APPLICATION OF RESISTIVITY IMAGE PROFILING FOR THE HSUEHSHAN TUNNEL

Dao-Tze Tsai, Fu-Lang Hwang, Shang-Chih Kao, Lee-Ping Shi

ABSTRACT

The 12.9km tunnel -- one of the most important development projects ever initiated by the Ministry of Transportation and Communication is set to open in 2005. If work remains on schedule, the journey between Taipei and Yilan will be reduced from the current two hours to just 40 minutes. The Peiyi Highway is considered a major breakthrough for Yilan's transportation and road development, and it will improve better situation for local economics. During the drilling process, it will face many challenges and risks. The worst conditions, which the engineers often stumble to suspend whole work, was the appearance of water suddenly.

Using the technique of RIP with geophysical survey, it could be helpful in detecting where the groundwater zone was. From the 2 major lines for demonstration with actual geology in conclusion, we got a suitable result to prove its practicability. It can be verified to improve security at drilling and predict some pitfall for engineers in safety reason.

INTRODUCTION

To get more information for finding out some hidden water in geophysical survey, the Resistivity Image Profiling (RIP) became the one of some important techniques to explore the location storing underground water on the route of Hsuehshan Tunnel. The RIP as shown in figure 1, which was used for the purpose of electrical surveys to determine the subsurface resistivity distribution by making measurements on the ground surface. In fact, The TSP technique was designed to produce an uninterrupted advance with calculable risks and a high degree of efficiency. For the reason of groundwater's low-resistively, it could be detected by an easy way to measure the resistively For the reason of groundwater's low-resistivity, it could be detected by an easy way to measure the resistivity underground, and find the source of water. Injecting current into the ground through two current electrodes and measuring the resulting voltage difference at two potential electrodes normally makes the resistivity measurements, underground, and find the source of water. Injecting current into the ground through two current electrodes and measuring the resulting voltage difference at two potential electrodes normally makes the resistivity measurements.

From the current and voltage values, an apparent resistivity value is calculated.

$\rho_a = k(V/I)$

Where k is the geometric factor that depends on the arrangement of the four electrodes. The apparent resistivity measurements made from the survey are normally plotted on a log-log graph paper. To interpret the data from such a survey, it is normally assumed that the subsurface consists of horizontal layers. In this case, the subsurface resistivity changes only with depth, but does not change in the horizontal direction. This 1-D model of the subsurface is used to interpret the measurements. And, the most severe limitation of the resistivity sounding method is that horizontal or lateral

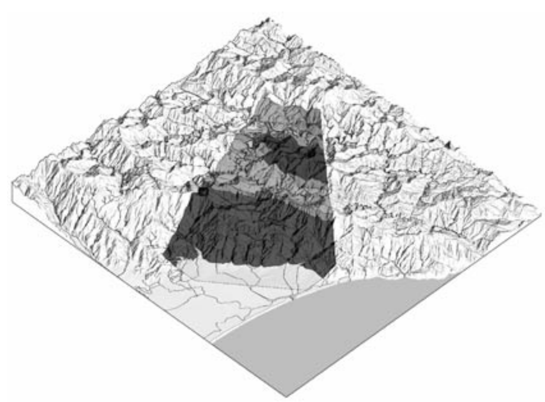

Figure 1. The surveyed area for RIP

Figure 2. The SYSCAL Junior made by IRIS INSTRUMENTS Ltd. for RIP

change in the subsurface resistivity is commonly found. Lateral changes in the subsurface resistivity will cause changes in the apparent resistivity values that might be, and frequently are, misinterpreted as changes with depth in the subsurface resistivity. The resistivity of ground water varies from 10 to 100 ohm-m depending on the concentration of dissolved salts. As the same reason to make risks, the hidden groundwater area will gush suddenly when the engineers drill nearby, and also have the distinction of low resistivity. It almost became the most dangerous thing in work.

