J. Ind. Geophys. Union (April 2013)
Vol.17, No.2, pp. 187-194

Geophysical investigations for solving seepage problems

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ABSTRACT
In many seepage problems, the streaming potential resulting from active water flow through hydraulic conduits are readily detectable by self potential method and hence this geophysical technique is commonly used to investigate dam seepages. However in the absence of fluid flow through the conduits, other geophysical methods can be used to locate seepage pathways.

This paper discusses three studies of geophysical investigations at various project sites highlighting successful utilization of other geophysical methods to identify seepage zones so that suitable remedial measures could be adopted to ensure the stability of the structure.

INTRODUCTION

Seepage is a frequent but undesirable phenomenon that endangers the function and may unfavorably impact the natural environment. Therefore it needs to be monitored thoroughly and in case where the seepage exceeds acceptable limits, appropriate preventive measures need to be undertaken. Excessive or unplanned seepage through Dam, Reservoir and Canal not only create serious problems in loss of water but also threaten the competency and integrity of the structures. These phenomena of seepage generally occur through joint/cracks, fractures or porous formation. Identification of such formation below ground surface is impractical by direct / conventional method of drilling, may be due to the size of sampling area and high cost. Hence, geophysical investigations are necessary to delineate the potential seepage zone.

Geophysical methods are non destructive methods oftenly used for the detection of cavities and voids, detection of water bearing aquifer for well development and determination of soil stratification. The use of these methods confers advantage as they are most effective, fast in collecting information about the subsurface at fraction of time and cost.

In many seepage problems, the streaming potential resulting from active water flow through hydraulic conduits are readily detectable by self potential method and hence this geophysical technique is commonly used to investigate dam seepages (Black & Corwin,1985,Payne & Corwin ,1999). However in the absence of fluid flow through the conduits, other geophysical methods such as electrical resistivity, gravity, magnetic and Ground penetrating Radar can be used to locate seepage pathways. This paper presents the studies of geophysical investigations at Borda (CWPRS Report,2000), Dharoi (CWPRS Report,1983) and Tungabhadra dams(CWPRS Reports, 2008) highlighting the successful utilization of other geophysical methods for solving seepage problems.

STUDY I

A 12.4 m high and 760 m long earthen dam was constructed during 1988 across a small stream, a tributary of Nirguda river near Borda village, Yeotmal District Maharashtra (Fig. 1) for increasing the irrigation potential of the area through Canal irrigation system. The implementation of this scheme was thought to be as one of the important relief measures for recurring drought condition in the area. The area mainly comprises of Rajura lime stone belt of the Vindhyan group. During the first impoundment of the reservoir in 1989, failure of reservoir competency was noticed by rapid depletion of water level in the reservoir without affecting the actual withdrawal. Hence, the geophysical investigations were sought to determine the causative factors for the water losses and to identify the zones affecting the reservoir competency.

Integrated geophysical investigation using electrical resistivity, gravity and magnetic techniques were used to delineate the presence of rock discontinuities, weak zones, cavities etc. in the sub surface (Fig 2). Electrical resistivity methods were used to determine general conductive or resistive nature of

