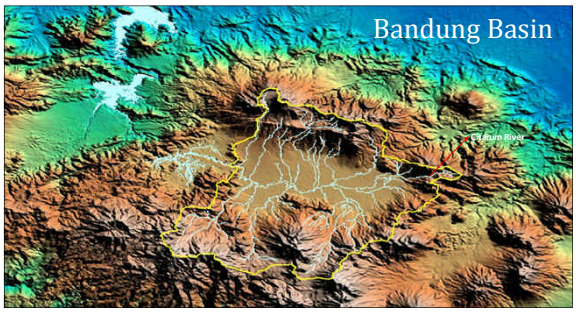
GEOSPATIAL MONITORING OF NATURAL HAZARDS IN THE CITY
(CASE STUDY : BANDUNG, INDONESIA)

ISG 2012, Kuala Lumpur, 25-26 November 2012



The central part has an altitude of about 665 m
and is surrounded by up to 2400 m high volcanic terrain.
The catchment area of the basin and surrounding mountains covers approximately 2300 km², and the Citarum river with its tributaries form the main drainage system of the basin catchment.

Authors

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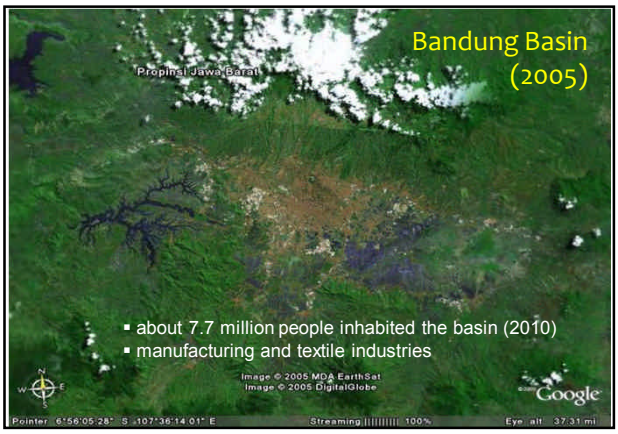
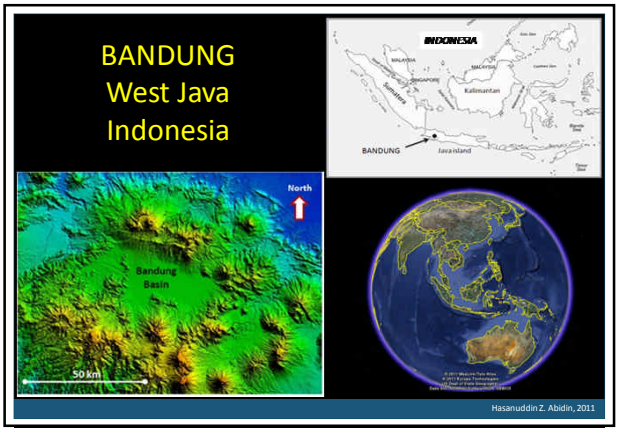
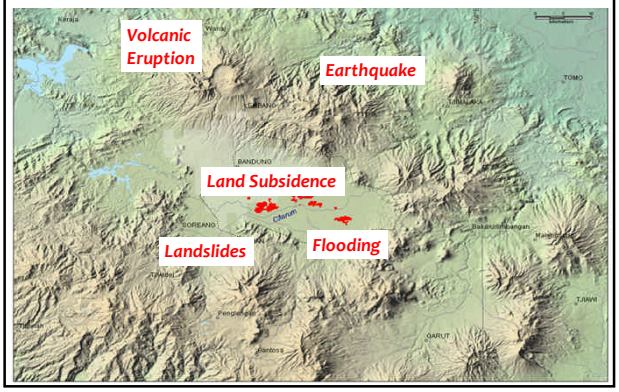
Jl. Gatot Subroto, Jakarta, Indonesia

