OPTIMIZATION OF DATA DENSITY OF MULTIELECTRODE MEASUREMENTS

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Abstract: *Investigations were performed that aimed at the reduction or rather at the optimization of the measured data density. For this purpose several datum levels of the measured apparent resistivity were omitted. Afterwards, the reduced data sets of the measured resistivity were inverted with a non-commercial 2-D inversion program. The resulting vertical sections were compared with that of the full data set. Two data sets from dike investigations in the provinces Nam Dinh and Thai Binh are selected for this study.*

The investigation has shown that a reduction of the data density of about 50 percent - without a significant loss of information - is possible. Some rules should be followed: It is not wise to omit the first and the last datum level. A more or less logarithmic distribution of the remaining datum levels yields the best results.

1. INTRODUCTION

Vietnam is situated in the monsoon zone. Thus, there are heavy rainfalls every year during the time from May to October. In order to protect the infrastructure and the population against floods in the rainy season, a network of riverdikes with a total length of more than 5000 km [1] has been built in the northern part of Vietnam.

But there are many dangers on the dike body:

- Low load capacity of the dike foundation.
- Inhomogeneities of the dike body due to the used unconsolidated materials.
- Termite nests.

At weak zones, the high pressure from the high water level can lead to fractures, fissures, slides of a bank and even to a breaking of the dike. For this reason, it is very important to find these weak zones and to repair them.

Due to this problem, the Institute of Geological Sciences at the Vietnamese Academy of Science and Technology and the Institute of Geophysics at the Technical University Clausthal (Germany) performed a joint project from 2001 to 2004. The aim of this project was the “Development of a geoelectrical technology to find termite nests in river dikes”. Further work included the investigation of lithological changes in the dike body and dike foundation.

Earlier investigations have shown that geoelectrical measurements are suitable to locate local fault zones, permeable zones, fractures, fissures, cavities and termite nests. Multielectrode measurements were carried out at different locations in the provinces Nam Dinh and Thai Binh in the northern part of Vietnam.

Unfortunately, geoelectrical multielectrode measurements require much time. Due to this, investigations were performed aiming at the reduction of the data quantity and consequently at the reduction of the needed time for each survey. Some of the measured data sets of the joint project were used for these investigations.

2 METHODOLOGY

2.1 Locations

The first location for the geoelectrical multielectrode measurements is situated at the dike section Yên Tho in the province Nam Dinh. The dike section of Yên Tho is situated on the left side of the river Day in the northwest of the province.

The main task at this location is to locate a clay lens, which lays in the dike foundation, and to determine its extension. Due to the clay lens there are landslides at this dike section.

The second location is a dike section near Hiep Hoa [7] in the province Thai Binh. The dike section is located on the right side of the river Tra Li, about 13 km in the northwest of the province capital Thai Binh.

This dike section is strongly effected by termite activities. The stability of the dike is highly endangered. Therefore, the main task is to locate the termite nests in the subsurface.

2.2 Geoelectrical measurements

At the dike section of Yên Tho, two profiles were measured: one parallel to the dike axis and the other one perpendicular to the first one. In this work only the horizontal profile will be regarded. A multielectrode system GMS 150 (GeoSys Leipzig, Germany) was used. The measurements were performed with a special three-electrode-configuration, which is also called Half-Wenner-configuration. An electrode distance of a = 4 m was chosen and 16 datum levels were measured.

At the second location, three profiles parallel to the dike axis were measured. The distance between the profiles was 2 m. The investigations concerning the data density were only performed on the central profile. The electrode configurations of a combined Half-Wenner and an equatorial dipole-dipole were used. The measurements were carried out with an electrode distance of a = 1 m and 14 datum levels.

2.3 Choice of electrode configuration

For geoelectrical resistivity profiling various electrode configurations can be used. Common configurations are Wenner-α and dipole-dipole. Earlier investigations have shown that a special three-electrode-configuration, which is also called Half-Wenner-configuration, offers several advantages for resistivity profiling with multielectrode systems [2, 6]:

- The number of measurements with a fixed number of electrodes is larger than for a Wenner-α or dipole-dipole configuration.
- With the same number of electrodes a greater depth of penetration can be reached.
- For the infinite electrode B a suitable location for current injection (low transfer resistance) can be found a large way outside the profile.
- The simple combination of a Half-Wenner forward configuration (A – na – M – na – N, a being the fixed electrode distance, n an integer factor) and a Half-Wenner backward configuration (N – na – M – na – A) with a fixed position of electrode M has proved to serve as a focussing tool [4]. The average of both readings results in a pseudo-section reflecting the main features of the subsurface resistivity distribution.
- The combination of two Half-Wenner readings is less sensitive to an undulating topography [2].