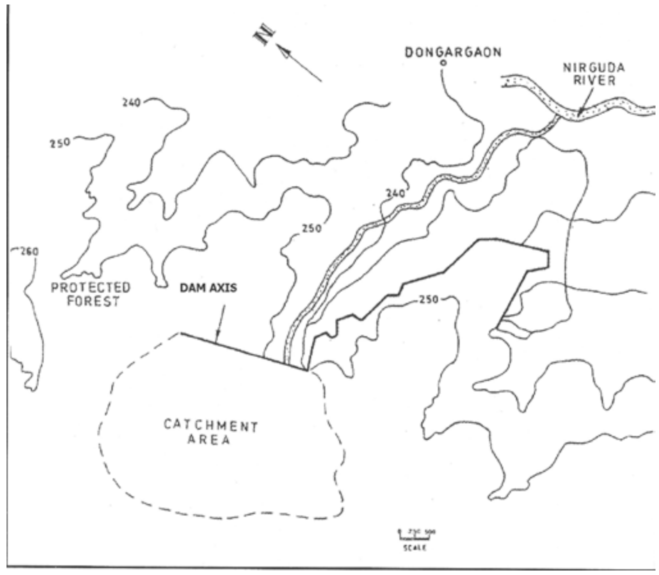


Figure 1. Location map of Borda Dam

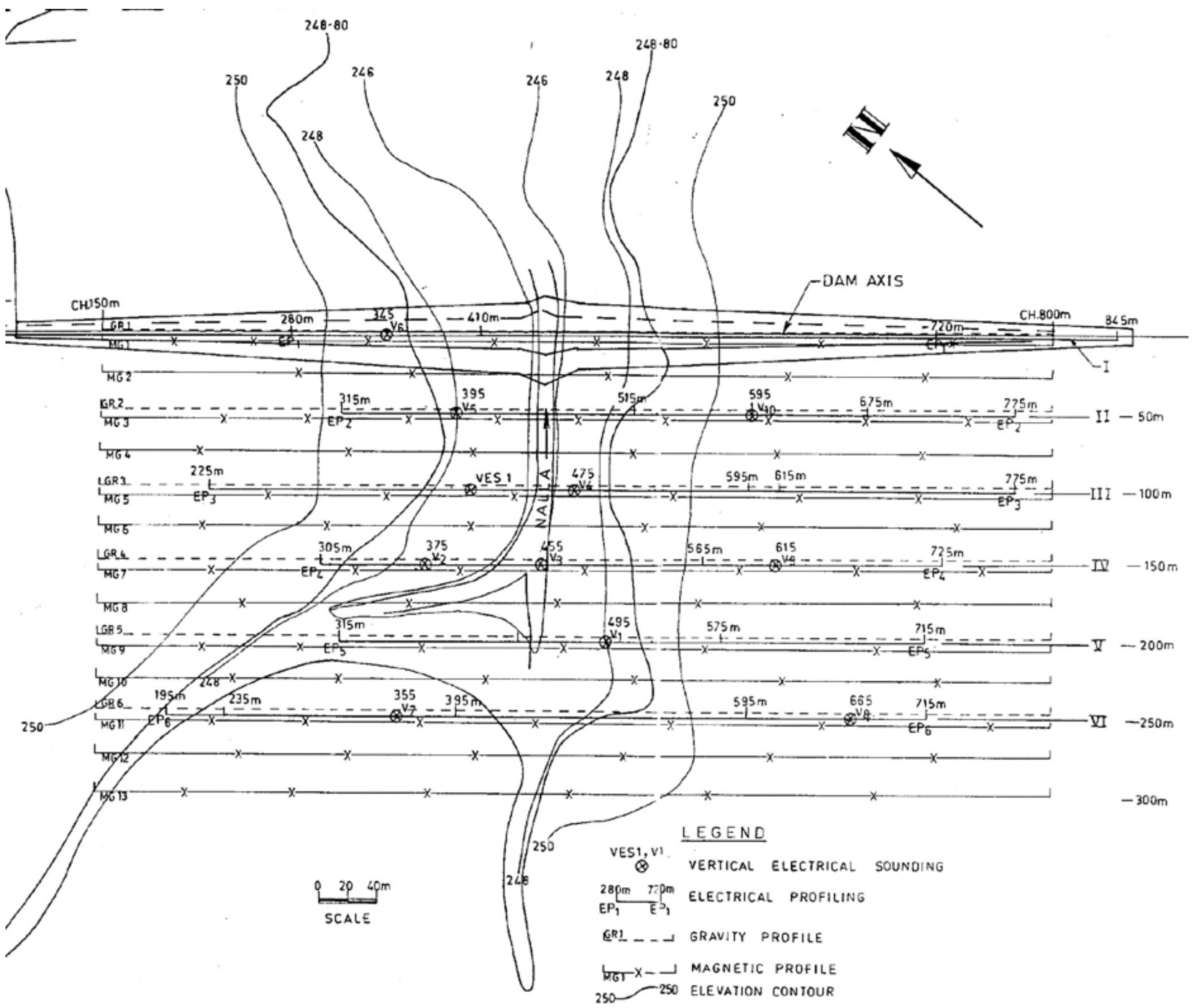


Figure 2. Map showing location of Electrical Resistivity, Gravity & Magnetic Survey