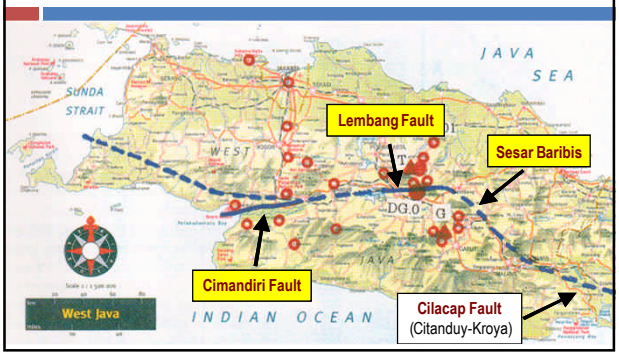




NATURAL HAZARDS IN BANDUNG CITY

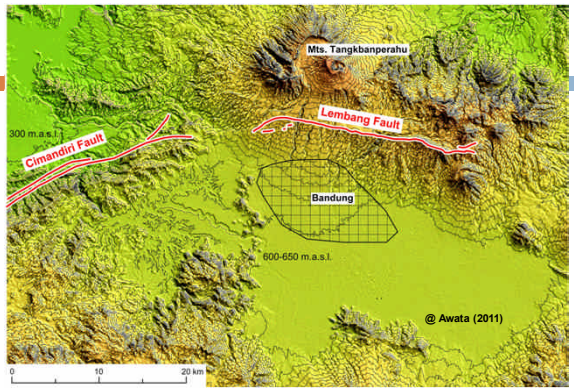


Faults of Concern in West Java

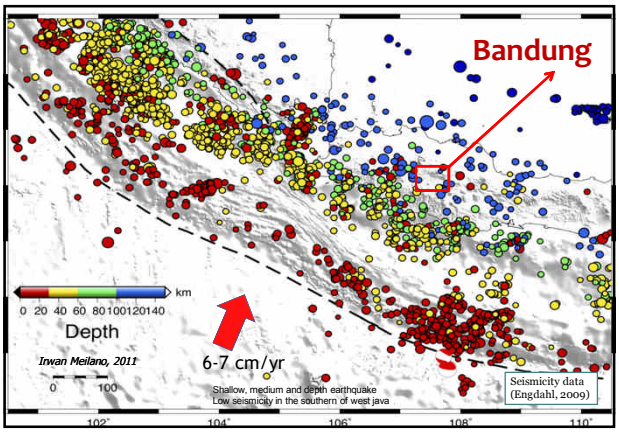


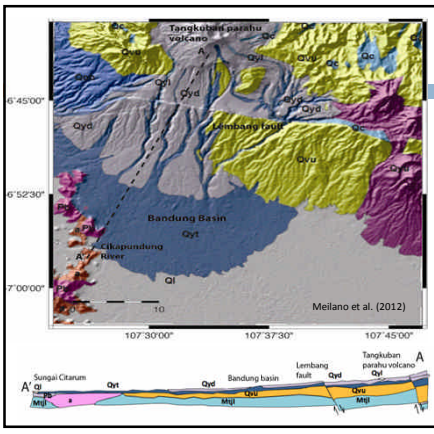
Earthquakes in Bandung Basin

- From Lembang Fault
- From Cimandiri Fault
- From Subduction

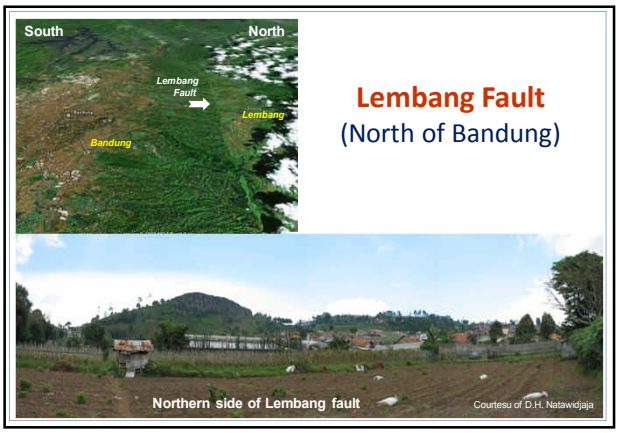


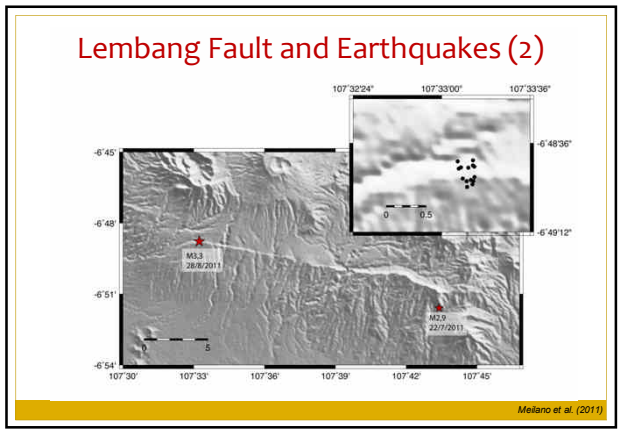
Bandung : Lembang & Cimandiri Faults

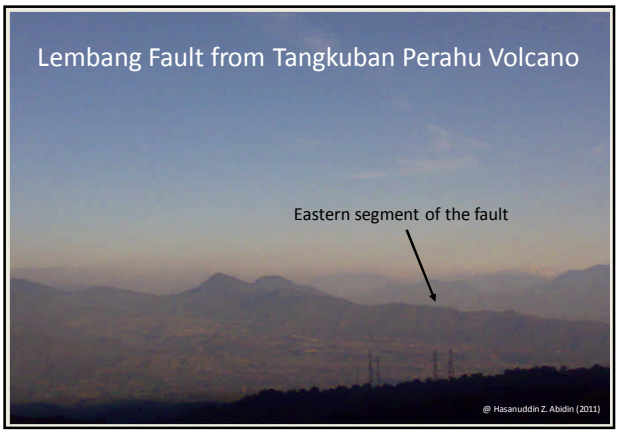


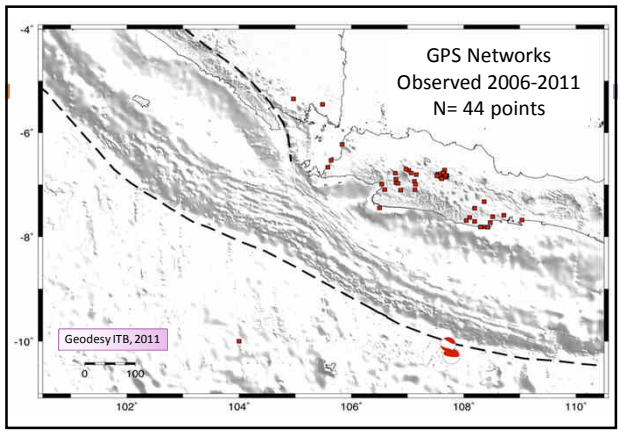


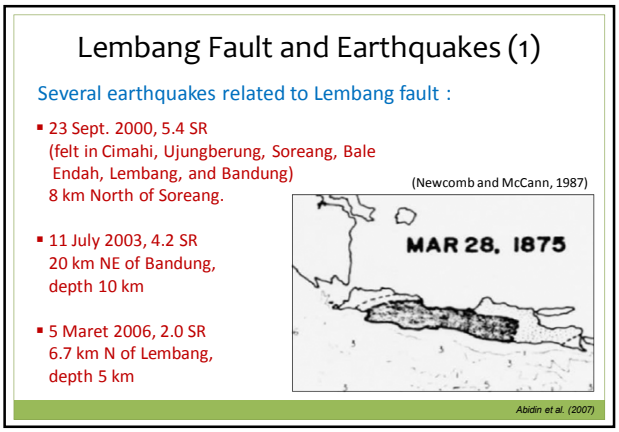
LEMBANG Fault

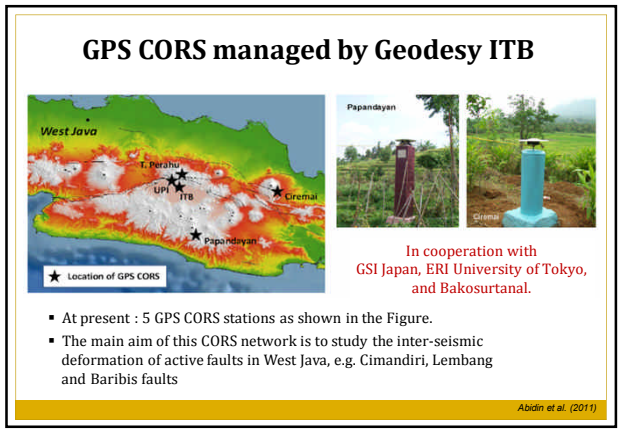

South
North
Lembang Fault
Lembang
Bandung
Lembang Fault
(North of Bandung)
Northern side of Lembang fault
Courtesu of D.H. Natawidjaja


Lembang Fault and Earthquakes (2)
Meilano et al. (2011)

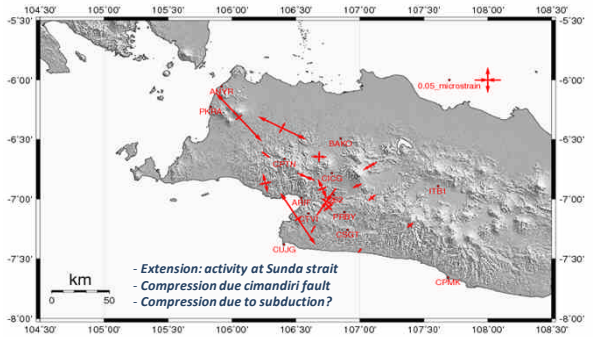

Lembang Fault from Tangkuban Perahu Volcano
Eastern segment of the fault
@ Hasanuddin Z. Abidin (2011)


