Post Tsunami helicopter borne electromagnetics in northern Sumatra:

HELIcopter Project Aceh

Annika Steuer,

B. Siemon, H.-J. Rehli and U. Meyer

Tsunami 2004

- 26.12.2004 earthquake with magnitude 9 and Tsunami
- more than 120.000 died and 110.000 injured in Aceh
- Destruction of 80 % of the private houses, infrastructure and public facilities in the coast regions
- Extensive flooding with saltwater disabled wells

Banda Aceh before and after the Tsunami

Motivation

HELP Aceh was initiated and funded by German Ministry of Economics through the Federal Institute for Geosciences and Natural Resources (BGR).

Intention of BGR:

- use its special expertise in groundwater exploration
- contribute to sustainable water supply
- fill the gap between first aid measures and reconstruction / rehabilitation

Cooperation partners

DJGSM
Direktorat Jenderal Geologi dan Sumber Daya Mineral
Departemen Energi dan Sumber Daya Mineral

DGGMR: Directorate General of Geology and Mineral Resources

BADAN PERENCANAAN PEMBANGUNAN NASIONAL
BAPPENAS

BAPPENAS: National Development Planning Agency

BRR
NAD – Nias

BRR: Executive Agency for the Rehabilitation and Reconstruction in Nanggroe Aceh Darussalam Province and Nias Islands

HELP ACEH

BGR Bundesanstalt für Geowissenschaften und Rohstoffe
GEOZENTRUM HANNOVER

January 7, 2005


May 18, 2004

Urgency

BAPPENAS and DGGMR asked
for direct help
in groundwater exploration

Also UNESCO, DEZA, THW,
and other organisations
needed help in freshwater exploratio

GTZ and the German embassy
supported the project.

Meulaboh

HELP ACEH (23.08.-21.10.2005)

BGR

Airborne geophysics and hydrogeological investigations focus on following coast regions of Aceh:

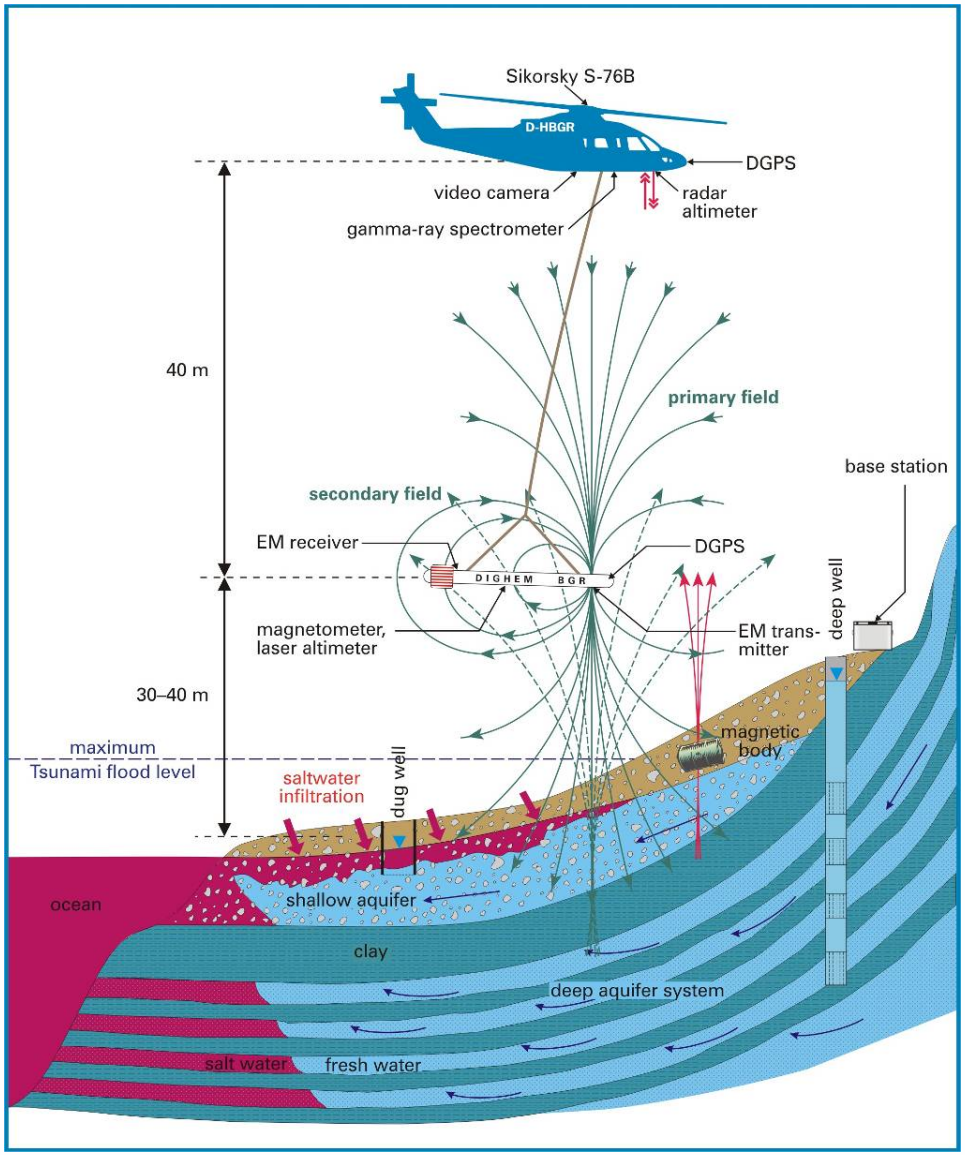
- Banda Aceh
- Calang
- Meulaboh

HELP SIGLI (22.10.-20.12.2005)

Coca-Cola Foundation Indonesia

Airborne geophysics, ground geophysics, hydrogeology and well siting:

- Sigli



BGR Helicopter System

Electromagnetics

DIGHEM$^{CP5\ DSP}$ Fugro Airborne Surveys

Frequencies

387 Hz, 1.8 kHz, 8.2 kHz, 41.6 kHz and 133.2 kHz

Coil separations

~ 8 m

Coil orientation: horizontal coplanar

Bird altitude:	30 m
Survey speed:	140 km/h,
Sampling rate:	10 Hz,
Sampling distance:	4 m

Navigation / Positioning

DGPS / radar and laser altimeter

Magnetics

Cs magnetometer

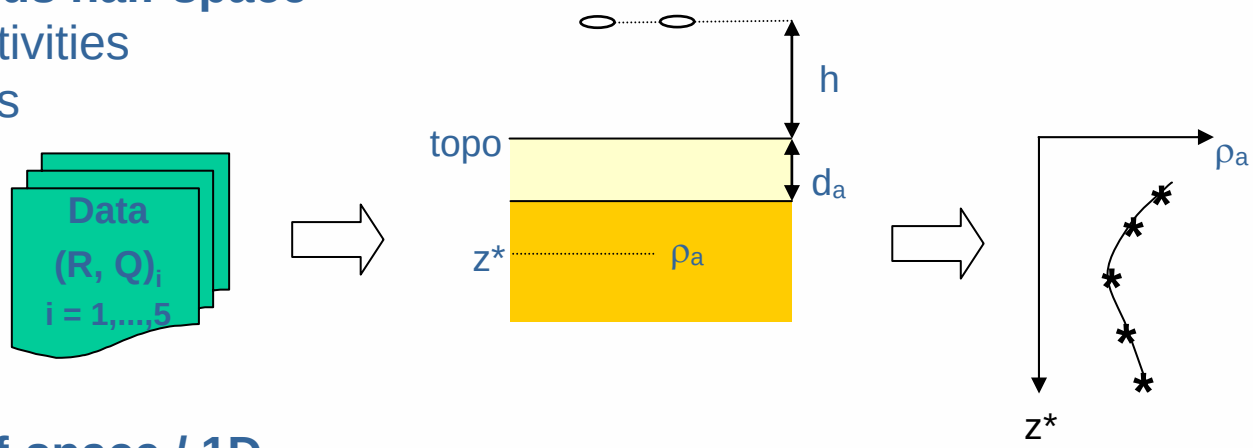
Radiometrics

256 channel gamma-ray spectrometer

HEM data inversion

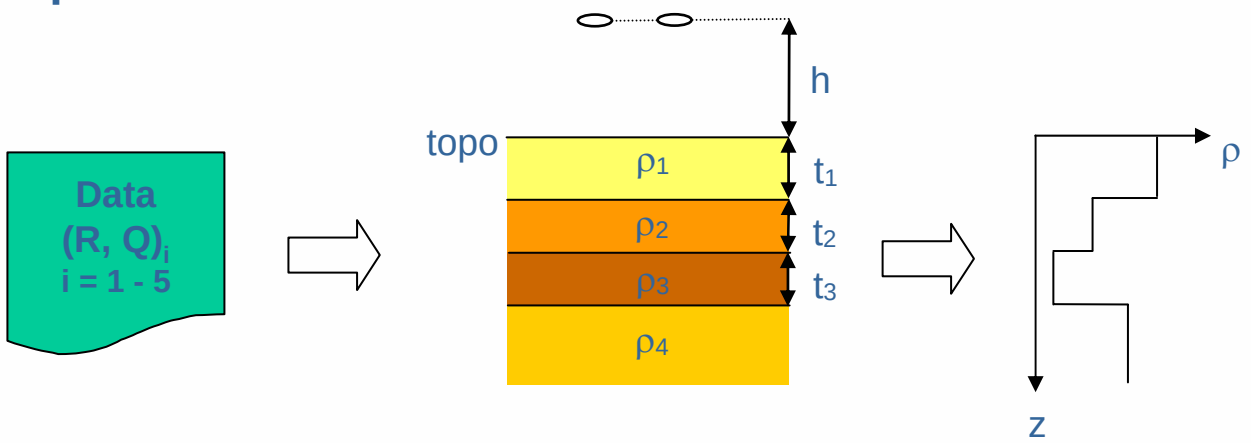
Model I: **homogeneous half-space**

- apparent resistivities
- centroid depths



Model II: **layered half-space / 1D**

- resistivity
- depths

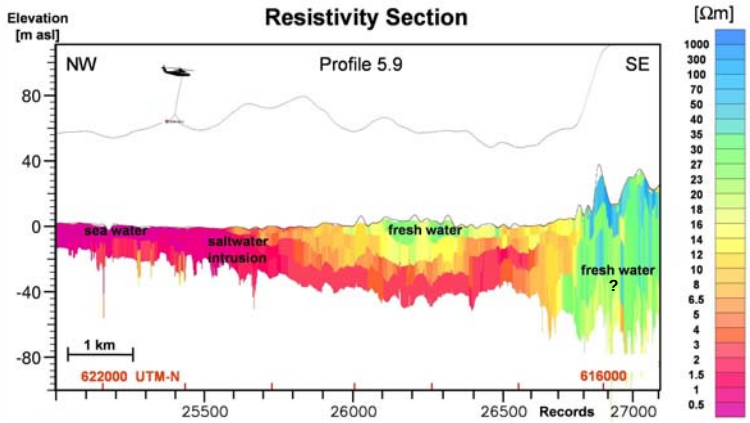


Presentation of HEM data

1-D inversions models

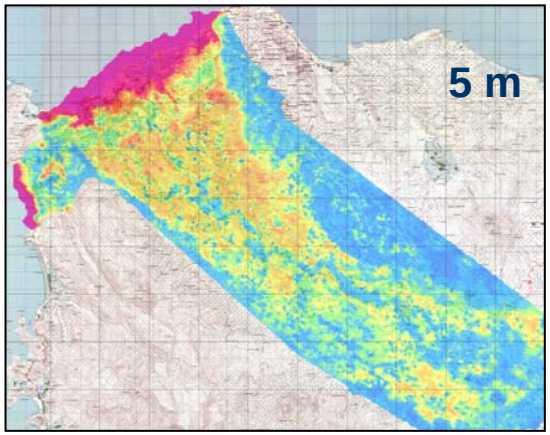
Resistivity cross-sections

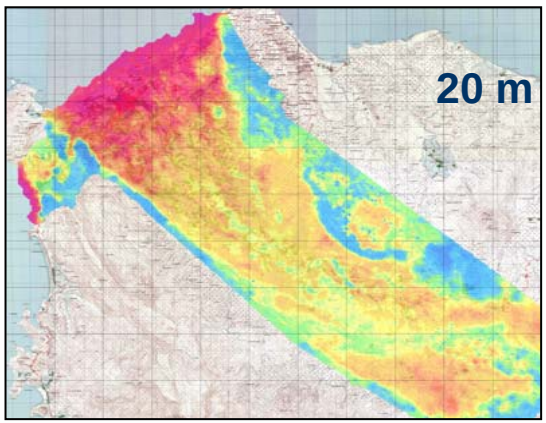
ρ**(z)** [Ωm]