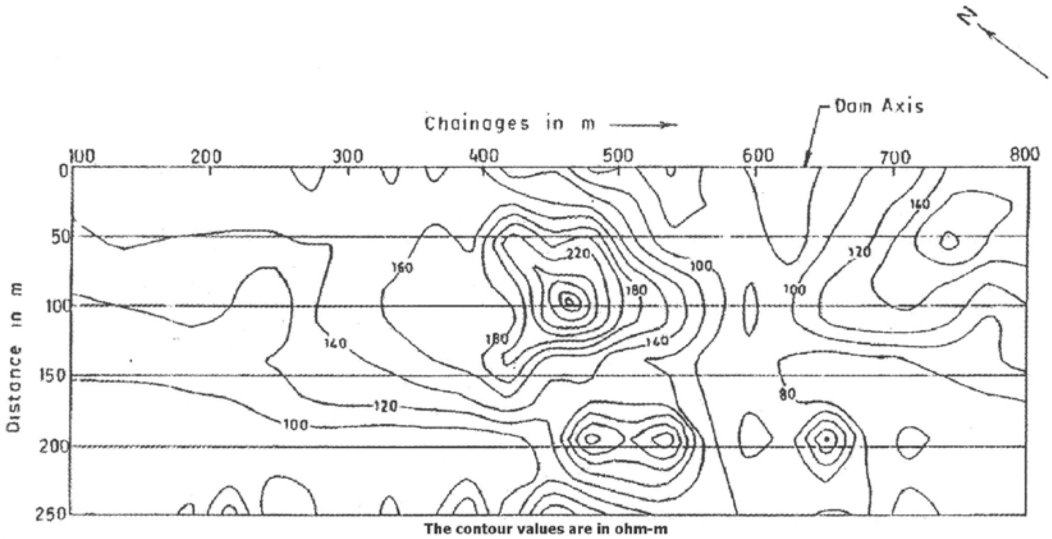


Figure 3. Map Showing Resistivity variation in Rock formation

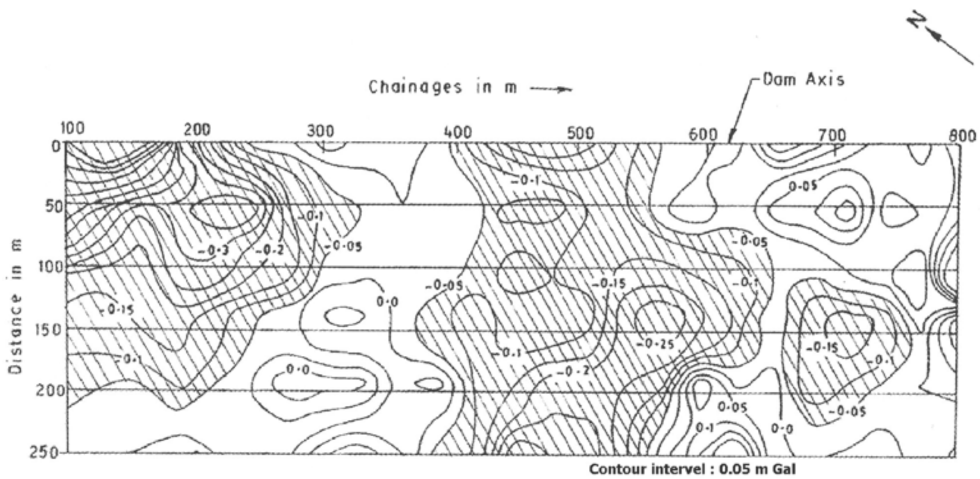


Figure 4. Results of Gravity Survey showing weak zones in the Rock formation

the formation and to identify the weathered / seepage zone in the area (Dobrin, 1976). Gravity techniques were applied to study the strength / compactness of the rock and to delineate the underground solution cavities/ sinkholes. Magnetic method was used to map clay filled cavities or pockets and fault/ fractured zones (Nettleton, 1976).

