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Emergency survey of the great earthquake impacting on water security in Kathmandu, Nepal

Principal Investigators
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Objectives of J-RAPID project

- To investigate impacts of the great earthquake on domestic water for local people, as well as natural water resources and water supply and treatment systems.
- To assess and propose emergency actions, such as securing sanitary condition related to water use, quick and efficient water treatment methods, possible alternative water sources, in Kathmandu and surrounding areas.

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Our SATREPS (Science and Technology Research Partnership for Sustainable Development) project has started in 2014

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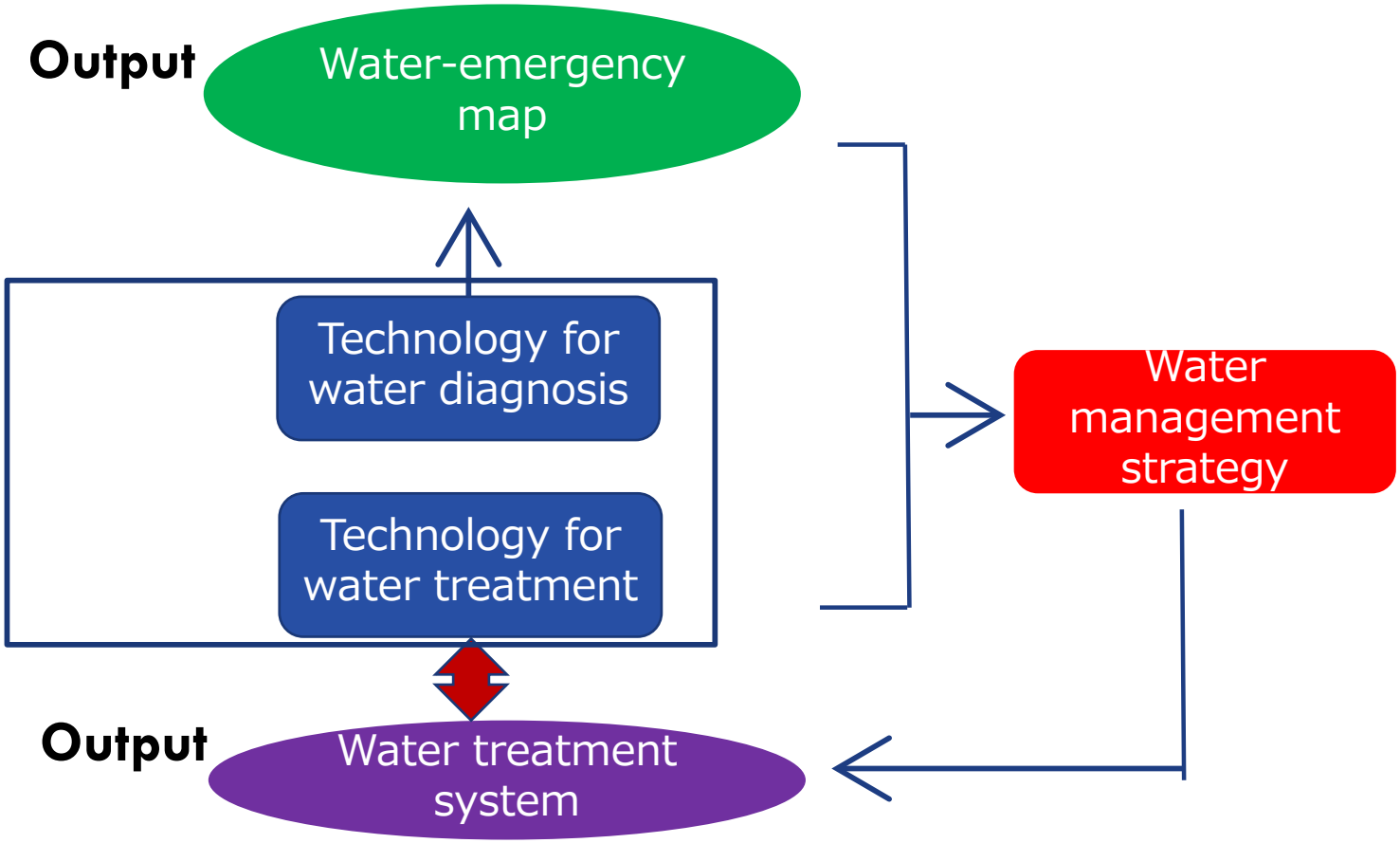
Water Security by Hydro-Microbiological Approach in Nepal (WASHmia)

Objectives of SATREPS (WASHmia)

- To ensure safe water supply by means of developing locally-fitted compact distributed (LCD) treatment technology, based on water diagnosis.



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5 working groups (WG1–5)

Working group		Output
WG1	**Water resources assessment**	Potable water resources situation, including water demand, consumption and supply in Kathmandu Valley, is studied and future forecast is conducted.
WG2	**Water quality assessment**	Situation and sources of groundwater pollution is studied.
WG3	**Microbial and public health assessment**	Microbiological situation of environmental water, such as groundwater, surface water, and rain water, in the Kathmandu Valley is studied.
WG4	**Water treatment system development**	Appropriate locally-fitted, compact and distributed (LCD) water treatment system for groundwater and surface water in Kathmandu Valley is developed.
WG5	**Socio-economic assessment**	Social and economic evaluation of the LCD water treatment system installation in Kathmandu Valley is studied.

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Survey groups and members

Survey group	Members from Univ. of Yamanashi, Japan	Members from Nepal	SATREPS WG
Water resources assessment	Y. Ichikawa (Kyoto Univ.) H. Ishidaira J. Magome	N. M. Shakya (IOE-TU)	WG1
Water quality assessment	T. Nakamura K. Nishida Y. Sakamoto	S. D. Shrestha (CDG-TU)	WG2
Microbial water quality assessment	F. Kazama E. Haramoto T. Toyama K. Mori Y. Tanaka Y. Yoneyama T. Kamei	J. B. Sherchand (IOM-TU) I. M. Amatya (IOE-TU)	WG3 & 4
Social evaluation	J. Shindo S. Muto	H. P. Timilsina (MoUD)	WG5
Geotechnical assessment	T. Suzuki T. Miyamoto K. Araki	-	-

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Water resources assessment group

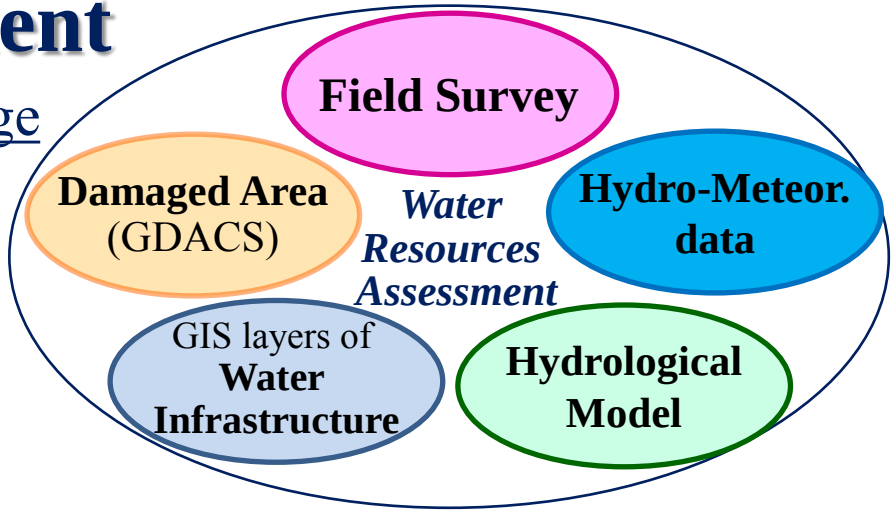
Water Resources Assessment

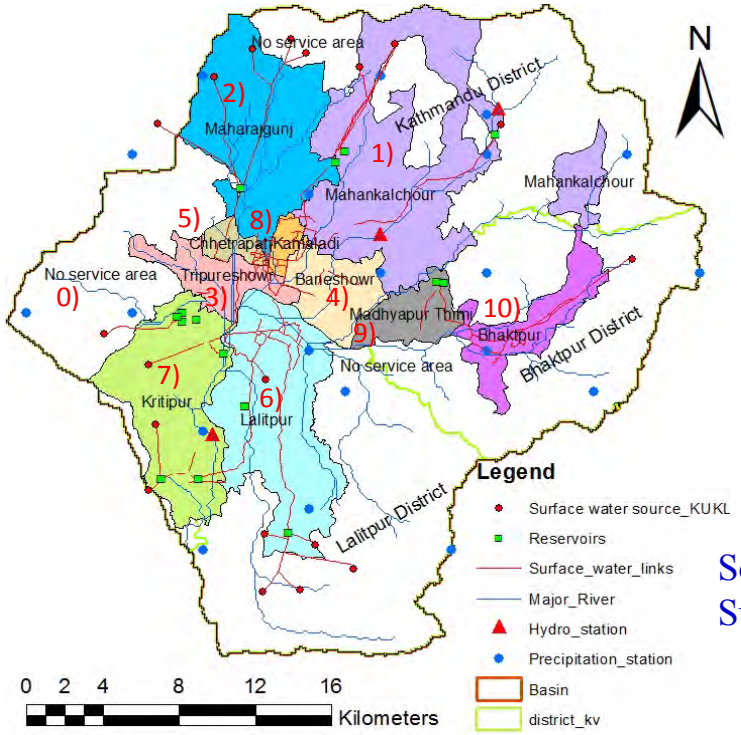
1) Survey of water infrastructure damage

- water intake & pipe network
- storage tank (rooftop/under ground)