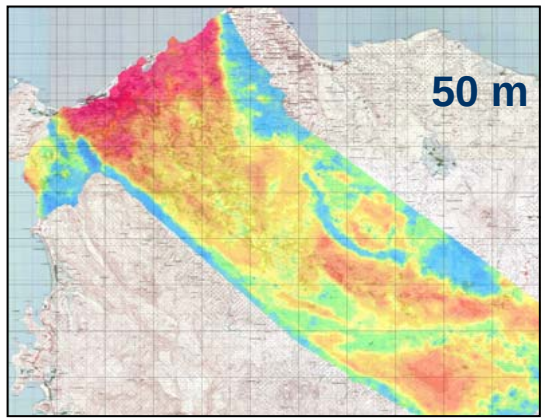


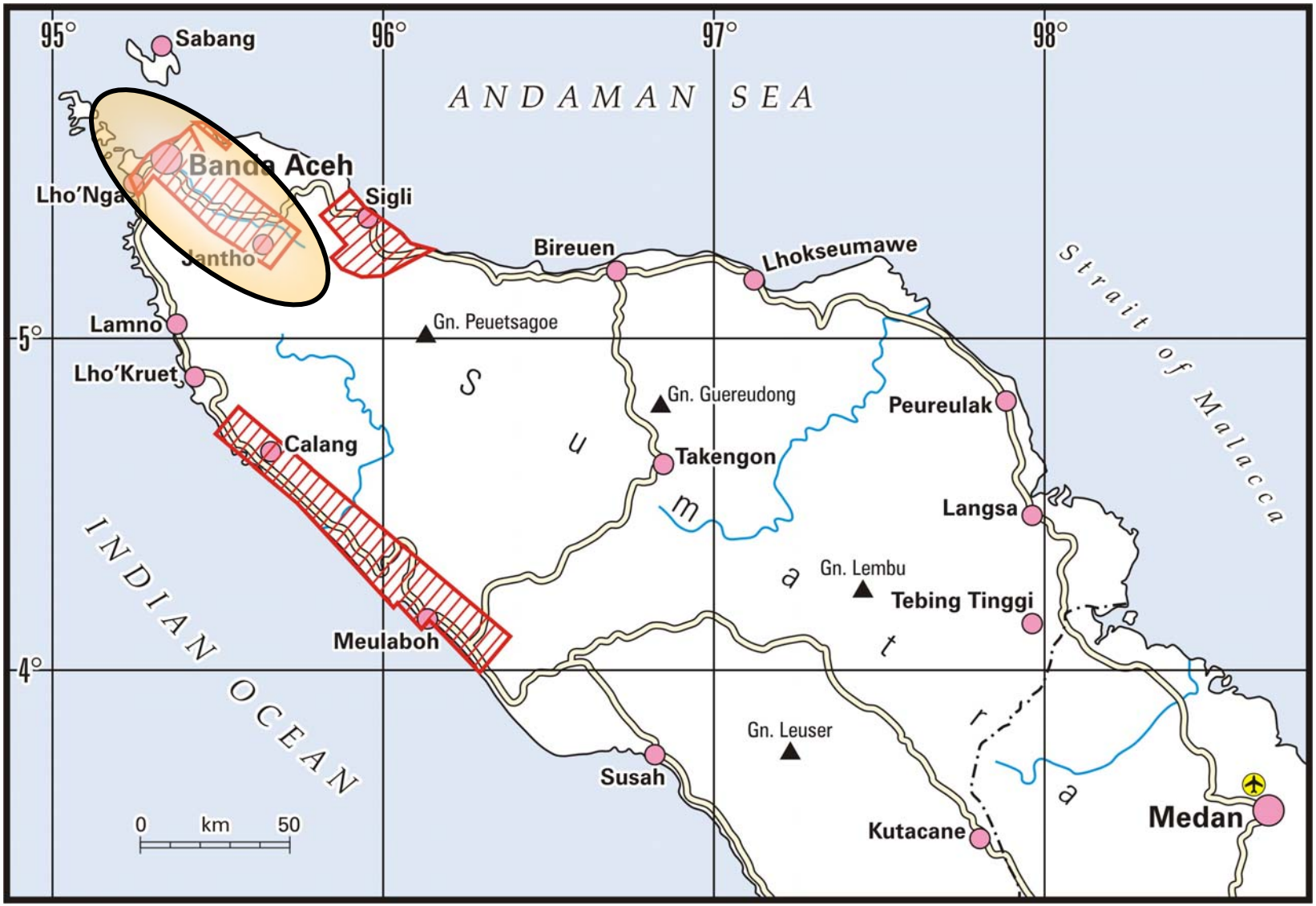
Resistivity maps at certain depths

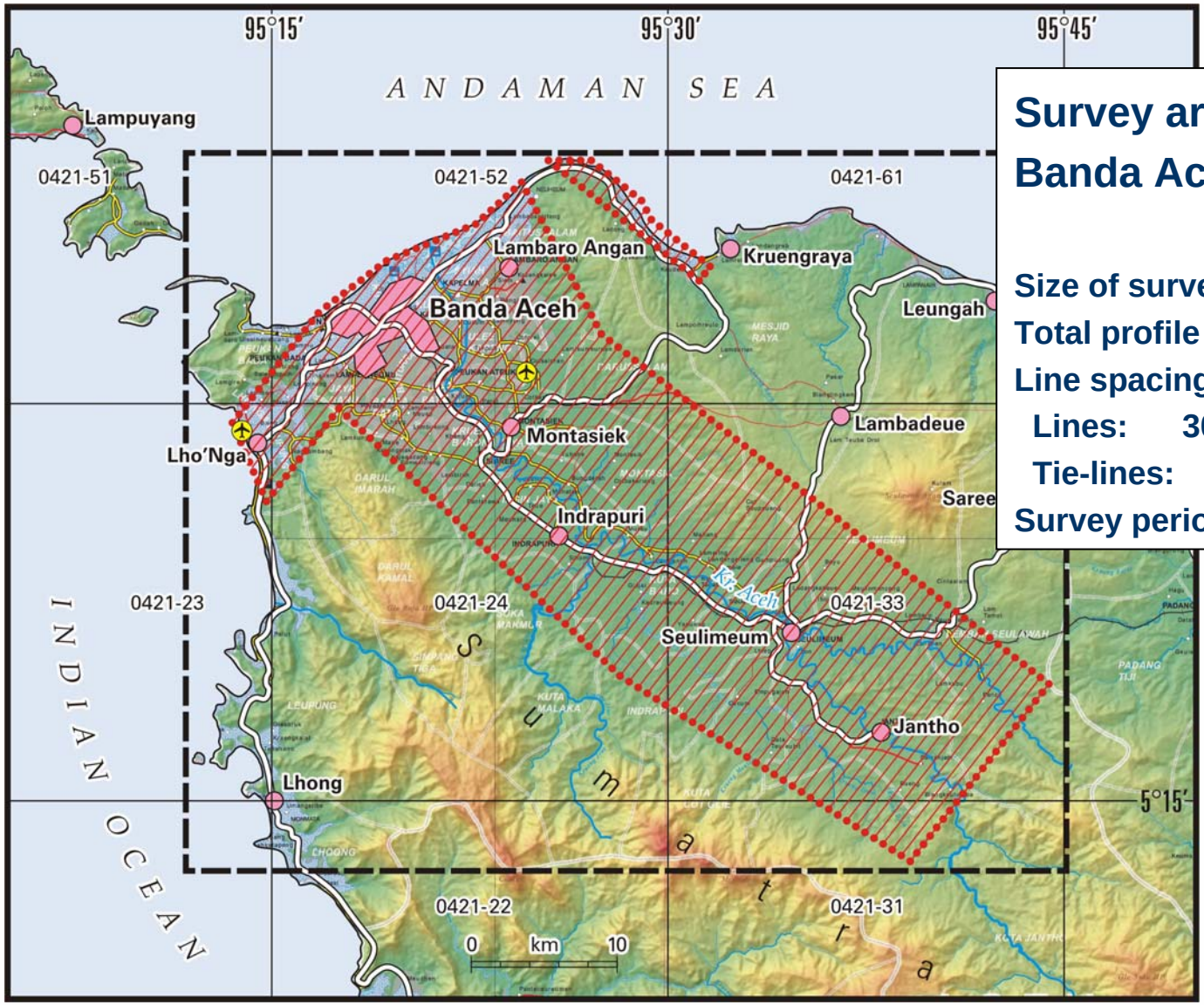
ρ [Ωm]







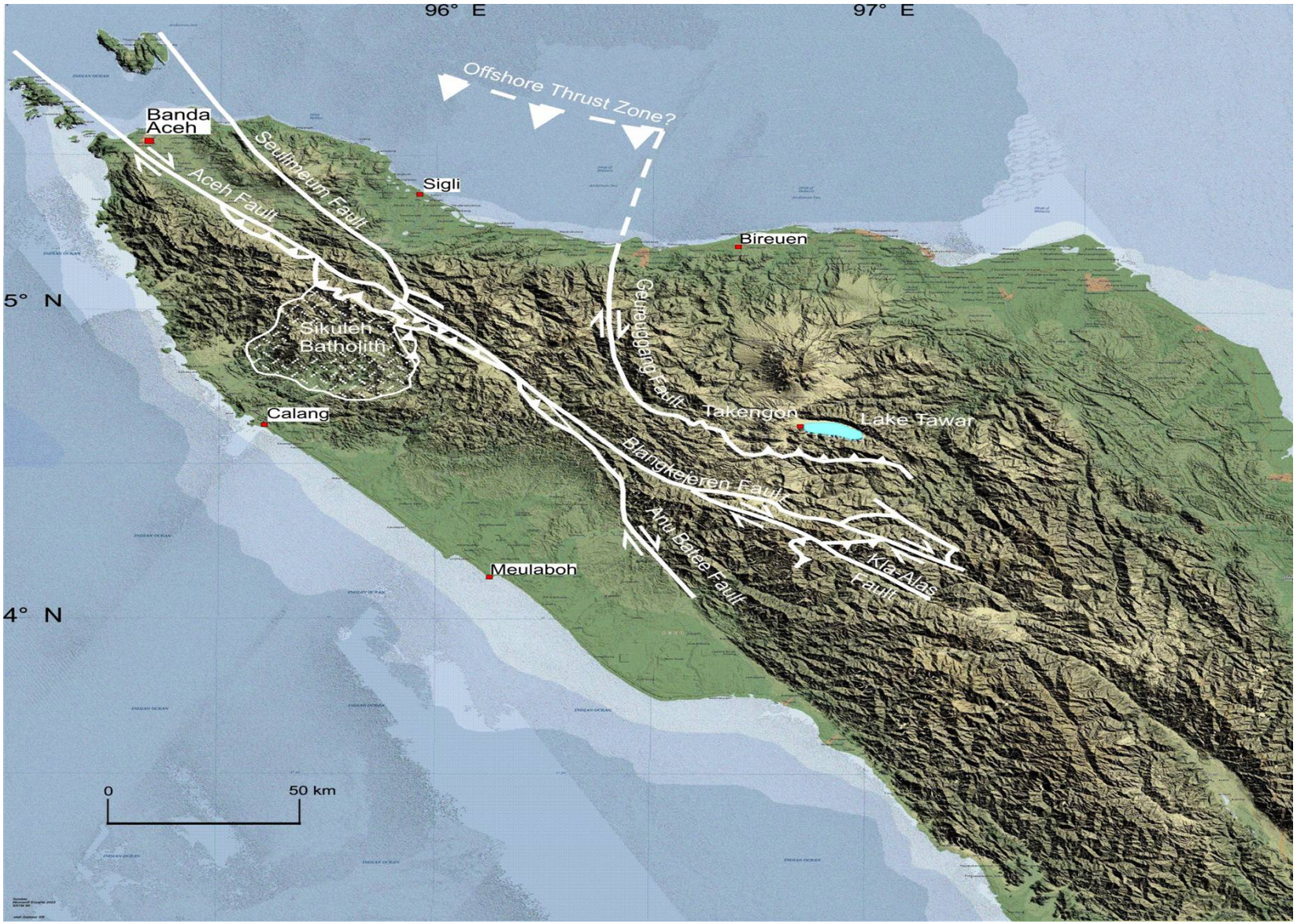

95°
96°
97°
98°
5°
4°
Sabang
ANDAMAN SEA
Banda Aceh
Lho'Nga
Jantho
Sigli
Bireuen
Lhokseumawe
Strait of Malacca
Lamno
Gn. Peuetsagoe
Lho'Kruet
S
u
m
a
t
r
a
Gn. Guereudong
Peureulak
Calang
Takengon
Langsa
INDIAN OCEAN
Gn. Lembu
Tebing Tinggi
Meulaboh
Gn. Leuser
Susah
Kutacane
Medan
0
km
50

