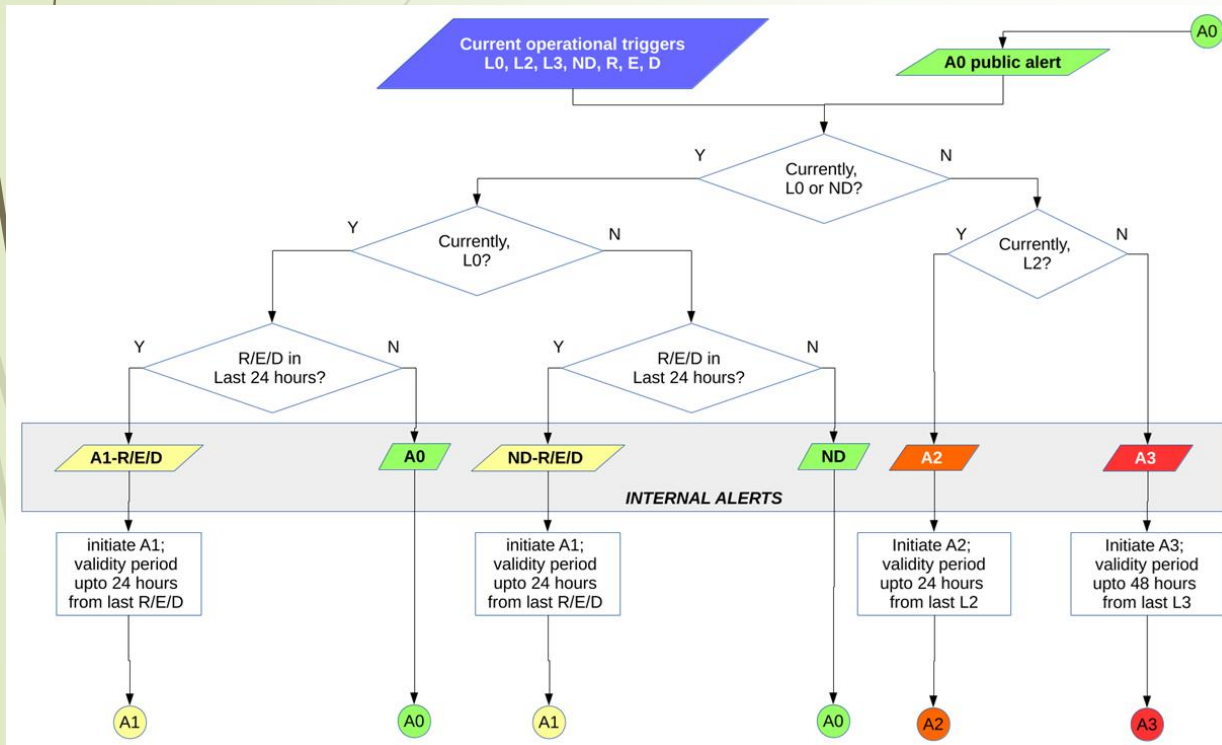
50 Sites with End to End Warning System

- Tilt & Moisture Sensors
- Automatic Weather Station
- Geodetic monitoring of active fissures
- Establish Landslide Early Warning Committee (LEWC)



Early warning protocol

Alert levels



ALERT LEVEL MESSAGES AND RECOMMENDED RESPONSES FOR LANDSLIDES

DOST - PHIVOLCS DEWS-L PROGRAM

ALERT LEVEL	DESCRIPTION	RECOMMENDED RESPONSE FOR LGU/LLMC	RECOMMENDED RESPONSE FOR THE COMMUNITY
A0	No significant ground movement	Proceed with routine monitoring	Proceed with daily activities
A1	Recent rainfall, earthquake, and/or other landslide-related event may trigger landslide	Prepare to assist households at risk in responding to higher alerts (A2 or A3) If conditions are safe, monitor every 4 hours	Prepare to respond to higher alerts (A2 or A3)
A2	Significant ground movement observed in the last 24 hours	Prepare to evacuate the households at risk If conditions are safe, monitor every 4 hours	Prepare to evacuate
A3	Critical ground movement observed in the last 48 hours; landslide may be imminent	Evacuate the households at risk	Evacuate