2) Survey of natural water resources

- water resources availability
- alternative water sources

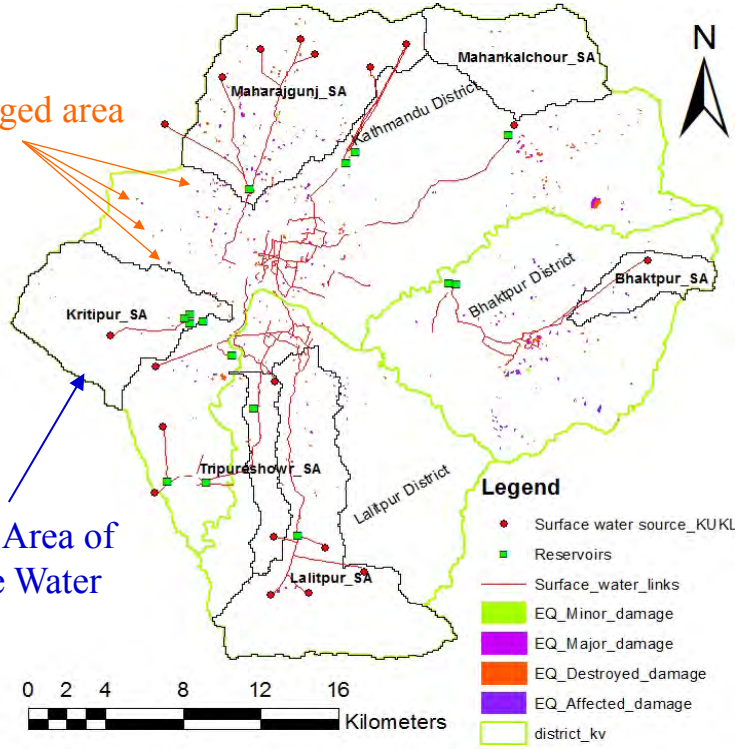




KUKL Service Area

E.Q. damaged area

Source Area of Surface Water



Source of Surface Water & E.Q. damaged Area

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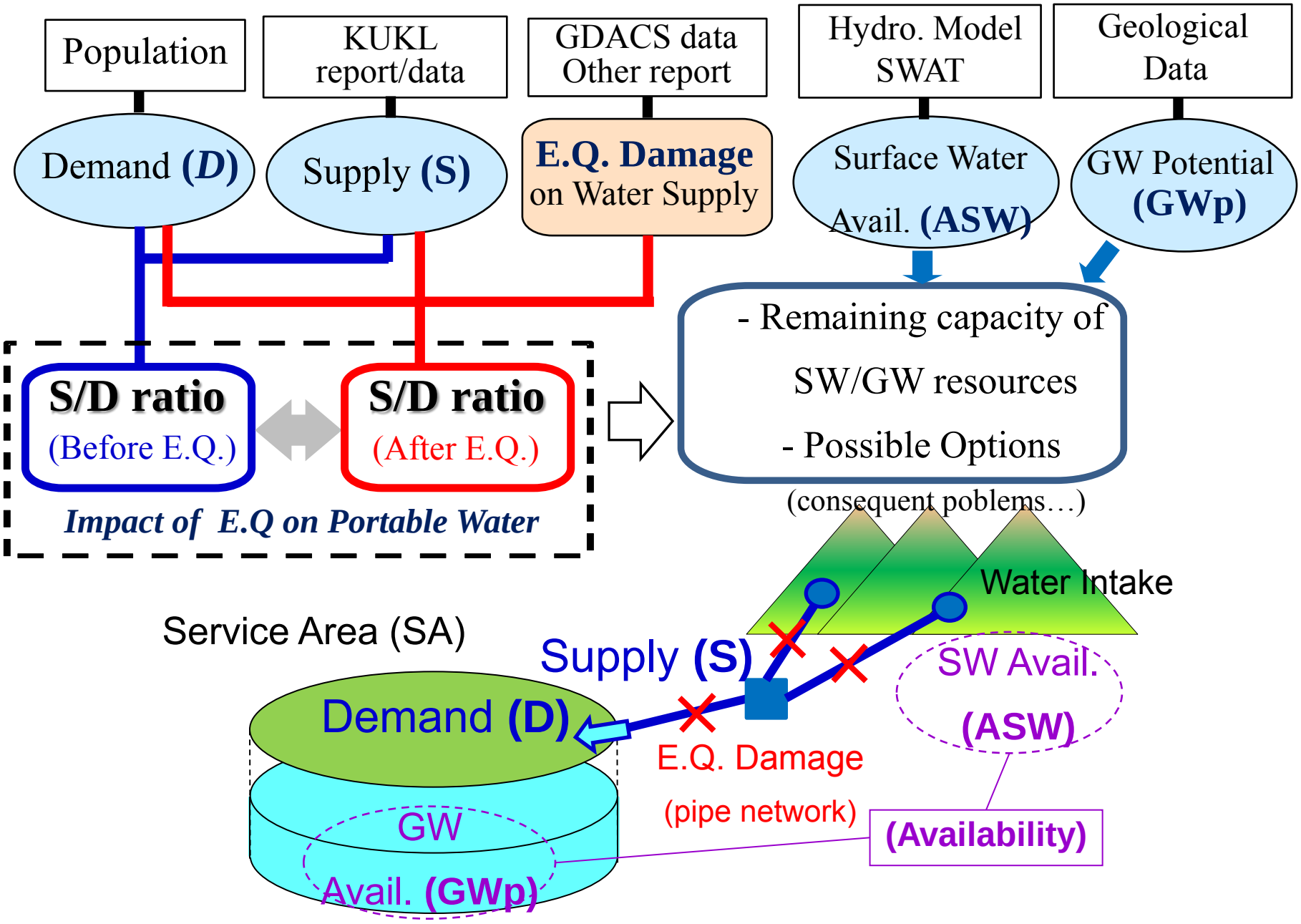
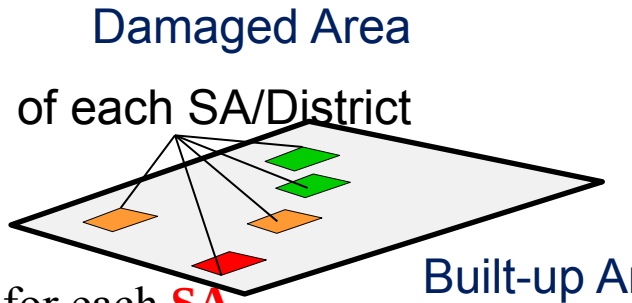
Methodology



Earthquake Damage Estimation

PDS_i : Percentage of Damage on Water Supply for each **SA**

$$PDS_i = \frac{PDA_i}{PDA_j} PDS_j$$

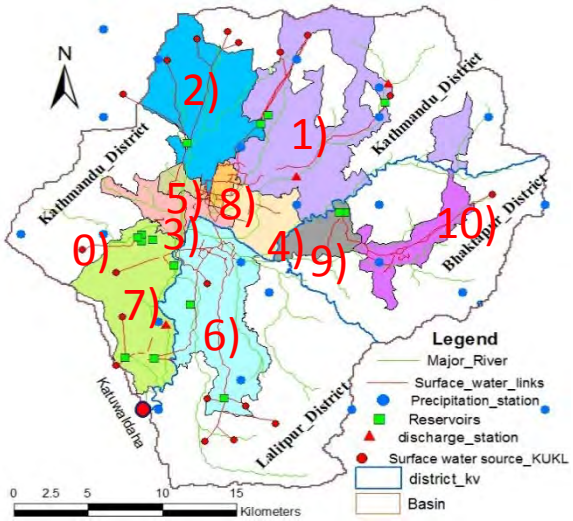


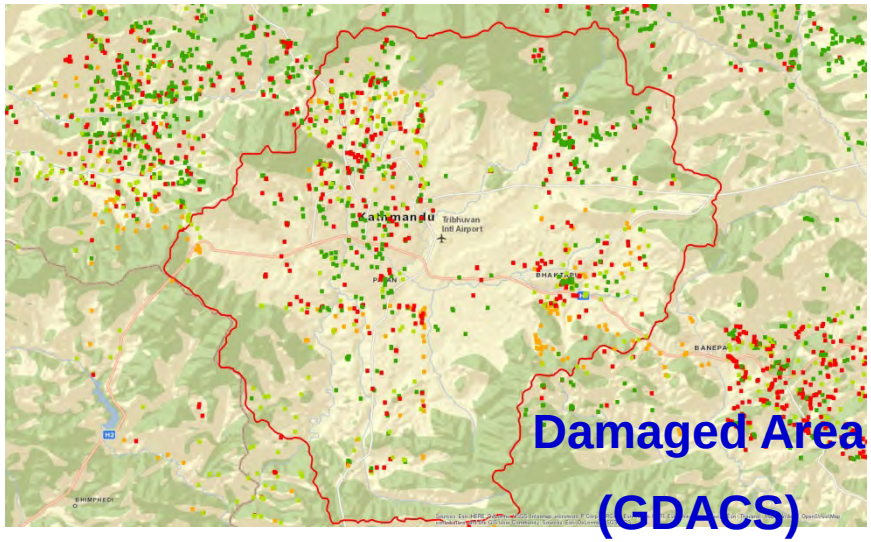
PDA_i : Percentage of Damaged Area for each **SA**

PDA_j : Percentage of Damaged Area for each **District**

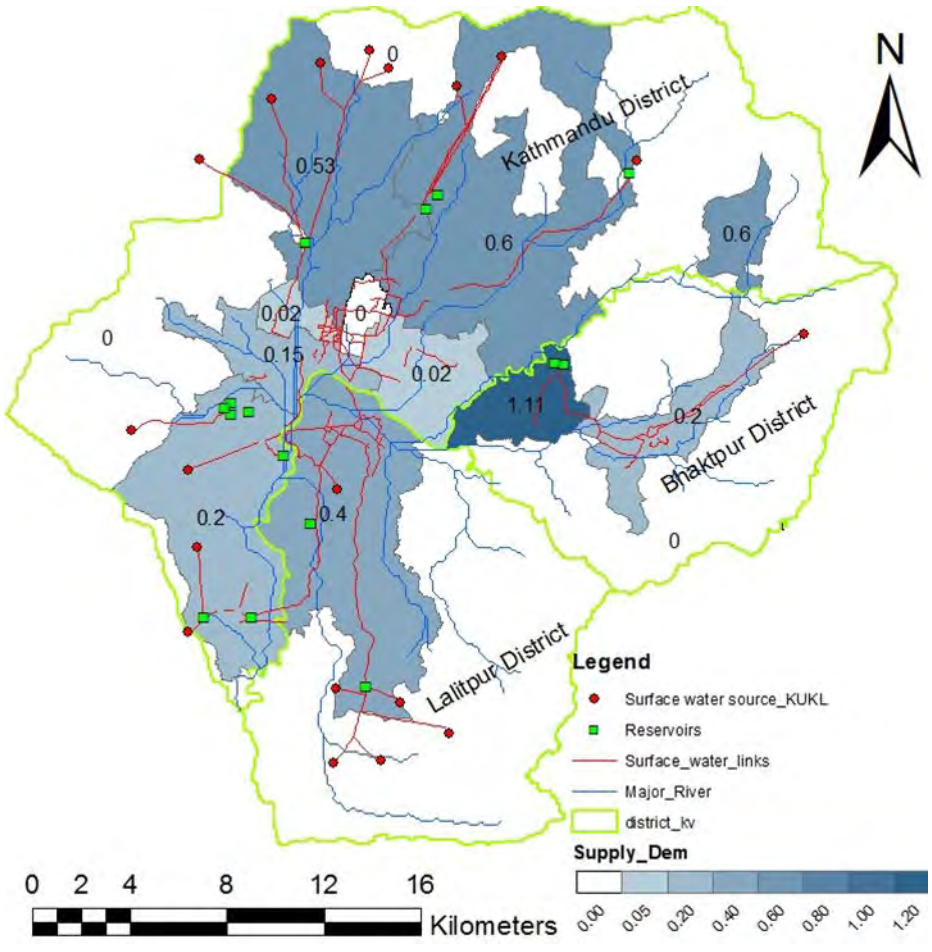
PDS_j : Percentage of Damage on Water Supply for each **District** (Rai R., 2015)