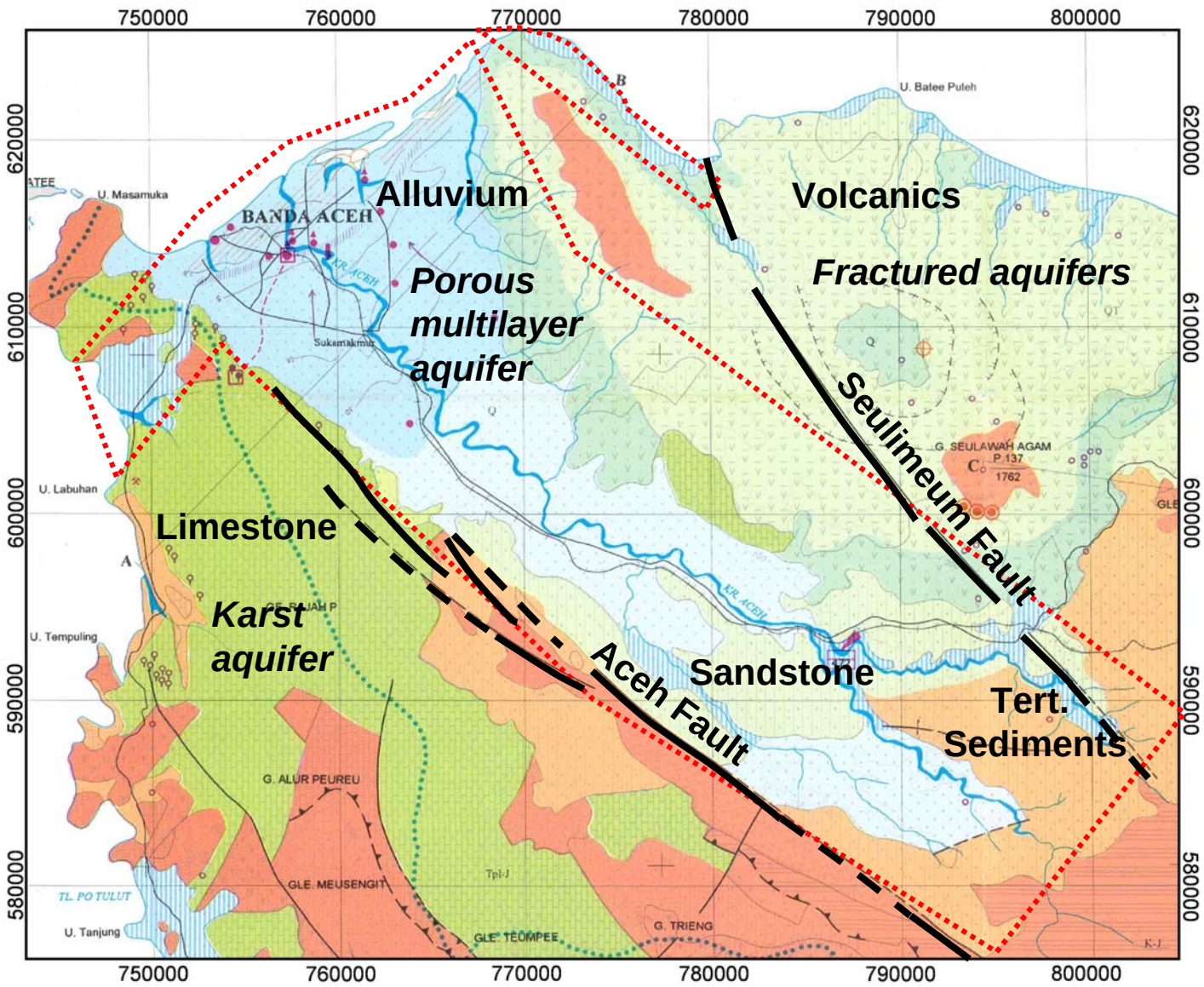


Survey area:
Banda Aceh / Aceh Besar

Size of survey area: ca. 1000 km²
Total profile length: ca. 4000 km
Line spacing:
- **Lines:** 300/900 m (SW - NE)
- **Tie-lines:** 1000 m (NW - SE)

Survey period: 23/08/ – 13/09/2005

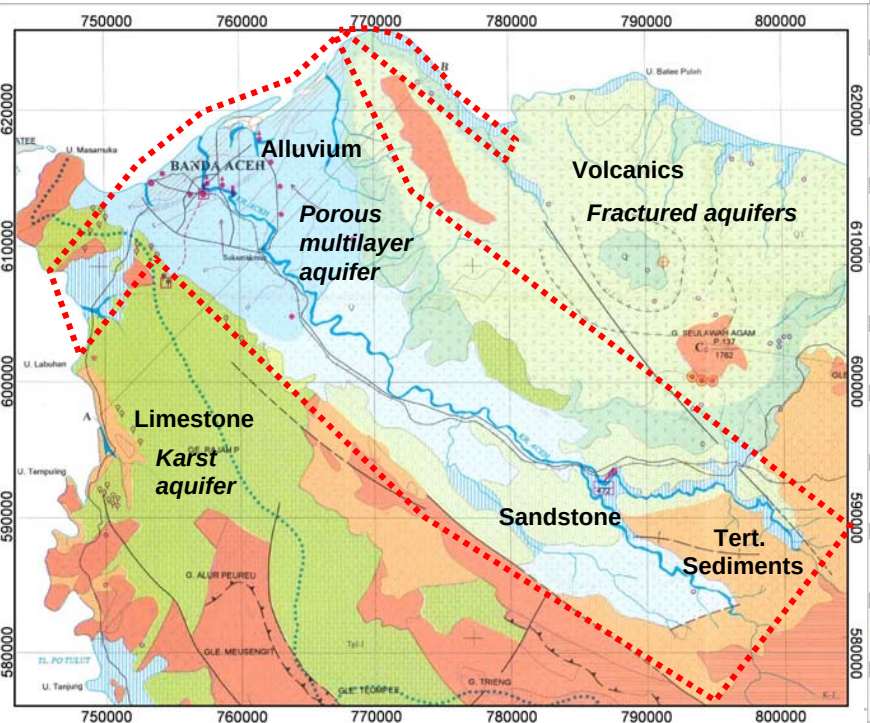

96° E
97° E
5° N
4° N
Offshore Thrust Zone?
Banda Aceh
Seulimeum Fault
Aceh Fault
Sigli
Bireuen
Sikuleh Batholith
Geureudong Fault
Calang
Takengon
Lake Tawar
Blangkejeren Fault
Ana Bakse Fault
Kla-Alas Fault
Meulaboh
0
50 km

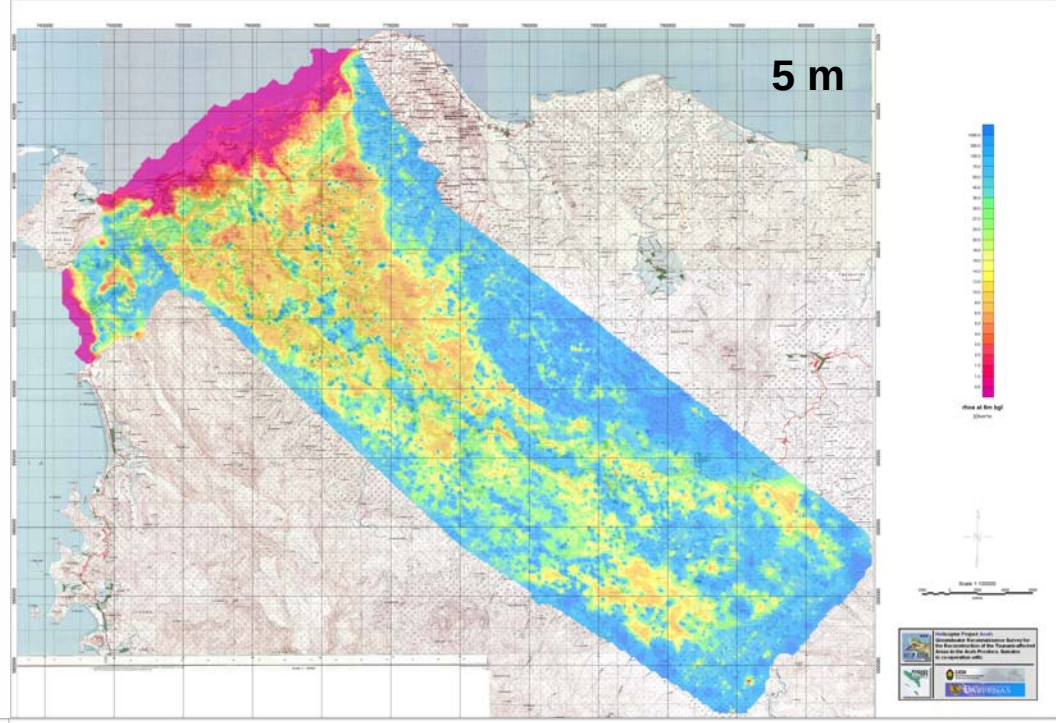

750000
760000
770000
780000
790000
800000
620000
610000
600000
590000
580000
Alluvium
Volcanics
Fractured aquifers
Porous multilayer aquifer
Seulimeum Fault
Limestone
Karst aquifer
Aceh Fault
Sandstone
Tert. Sediments
BANDA ACEH
U. Masamuka
U. Batee Puleh
U. Labuhan
U. Tempuling
U. Tanjung
G. SEULAWAH AGAM
G. ALUR PEUREU
G. TRIENG
GLE. MEUSENGIT
GLE. TEUMPEE
TL. PO TULUT
Sukamakmur
KR. ACEH

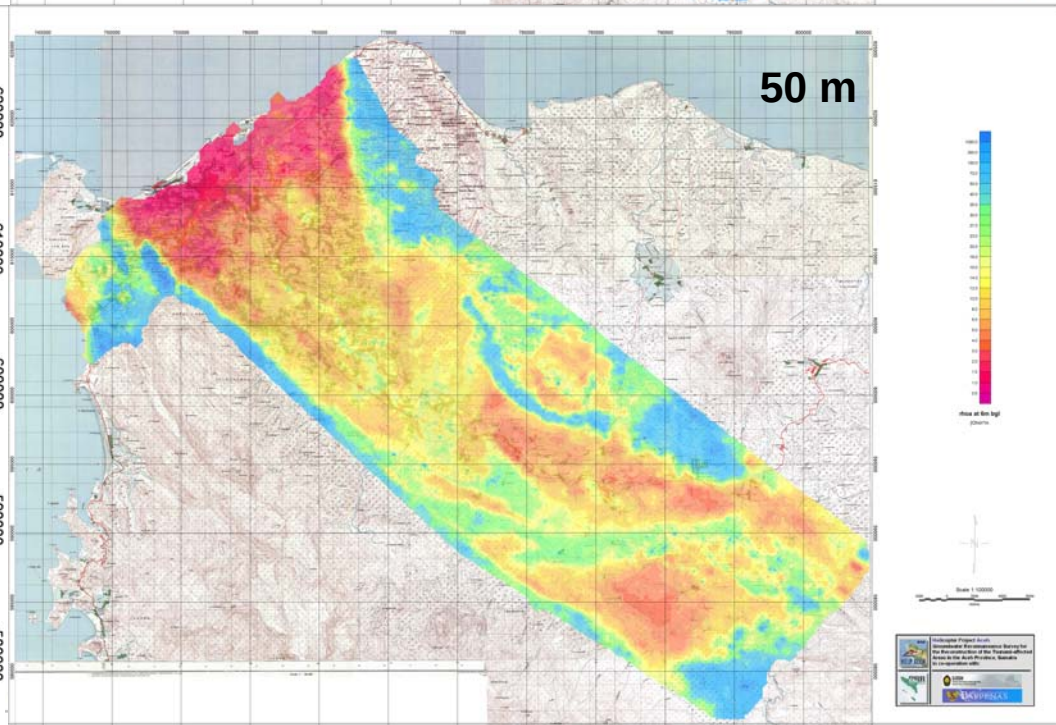
Results of the 1D-Inversions

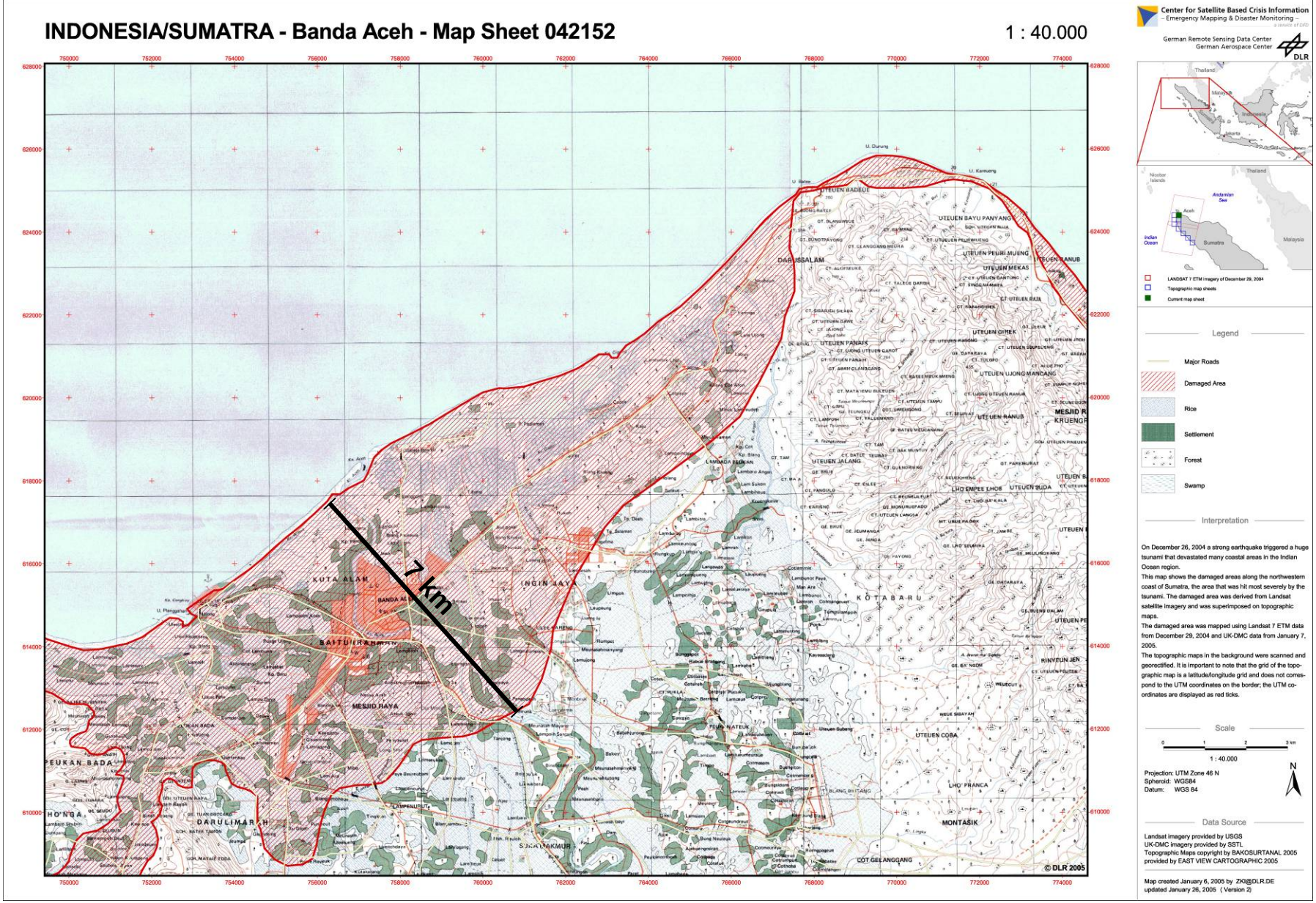
Electrical resistivity up to 80 m depth.