GPS Networks
Observed 2006-2011
N= 44 points
Geodesy ITB, 2011

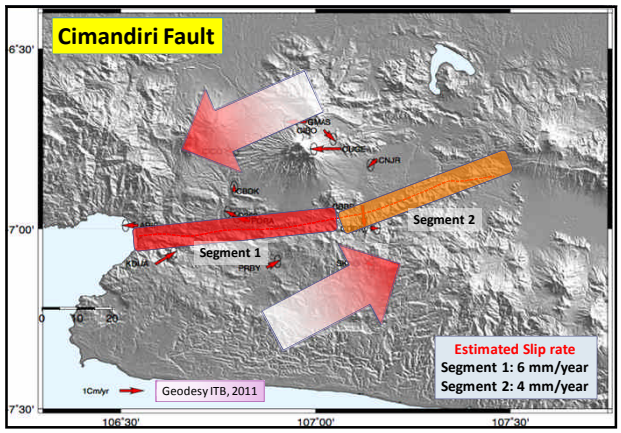

Lembang Fault and Earthquakes (1)
Several earthquakes related to Lembang fault :
23 Sept. 2000, 5.4 SR
(felt in Cimahi, Ujungberung, Soreang, Bale Endah, Lembang, and Bandung)
8 km North of Soreang.
11 July 2003, 4.2 SR
20 km NE of Bandung,
depth 10 km
5 Maret 2006, 2.0 SR
6.7 km N of Lembang,
depth 5 km
(Newcomb and McCann, 1987)
MAR 28, 1875
Abidin et al. (2007)


GPS CORS managed by Geodesy ITB
West Java
Papandayan
Location of GPS CORS
In cooperation with
GSI Japan, ERI University of Tokyo, and Bakosurtanal.
At present : 5 GPS CORS stations as shown in the Figure.
The main aim of this CORS network is to study the inter-seismic deformation of active faults in West Java, e.g. Cimandiri, Lembang and Baribis faults
Abidin et al. (2011)

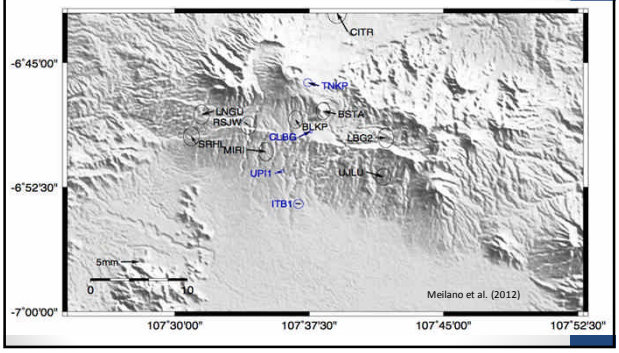
GPS derived Strain



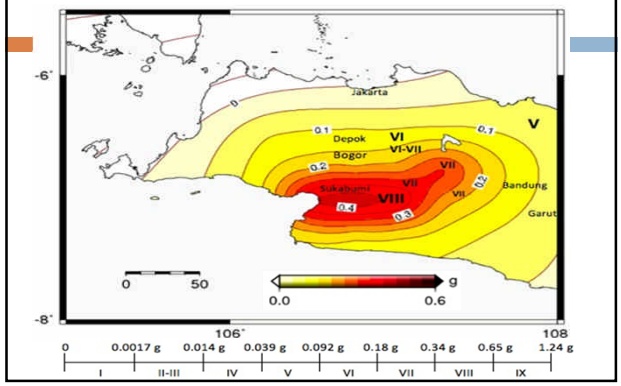
Cimandiri Fault



Lembang Fault: GPS derived Displacements

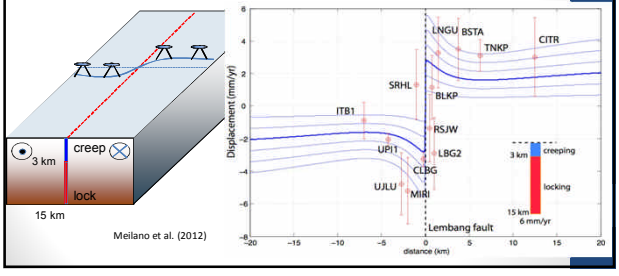


Cimandiri Fault: Preliminary calculated PGA (NGA)



Lembang Fault : Creeping dan Locking model

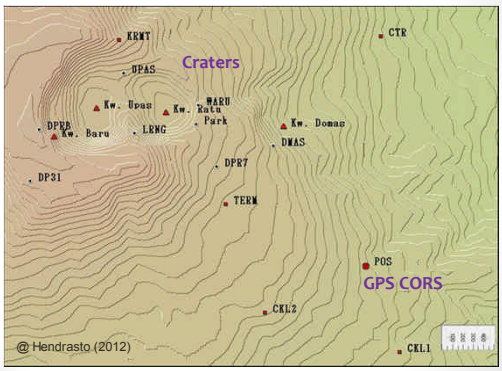
$$G_{GPS} = \frac{V_{slip}}{\pi}\left(\tan^{-1}\left(\frac{X_{GPS}}{d_{lock}}\right) + \tan^{-1}\left(\frac{d_{creep}}{X_{GPS}}\right)\right)$$



Volcanic Eruption of Tangkuban Perahu

Elevation : 2087 m
Eruptions: ..., 1910, 1994
Active Craters : 9 (nine)

GPS Network for Monitoring Tangkuban Parahu Volcano



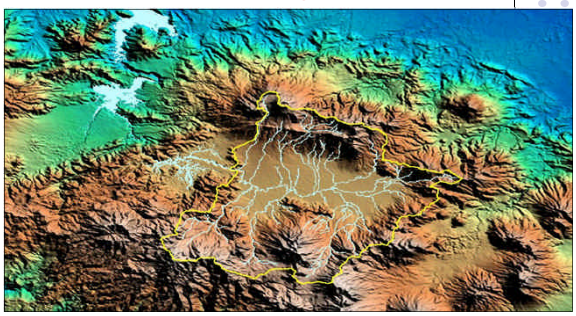
Flooding in South Bandung

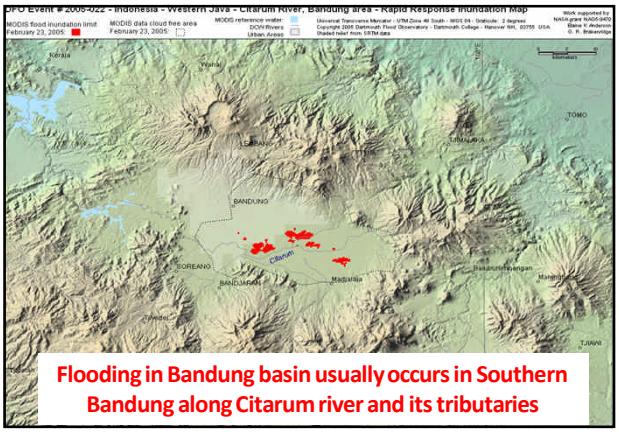
Sumber: http://www.kompas.com/data/photo/2010/02/20/3696729p.jpg

Flooding in Bandung basin

Landslides in Bandung

- In hilly areas
- During rainy season





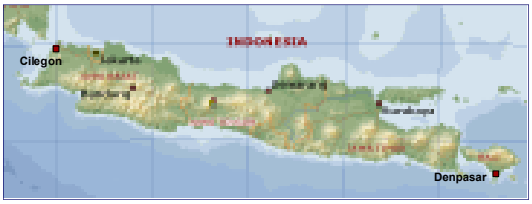
Flooding in Bandung basin usually occurs in Southern Bandung along Citarum river and its tributaries

Landslides in Bandung

Geospatial information is needed for indicating and mapping landslide prone areas