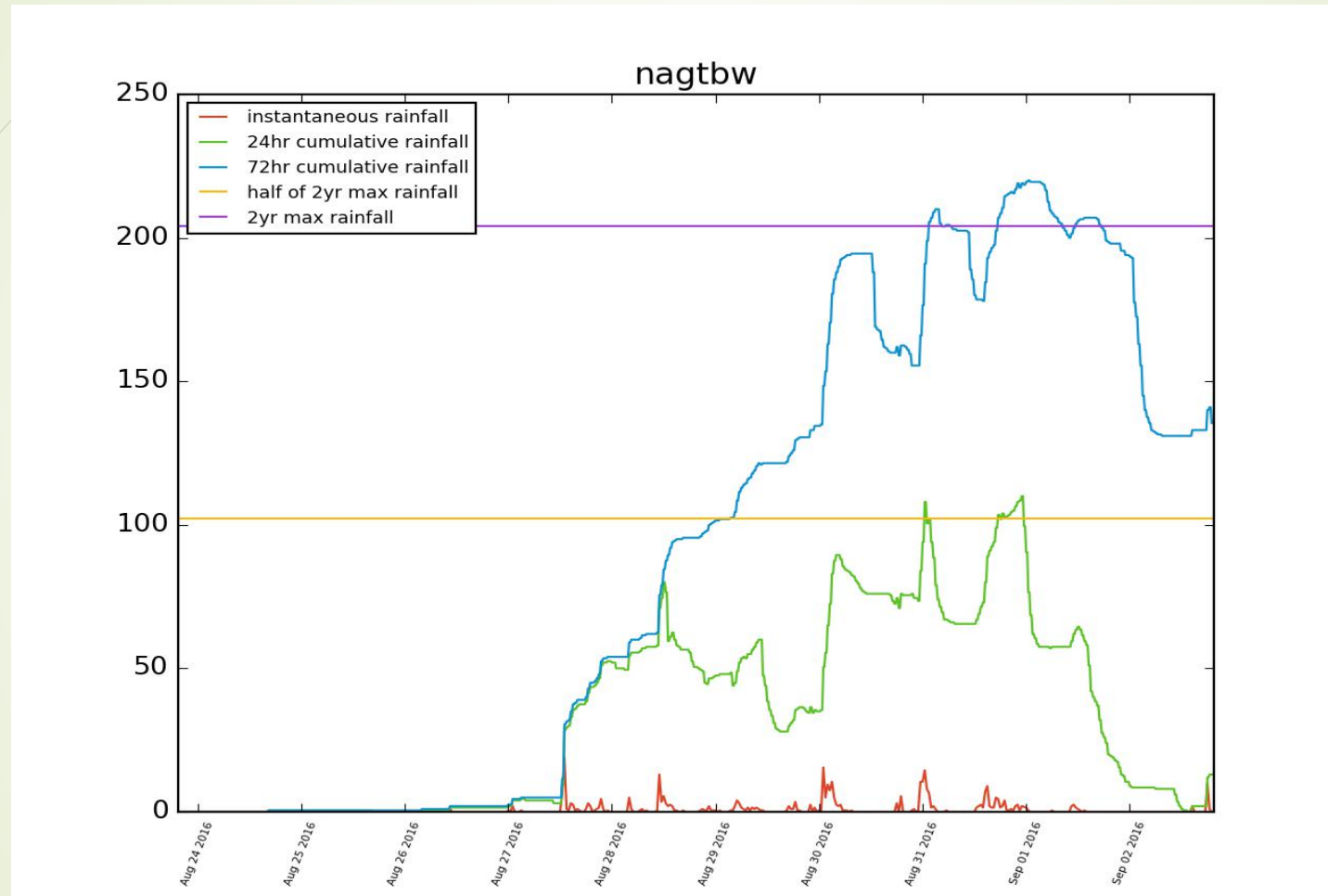
The Philippine Institute of Volcanology and Seismology (PHIVOLCS) is the implementing agency of the DEWS-L Program.
PHIVOLCS Building, C. P. Garcia Avenue, UP Campus, Diliman, Quezon City 1101
Tel. Nos.: 426-1468 to 79 loc 129 or 920-7058