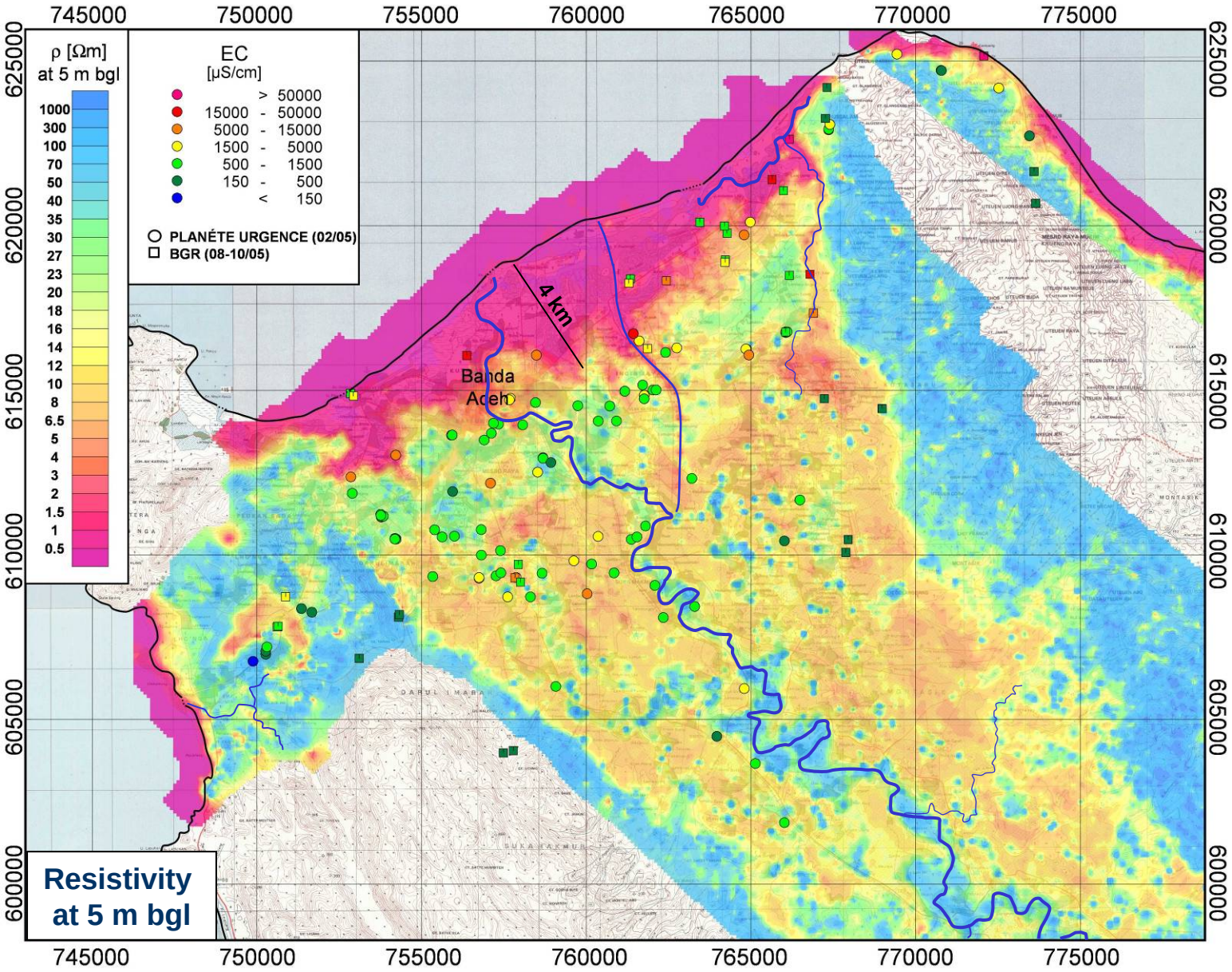
Pink: Saltwater
Red, Orange: Brackish Water, Clay
Green: Groundwater, Sediments
Blue: Limestone, Volcanics

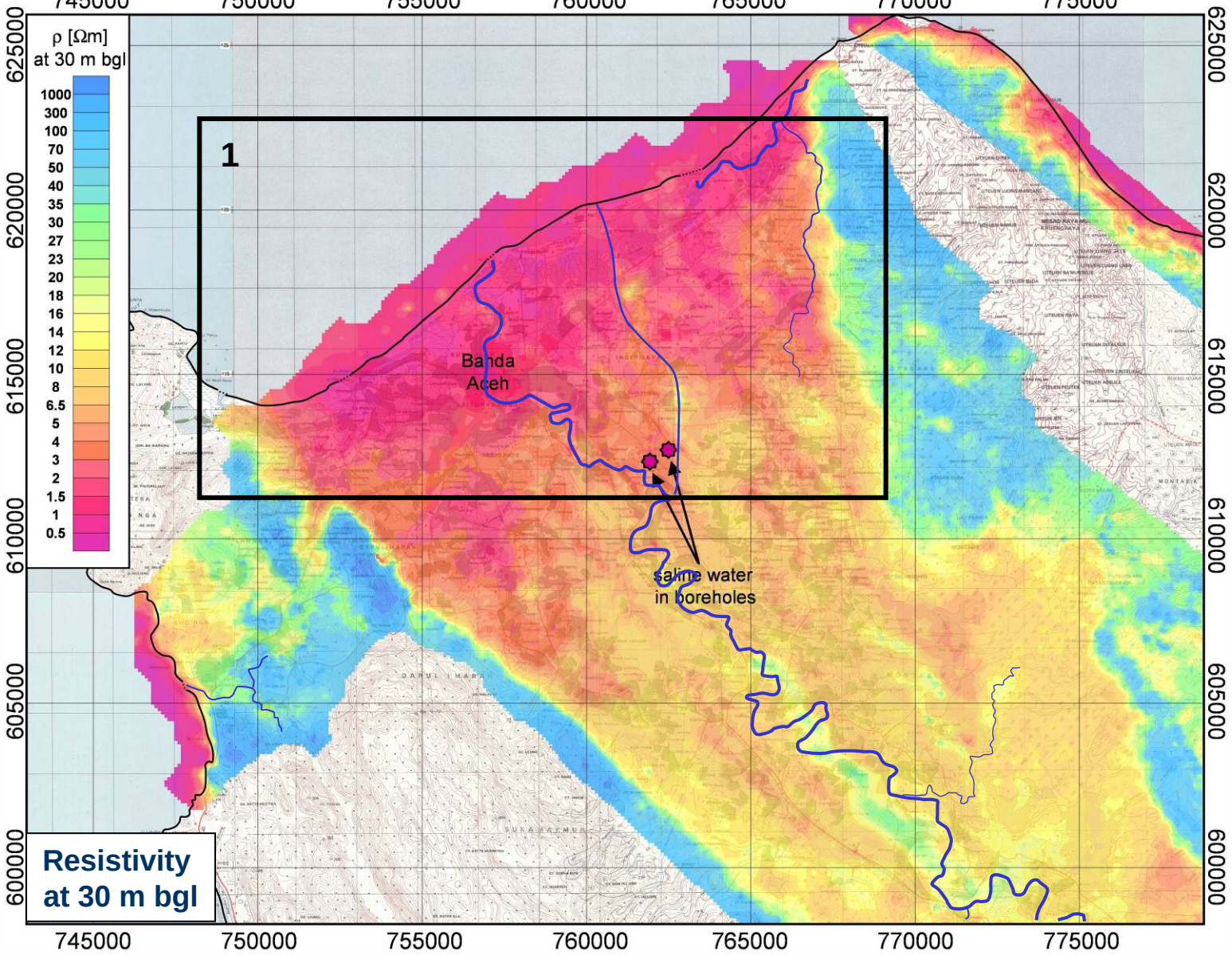


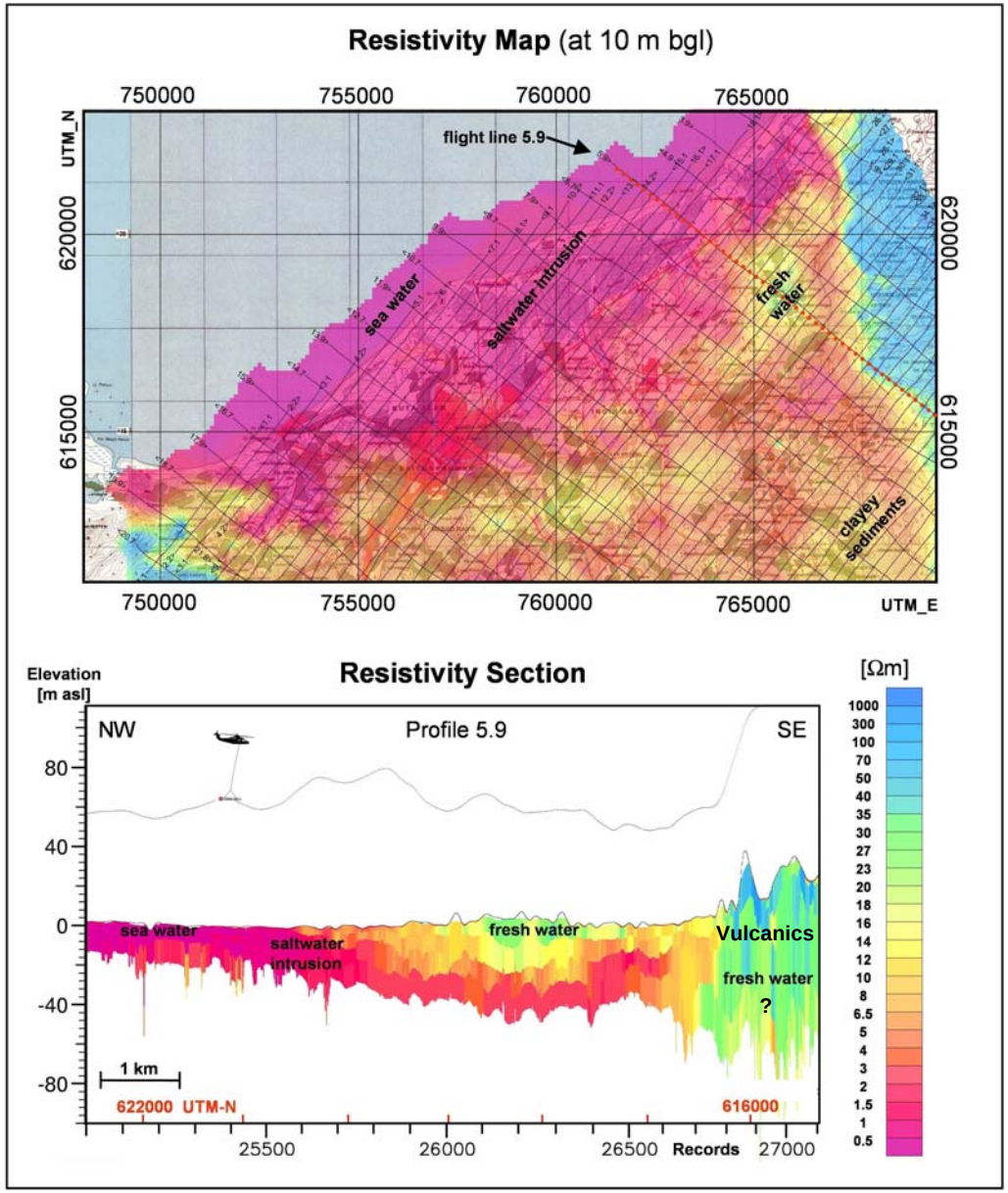





INDONESIA/SUMATRA - Banda Aceh - Map Sheet 042152
1 : 40.000
7 km
© DLR 2005
Center for Satellite Based Crisis Information
– Emergency Mapping & Disaster Monitoring –
German Remote Sensing Data Center
German Aerospace Center
DLR
Legend
Major Roads
Damaged Area
Rice
Settlement
Forest
Swamp
Interpretation
On December 26, 2004 a strong earthquake triggered a huge tsunami that devastated many coastal areas in the Indian Ocean region.
This map shows the damaged areas along the northwestern coast of Sumatra, the area that was hit most severely by the tsunami. The damaged area was derived from Landsat satellite imagery and was superimposed on topographic maps.
The damaged area was mapped using Landsat 7 ETM data from December 29, 2004 and UK-DMC data from January 7, 2005.
The topographic maps in the background were scanned and georectified. It is important to note that the grid of the topographic map is a latitude/longitude grid and does not correspond to the UTM coordinates on the border; the UTM coordinates are displayed as red ticks.
Scale
1 : 40.000
Projection: UTM Zone 46 N
Spheroid: WGS84
Datum: WGS 84
Data Source
Landsat imagery provided by USGS
UK-DMC imagery provided by SSTL
Topographic Maps copyright by BAKOSURTANAL 2005
provided by EAST VIEW CARTOGRAPHIC 2005
Map created January 6, 2005 by ZKI@DLR.DE
updated January 26, 2005 (Version 2)