Hasanuddin Z. Abidin, 2012

Land Subsidence in Indonesian Cities



Observed land subsidence :

- Jakarta
- Bandung
- Semarang

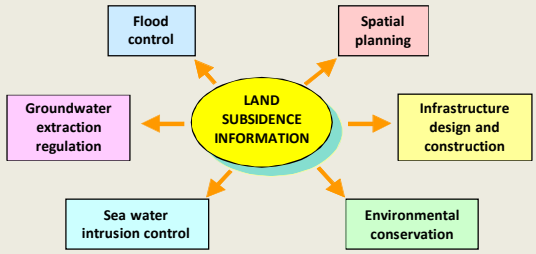
Expected land subsidence :

- Surabaya
- Denpasar
- Cilegon
- Medan

observed decrease in groundwater level

Hasanuddin Z. Abidin, 2006

IMPORTANCE OF LAND SUBSIDENCE INFORMATION



Hasanuddin Z. Abidin, 2006

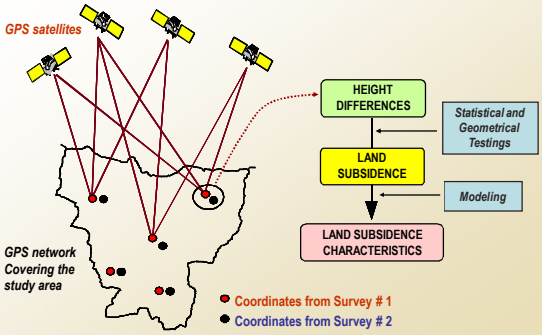
Geodetic Methods for Land Subsidence Monitoring

City	Leveling	GPS	InSAR	Gravity
Jakarta	Since 1982	Since 1997	Since 2005	Since 2008
Bandung	Limited	Since 2000	Since 2007	Since 2008
Semarang	Since 1999	Since 2008	Since 2007	Since 2002

GRD of ITB mainly involved with GPS Surveys and InSAR.

Hasanuddin Z. Abidin, 2012

PRINCIPLE OF LAND SUBSIDENCE MONITORING USING REPEATED GPS SURVEY METHOD



Hasanuddin Z. Abidin, 2006

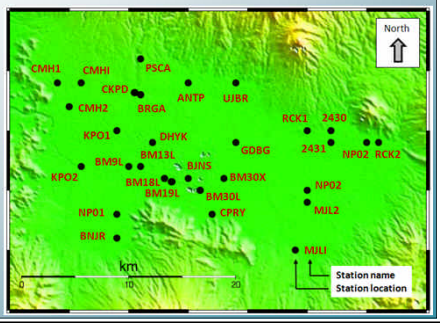
Types of Land Subsidence

- subsidence due to groundwater extraction,
- subsidence induced by the load of constructions (i.e. settlement of high compressibility soil),
- subsidence caused by natural consolidation of alluvium soil, and
- tectonic subsidence.

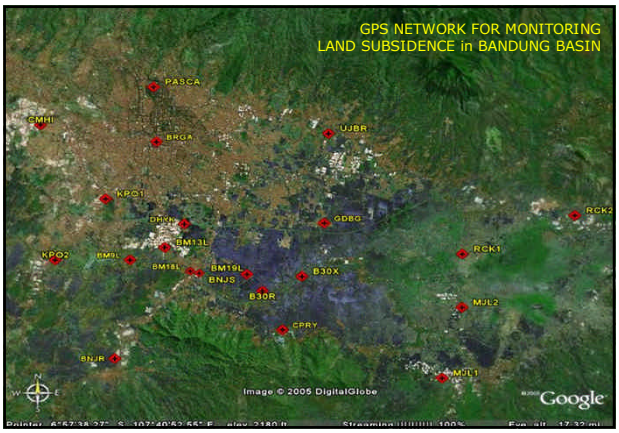
Hasanuddin Z. Abidin, 2006

GPS NETWORK FOR MONITORING LAND SUBSIDENCE in BANDUNG BASIN

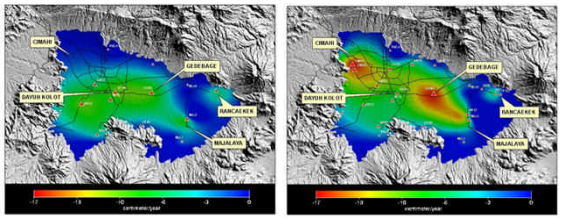
S-1 : 21-24 Feb. 2000
S-2 : 21-30 Nov. 2001
S-3 : 11-14 July 2002
S-4 : 1-3 June 2003
S-5 : 24-27 June 2005
S-6 : 20-23 Augt 2008
S -7 : July 2009
S-8 : July 2010
S-9 : August 2011
S-10 : August 2012



Hasanuddin Z. Abidin, 2012



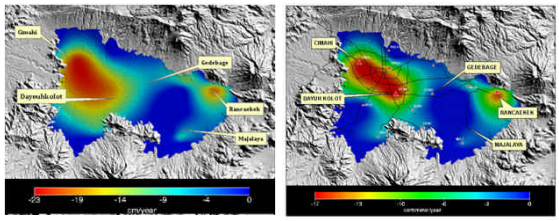
GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (3)



June 2005 – Augt 2008 Augt 2008 – July 2009

Hasanuddin Z. Abidin, 2011

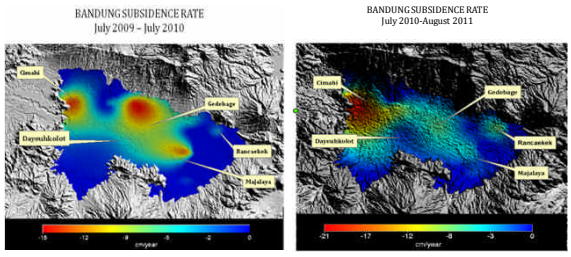
GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (1)



Feb. 2000 – Nov. 2001 Nov 2001 – July 2002

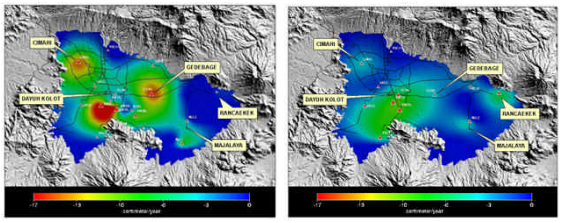
Hasanuddin Z. Abidin, 2011

GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (4)



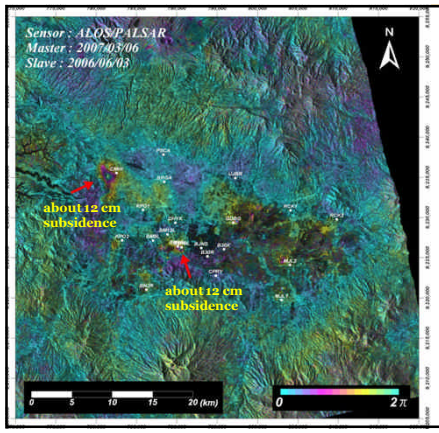
Hasanuddin Z. Abidin, 2011

GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (2)