In the geophysical survey of the Hsuehshan Tunnel, we wondered where the source of groundwater was, and how many risks it will cause. After the field survey, the resistance measurements are reduced to apparent resistivity values. Practically all-commercial multielectrode systems come with the computer software to carry out this conversion. It was not only to make a good detected result where the groundwater was, but also anticipated a great inpouring of groundwater when drilling processed.

At some condition, it was suitable to combine the RIP's result with the well log. It obtained a suitable comparison between RIP with well log. This study aim to show the application for the fault- distribution analysis in geophysical survey. Section 2 states the local situation about the Hsuehshan Tunnel area. The main principle of RIP, analysis mode for RIP data and the collocation for equipment are showed in Section 3. Finally, the demonstration and conclusion by using RIP for the Hsuehshan Tunnel is given in Section 4.

LOCAL SITUATION

Development of the tunnel, which began in July 1991, has been a trying task. If work remains on schedule, the journey between Taipei and Ilan will be reduced from the current two hours to just 40 minutes. Now, the Peiyi Expressway is considered a major breakthrough for Ilan's transportation and road development. Because of the high-mountain barrier, people from Ilan have had to trek along the coastal way to Taipei or by lengthier and more treacherous mountain routes (shown as figure 3). When completed, it will become a key to improve the road efficiency which just like to link Switzerland and Italy or another that links Switzerland and France. The greater part of the Hsuehshan Tunnel consists of a might sequence of indurated and metamorphosed argillaceous Tertiary sediments. The structure of the metamorphic rocks is complex by many folds and faults owing to the plate cataclysm near Taiwan.

Through the Hsuehshan Range, there is a high rock-cover over 700m. The stratigraphic distribution, which stretched from the west-side Tertiary Miocene to the east-side the west-side Tertiary Eocene, consisted of Fangchiao Formation, Magun Formation, Tatungshan Formation, Tzuku sandstone, Kankou Formation and Szeleng Sandstone. In major, the lithology of Hsuehshan Tunnel west-side was sandstone, shale, argillite and alternations of sandstone and shale. The other way, the lithology of Hsuehshan Tunnel east-side was argillite and Szeleng Sandstone. The east-side rock structure was more