ρ [Ωm]
at 5 m bgl
1000
300
100
70
50
40
35
30
27
23
20
18
16
14
12
10
8
6.5
5
4
3
2
1.5
1
0.5
EC
[µS/cm]
> 50000
15000 - 50000
5000 - 15000
1500 - 5000
500 - 1500
150 - 500
< 150
PLANÈTE URGENCE (02/05)
BGR (08-10/05)
4 km
Banda Aceh
Resistivity at 5 m bgl
745000
750000
755000
760000
765000
770000
775000
625000
620000
615000
610000
605000
600000

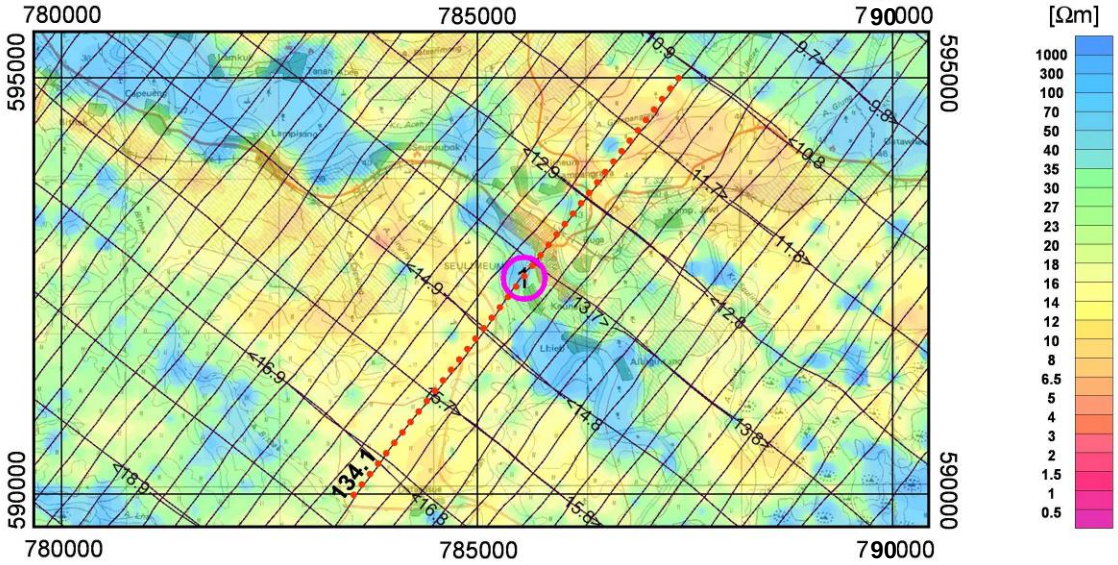

ρ [Ωm]
at 30 m bgl
1000
300
100
70
50
40
35
30
27
23
20
18
16
14
12
10
8
6.5
5
4
3
2
1.5
1
0.5
1
Banda
Aceh
saline water
in boreholes
Resistivity
at 30 m bgl
745000
750000
755000
760000
765000
770000
775000
625000
620000
615000
610000
605000
600000

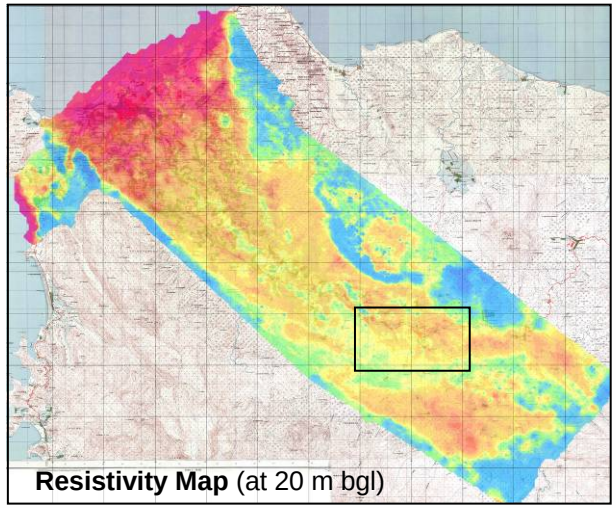


Requests of help agencies:

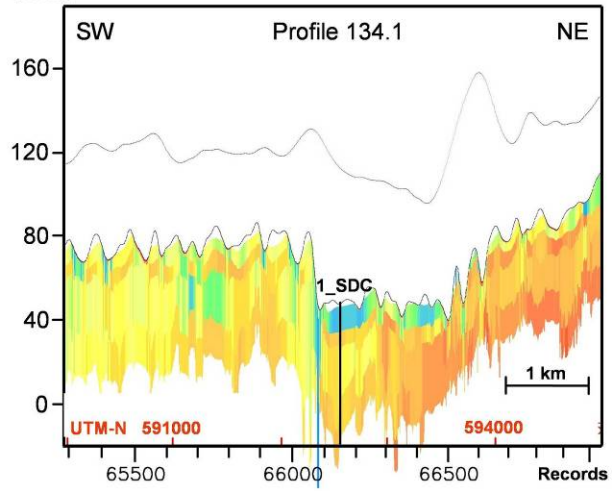
- Groundwater:
  - Location
  - Depth
- Waste site (GTZ)

Resistivity Map (at 8 m bgl)





Resistivity Section



Profile: L134.1:12015

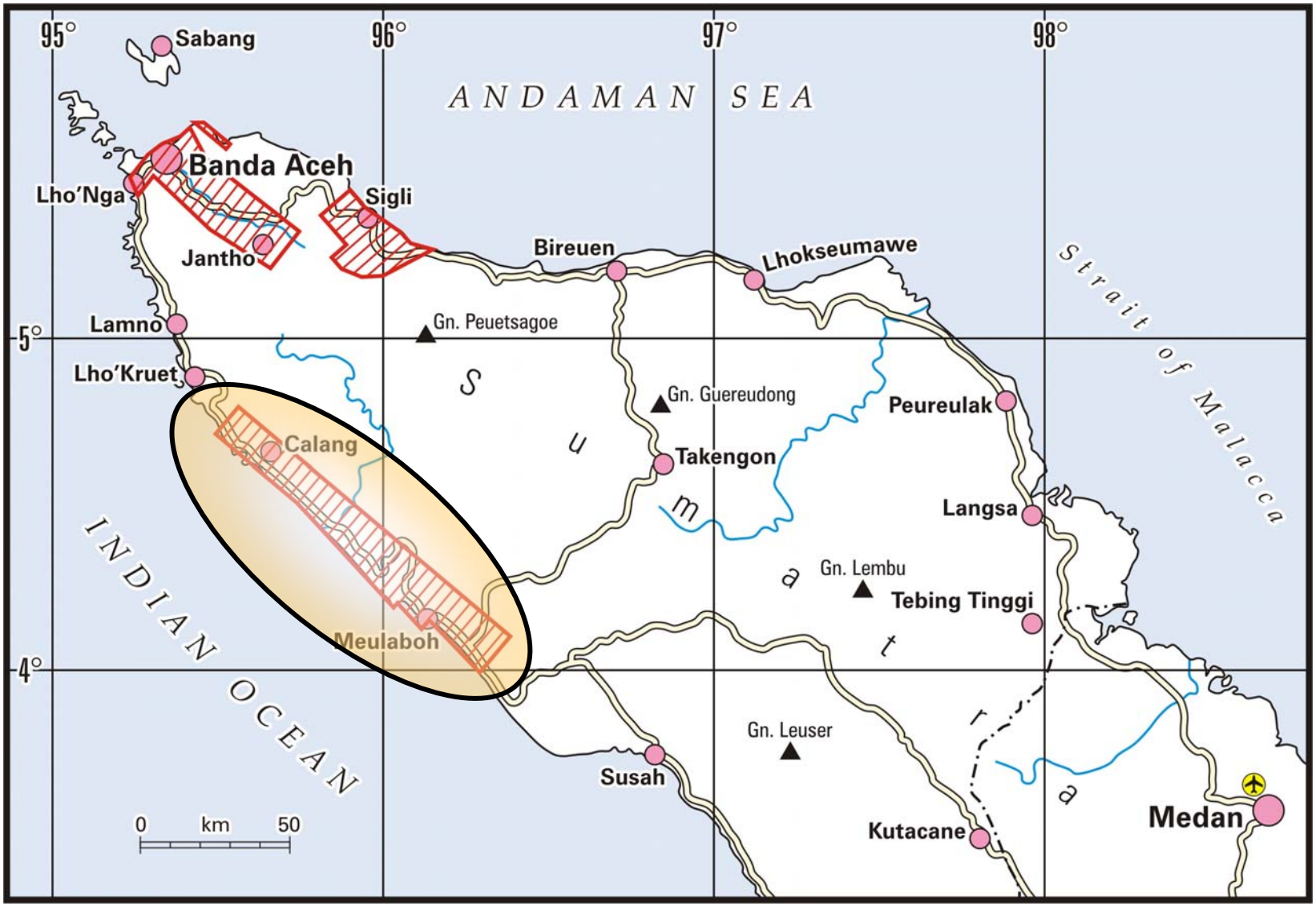
Borehole name:	1_SDC	
Borehole coordinates (E,N):	785566	592594
Profile coordinates (E,N):	785551	592605
Record:	66159	
Distance to profile [m]:	19	

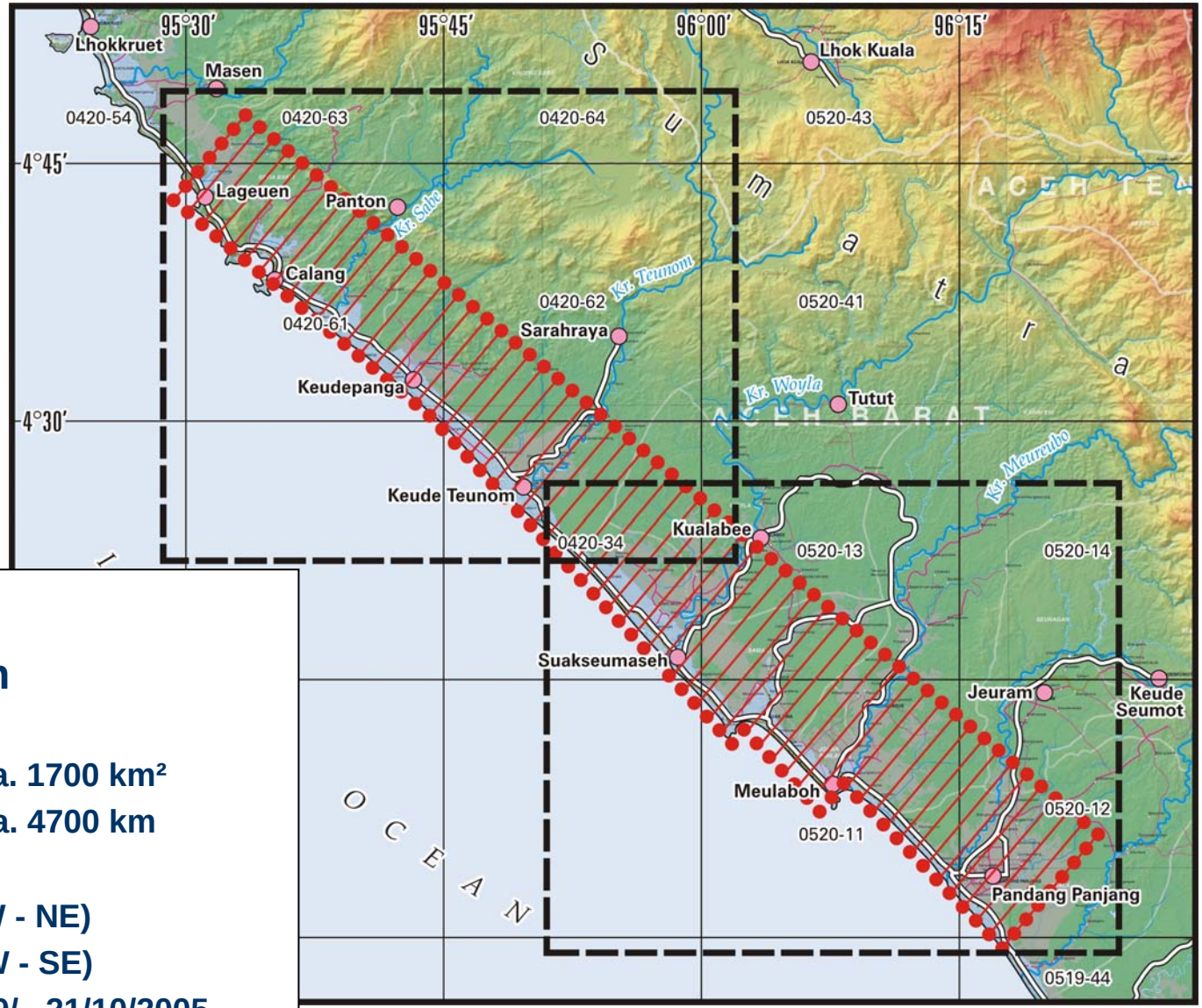
Averaged resistivity model:

Resistivity [Ωm]:	5050	44.3	9.5	13.0	10.5
Thickness [m]:		2.4	11.5	7.6	22.7
Depth [m bgl]:	0.0	2.4	13.9	21.5	44.2
Elevation [m asl]:	49.4	47.0	35.6	28.0	5.2

First request from Swiss Agency for Development and Cooperation (SDC):

How deep should we drill?