July 2002 – June 2003 June 2003 – June 2005

Hasanuddin Z. Abidin, 2011

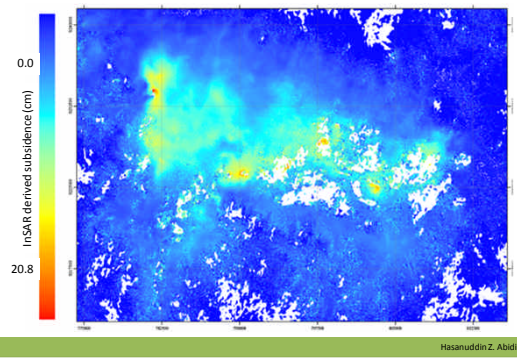


InSAR derived Subsidence

June 2006 to March 2007 (about 9 months)

Reference: Deguchi and Maruyama (2007) ERSDAC Japan

InSAR : Januari 2009 hingga Desember 2009



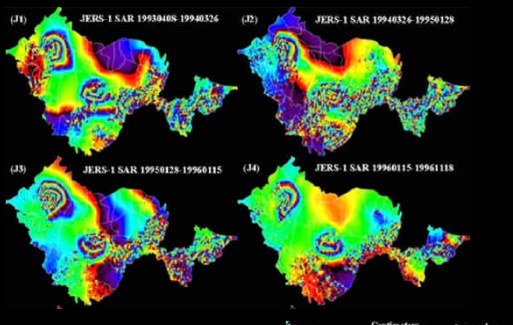
Hasanuddin Z. Abidin, 2011

IMPACTS OF LAND SUBSIDENCE

- Malfunction of drainage system.
- Changes in river canal and drain flow systems.
- The wider expansion of inland & coastal flooding areas.
- Cracking of buildings and infrastructure.
- Lowering the quality of living environment and life (e.g. health and sanitation condition) in the affected areas.
- Increasing the maintenance costs for the affected buildings and infrastructure.

Hasanuddin Z. Abidin, 2011

InSAR derived Subsidence : 1993 - 2010



Sumantyo et al. (2012)

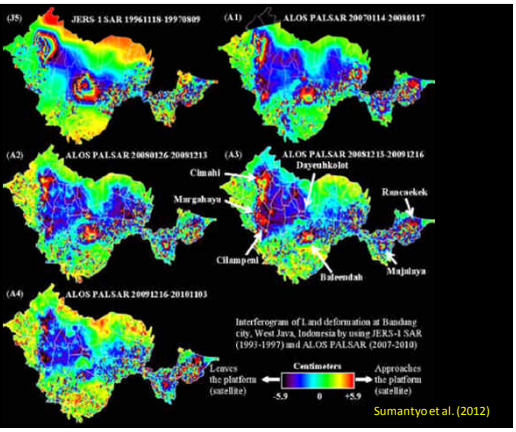
Mapping of land subsidence impact in Bandung Basin

Field survey has been done to map and evaluate the impacts of land subsidence in Bandung basin.

Field survey area focused in the large subsidence area and beside taking pictures we were doing some interview with local people.

A: Rancaekek, B: Leuwigajah, C: Ujungberung, D: Gedebage, E: Dayeuh Kolot, F: Leuwigajah

Hasanuddin Z. Abidin, 2011



Sumantyo et al. (2012)

Impacts of Land Subsidence in Bandung (1)

A: Rancaekek, B: Leuwigajah, C: Ujungberung, D: Gedebage, E: Dayeuh Kolot, F: Leuwigajah

Hasanuddin Z. Abidin, 2011

Impacts of Land Subsidence in Bandung (2)

G: Dayeuh Kolot H: Cimahi I: Gedebage
J: Gedebage K: Leuwigadjah L: Dayeuh Kolot

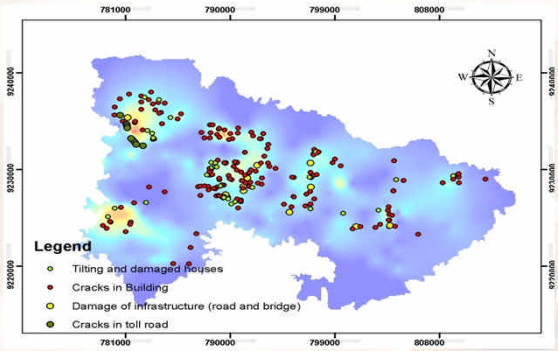
Hasanuddin Z. Abidin, 2011

EVIDENCE OF LAND SUBSIDENCE IN BANDUNG (Dayeuh Kolot)

Shortened distances from the roof and street to the floor

Hasanuddin Z. Abidin, 2011

Mapping of land subsidence impact in Bandung Basin



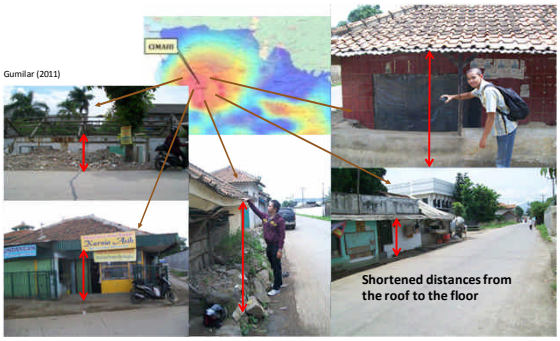
Abidin et al. (2012)

EVIDENCE OF LAND SUBSIDENCE IN BANDUNG (Gede Bage)

Shortened distances from the roof to the floor and the street to the floor

Hasanuddin Z. Abidin, 2011

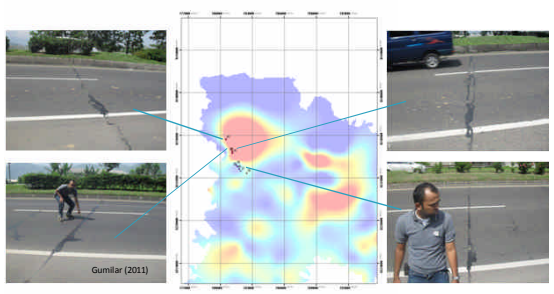
EVIDENCE OF LAND SUBSIDENCE IN BANDUNG (Cimahi)



Shortened distances from the roof to the floor

Hasanuddin Z. Abidin, 2011

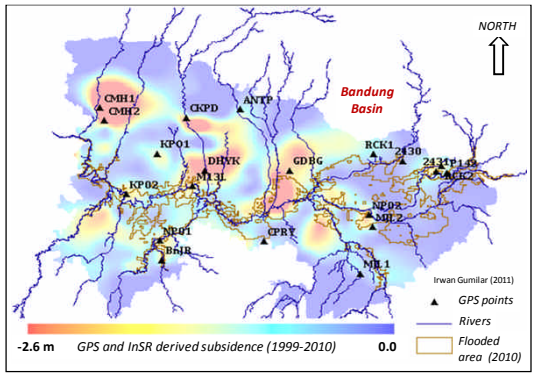
EVIDENCES OF LAND SUBSIDENCE IN BANDUNG BASIN