2.4 Optimization of data density

The measured apparent resistivity data of all datum levels are inverted with the non-commercial 2-D inversion program DC2DSIRT [3], which is based on a finite difference forward modelling [8] and a simultaneous iterative reconstruction technique [5].

In the next step selected datum levels of the apparent resistivity data are omitted. For this occasion, in the majority of cases, a logarithmic distribution of the remaining datum levels was selected. The reduced data sets are inverted using the program DC2DSIRT.

3 RESULTS AND DISCUSSION

3.1 Yên Tho

The measurements on dike Yên Tho used all datum levels from 1 to 16 with only omitting datum level 15. The original inversion result of all measured data is presented in Fig. 1a.

First, half of the datum levels were deleted. The inversion results are shown in Fig. 1b and 1c. Fig. 1d presents the inversion result that considers eleven datum levels. This corresponds to a reduction of about 8 percent (see Tab. 1). The inversion result in Fig. 1e is based on the data from only five datum levels. It can be seen that the vertical resistivity section starts to get disturbed. That's why in the next step seven datum levels with a more or less logarithmic distribution were chosen. The inversion results can be seen in Fig. 1f. Finally, this data set was modified by omitting every second measurement in the last three datum levels. The resulting resistivity section is given in Fig. 1g.

The different 2-D inversion results are similar to each other. Even Fig. 1e, containing only five datum levels, displays the clay lens. Even if this reduced data set corresponds to a reduction of about 58 percent, the disturbance of the vertical resistivity section proved to be not sensible to the omission of so much datum levels.

A comparison of the different inversion results shows that Fig. 1c, which contains only half of the measured datum levels, deviates strongly from the other resistivity sections. It can be observed that the resistive layer near the surface has been suppressed. The reason hereof is the elimination of the first datum level, which is obviously necessary for the inversion procedure. The vertical resistivity section in Fig. 1f gives a good image of the clay lens in the underground, and also the high resistive layer near the surface is shown. This 2-D inversion result corresponds to a reduction of about 41 percent. The final vertical resistivity section in Fig. 1g , where in the last three datum levels every second measurement is omitted, corresponds to a reduction of about 50 percent.

The number of measured datum levels, the number of measurements and the resulting reduction of measurements are listed in Table 1.