February 2016



Monitoring and early warning thresholds

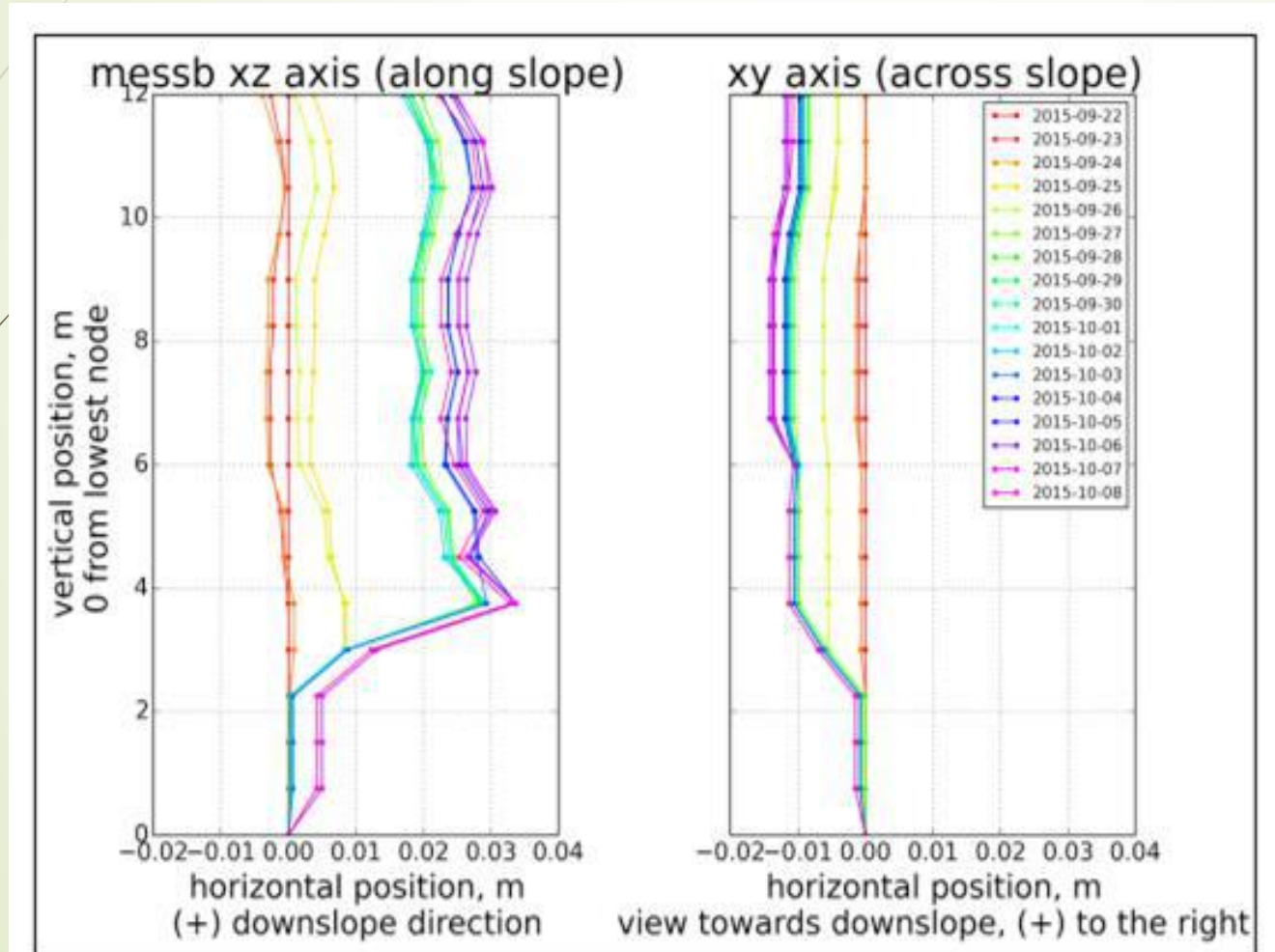
□ Preliminary thresholds : Rainfall



Plot for evaluating 1- and 3-day cumulative rainfall against their respective thresholds ($\frac{1}{2}$ of 2 yr max, and 2 yr max)