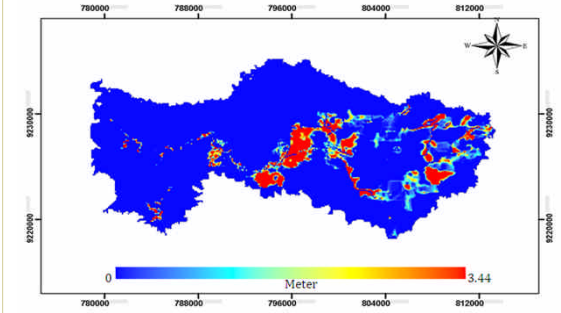
Crack on the highway (TOL Padalarang Cileunyi – Kilometer Pasirkoja)

Hasanuddin Z. Abidin, 2011

Land Subsidence and Flooding in Bandung Basin

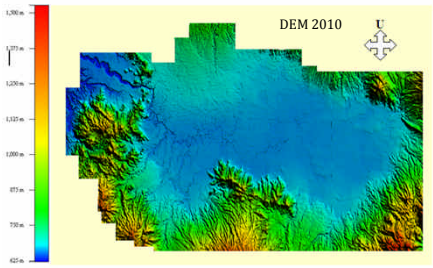


Flooding area 2010 and its depth without subsidence impact



Gumilar et al. (2012)

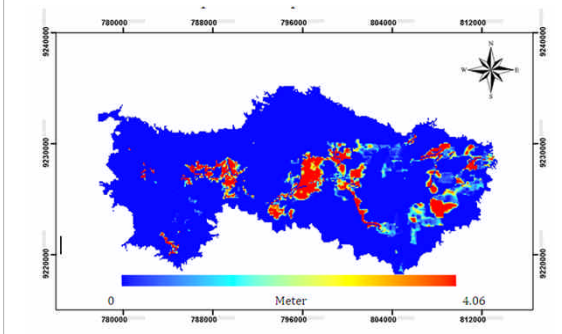
Modeling Flood in Bandung



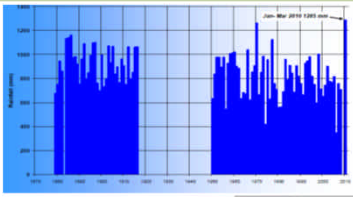
The flooding area in Bandung Basin modelled by using SOBEK software from Deltares (Holland). Sobek software designed to estimate 2D flooding area. The input of this software are the rainfall data, geometry of Citarum river, land use, and Digital Elevation Model (EDM) in 2010.

Gumilar et al. (2012)

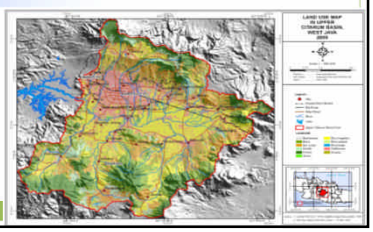
Flooding area 2010 and its depth with subsidence impact



Gumilar et al. (2012)

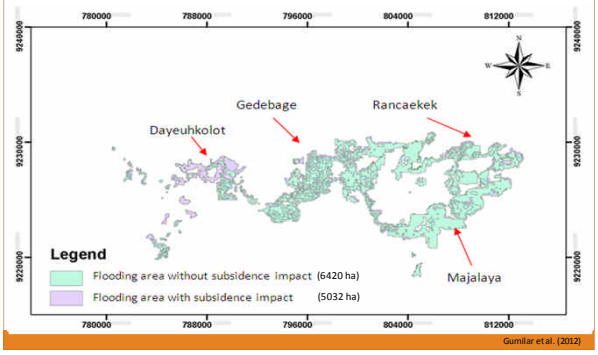


Rainfall data in Bandung basin in 1970-201 (PUSAIR dan Deltares, 2010)



Land use map of Bandung Basin 2006 from Landsat image (PUSAIR dan Deltares, 2010)

Differences in flooding coveragearea with and without subsidence impact



Gumilar et al. (2012)

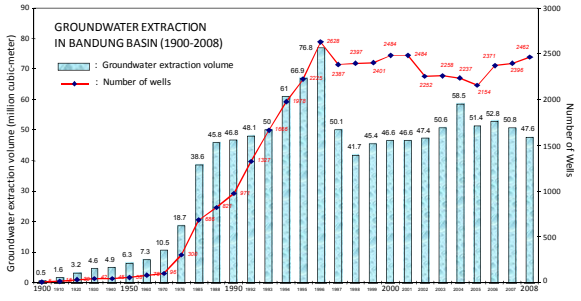
Causes of Land Subsidence in Bandung ?

- Excessive groundwater extraction
- Natural consolidation of alluvium soil
- Load of buildings and constructions
- Tectonic activities

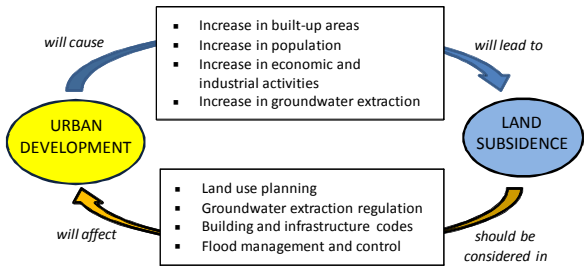
Contribution of each causes in spatial and temporal domain, is not fully known yet.

Hasanuddin Z. Abidin, 2011

GROUNDWATER EXTRACTION IN BANDUNG
[Badan Geologi, 2009]

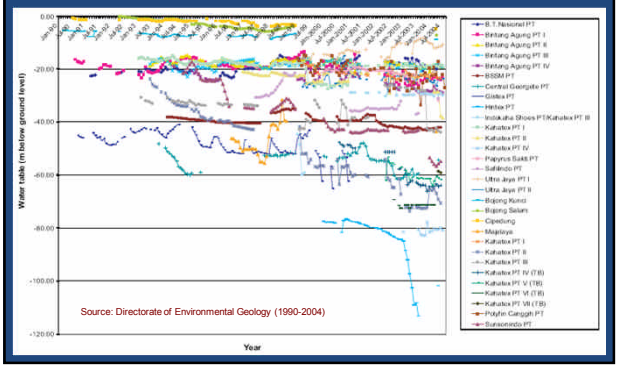


Urban Development and Subsidence in Bandung Basin

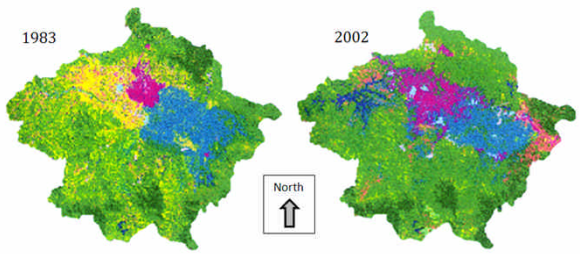


Hasanuddin Z. Abidin, 2011

GROUNDWATER TABLE DEPLETION RECORDED BY MONITORING WELLS IN METROPOLITAN BANDUNG (1990–2004)



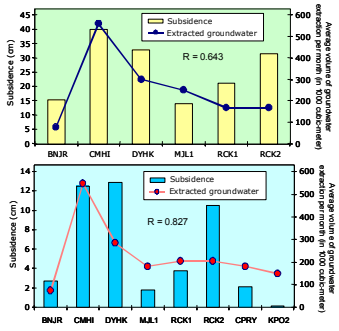
LAND USE CHANGES IN BANDUNG BASIN
adapted from *Sampurno* (2006).