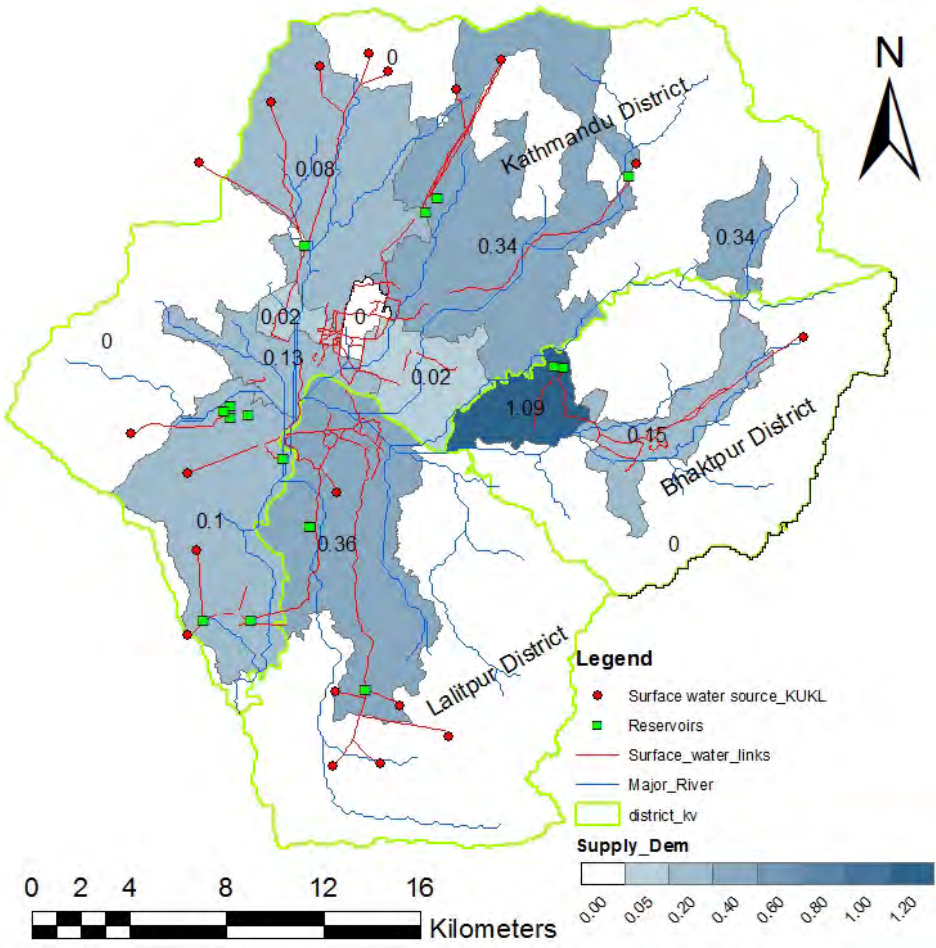
Kathmandu: 30 % reduction of W.S., **Lalitpu: 28 %**, **Baktapur: 18 %**





Supply/Demand ratio (Wet season, before and after GE2015)



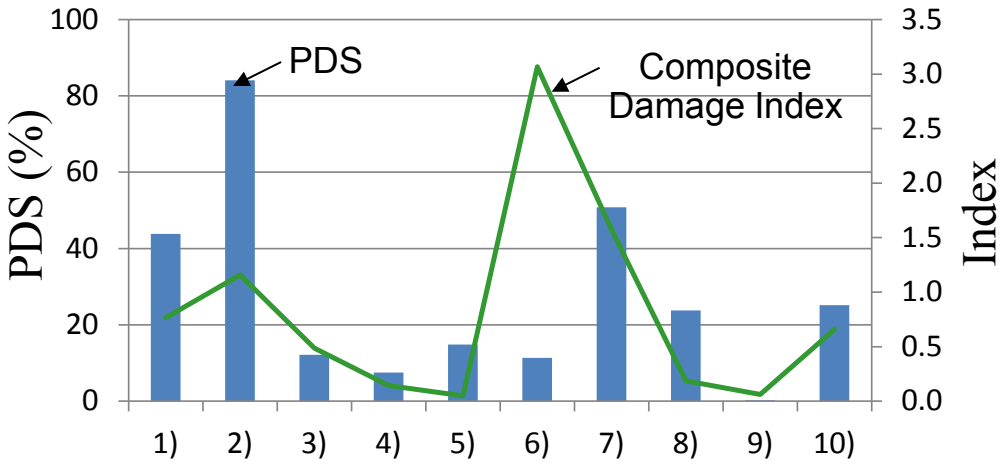


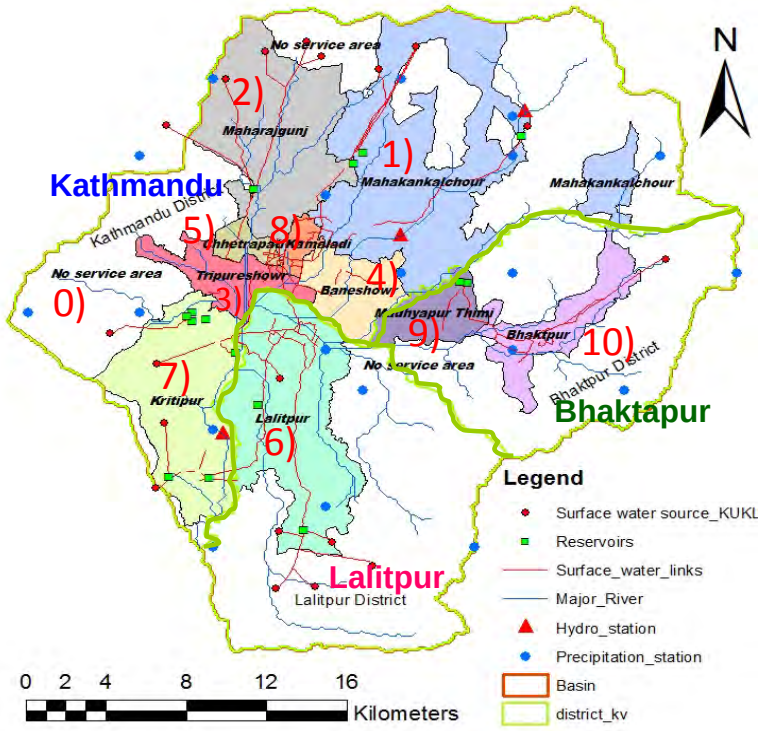
- Only the SA no 9 demand is fully satisfied by KUKL on wet season

	No. of pipe break down	Length of pipe damage (km)	Total estimated budget (NRs)	Total days required for maintenance (days)
1)	38	100	17.7	132
2)	11	900	11.6	144
3)	8	75	2.6	127
4)		145	0.8	14
5)	1		0.2	14
6)	17	1550	119	330
7)	250		8.9	164
8)	3	75	1.6	37
9)	2		1	15
10)	3	105	7.2	171

- Normalized by Max. value
- And up (4 components)

Composite Damage Index





*PDS = Percentage of Damage on Water Supply

= 100 − (Water Supply Ratio) [%]

Water quality assessment group

Water Quality Assessment

1) Survey of Groundwater quality

- To clarify the earthquake effects on water quality for community dug wells (sallow Gw.)