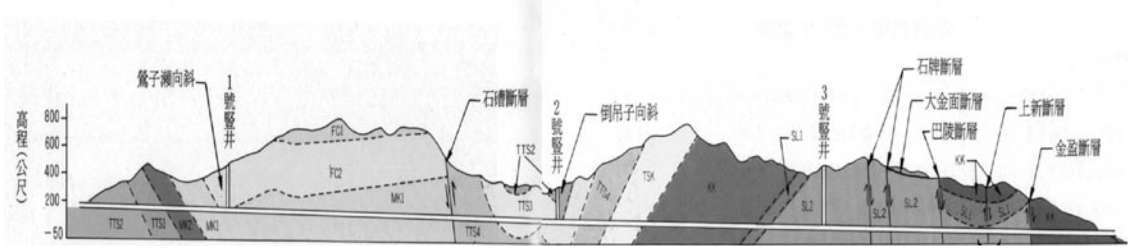

Figure 3. The simple geological profile for the Hsuehshan Tunnel

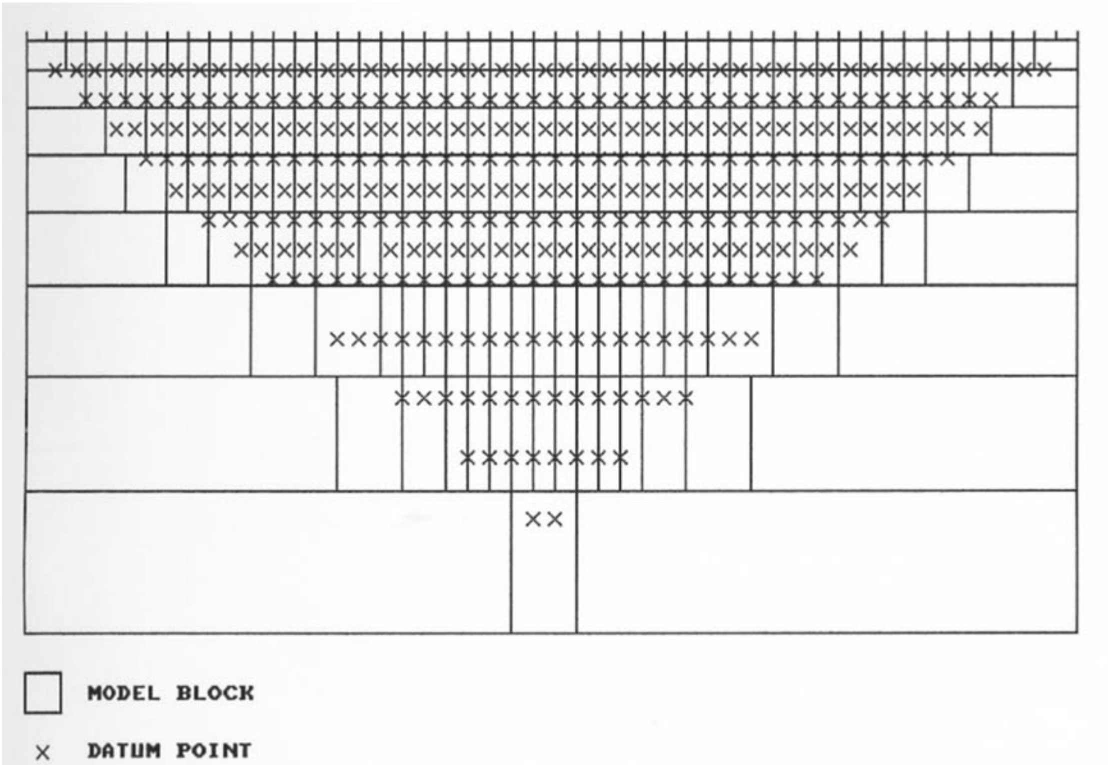

Figure 4. The subdivision of the subsurface into rectangular blocks. (This pattern was abridged from M.H. Loke, Electrical Imaging Surveys for Environmental and Engineering Studies)

broken than the west-side. It was expected to cross six faults(Shihchiao fault, Shihpai fault, Palin fault, Sanghsin fault and Chingyin fault) and two synclines(Yingtzulai syncline and Daodiaotzu syncline). The whole geological changes could not understand well before the drilling-work started. So that, there is a suitable mode to make it safely by keeping sliding method with geophysical exploration and geological intensification.

The tunnel builders conducted a thorough scanning of the geology of the strata of the range by airlifting sonar, a global positioning system and other advanced equipment by helicopter to the top of the range in order to find out what exactly was in the mountains that made the engineering task so Herculean. However, they were only able to scan about 300m into the mountain, leaving more than 100m of further depth still a mystery. It should progress a more accurate method to explorate the particularity of rock and the position of fault in depth over 300m.

THE DATA ANALYSIS AND RESULT OBTAINED FROM RIP

The inversion routine used by the analysis program is based on the smoothness-constrained least-squares method. This technique is more than 10 requires less memory. The conventional Gauss-Newton method in this analysis program is also useful. The 2-D model used by the analysis program divides the subsurface into a number of rectangular blocks shown as figure 4.

The purpose of the analysis program is to determine the resistivities of the rectangular blocks that will produce an apparent resistivity pseudosection that agrees with the actual measurements. For the pole–pole, dipole-dipole arrays, the thickness is set to about 0.9 and 0.3 times the electrode spacing respectively. The thickness of each subsequent deeper layer is increased by 10% (or 25%). The depths of the layers can also be changed manually by the user. The optimisation method basically tries to reduce the dififference between the calculated and measured apparent resistivty values by adjusting the root-mean-squared (RMS) error. However the model with the longest possible RMS error can sometimes show