Total six electrical resistivity, six gravity, thirteen magnetic profiles and eleven vertical electrical soundings were taken on the upstream side of the Dam. The result of electrical resistivity profiling survey indicates the non uniformity in the rock formation with depth because of the presence of voids (Fig 3). The result of gravity survey indicates weak / disturbed bedrock due to the presence of large number of small communicating voids (Fig 4). These results were also corroborated by electrical sounding results. Wherever the low gravity values are obtained, the sounding results show less resistivity in the bedrock. In the gravity high zone the bedrock resistivity is high. The result of magnetic survey did not reveal any significant anomaly in the area as there is no subsequent thick infilling of ferrugenous rich content of material in the cavities.

The zone identified by electrical resistivity sounding and gravity survey were considered as weak due to the presence of void. These zones may be responsible for the water losses in the reservoir area. Clay blanketing and grouting were suggested as a remedial measure for stopping these water losses.

STUDY II

The Dyke No.1 of Dharoi Dam, Gujarat (Fig.5) was constructed on a stream which was also bunded up earlier on the downstream of dyke known as old Babsar tank. Excessive seepage was noticed at the downstream toe of the dyke which continued even after the construction of the loading berm and partly grouting the foundation through the bottom of the cut off trench (COT) (which was excavated up to a depth of R.L. 173 m). It was feared that increasing seepage may pose problem to the dyke structure. A geophysical survey comprising seismic refraction and electrical resistivity sounding and profiling was carried out to delineate the zones that are prone to excessive seepage so that suitable remedial measures could be adopted to ensure the stability of the dyke. The area mainly comprises of granite and granitic gneiss with intercalation of biotite schist covered with an overburden of dark brown soil .

Total three underwater and one land seismic profiles, four electrical resistivity soundings and two electrical resistivity profiles were carried out on the downstream of dyke parallel to the axis (Fig.6). The result of seismic refraction survey revealed the presence of low velocity zones below the bed level of COT (Fig.7). These zones were also identified by electrical resistivity results. These zones appear to be continuous from the downstream toe of the dyke to the Babsar tank. It was inferred that these weak zones in the bedrock may be responsible for the observed seepage. Grouting in the bedrock foundation was suggested as a remedial measures for stopping the seepage.

STUDY III

Tungabhadra Project (Fig 8) is a multi purpose reservoir project located at Munirabad, about 5 Km from Hospet, Karnataka State. The project is regulating water supply for irrigation through Left Branch Canal (LBC) to Karnataka State. The average height of the branch canal is 3.65 m and the bed width is 9.76 m. The water column in the canal during peak flow period is about 2.76 m. The high embankment portion is lined with 10 cm thick cement concrete. The right and left banks of the branch are designed for canal service and inspection roadways respectively.