2) Survey of natural water resources

- water resources availability
- alternative water sources

→Mountain spring water

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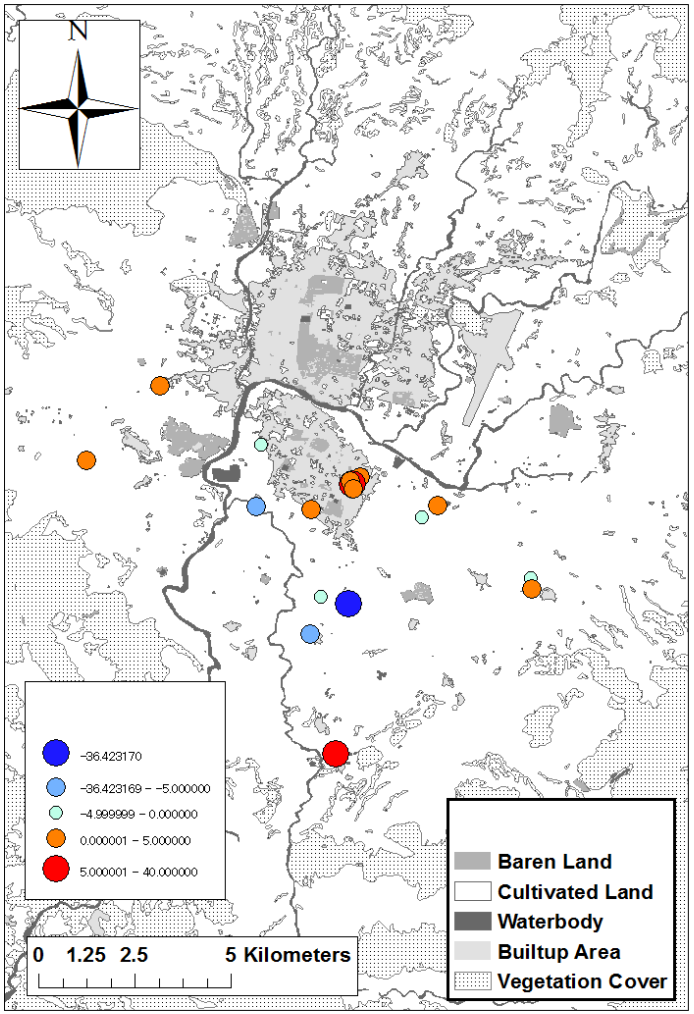
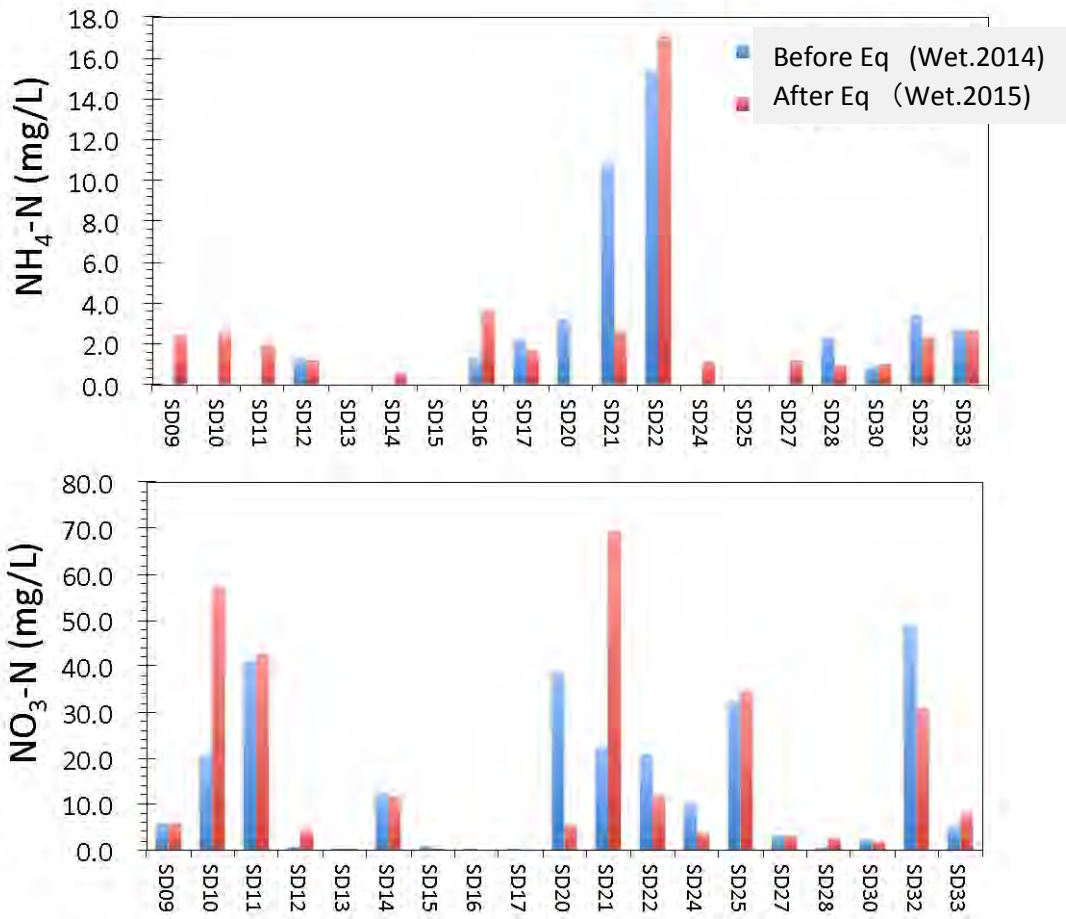
Damages for sewage system affected Gw. quality?





- Both negative and positive effects for nitrogen contamination were detected.
- Nitrogen contamination had occurred before Eq.

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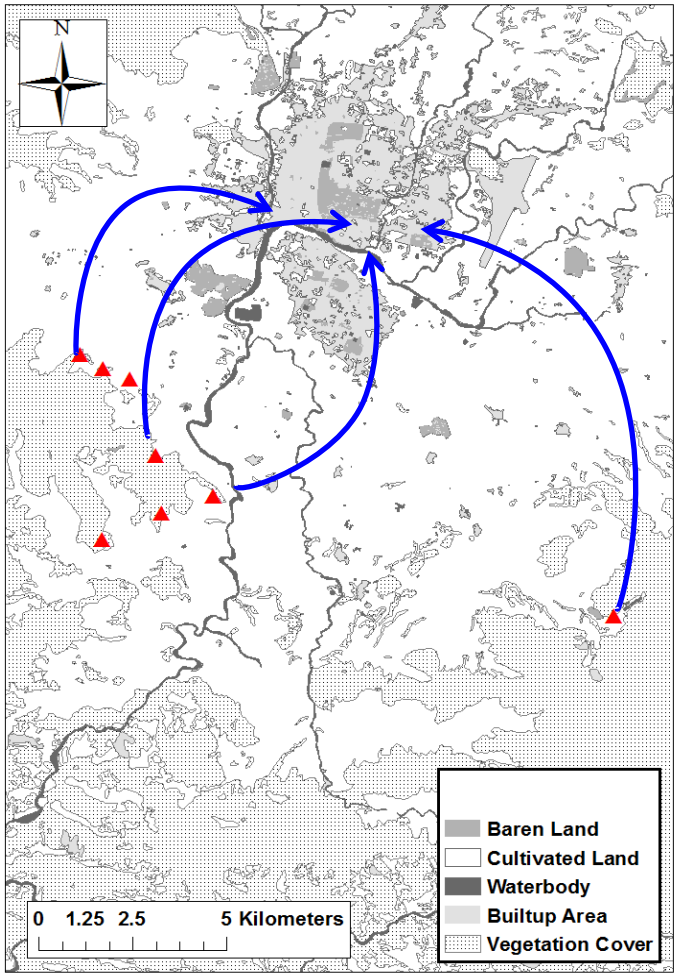
Mountain springs as an alternative water resources



Sattmul Spring

Godavari Spring

Before EQ.

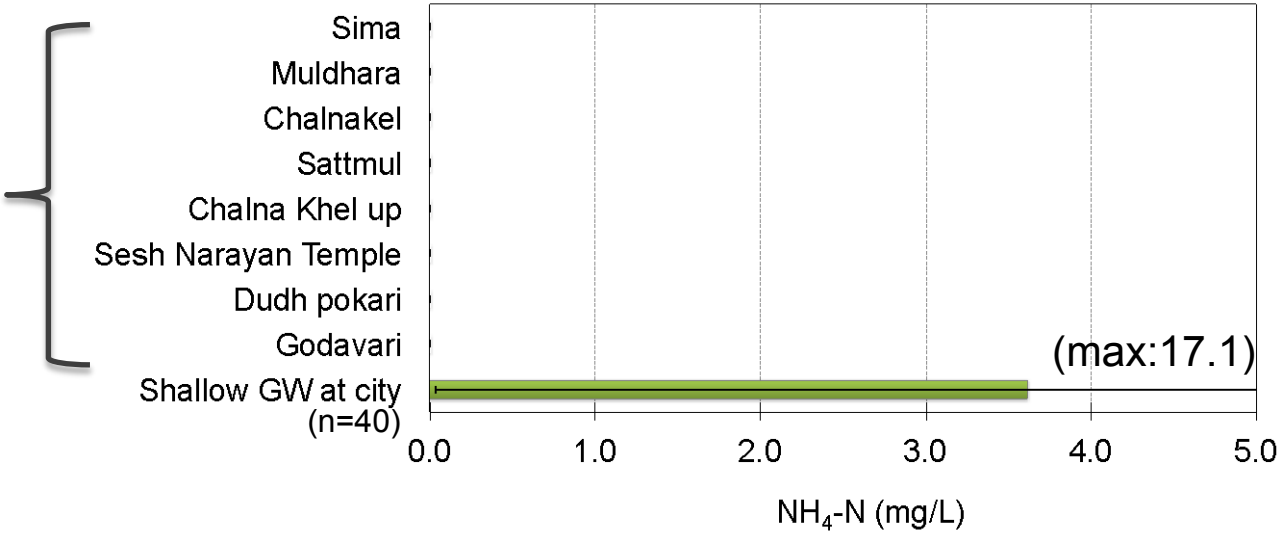
26-Apr-2015

8 mountain spring water were collected after Eq.

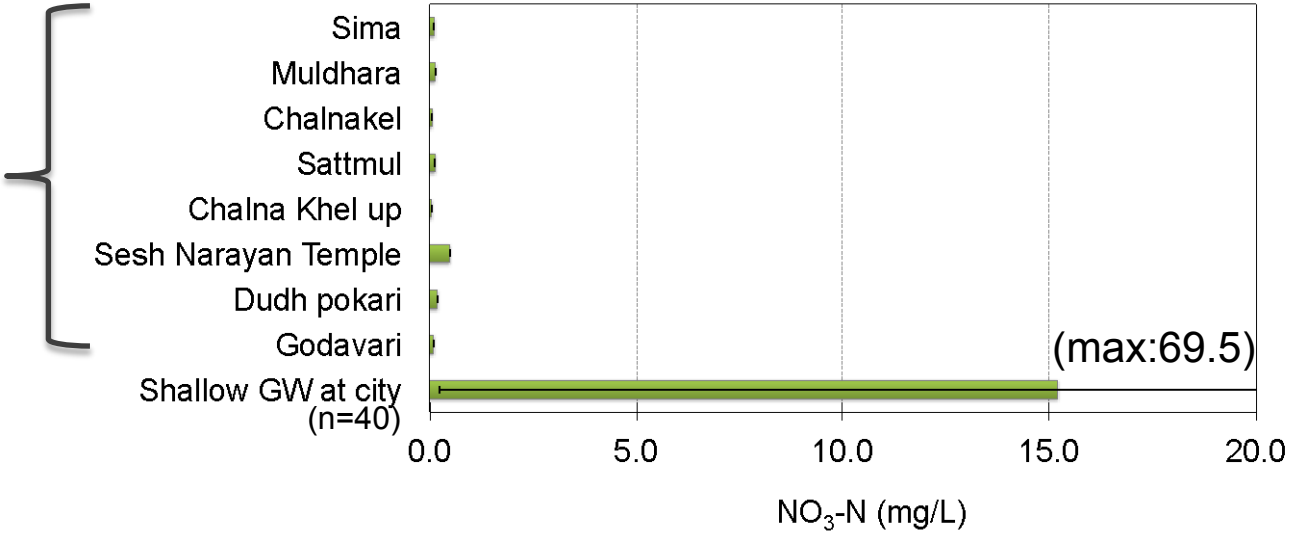
during wet (Sep. 2015) and dry (Mar. 2016)