The urban areas are indicated with the red-pink colour region.

Hasanuddin Z. Abidin, 2009

Land Subsidence and Groundwater Abstraction



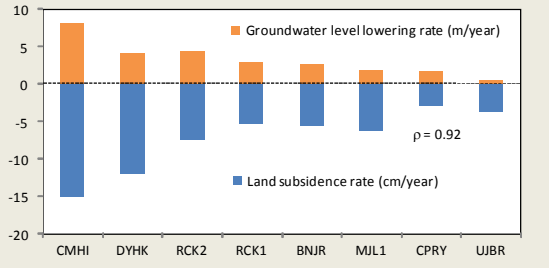
INITIAL HYPOTHESIS :
Land subsidence observed in several locations in Bandung basin is caused by an excessive groundwater abstraction.

GPS survey results show that this hypothesis is not always true for all observed stations.

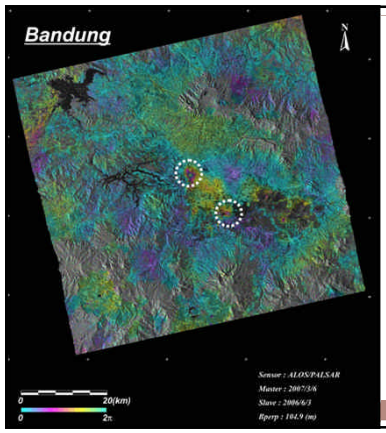
WHY ?
- the registered groundwater abstraction volume does not reflect the real groundwater abstraction, and/or
- the land subsidence is also governed by other factors.

Hasanuddin Z. Abidin, 2006

Groundwater Level Lowering and Land Subsidence in Bandung Basin



Hasanuddin Z. Abidin, 2009



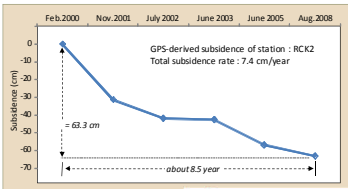
InSAR derived Subsidence

however shows that the largest subsidence

occurred inside the textile industry area complex

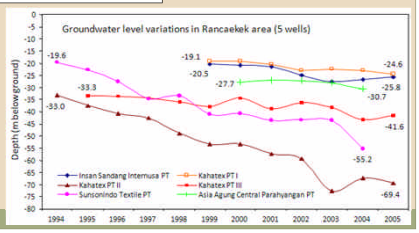
Excessive Groundwater Extraction ?

Hasanuddin Z. Abidin, 2006

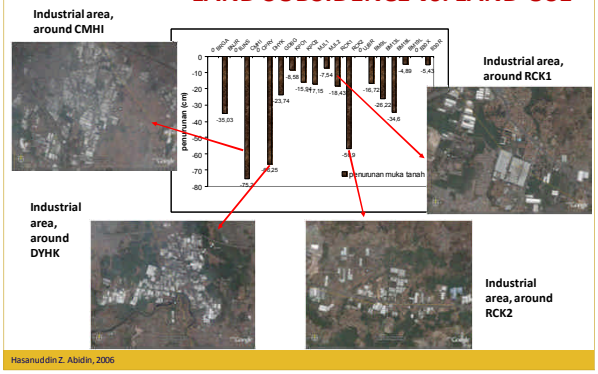


Subsidence of the RCK2 station located in the Rancaekek area from 2000 to 2008.

Indication of groundwater level fall in the Rancaekek area, adapted from *Wirakusumah* (2006).



LAND SUBSIDENCE vs. LAND USE

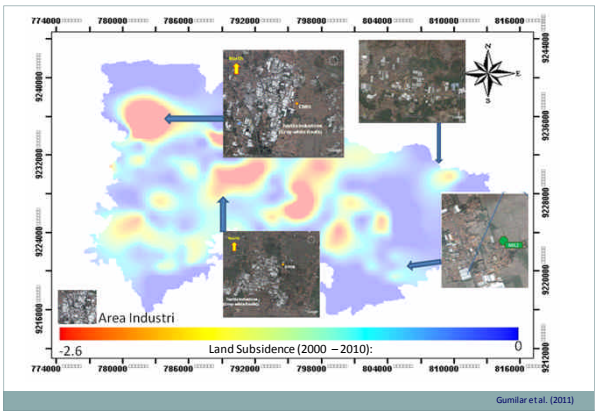


Hasanuddin Z. Abidin, 2006

Groundwater Level Lowering and Land Subsidence in Bandung Basin

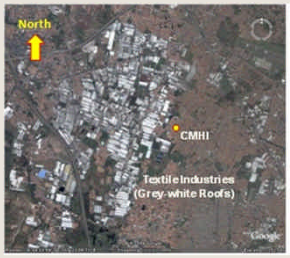
Groundwater level lowering rate, adapted from *Ruchijat* (2006)			Average subsidence rate (from GPS surveys)		
Area	Rate (m/year)	Period	GPS station	Rate (cm/year)	Period
North Cimahi	1.3 – 8.0	1994–2004	CMHI	-15.1	2000-2005
South Cimahi	0.2 – 3.2	1994–2004			
Dayeuh Kolot	≈ 2.4	1980-2004	DYHK	-12.0	2000-2008
	0.2 – 4.1	1994–2004			
Rancaekek	0.5 – 4.2	1993–2004	RCK2	-7.4	2000-2008
Cileunyi	2.3 – 2.8	2000–2004	RCK1	-5.3	2000-2008
Banjaran	0.3 – 2.5	1989–2004	BNJR	-5.6	2000-2008
Majalaya	≈ 1.8	1980-2004	MJL1	-6.3	2001-2003
Ciparay	0.4 – 1.6	1992–2004	CPRY	-3.0	2001-2002
Ujung Berung	0.2 – 0.5	1994–2004	UJBR	-3.6	2001-2003

Hasanuddin Z. Abidin, 2009



Gumilar et al. (2011)

Location of GPS Stations CMHI and DYHK
(in the areas of textile industries)

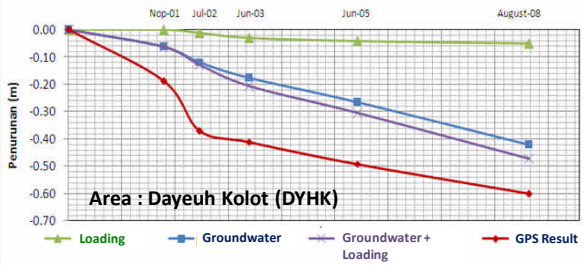


Subsidence rate (2009 – 2010):
14.5 cm/year

Subsidence rate (2009 – 2010):
7.4 cm/year

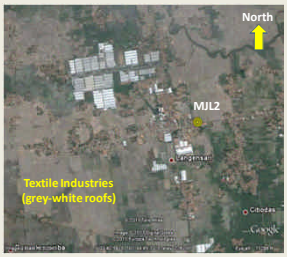
Hasanuddin Z. Abidin, 2011

Land Subsidence : Groundwater Extraction and Loading

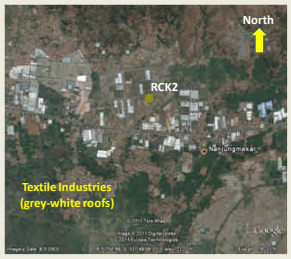


Ref : Taufiq et al. (2009)