Monitoring and early warning thresholds

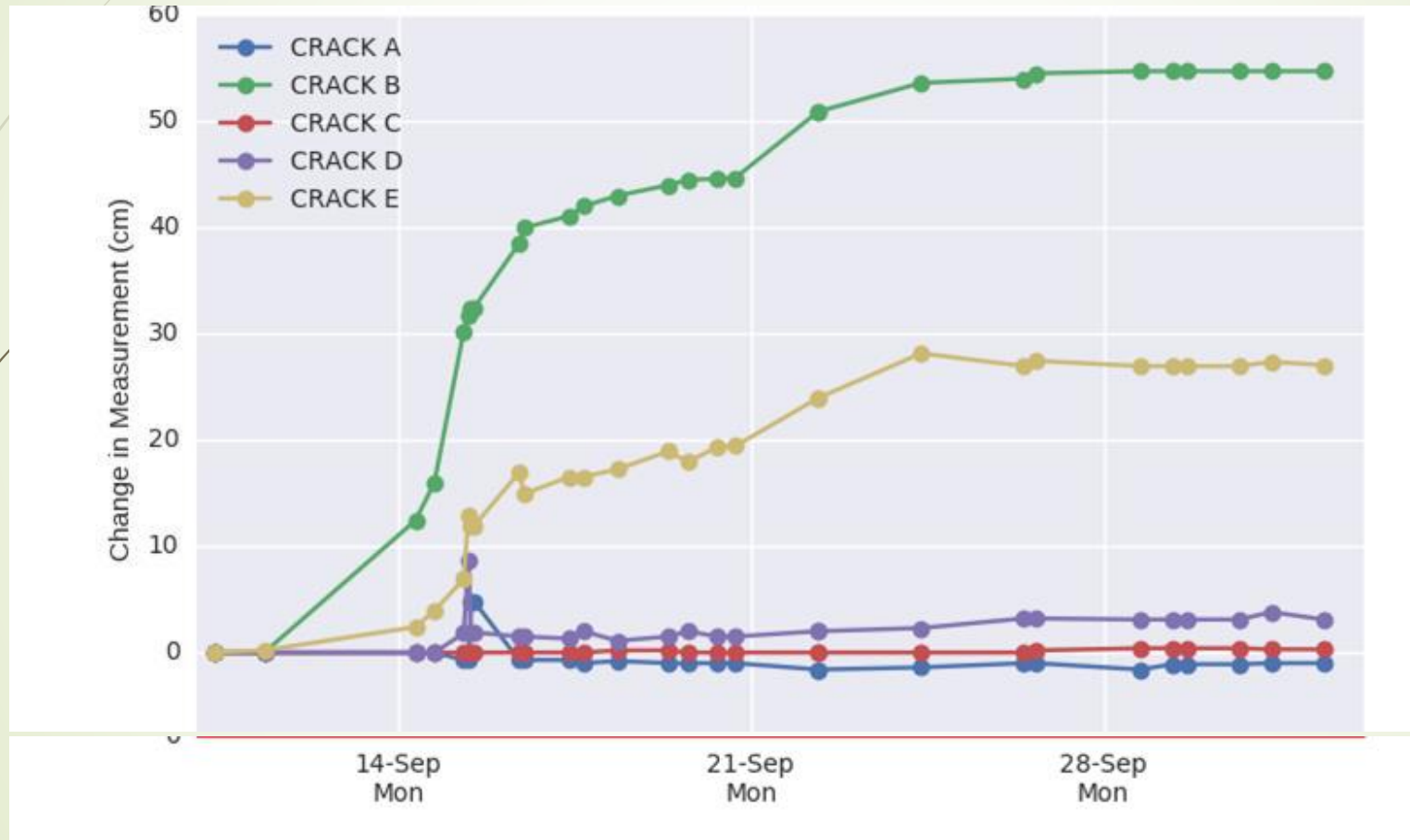
- Preliminary thresholds:
- Landslide movement: Tilt data from borehole sensors



Displacement data from sensors

Monitoring and early warning thresholds

- Preliminary thresholds:
- Landslide movement: Crack displacements at the surface