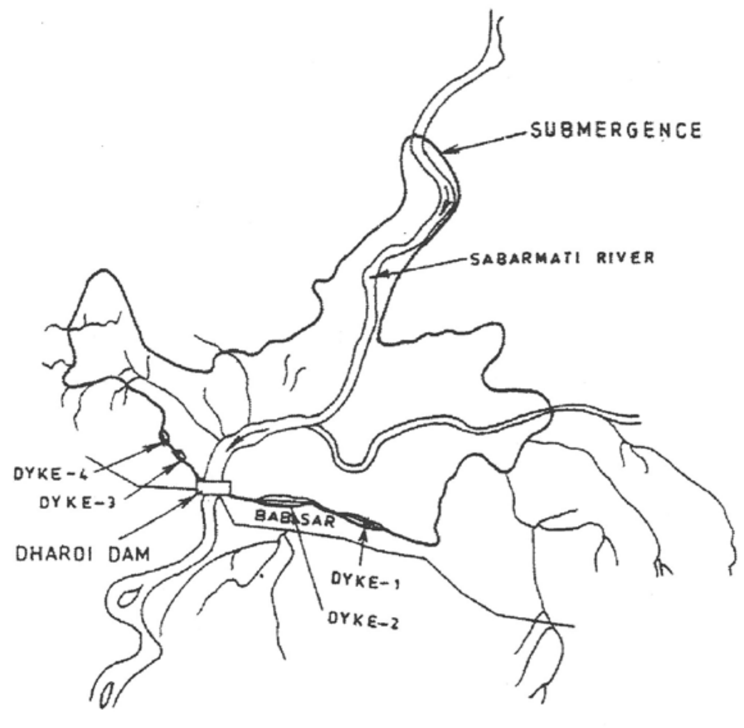


Figure 5. Location map of Dharoi Dam and Dyke no.1

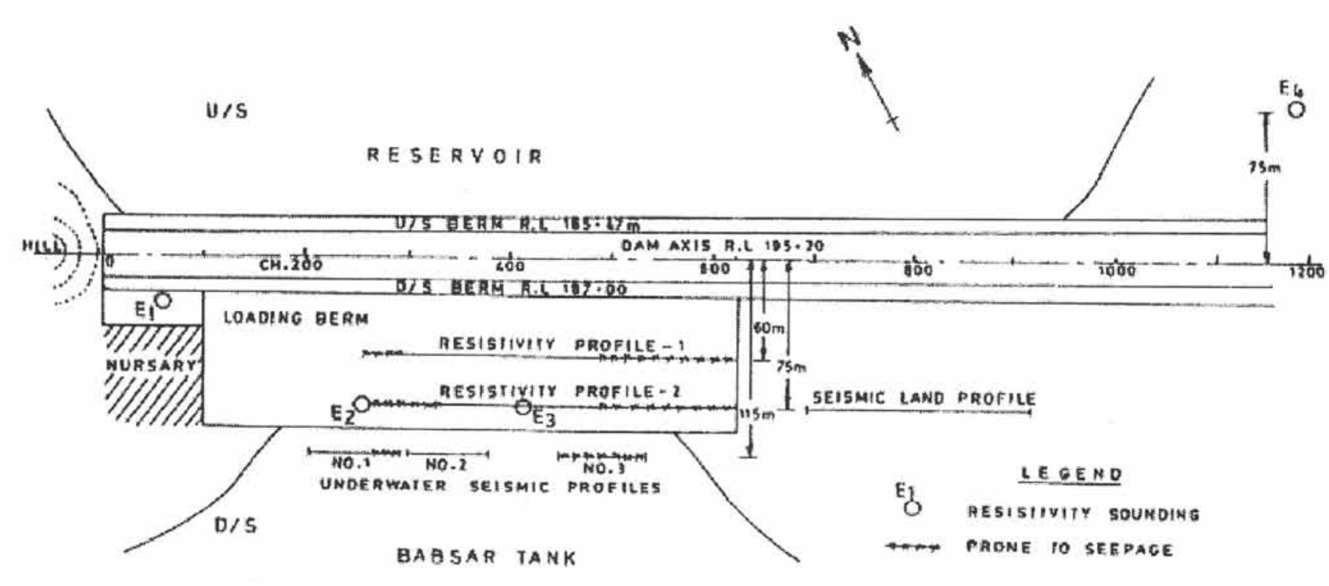