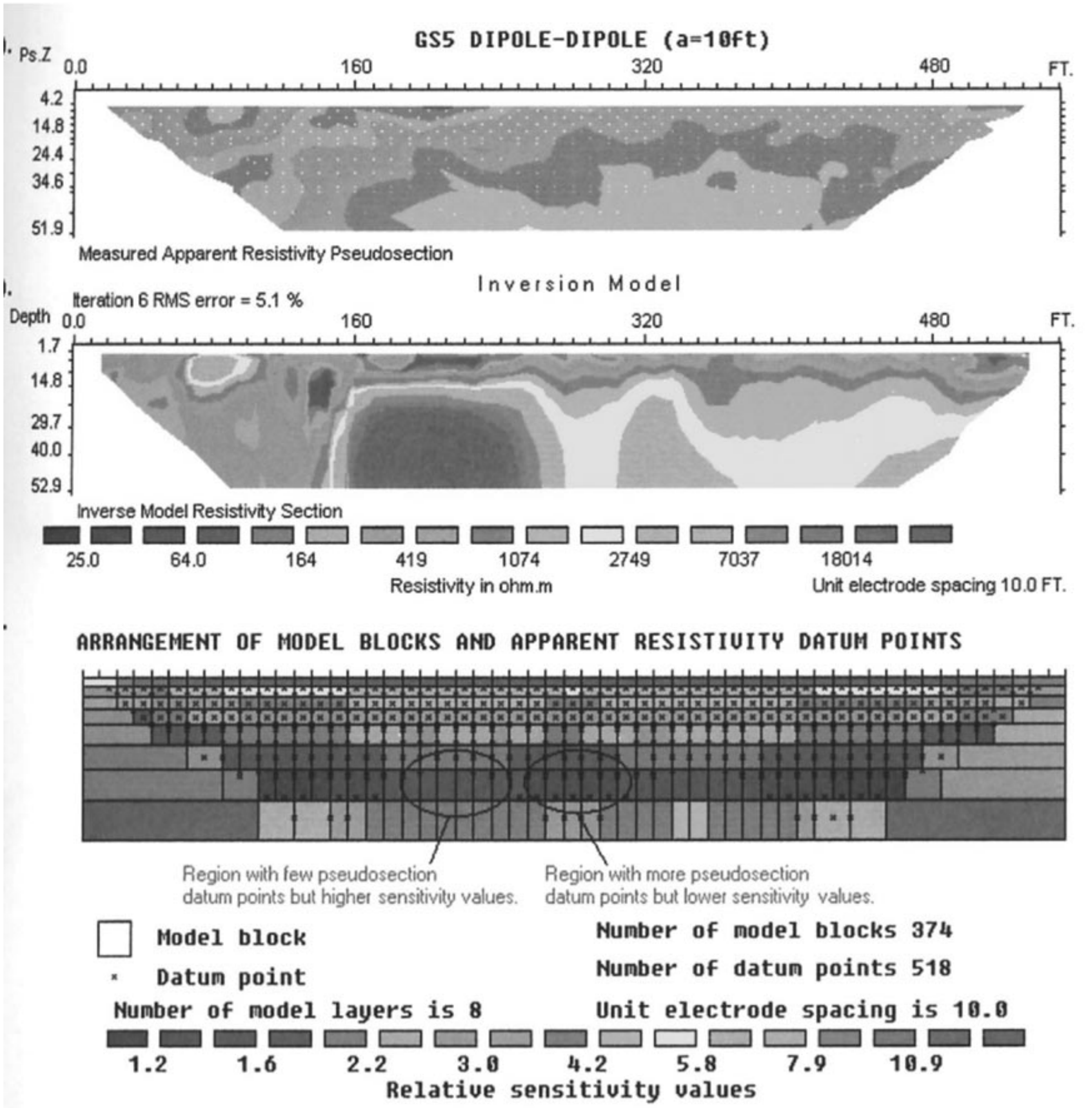

Figure 5. The apparent resistivity pseudosection, inversion model and model blocks used by the inversion program. (This pattern was abridged from M.H. Loke, Electrical Imaging Surveys for Environmental and Engineering Studies)

large and unrealisitic variations in the model resistivity values and might not always be the "best" model from a geplogical perspective. In general the most prudent approach is to choose the model at the interation after which the RMS error does not change significantly. The result of the RIP's survey for the Hsuehshan Tunnel is shown as figure 6 and 7.