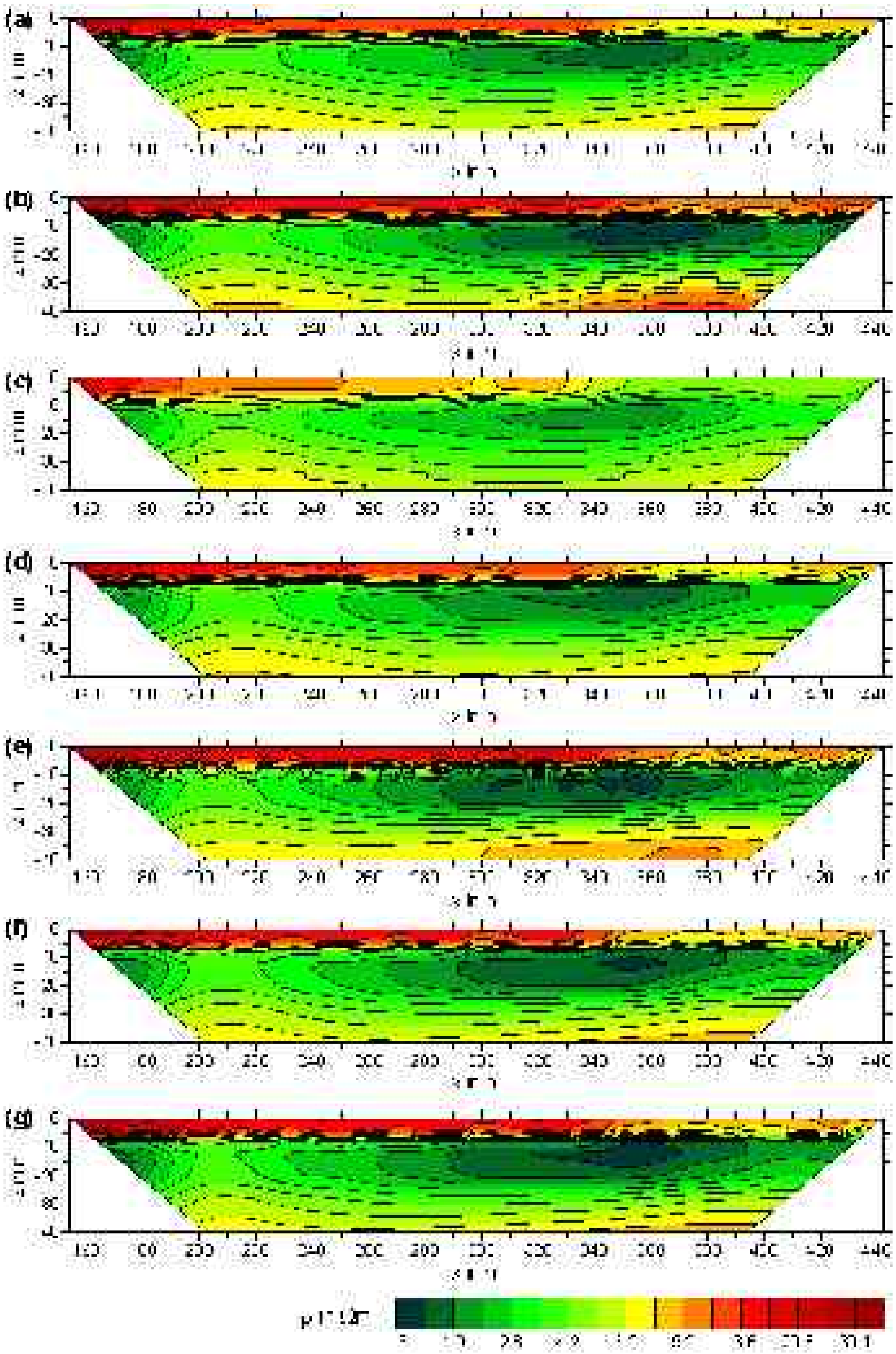

Figure 1. *Location Yên Tho: Vertical resistivity sections generated with varying data quantity.*
(a) Original profile: all datum levels.
(b) Datum levels: 1, 3, 5, 7, 11, 13 and 16.
(c) Datum levels: 2, 4, 6, 8, 10, 12 and 14.
(d) Datum levels: 1, 2, 3, 4, 5, 6, 8, 10, 12, 14 and 16.
(e) Datum levels: 1, 2, 4, 8 and 16.
(f) Datum levels: 1, 2, 3, 4, 6, 10 and 16.
(g) Datum levels: 1, 2, 3, 4, 6, 10 and 16 (at the last three datum levels: only each second measurement).

Table 1. Reduction of measurements, Yên Tho

Inversion	Number of datum levels	Number of measurements	Reduction of measurements in %
(a)	15	1412	0
(b)	7	649	54,04
(c)	8	827	41,43
(d)	11	1295	8,29
(e)	5	595	57,86
(f)	7	836	40,79
(g)	7 (*)	709	49,79

(*) At the last three datum levels: only each second measurement

3.2 Hiep Hoa

The measurements at the dike section Hiep Hoa used all datum levels from 1 to 14. The original inversion result is shown in Fig. 2a.

Contrary to the investigations from the first location, in this case, the data set of the measured apparent resistivity was only prepared two times. First, seven datum levels with a more or less logarithmic distribution were chosen. The 2-D inversion result hereof is shown in Fig. 2b. In the next step, at the last three datum levels every second measurement of the reduced data set was omitted. The inversion result is displayed in Fig. 2c.

A comparison of the three inversion results shows only slight differences. Each vertical resistivity section displays the high anomalies near the surface at the same locations. There are small changes in the intensity of the anomalies. The resistivity contrast slightly increases from the original vertical resistivity section in Fig. 2a to that one, which is displayed in Fig. 2c.

The number of datum levels, the number of measurements and the resulting reduction of measurements are listed in Table 2. The table shows that the final vertical resistivity section yields a reduction of about 57 percent.