Spring with Shallow GW quality (Nitrogen contamination)

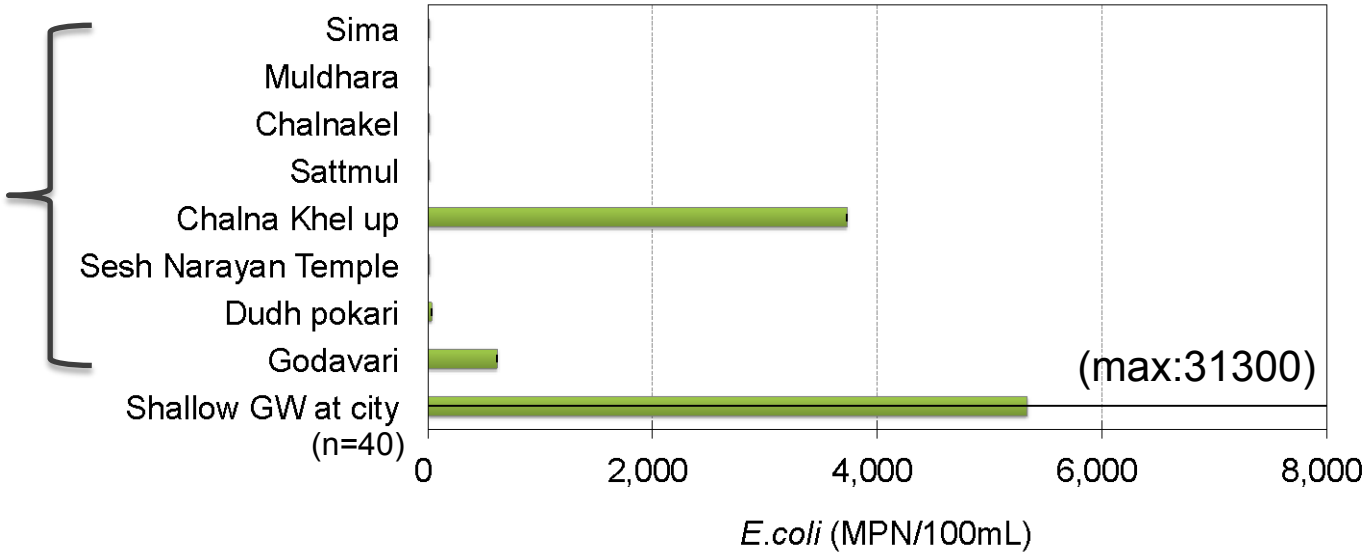
Spring water



Spring water



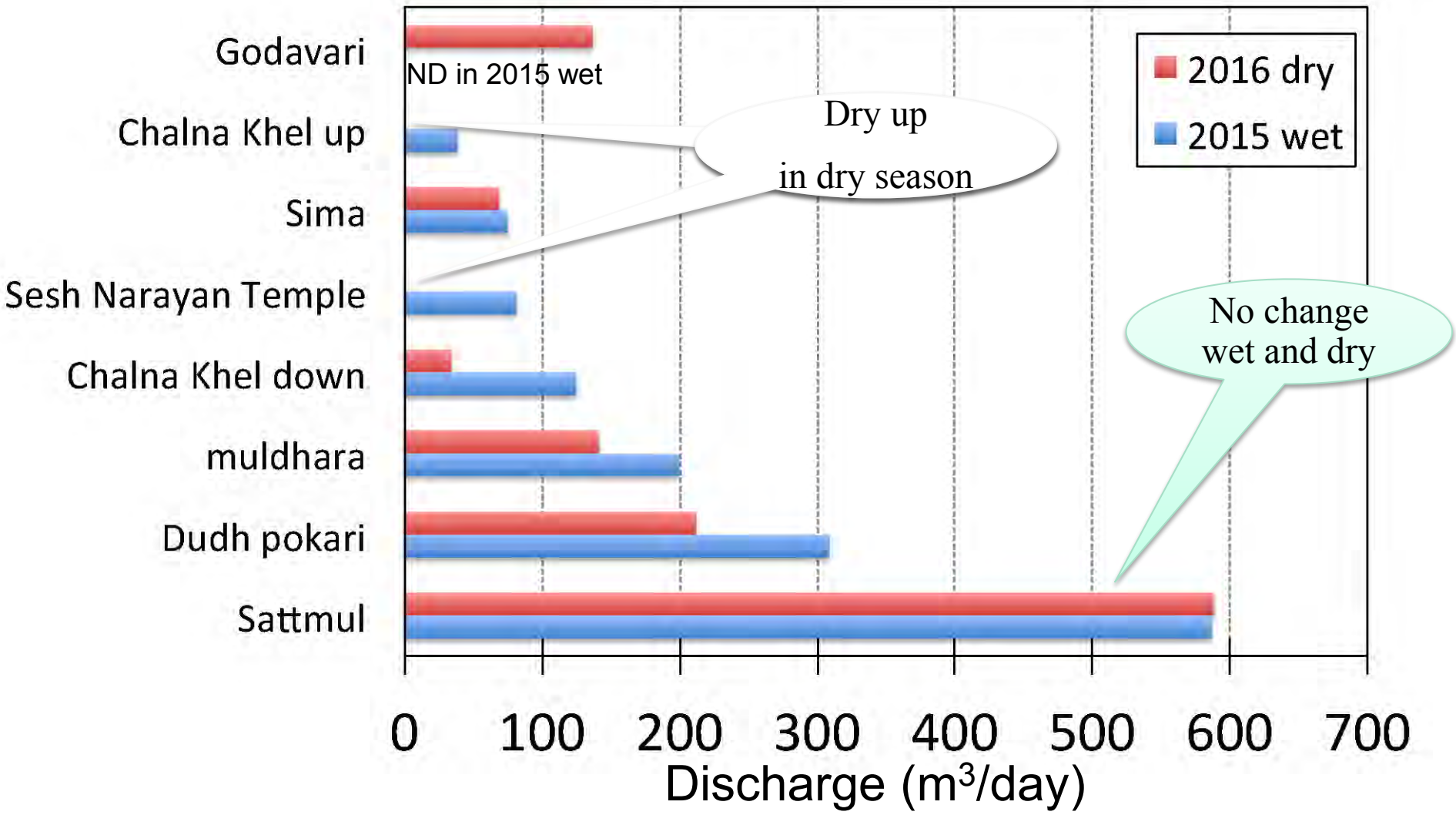
Spring with shallow GW quality (*E.coli* Contamination)



- Local contamination was detected from 2 springs.

→Water quality evaluation even in the mountain springs are recommended.

Spring Discharges



Microbial water quality assessment group

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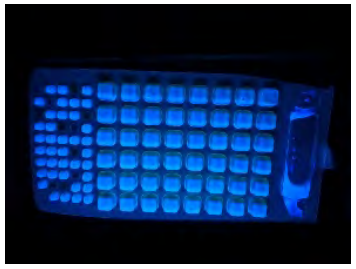
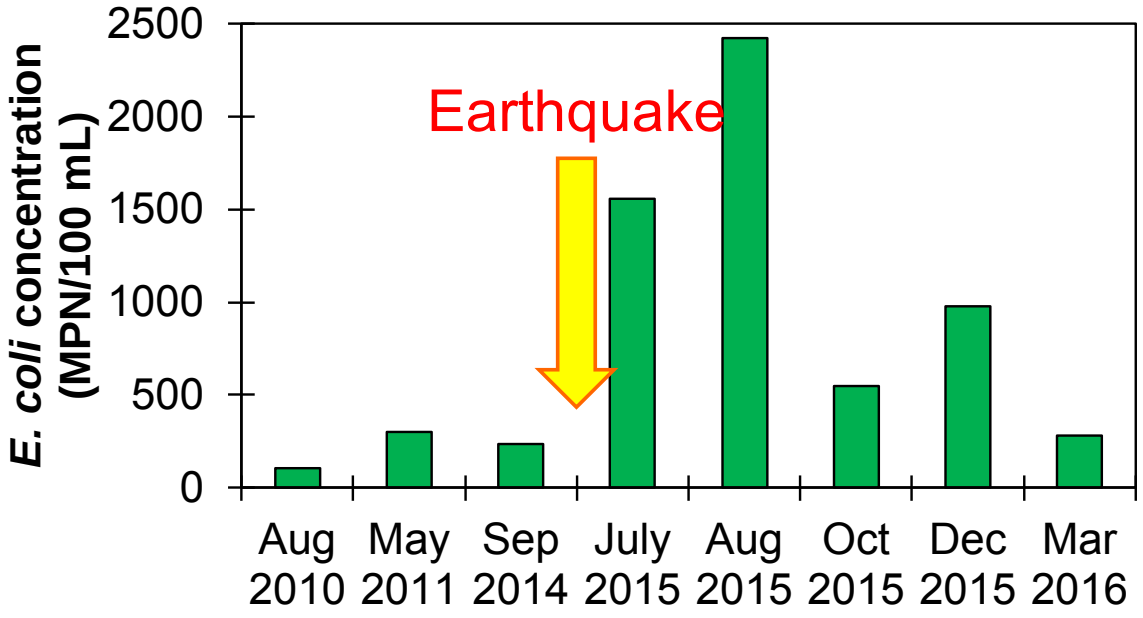
Microbial water quality assessment

- To evaluate the effects of the earthquake on microbial water quality in drinking water sources (collaborating with Water quality assessment group).
- To evaluate the applicability of water treatment systems/devices which can be used in cases of water emergency to microbial removal in water.

Escherichia coli concentrations in water supplied with a water tanker in Maitighar





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Locally-fitted, compact and distributed (LCD) water treatment system

- Sponge tray water treatment system installed at Jwagal showed the mean removal ratio of 78.9% (0.68 $\log_{10}$) for total coliforms, indicating a potential use of this system for domestic water production.

Influent

Effluent

Removal ratio of total coliforms

December 2015

63.5% (0.44 $\log_{10}$)

March 2016

87.7% (0.91 $\log_{10}$)

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Portable devices for microbial removal

- Pet bottle filled with activated carbon could remove 98.1% (1.72 $\log_{10}$) of *E. coli* in contaminated water.