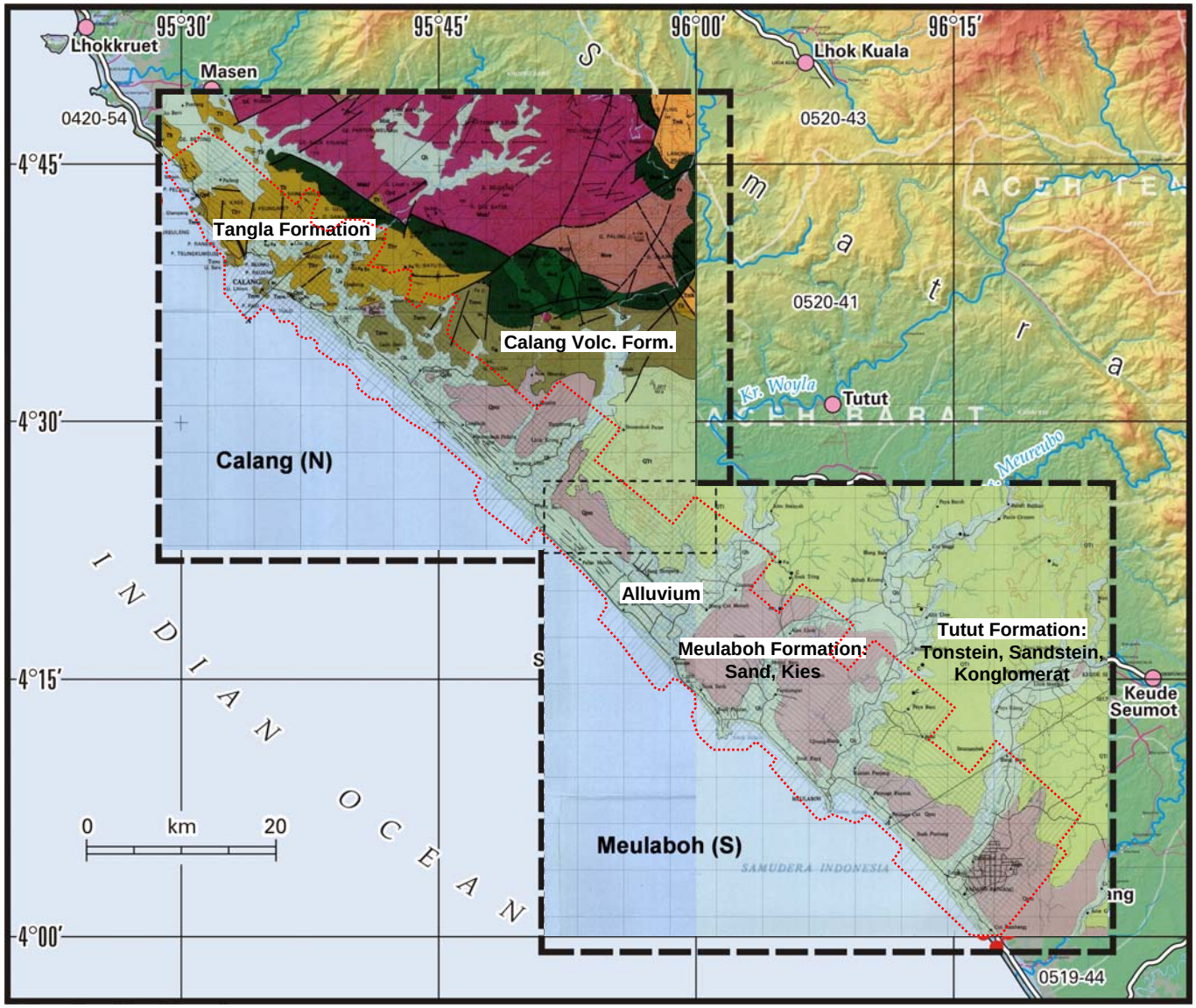

95°
96°
97°
98°
5°
4°
Sabang
ANDAMAN SEA
Banda Aceh
Lho'Nga
Sigli
Jantho
Bireuen
Lhokseumawe
Strait of Malacca
Lamno
Gn. Peuetsagoe
Lho'Kruet
S
u
m
a
t
r
a
Gn. Guereudong
Peureulak
Takengon
Calang
Langsa
Gn. Lembu
Tebing Tinggi
INDIAN OCEAN
Meulaboh
Gn. Leuser
Susah
Kutacane
Medan
0
km
50



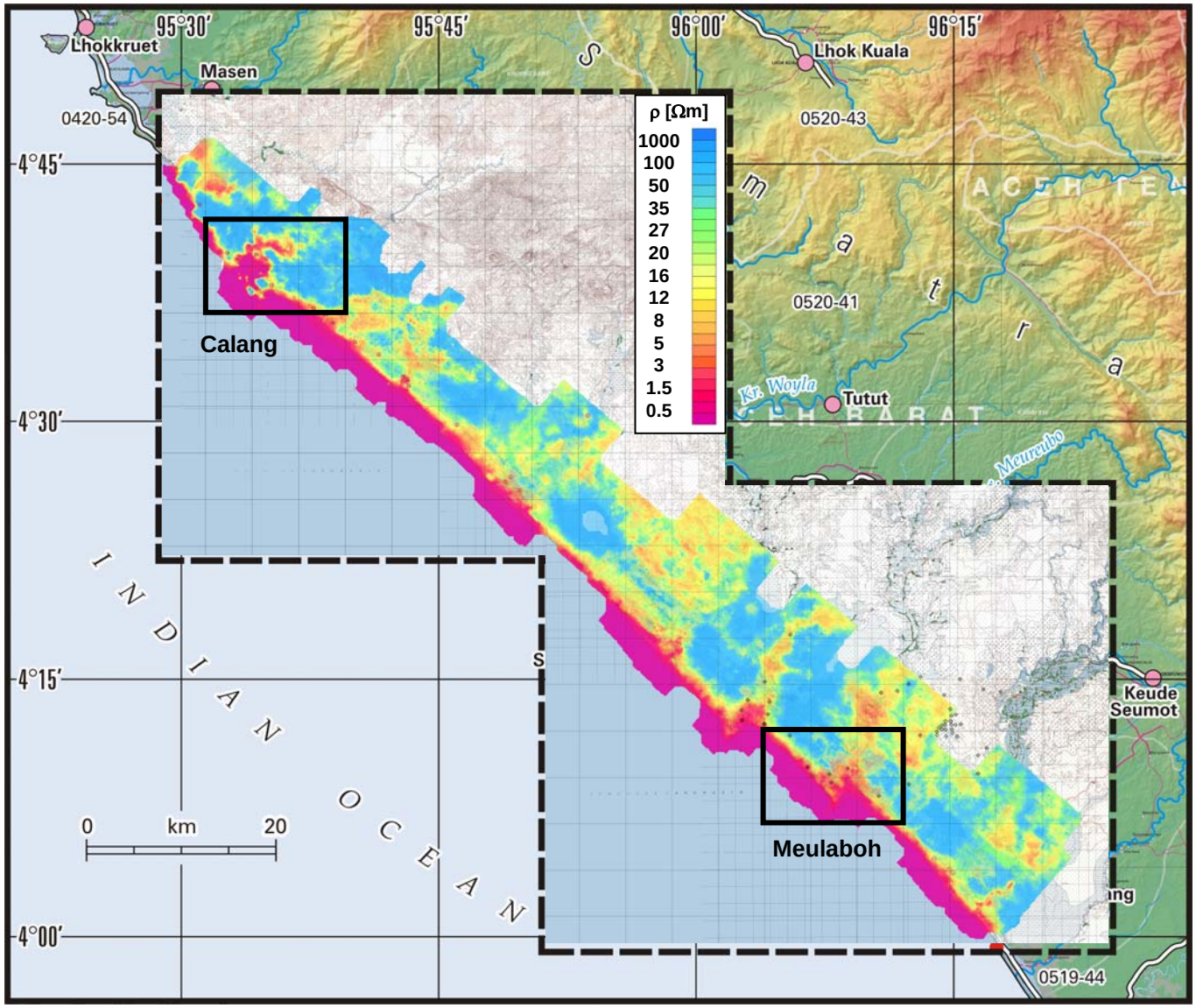
Survey area:
Calang - Meulaboh

Size of survey area: ca. 1700 km²
Total profile length: ca. 4700 km
Line spacing:
- **Lines:** 500 m (SW - NE)
- **Tie-lines:** 500 m (NW - SE)

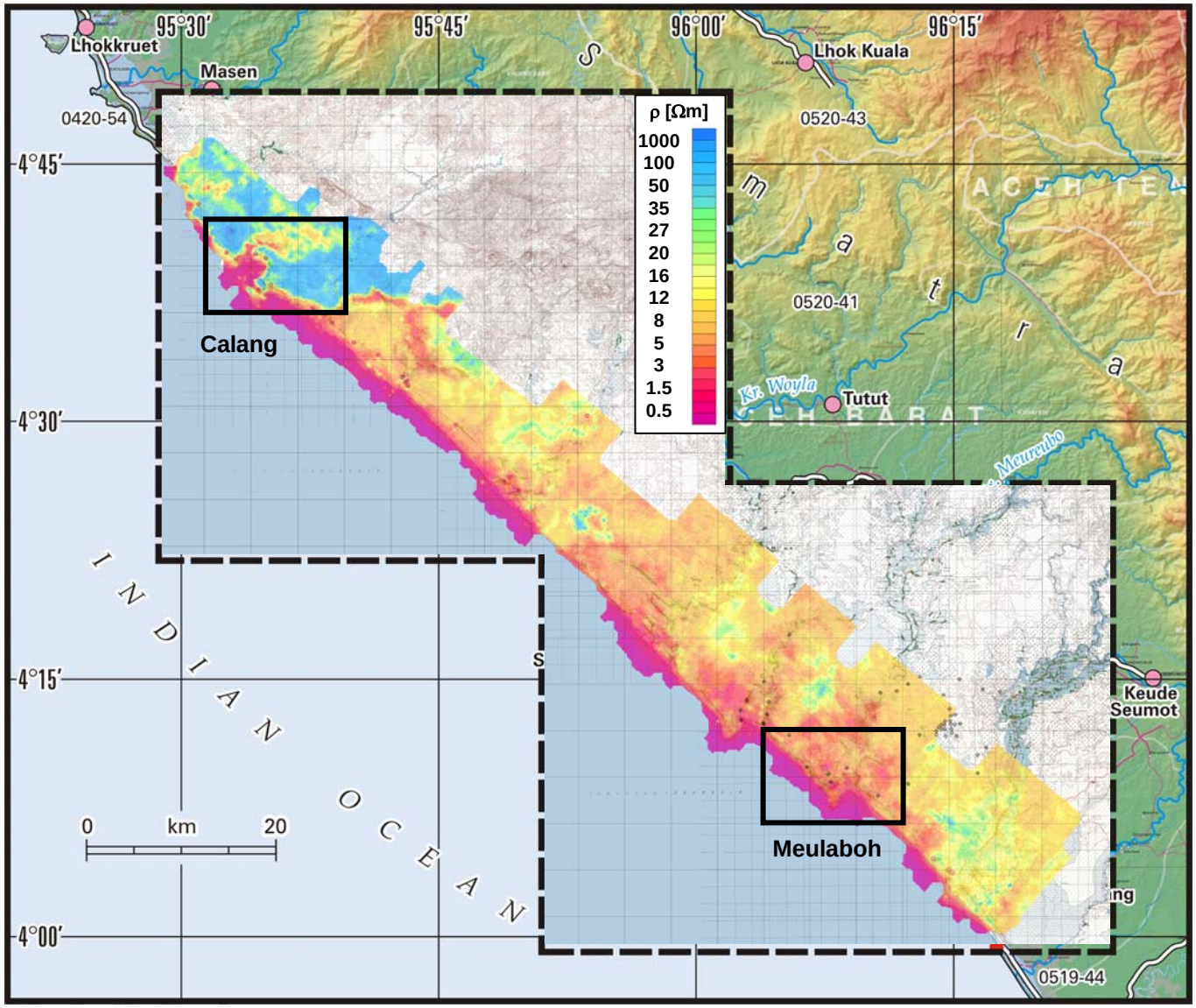
Survey period: 14/09/– 21/10/2005


95°30′
95°45′
96°00′
96°15′
Lhokkruet
Masen
Lhok Kuala
0420-54
0520-43
4°45′
4°30′
4°15′
4°00′
Tangla Formation
Calang Volc. Form.
0520-41
Kr. Woyla
Tutut
Calang (N)
Alluvium
Meulaboh Formation:
Sand, Kies
Tutut Formation:
Tonstein, Sandstein,
Konglomerat
Keude
Seumot
INDIAN OCEAN
0 km 20
Meulaboh (S)
SAMUDERA INDONESIA
0519-44