DEMONSTRATION AND CONCLUSION

With the investigation depth about 900m, the RIP technique provide the tunnel engineers to know where the groundwater was. It's an important survey to compare with geological prognosis and probing by predrilling. Showing as the diagram before, there are 2 RIP survey lines which predicted for the Hsuehshan Tunnel to avoid the hidden risks. It can be demonstrated by the match rate as shown in table 1. Before dealing with the more complex types of surveys, RIP provide briefly at the resistivity values of some rocks and soils that is rich-jointed. It usually became

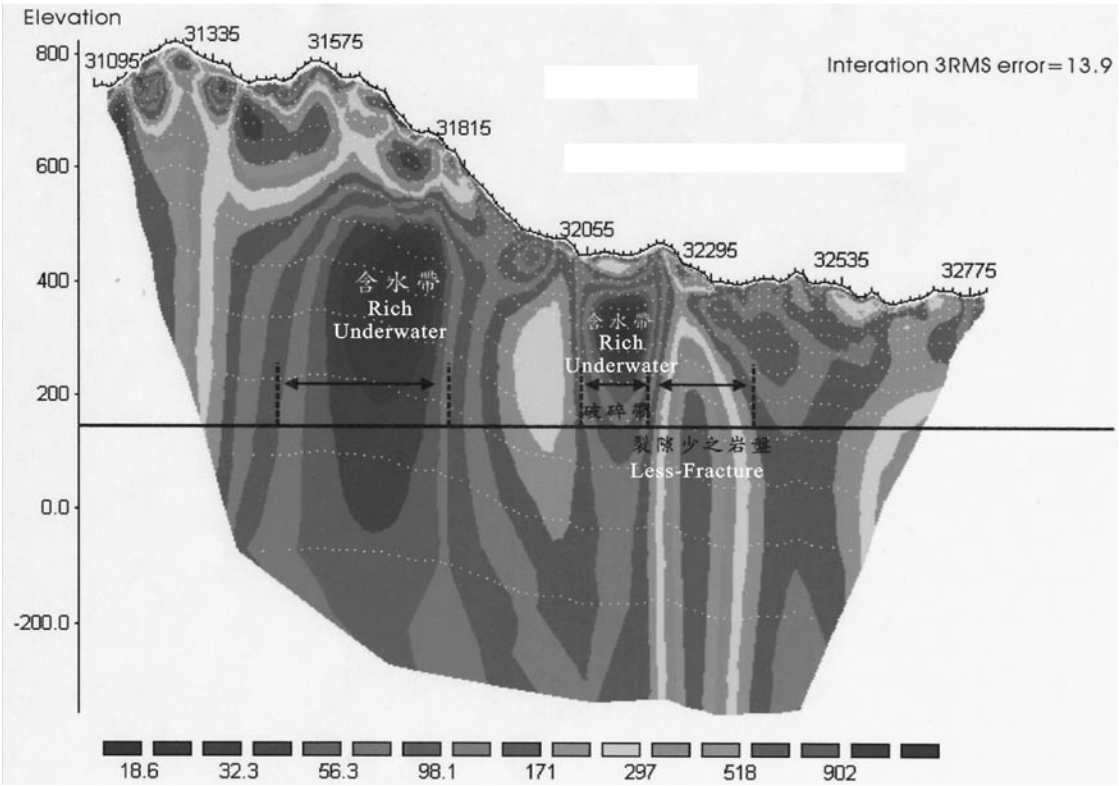

Figure 6. The No.1 RIP profile for the Hsuehshan Tunnel

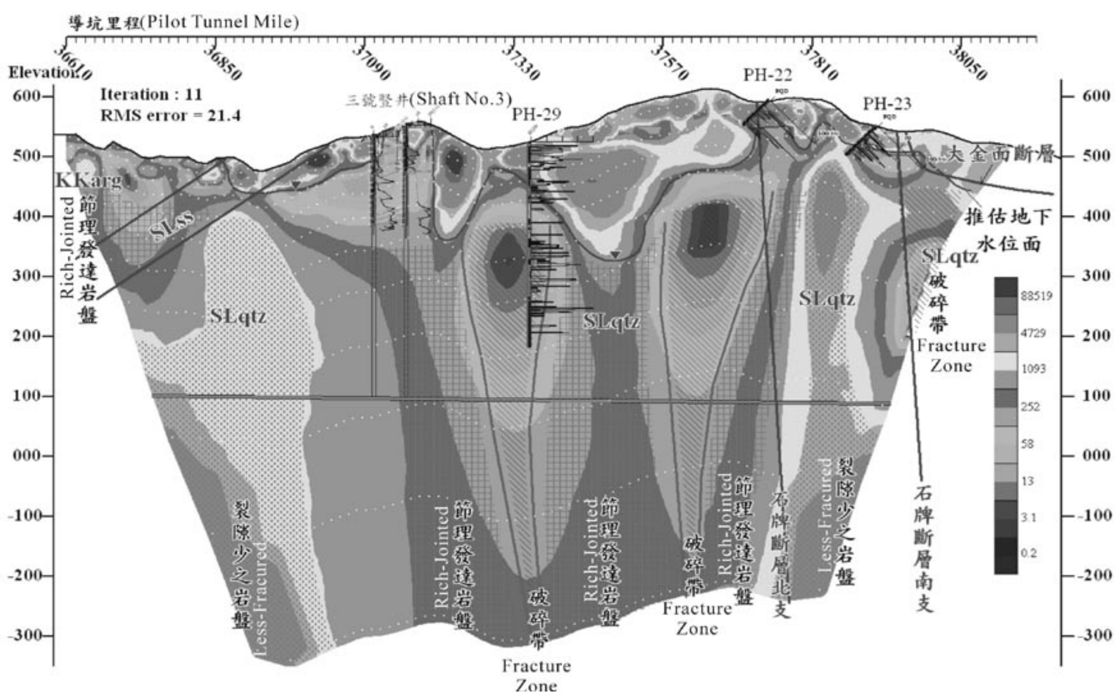

Figure 7. The No.2 RIP profile for the Hsuehshan Tunnel

Table 1. The geological comparsion with RIP result in the Hsuehshan Tunnel

Position	Geological condition	Wedth(m)	RIP's survey
A. Szeleng Sandstone			
37k+200~37k+190	Joint grown zone	10	Detected
36k+765~36k+740	Fault zone with water	25	Out of range
36k+650~36k+685	Fracture zone	35	Out of range
36k+000~35k+950	Dense joint with water	50	Out of range
B. Tatungshan Formation, Tzuku sandstone, Kankou Formation			
34k+835~34k+880	Joint grown zone	45	Unsurvey
34k+300~34k+340	Joint grown zone	40	Unsurvey
34k+100~34k+140	Fault shear zone	40	Unsurvey
33k+805~33k+850	Fault shear zone	45	Unsurvey
33k+550~33k+575	Fault shear zone	25	Unsurvey
32k+470~33k+075	Fracture zone with fold	605	Unobservable
C. Section Shihchiao fault			
31k+820~32k+150	Fault zone with water	330	Detected
32k+045~32k+085	Fault zone	40	Detected
32k+485~32k+525	Fault zone	40	Unobservable
D. Magun Formation, Tungshan Formation			
30k+880~30k+920	Shear zone	40	Out of range
31k+310~31k+120	Shear zone	50	Detected
31k+310~31k+390	Fracture zone	80	Detected
31k+665~31k+700	Shear zone	35	Detected
31k+725~31k+750	Fault shear zone	25	Detected
31k+785~31k+830	Fault shear zone	45	Detected

the joint grown zone, fault zone, and fracture zone with groundwater. We can take a nice demonstration that match with the actual condition.

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