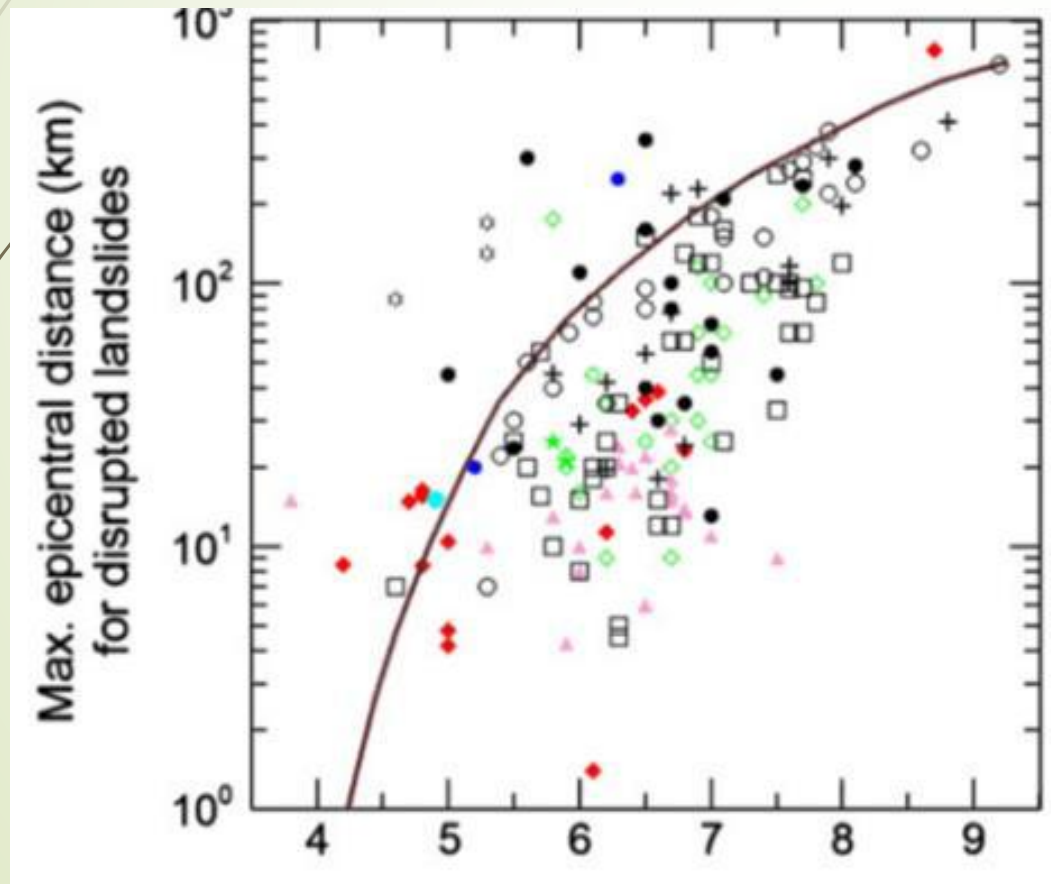
Displacement data from community (LEWC)

Monitoring and early warning thresholds

□ Preliminary thresholds

➤ Earthquake

➤ Magnitude, epicentral distance from PHIVOLCS SOEPD



Earthquake-induced landslide threshold as function of earthquake magnitude (x-axis), and epicentral distance (y-axis) for disrupted landslides Delgado et al. (2011)