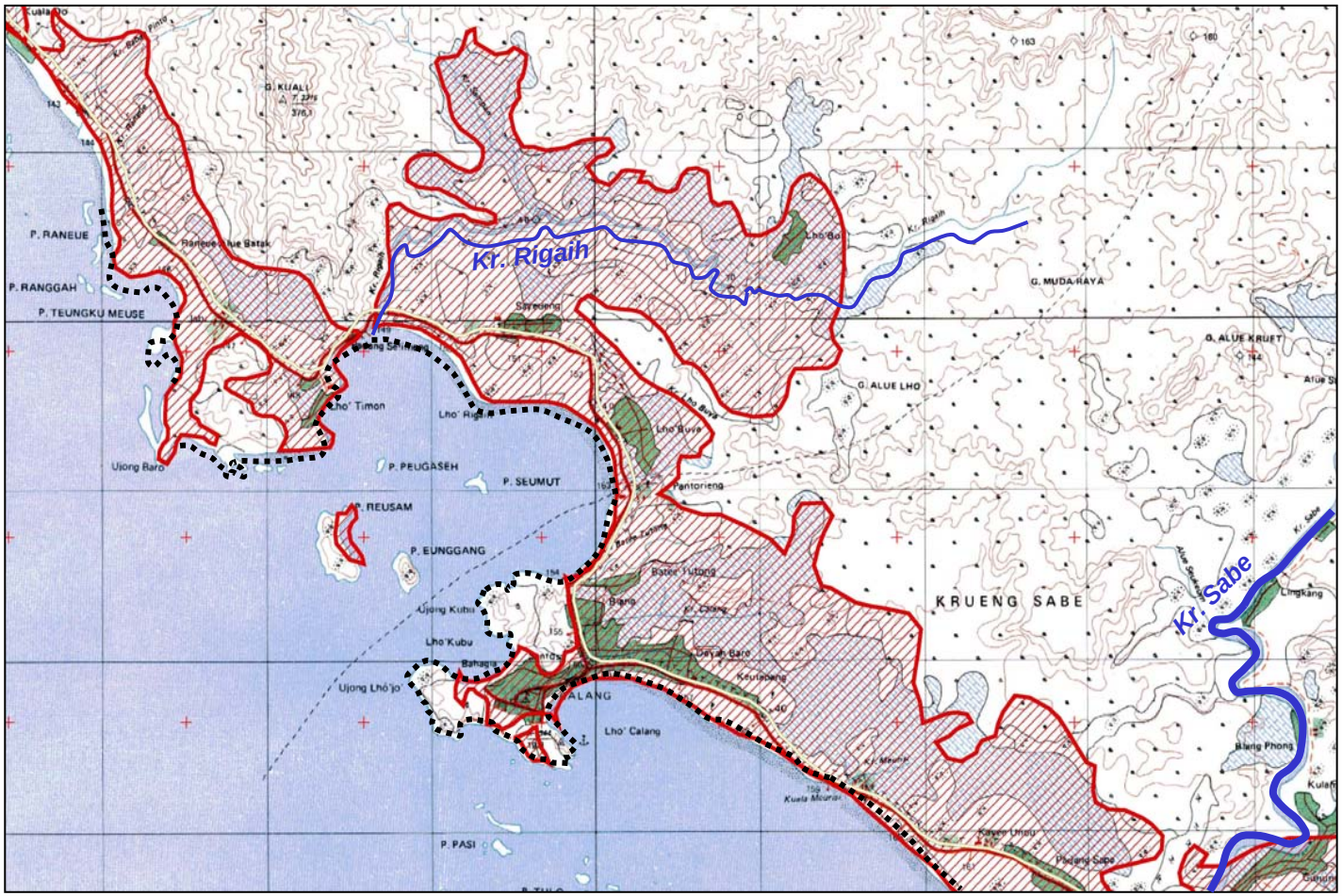
Resistivity at 10 m bgl



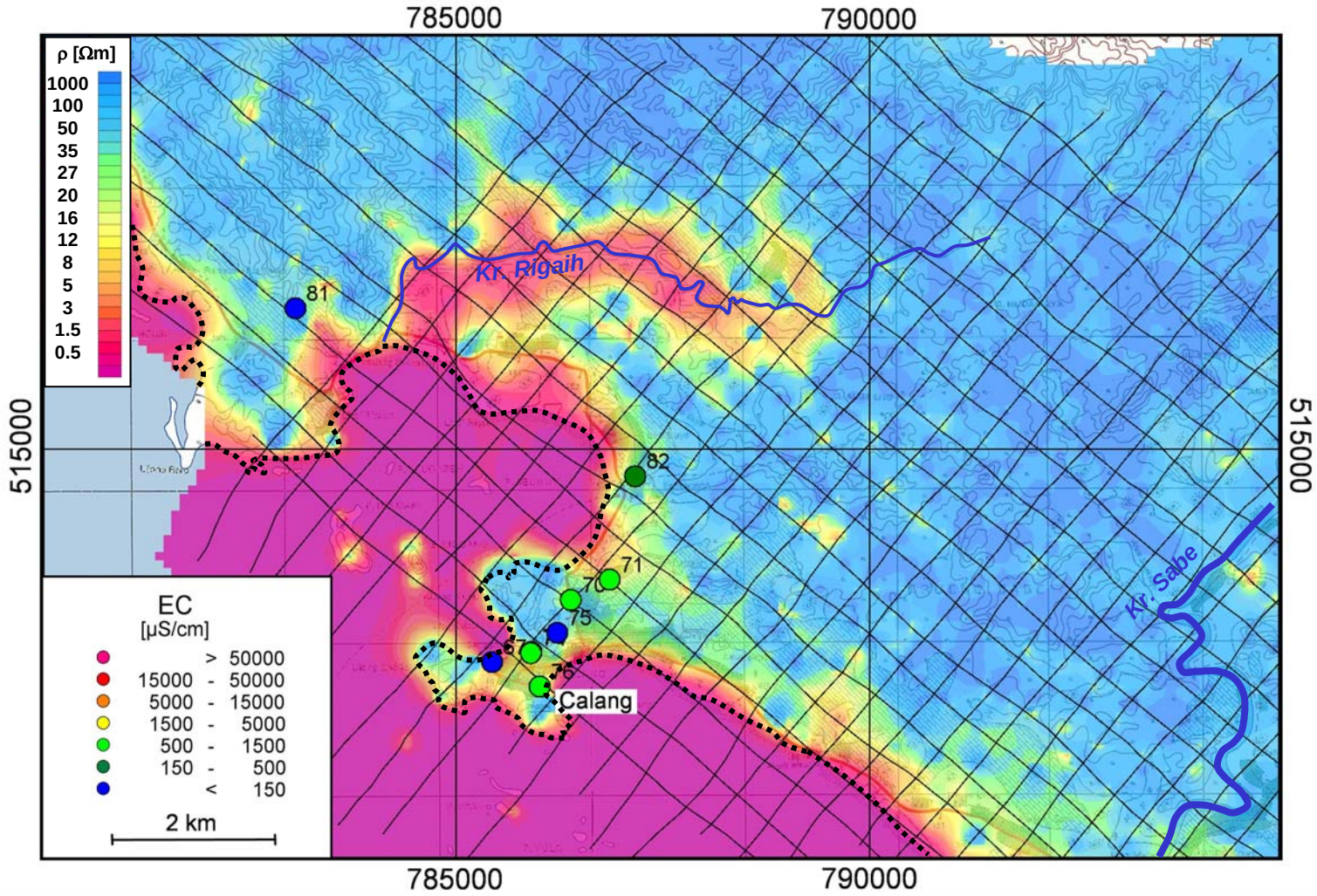
Resistivity at 40 m bgl



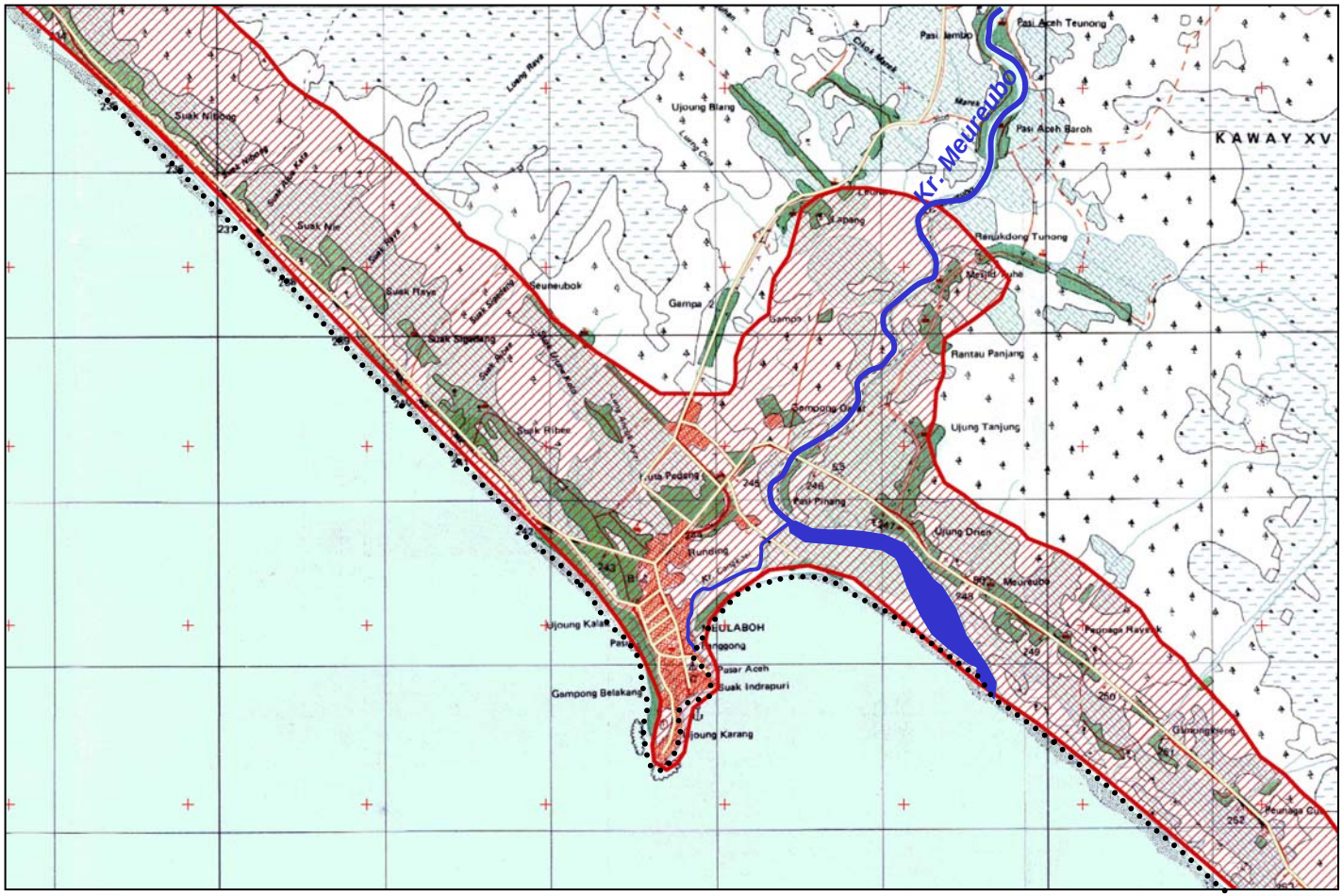
Calang: Extension of the flood



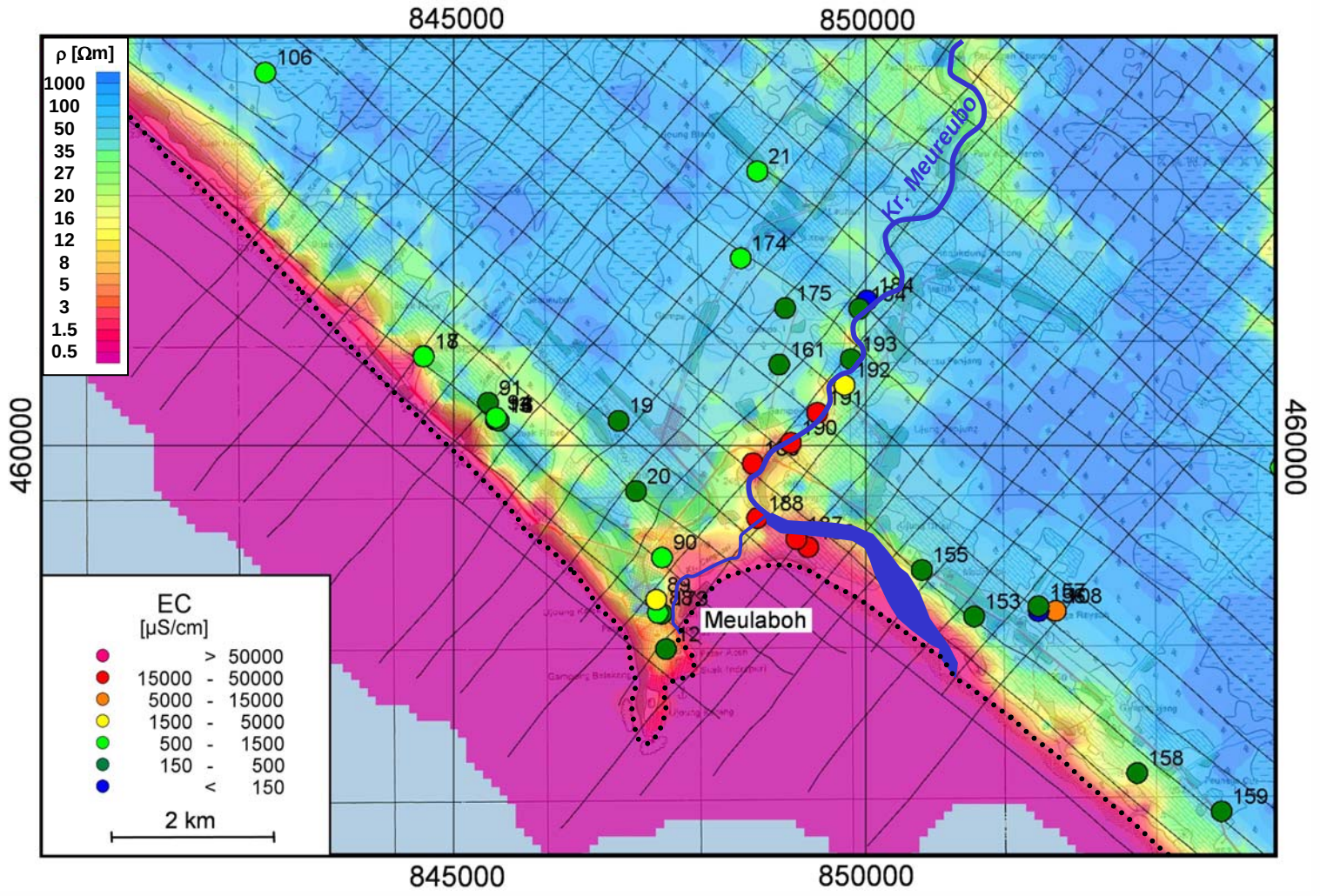
Calang: Resistivity at 5 m bgl



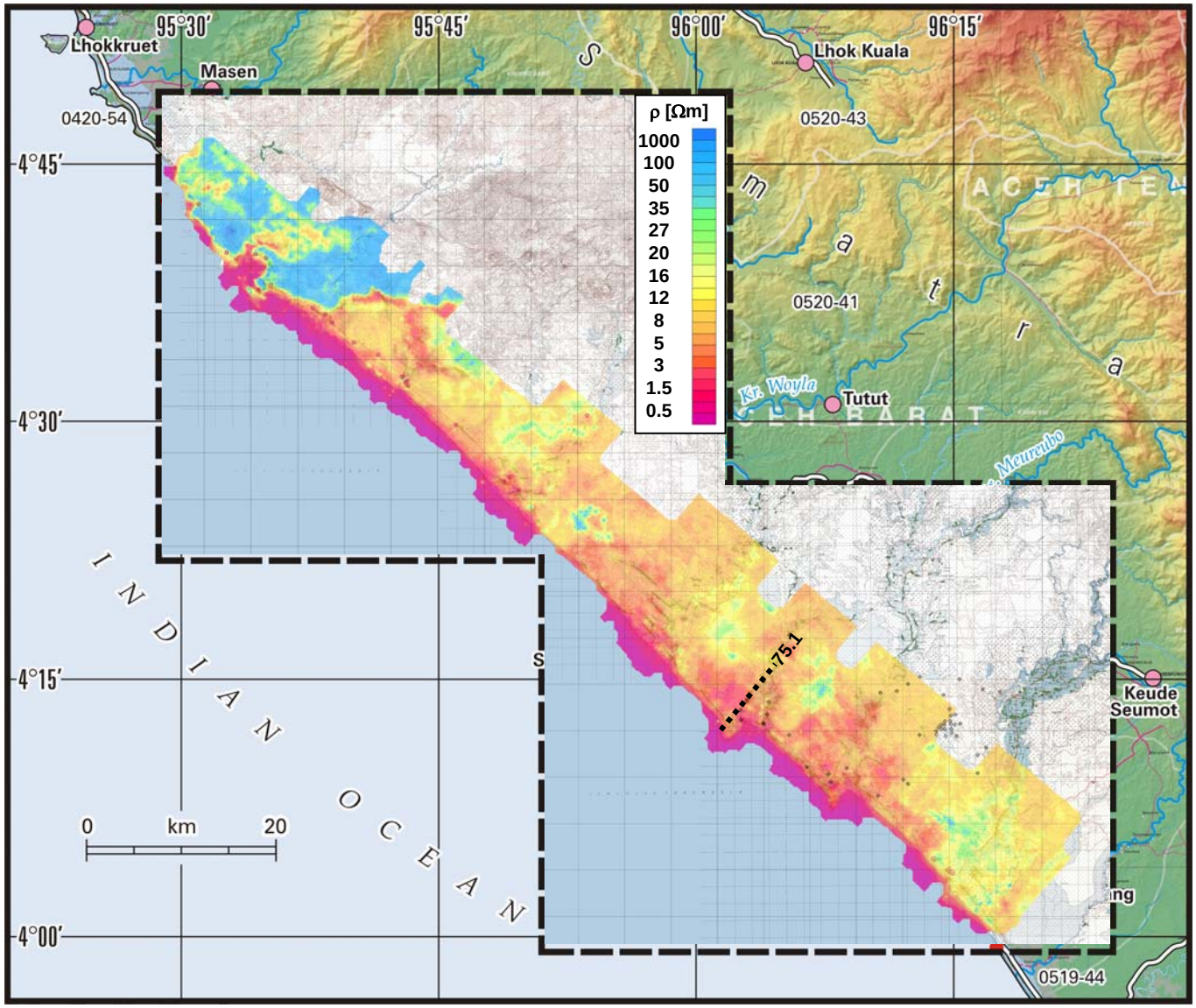
Meulaboh: Extension of the flood

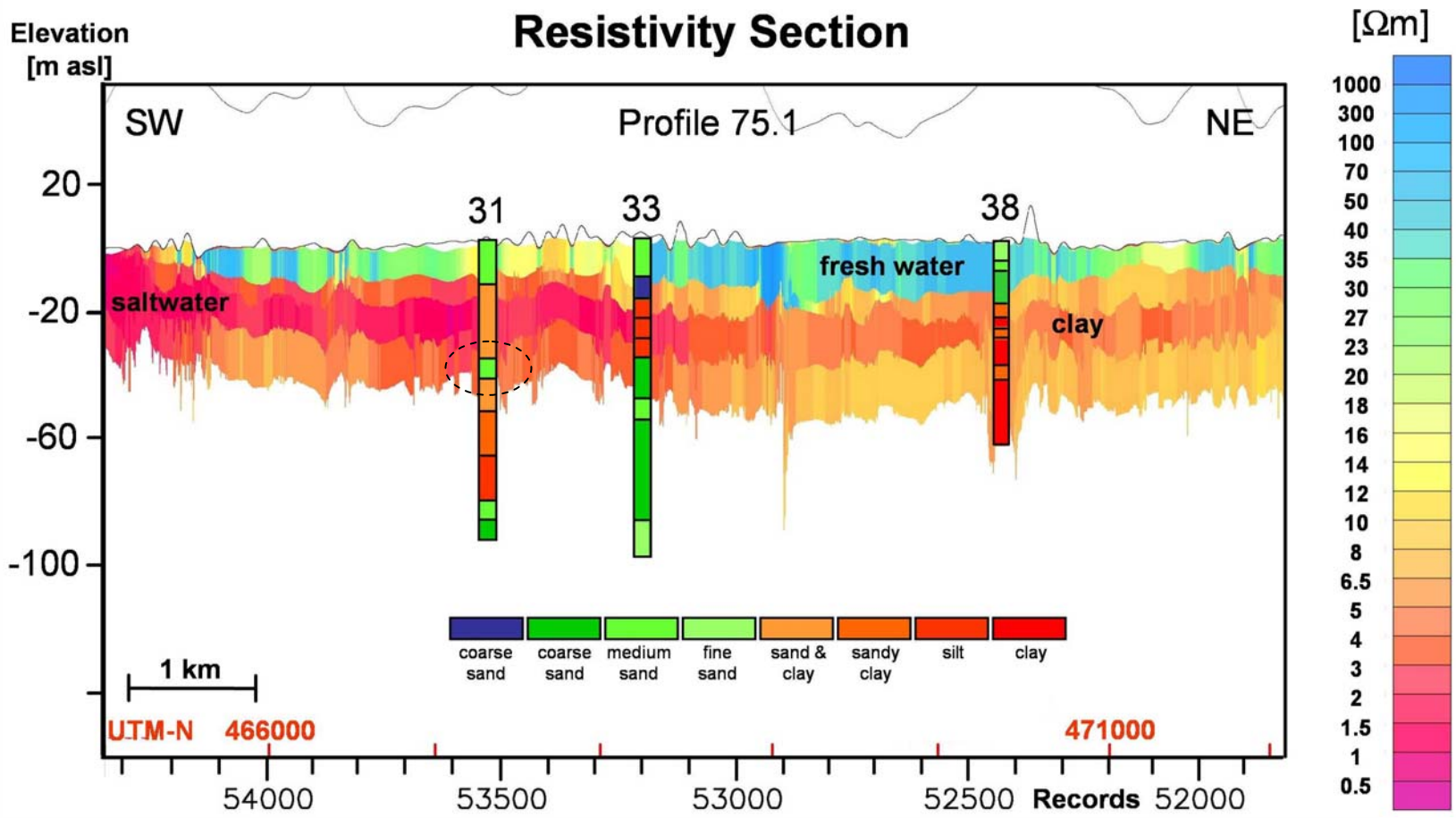


Meulaboh: Resistivity at 5 m bgl.



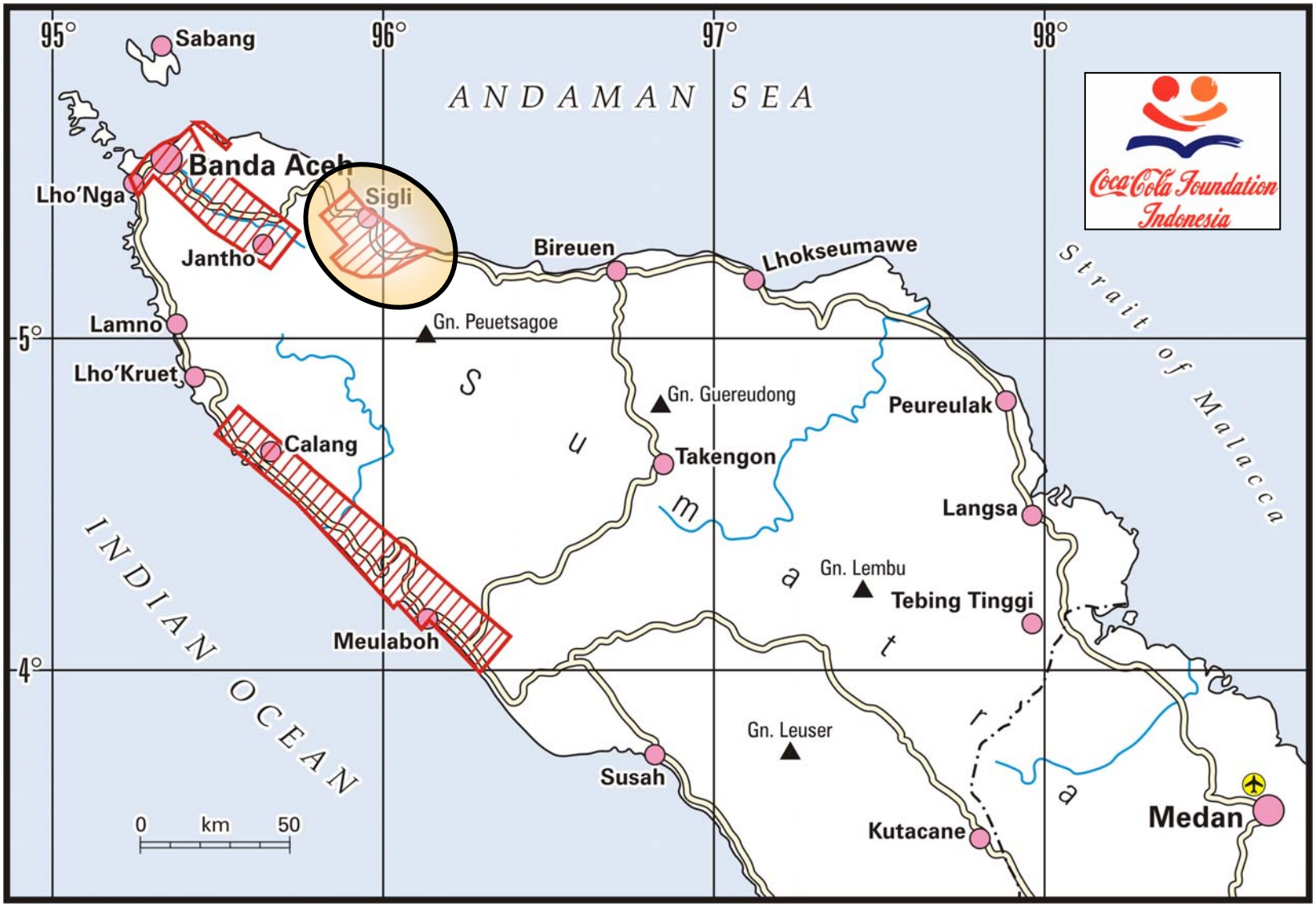
Resistivity at 40 m bgl.




Resistivity Section
Elevation
[m asl]
SW
Profile 75.1
NE
20
-20
-60
-100
31
33
38
saltwater
fresh water
clay
coarse sand
coarse sand
medium sand
fine sand
sand & clay
sandy clay
silt
clay
1 km
UTM-N
466000
471000
54000
53500
53000
52500
Records
52000
[Ωm]
1000
300
100
70
50
40
35
30
27
23
20
18
16
14
12
10
8
6.5
5
4
3
2
1.5
1
0.5

Main results

- Mapping of shallow to medium deep fresh- and saltwater occurrences
- Support of project partners and help agencies in questions of groundwater, like recommendations for well locations, etc.
- 3D data base for geology, hydrogeology and geo-techniques


95°
96°
97°
98°
5°
4°
Sabang
ANDAMAN SEA
Banda Aceh
Lho'Nga
Sigli
Jantho
Bireuen
Lhokseumawe
Strait of Malacca
Lamno
Gn. Peuetsagoe
Lho'Kruet
S
u
m
a
t
r
a
Gn. Guereudong
Peureulak
Calang
Takengon
Langsa
INDIAN OCEAN
Gn. Lembu
Tebing Tinggi
Meulaboh
Gn. Leuser
Susah
Kutacane
Medan
0
km
50
Coca-Cola Foundation Indonesia

HELIcopter Project Aceh – HELP ACEH

Project management:	U. Meyer, H.-J. Rehli,
Flight team:	K.-H. Meinhardt, J. Scheiwein, M. Schütt, W. Voß
Data analysis:	B. Siemon, B. Röttger†, A. Steuer, J. Pielawa,
Hydrogeology:	D. Plöthner, H. Klinge,
Ground geophysics:	D. Eberle, H. Schmidt