Figure 6. Plan showing location of Seismic, Electrical Profiles & Sounding

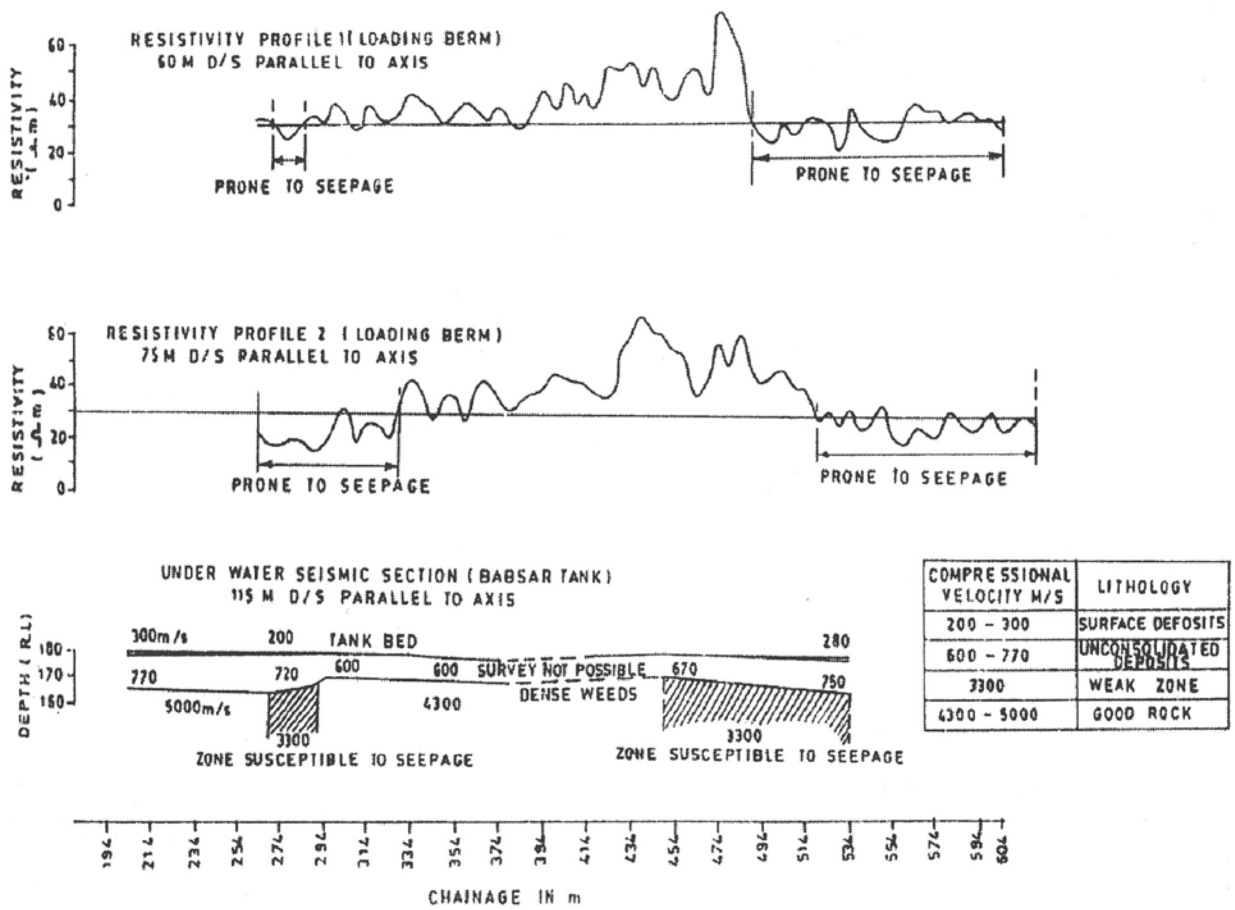