Location of GPS Stations MJL2 and RCK2
(in the areas of textile industries)



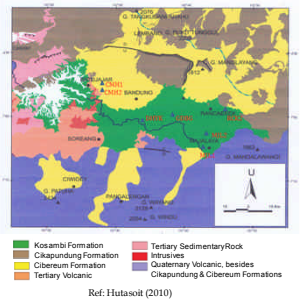
Subsidence rate (2005-2008):
6.5 cm/year



Subsidence rate (2005 – 2008):
5.9 cm/year

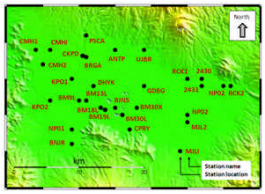
Hasanuddin Z. Abidin, 2011

Land Subsidence and Natural Consolidation of Alluvium Soil

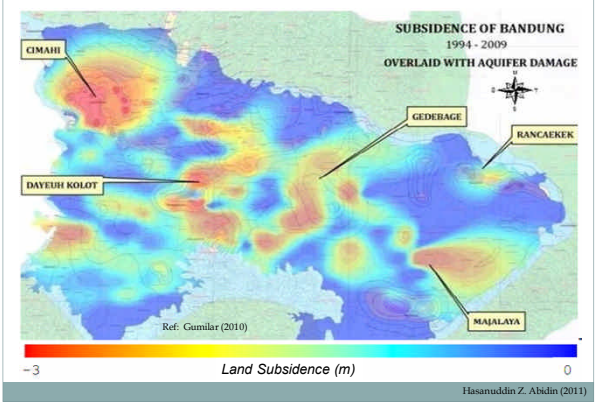


Ref: Hutasoit (2010)

Kosambi formation
= lake alluvium (sediment)

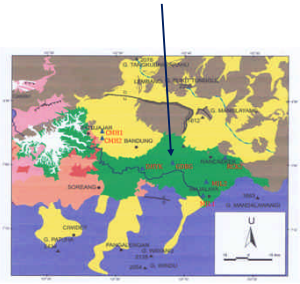


Hasanuddin Z. Abidin (2011)



Hasanuddin Z. Abidin (2011)

Location of GPS Stations GDBG

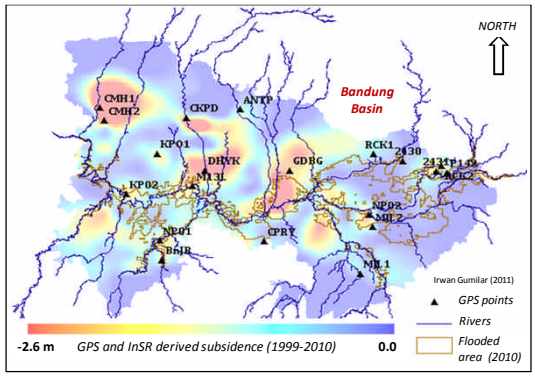


Subsidence rate (2009 – 2010):
9.1 cm/year

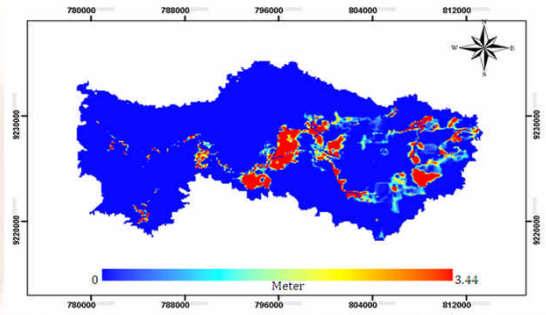
Combined effects of groundwater abstraction and natural consolidation ?

Hasanuddin Z. Abidin (2011)

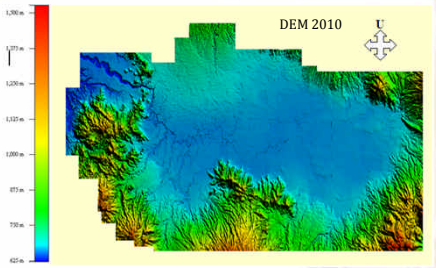
Land Subsidence and Flooding in Bandung Basin



Flooding area 2010 and its depth without subsidence impact

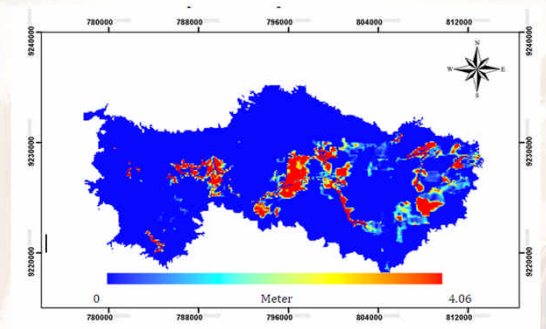


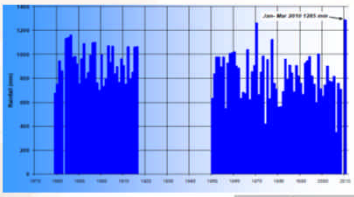
Modeling Flood in Bandung



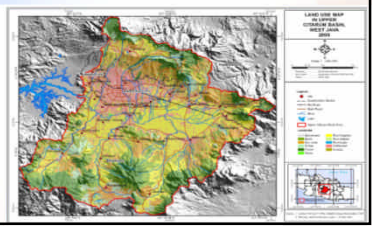
The flooding area in Bandung Basin modelled by using SOBEK software from Deltares (Holland). Sobek software designed to estimate 2D flooding area. The input of this software are the rainfall data, geometry of Citarum river, land use, and Digital Elevation Model (EDM) in 2010.

Flooding area 2010 and its depth with subsidence impact



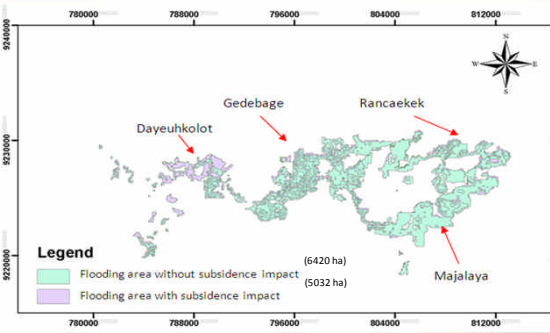


Rainfall data in Bandung basin in 1970-201 (PUSAIR dan Deltares, 2010)



Land use map of Bandung Basin 2006 from Landsat image (PUSAIR dan Deltares, 2010)

Differences in flooding coveragearea with and without subsidence impact



CLOSING REMARKS

- Bandung is prone toward several natural hazards
- Main threat comes from :
  - ✓ Flooding
  - ✓ Land Subsidence
  - ✓ Volcanic eruption
  - ✓ Earthquake
  - ✓ Landslide
- Good and reliable geospatial data and information in both spatial and temporal domain is needed for natural hazard mitigation process.