Table 2. Reduction of measurements, Hiep Hoa

Inversion	Number of datum levels	Number of measurements	Reduction of measurements in %
(a)	13	3641	0
(b)	7	1953	46,36
(c)	7 (*)	1575	56,74

(*) At the last three datum levels: only each second measurement

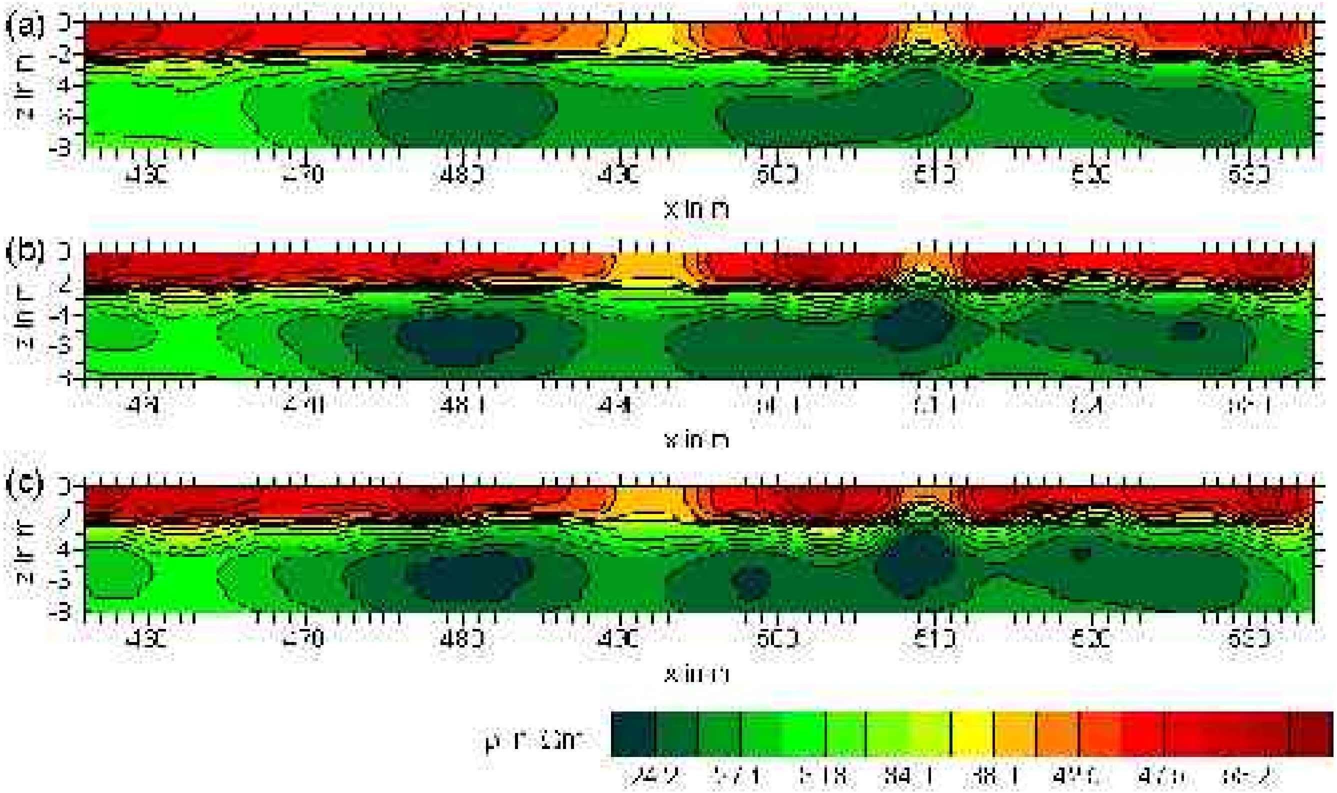

Figure 2. *Location Hiep Hoa: Vertical resistivity sections generated with varying data quantity.*
(a) Original profile: all datum levels.
(b) Datum levels: 1, 2, 3, 4, 6, 9 and 14.
(c) Datum levels: 1, 2, 3, 4, 6, 9 and 14 (at the last three datum levels: only each second measurement).

4 CONCLUSIONS

The investigations to optimize the data density and thus to reduce the measuring time have shown that a reduction of the needed datum levels is possible without a significant loss of information on the subsurface structures.

In the case of the multi-electrode measurements at the dike section of Yên Tho, it could be seen that it is not wise to omit the first datum level. The reason hereof is that this datum level and the last one are important for the inversion algorithm.

An empirical procedure of the investigations leads to the result that the 2-D inversion result of a reduced data set, which contains only seven datum levels with more or less logarithmic distribution, yields a good correspondance with the inversion result of the original data set. It is even possible to omit every second measurement in the last three datum levels of the reduced data set without a significant change of the inversion result. Thus, in the case of the location of Yên Tho, a reduction of the number of measurements of about 50 percent was possible.

In the case of Hiep Hoa, the investigations result in a reduction of the number of measurement of more than 56 percent without a significant loss of information.

5 ACKNOWLEDGEMENT

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