Figure 7. Results of Seismic & Electrical Profiles

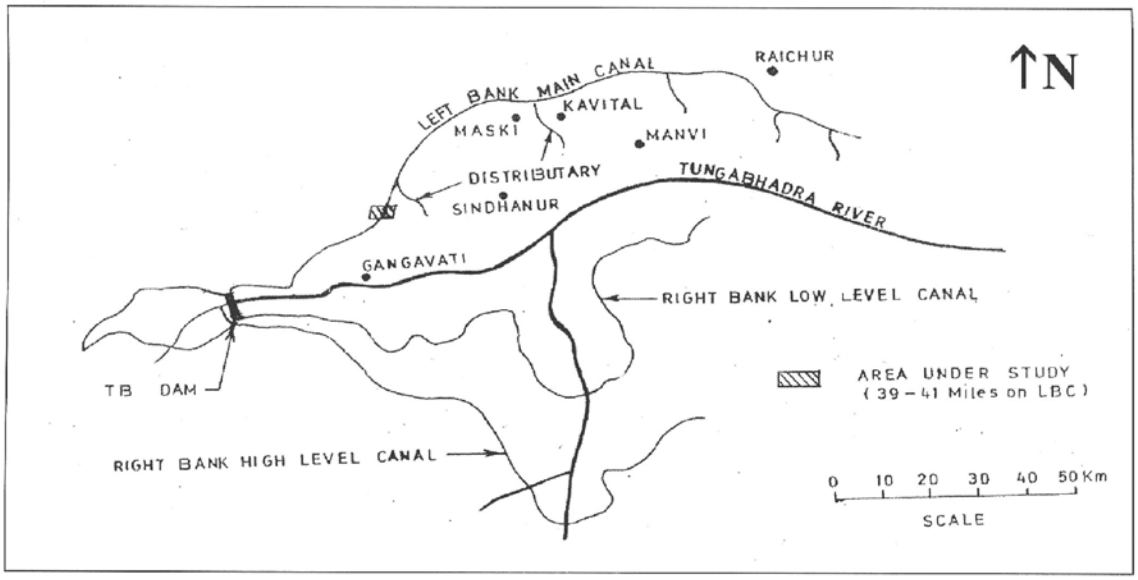
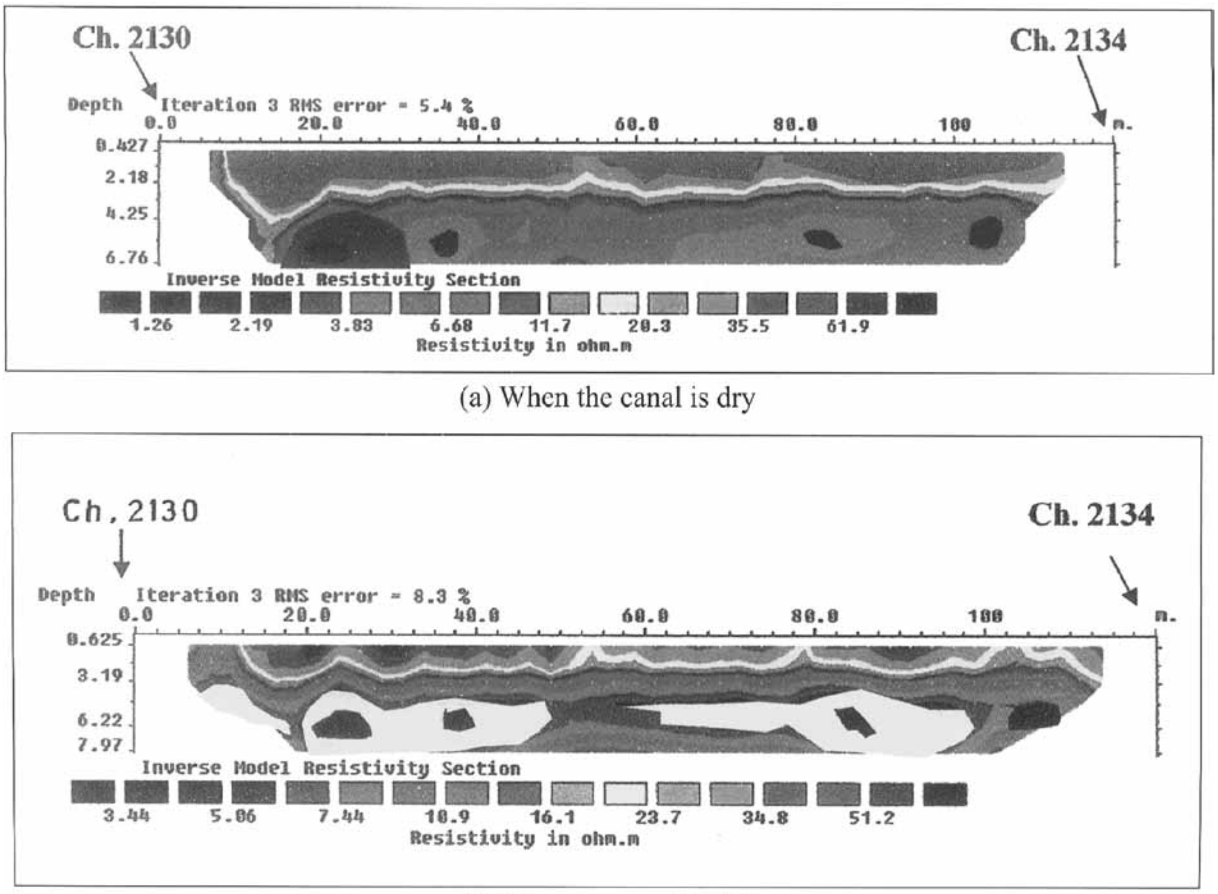