Monitoring and early warning thresholds

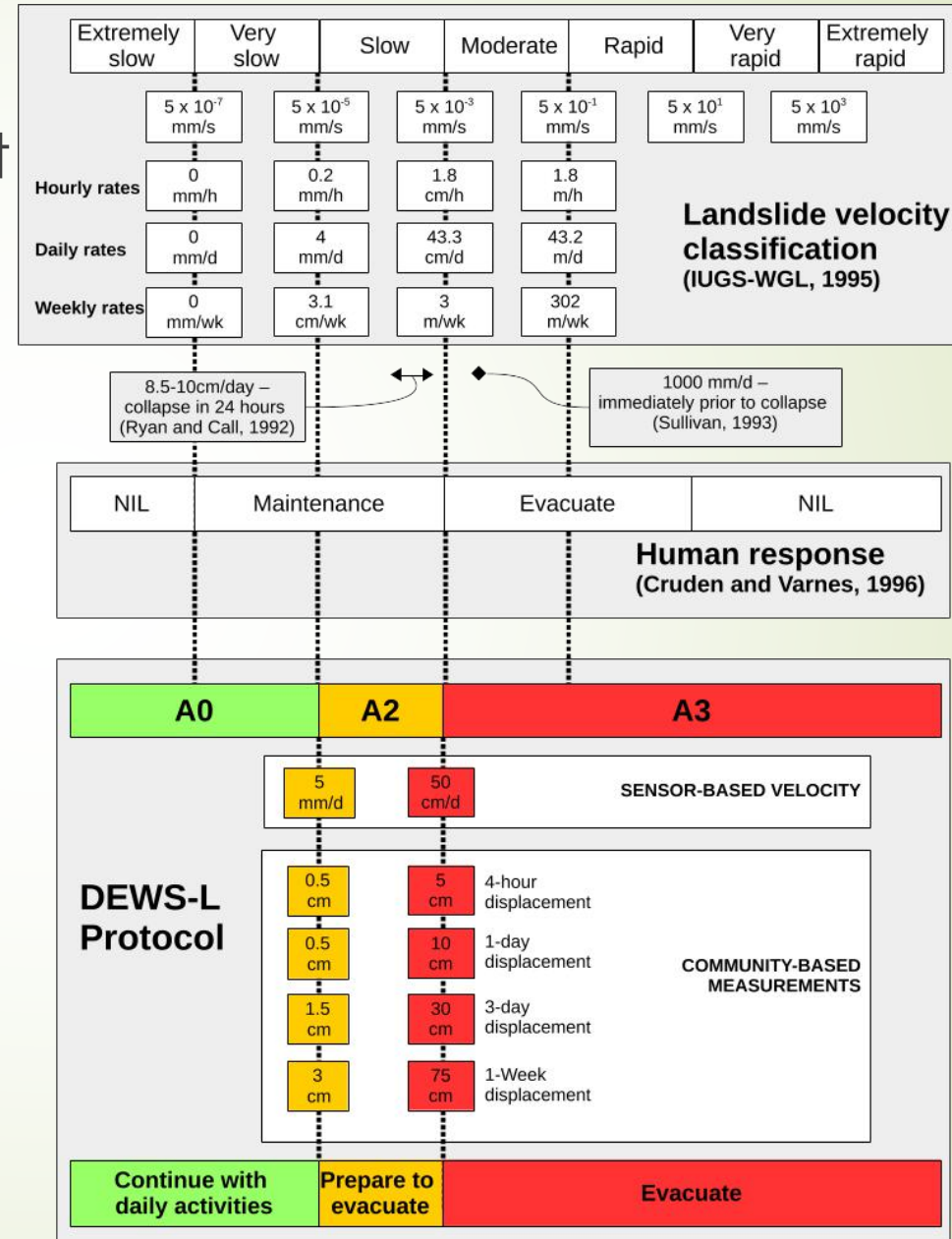
- Early warning protocol
 - Operational triggers

Trigger	Sym- bol	Description	Threshold
Rainfall	R0	No landslide-triggering rainfall event detected	1- and 3-day cumulative rainfall values are below threshold conditions (see R1, below)
	R1	Recent rainfall may trigger landslide	1-day cumulative rainfall $> \frac{1}{2}$ of 2-year maximum daily rainfall; OR 3-day cumulative rainfall > 2 -year maximum daily rainfall
Earthquake	E0	No landslide-triggering earthquake event detected	Earthquake magnitude – epicentral distance plots above the critical line of Delgado et al. (2011)
	E1	Recent earthquake may trigger landslide	Earthquake magnitude – epicentral distance plots below the critical line of Delgado et al. (2011)
On-demand monitoring request	D0	No monitoring requests by LGU and community	n/a
	D1	Monitoring requested by LGU or community due to rainfall, earthquake or other landslide-related observations	n/a
Landslide movement	L0	No significant movement	Velocity $\leq 5^{mm}/day$
	L2	Significant movement	Velocity $> 5^{mm}/day, \leq 50^{cm}/day$
	L3	Critical movement	Velocity $> 50^{cm}/day$

Table 5.1. Description and threshold details of operational triggers used in the Protocol