Removal ratio of *E. coli*: 98.1% (1.72 $\log_{10}$)

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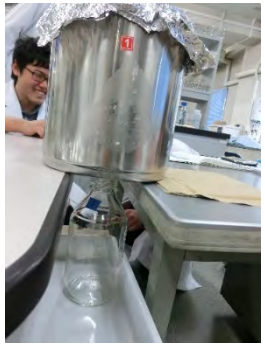
Household water filter

- Commercially available water filter worked well to remove *E. coli*, but not for coliphages.

Volume filtered (L)	Removal of ***E. coli***
0	99.98% (3.73 log)
50	99.98% (3.62 log)
100	99.53% (2.33 log)
Volume filtered (L)	**Removal of coliphage MS2**
100	0–18.9% (<0.09 log)



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Social evaluation group

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Activities of Social Evaluation Group

I. Objectives

- To clarify the earthquake effects on domestic water use, health and quality of life of residents
- To develop the method for measuring community resilience (relating to water management) to earthquake

II. Methods

Focus group discussion

Questionnaire survey

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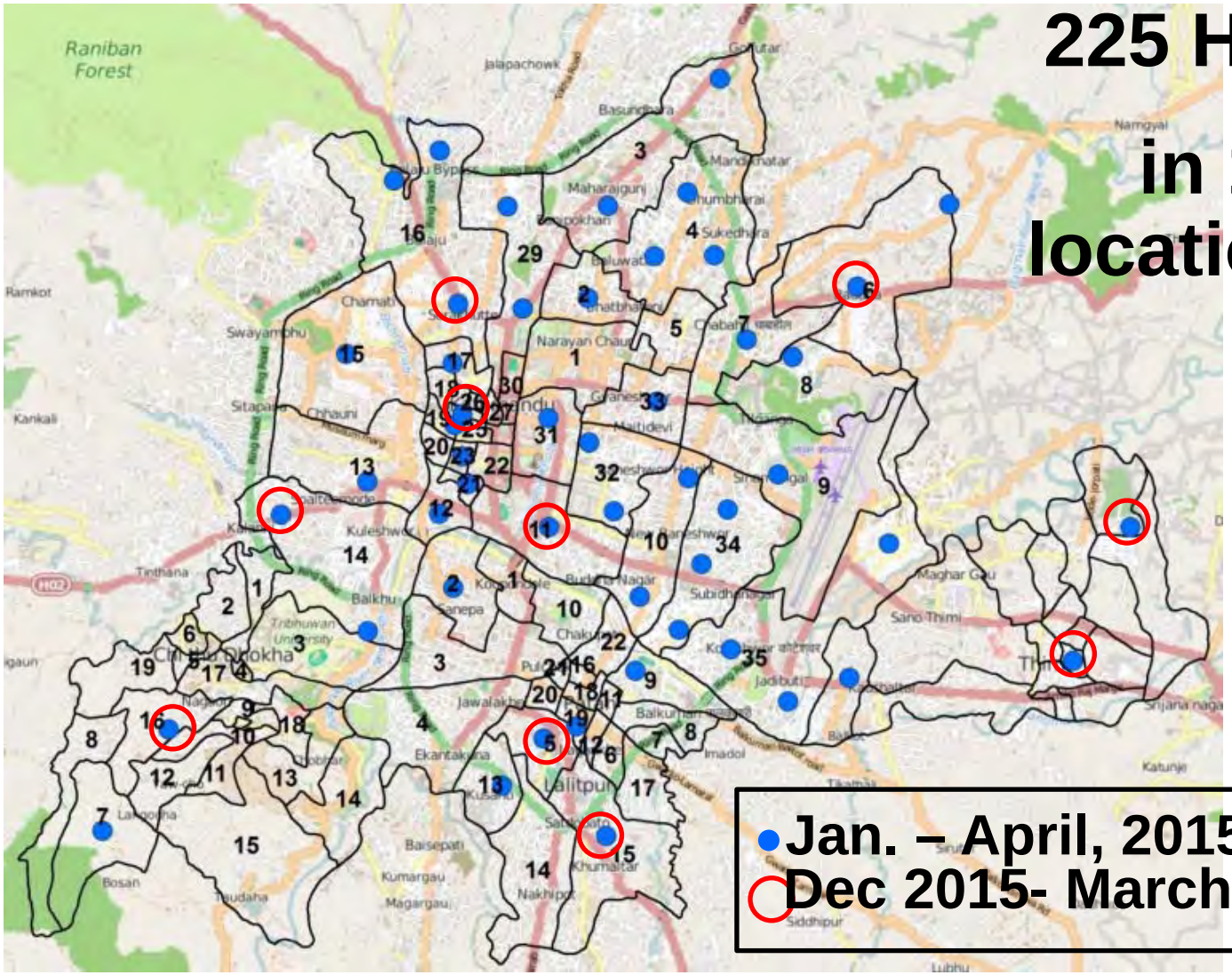
(1) Questionnaire survey on water availability and use, perception, QOL before and after the earthquake

Date	Feb. to April, 2015 (In SATREPS)	December 2015 – (In SATREPS and J-RAPID)
Place	Kathmandu, Madhyapur Thimi, Lalitpur municipalities	
No. of households	1139 (1500 was planned)	300* until Feb. 2016 1200 after then
Contents	Health status, Household water system , Hygiene behaviour, Quality of life (WHOQOL-BREF)	Same as before + Impact of earthquake on water system (Just after the earthquake and current)

* 225 HHs are same as the 1st survey and used for comparison

Questionnaire survey before and after the earthquake



225 HHs in 10 locations

Impact of earthquake: Situation after one month of EQ

Piped water	N	%
Not available	19	14
Less, same quality	15	11
Less and poor quality	22	16
Same volume, poor qual.	7	5
Same as before	75	54
Total	138	100

Over all water for domestic use	N	%
No water	39	17
Less than half	37	16
More than half	8	4
Same as before	123	54
More than before	19	8
Total	226	100

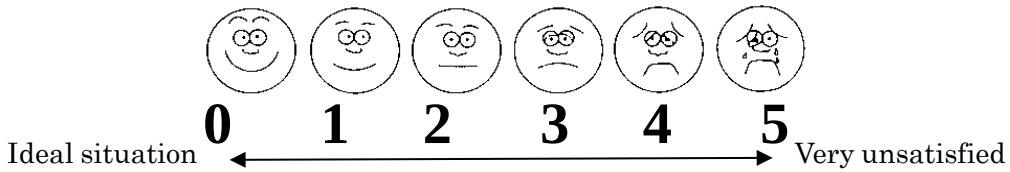
Management of water	N	%
Could not manage	7	3
Could manage but very difficult	126	57
Could manage without any problem	88	40
Total	221	100

Management strategies	N	%
Used stored water	169	75
Bringing water from other places	36	16
Used sources not used before	3	1
Buying water	179	79
Water provided from volunteers	0	0

Comparison of water availability and use before and after the Earthquake (Paired t-test)

Water availability and use		Mean	N	Std.	P-value
Water consumption (LPCD)	Before	117	226	106	<0.001
	After	63	226	83	
Piped water amount use per day	Before	250	74	215	<0.001
	After	79	74	99	
Piped water supply hours/ week	Before	5	93	9	>0.05
	After	5	93	17	
Groundwater amount use/day	Before	367	81	290	<0.001
	After	200	81	215	
BJW amount used/ day	Before	24	118	10	<0.001
	After	15	118	15	
Amount of tanker water used per day	Before	223	41	151	>0.05
	After	221	41	129	
Monthly cost of water	Before	1657	205	1827	<0.05
	After	1266	205	1201	

Changing the **perception** for situation of **water quality and quantity**



Scores	Before EQ		One month after EQ		Current (After 8-11 months of EQ)	
	N	%	N	%	N	%
Good (0 &1)	95	42	47	21	71	31
Medium (2&3)	103	46	140	62	119	53
Bad (4&5)	28	12	39	17	36	16

Medians of answer are 2 for all periods

Scores change		No change	Worsening	Improving
Before to 1month	Damaged*	15 (24%)	39 (62%)	9 (14%)
	Not damaged	87 (53%)	58 (36%)	18 (11%)
1 to 8-11 months	Damaged	15 (24%)	41 (65%)	7 (11%)
	Not damaged	98 (60%)	42 (26%)	23 (14%)

*** Damaged : 3 locations among 10.**

Changes in Quality of Life (WHOQOL-PREF) (Paired t-test)

QoL domains		Mean	N	Std.	P-value
Over all quality of life	Before	2.8	223	0.6	<0.001
	After	2.6	223	0.6	
Physical health domain QoL	Before	14.0	223	2.4	<0.001
	After	12.9	223	1.8	
Psychological health domain QoL	Before	13.9	224	1.8	<0.05
	After	13.4	224	1.7	
Social relationship domain QoL	Before	14.7	223	2.6	<0.001
	After	13.4	223	2.0	
Environment domain QoL	Before	13.1	223	1.6	<0.001
	After	12.6	223	1.5	

(2) Focus Group Discussion

Place		Kokhana, Lalitpur	Gongabu, Kathmandu	Chyasal, Patan, Lalitpur
Participants	Aug 2015	14 women	9 women	8 men and 4 women
	March 2016	13 women	10 women	9 men and 4 women
Damage		Severe	Moderate to severe	Moderate

Discussion themes

- Water management before and after earthquake (water source, piped water supply, storage, quality and treatment)
- Damage of water system by the earthquake
- Hygiene and health impact

Words extracted from the conversation were classified into 4 categories: **Adaptation**, **Robustness**, **Redundancy**, **Rapidity** relating with resilience.

Effects of water scarcity to the resilience after the earthquake

Kokhana

Gongabu

Chyasal

Rating of water system before and after the earthquake

Mean score of participants at the 2nd FGD: 0 (Worst), 10 (Best)

	Kokhana, Lalitpur		Gongabu, Kathmandu		Chyasal, Patan, Lalitpur	
	Quality	Quantity	Quality	Quantity	Quality	Quantity
Pre-GEQ	7.3	7.3	7.6	6.5	2.0	2.3
Post-GEQ	2.6	2.6	4.6	3.6	1.3	1.3

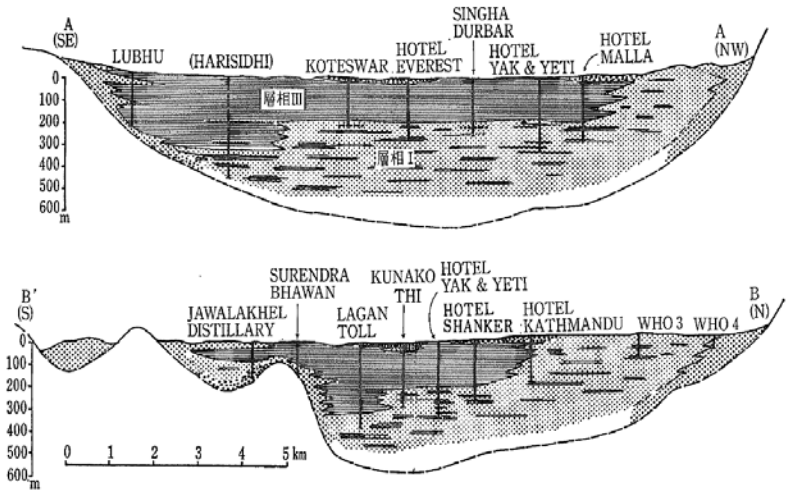
- **Adaptation** fetching from other place, stored in a tank, collect rainwater, use water wisely……
- **Robustness** water is not enough, due to lack of money, breaking of pipe, drinking water is mixed with sewerage……
- **Rapidity** didn't get piped water for two month, for three month….
- **Redundancy** had well, tanker had come, no water in stone spouts, community tanks are empty……

Poor resilience due to slow restoration of water system, reduction of redundancy in dry season etc.

Geotechnical assessment group

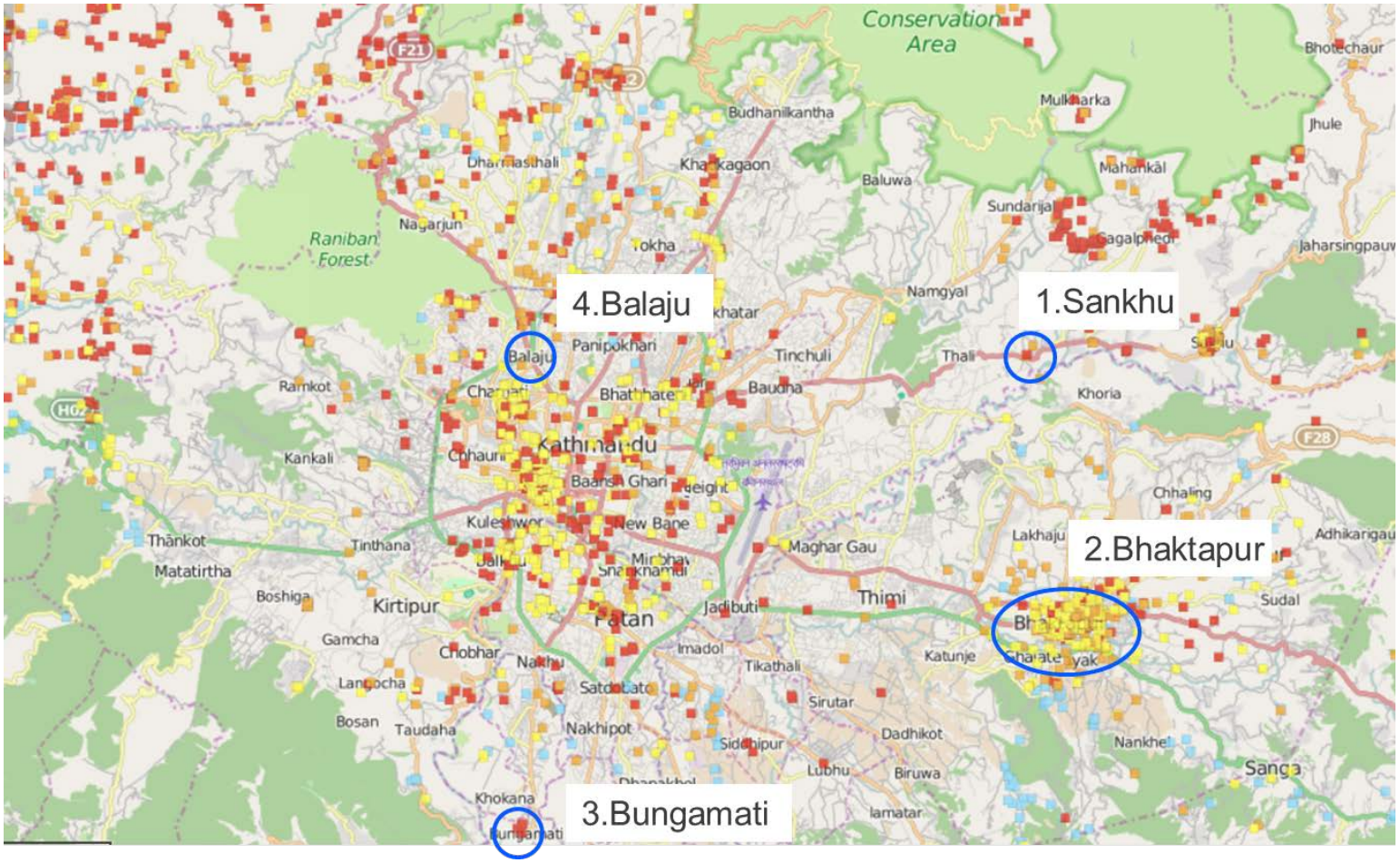
Evaluation of ground vibration characteristics

- Modeling the soil structure of Kathmandu Valley
  - to reflect its characteristic basin structure
  - through bibliographic survey & field test
- Analysis of ground vibration characteristics
  - to evaluate ground motion and strain concentration
  - through numerical simulations



Natori et al. (1980): Natural gas in the Kathmandu Valley, Chishitsu News

Field survey of damage situation



Distribution of structural damage in Gorkha Earthquake

from Global Disaster Alert Coordination System

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Field survey of damage situation

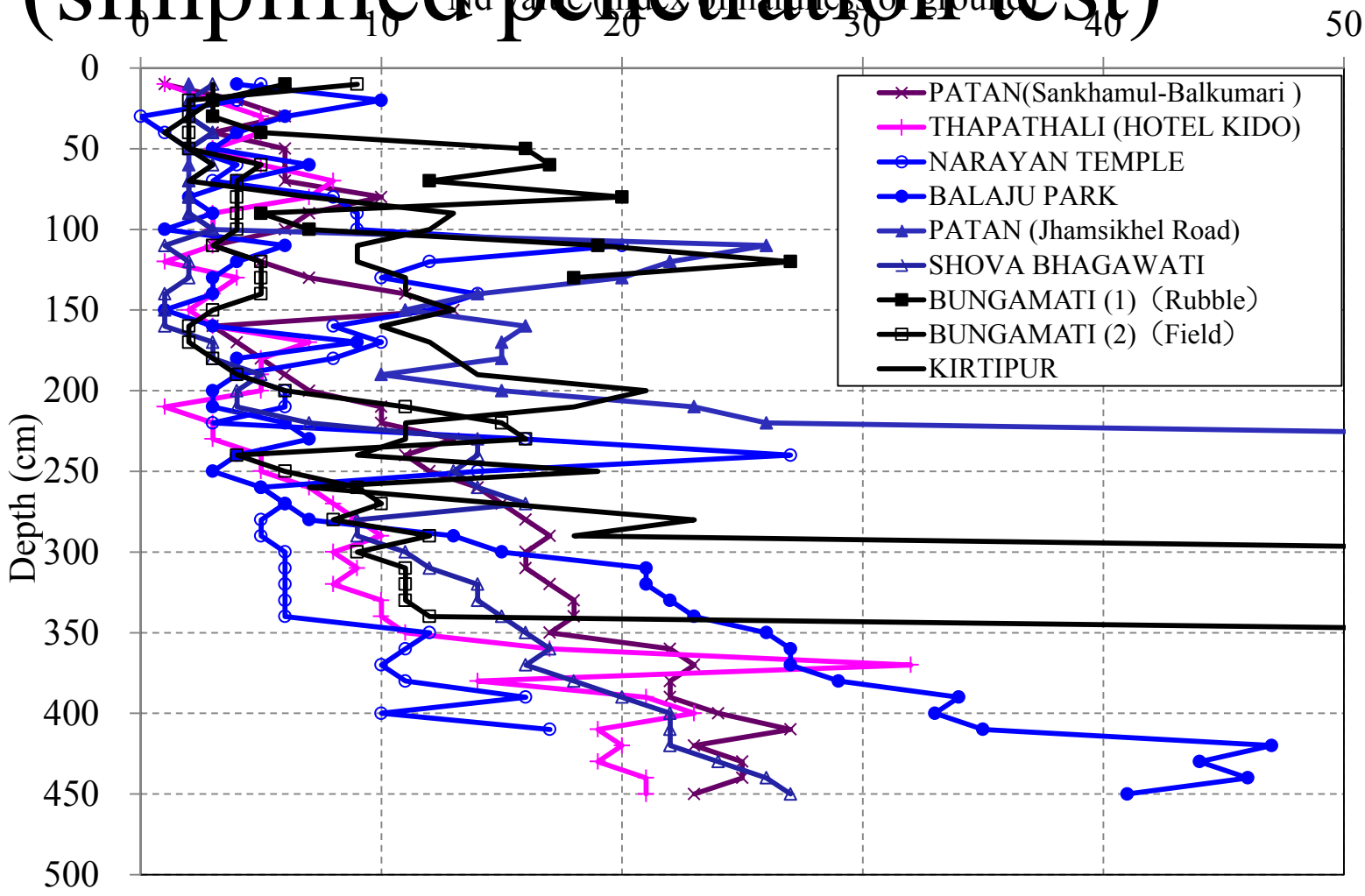
- Field survey of damage situation
  - Difference of extent of damage between center & periphery