Monitoring and early warning thresholds

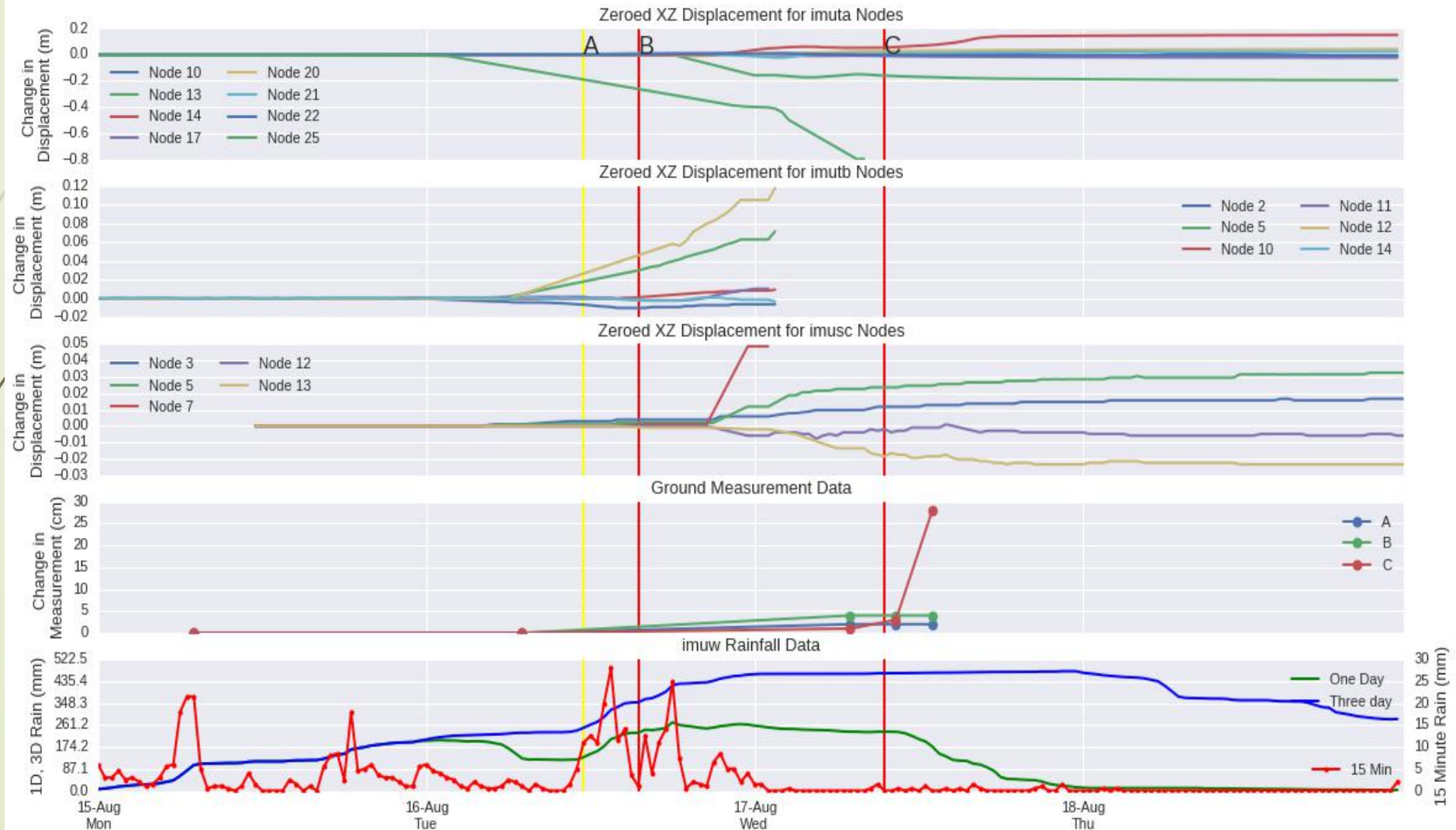
Preliminary thresholds Landslide movement



Some monitoring event

Immuli, Pidigan, Abra

Immuli Event Timeline from 2016-08-15 00:00 to 2016-08-18 23:30



Issuance of Warning to Stake Holders

REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF SCIENCE AND TECHNOLOGY
PHILIPPINE INSTITUTE OF VOLCANOLOGY AND SEISMOLOGY

PHIVOLCS Bldg., C.P. Garcia Ave., University of the Philippines Campus, Diliman, Quezon City
Tels. (+632) 426-1468 to 79 loc 112, 129; (+632) 926-2611, (+632) 920-7058
Fax: (+632) 929-8366
Website: www.phivolcs.dost.gov.ph

**PRIMER ON THE LANDSLIDE-RELATED EVACUATION
OF UPPER and LOWER MESOLONG COMMUNITIES IN BARANGAY STO. NIÑO, TALAINGOD,
DAVAO DEL NORTE**
20 October 2015

What happened at Upper and Lower Mesolong?