masonry &

Collapse of masonry buildings

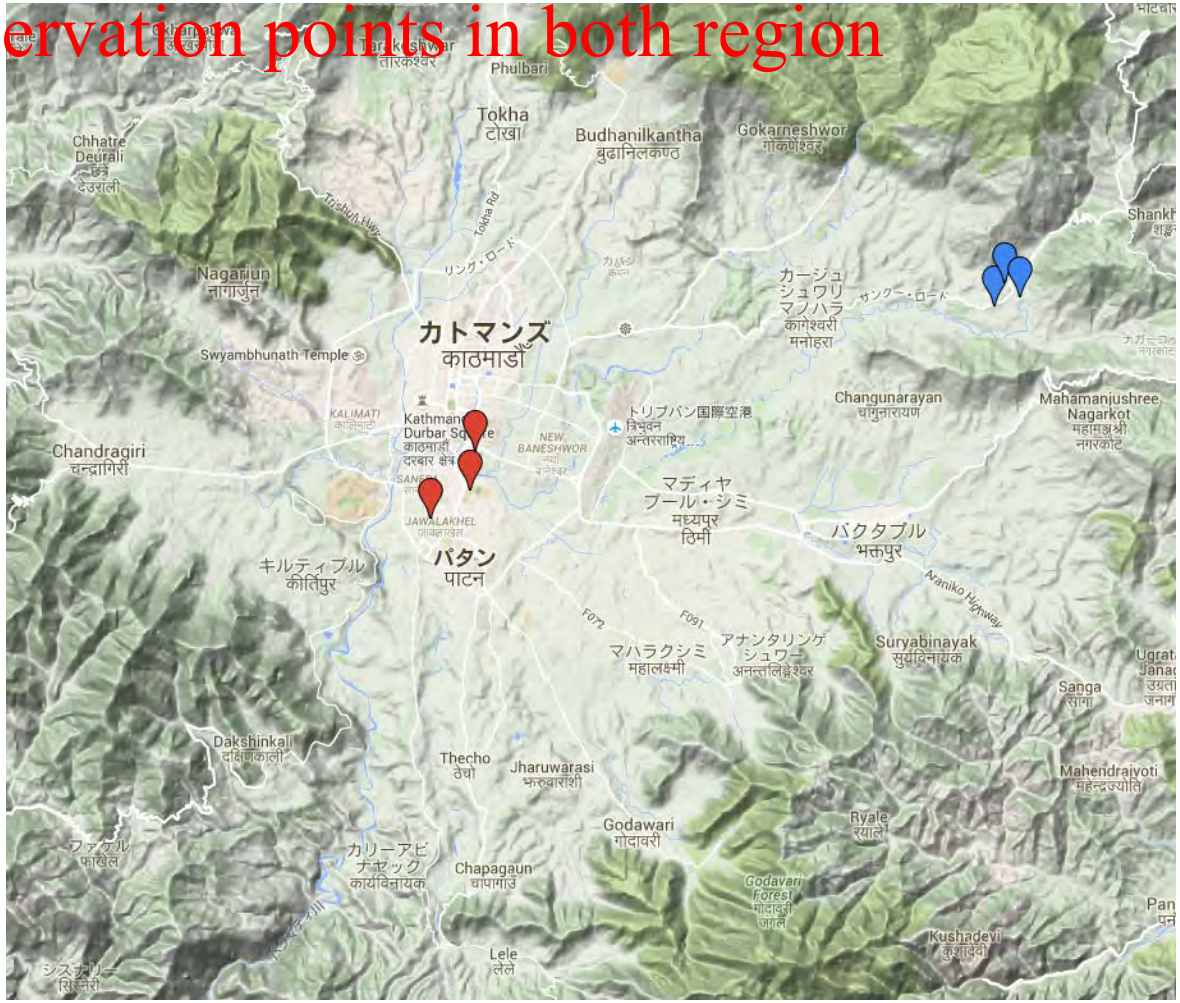
Damage of a concrete pillar

Survey of hardness of ground (simplified penetration test)



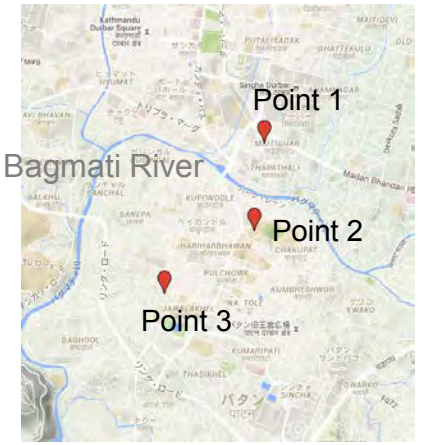
Microtremer survey

- Comparison of center & periphery
  - Kathmandu & Sakhu
  - 3 observation points in both region

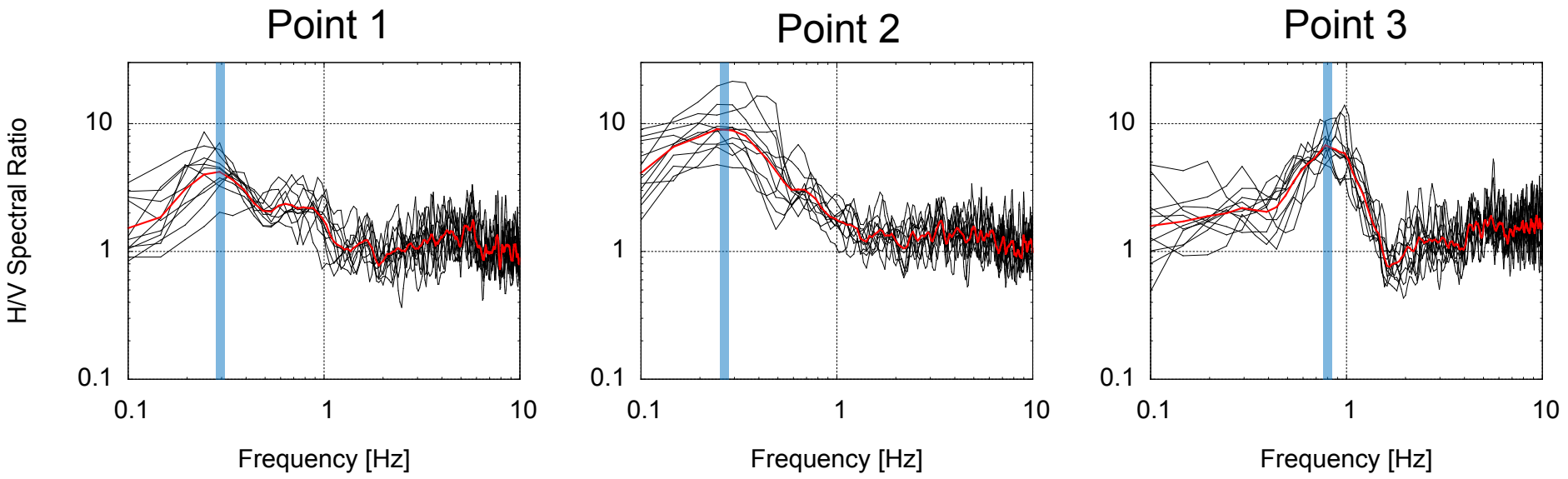


H/Vspectral tatio : Kathmandu

- Observation point 1 & 2
  - Peak period T=3~4s（0.25~0.3Hz）
  - Matches strong motion characteristics & damage situation

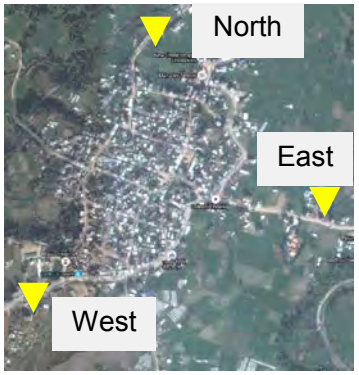


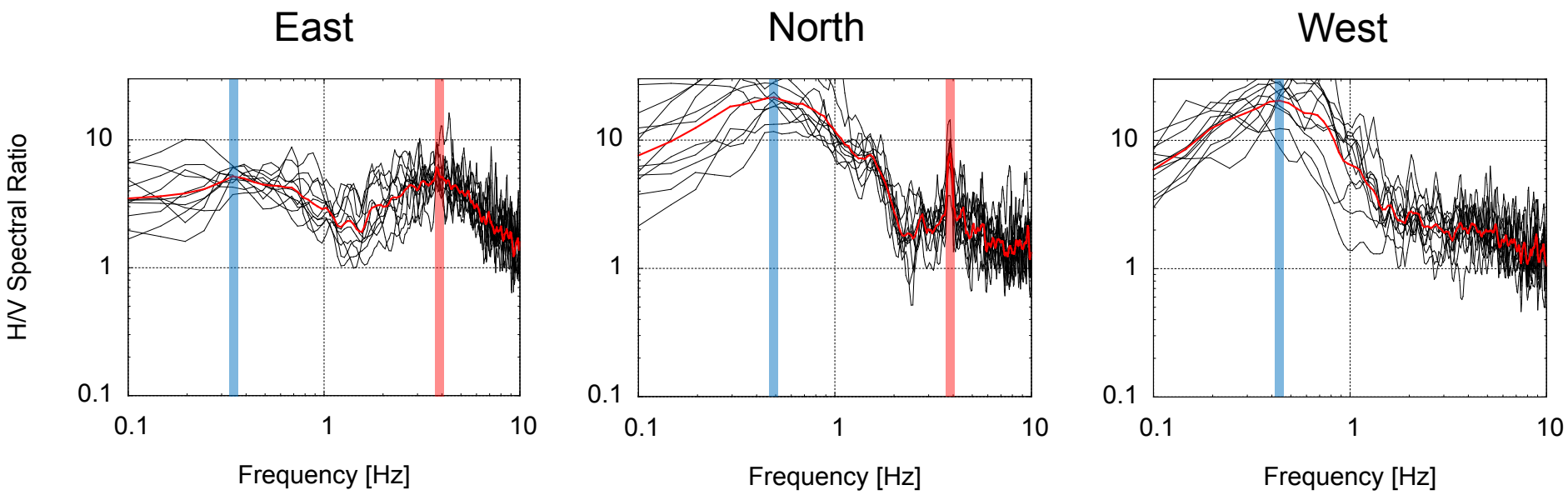
- Observation point 3
  - T~1.0s : indicates relatively shallow bedrock
  - Inclination of bedrock between point 1&2-3: strain concentration is supposed



H/Vspectral tatio : Sankhu

- East & North
  - Peak exist both in long & short period(3~4Hz)
    - indicates contrast of soil structure within the sediments
  - Amplification of short-period components led structural damage
- West
  - Similar tendency to Kathmandu
  - difference of the soil structure between East, North & West
    - strain concentration is supposed





Conclusion

- Field survey of damage situation
  - Difference of extent of damage between center & periphery
    - Heavy damage of masonry & RC structures in the periphery

- Evaluation of soil characteristics through microtremer survey
  - Differnce of soil structure between center & periphery

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