A pre-emptive evacuation of 188 families from Sitios Upper Mesolong and Lower Mesolong in Barangay Sto. Niño was ordered by the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Talaingod on September 15, 2015. The MDRMO responded to a landslide threat based on information from PHIVOLCS. Residents stayed at the evacuation center for about one to two weeks; the Upper Mesolong residents returned to their homes on September 21, and those from Lower Mesolong on September 30.

The local landslide monitoring committee (LLMC) provided measurements of monitored cracks in Upper and Lower Mesolong. PHIVOLCS studied these information and forwarded the alerts and recommended responses to the LGUs and LLMC for their actions. The table below summarizes the alerts and responses before, during, and after the evacuation.

Sito	Date	PHIVOLCS information	Actual local response
Lower Mesolong	Sep 14	significant ground movement; A1; Prepare to evacuate the potentially affected households.	monitoring by LLMC/LGU
	Sep 15-30	critical ground movement; A2; Evacuate the potentially affected households.	Pre-emptive evacuation ordered at 10AM Sep 15 by MDRMO; monitoring by LLMC/LGU
	Sep 30	no significant ground movement; A0; Proceed with daily activities	MDRRMO allows Lower Mesolong community to return to their homes; monitoring by LLMC/LGU
Upper Mesolong	Sep 15	no significant ground movement; A0; Proceed with daily activities	Pre-emptive evacuation ordered at 10AM Sep 15 by MDRMO
	Sep 18-21	significant ground movement; A1(ND-L); Prepare to evacuate the potentially affected households.	(community already at evacuation center)
	Sep 21-Oct 1	no significant ground movement; A0; Proceed with daily activities	MDRRMO allows Upper Mesolong community to return to their homes on Sep 21; monitoring by LLMC/LGU

Why was there an evacuation of the residents?

There is an agreement among PHIVOLCS, the LGUs of Sto. Niño, Talaingod, and Davao del Norte, and the residents of Upper and Lower Mesolong to test and implement a landslide early warning system in the two sitios of Sto. Niño. The evacuation and associated early warning activities are part of the implementation of this system.



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Fax: (+632) 929-8366
Website: www.phivolcs.dost.gov.ph



DEWS-L PROGRAM LANDSLIDE ALERT LEVEL INFORMATION: PUG-2017-039

Location:	Sitio Longlong, Brgy. Puguis, La Trinidad, Benguet
Date/Time	30 May 2017, 08:00 PM
Alert Level Released:	A1 (Recent rainfall may trigger landslides), valid until 31 May 2017, 12:00 MN
Recommended Response:	Prepare to assist households at risk in responding to higher alerts (A2 or A3).

AREA SITUATION:

RAINFALL

Accumulated rainfall exceeded threshold values last **27 May 2017, 04:30 PM**. Most recent re-trigger/s occurred on **29 May 2017, 11:30 PM, 29 May 2017, 05:00 PM, 29 May 2017, 03:30 PM**.
Detail: 3-day cumulative rainfall (194.15 mm) exceeded threshold (193.39 mm)

GROUND MOVEMENT

No significant ground movement detected.

HOUSEHOLDS AT RISK

At least 50 households, Pico-Lamtang Road

OTHER RECOMMENDATIONS:

For the Landslide Early Warning Committee (LEWC): If conditions are safe, monitor the site daily at 7:30 AM, 11:30 AM and 3:30 PM; report new ground data on **31 May 2017, 7:30 AM**.

For the Community: Prepare to respond to higher alerts (A2 or A3). Report landslide-related changes observed in the surroundings to the LEWC/LGU.

NOTE: This Bulletin contains the official Alert Level and Recommended Response of the DEWS-L Program for Brgy. Puguis and will hold true until a new bulletin is released.

Please proceed to the links [Landslide Alert Level Based on Ground Movement](#) and [Alert Levels and Recommended Responses](#) for references.

Next bulletin on: 31 May 2017, 12:00 MN

Prepared by: MV, MN



DEWS-Landslide Monitoring Dashboard



Latest Site Alerts

Site Name	Initial Trigger Timestamp	Latest Re-trigger Timestamp	Internal Alert
Cudog	16 July 2016 23:30:00	17 July 2016 19:30:00	A1-R

Sites Under 3-Day Extended Monitoring

Site Name	End of Previous Alert Validity	Monitoring Start
Boloc	18 July 2016, 08:00:00	19 July 2016, 12:00:00
Gaas	18 July 2016, 08:00:00	19 July 2016, 12:00:00



➤ Thank you