Figure 8. Location map of Tungabhadra Dam Command Area



(a) When the canal is dry

(b) When the canal is full

Figure 9. Electrical Resistivity Images in Canal dry & flow conditions

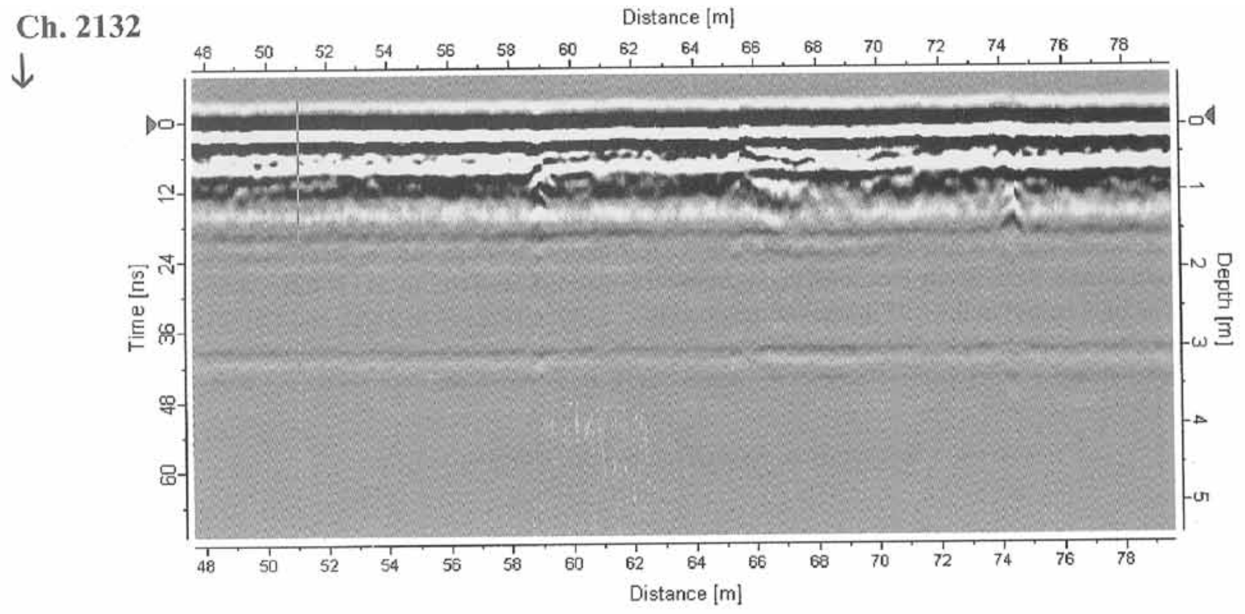


Figure 10. Typical Radargram of GPR on concrete slope

Though the main purpose of the banks was to withstand full pressure of water above the ground level, still in some high embankment reaches canal breach took place when canal was in filling. The reach between miles 39 to 41 is one of such vulnerable zone of the LBC, where there was a continuous water seepage in spite of repairs. Engineers of Tungabhadra Dam were of the opinion that the presence of cavities was responsible for these seepages. Therefore, geophysical investigations were suggested to delineate the concealed cavities, if any.

Accordingly, the investigations were carried out by employing three methods viz. Electrical Resistivity Profiling (ERP), Electrical Resistivity Imaging (ERI) and Ground Penetrating Radar (GPR) methods. ERP and ERI methods were applied both in dry and water filled conditions of the canal and on the flat top of the embankment. On the other hand GPR was applied on the canal concrete slope and only in dry condition of the canal.

The result of electrical resistivity profiling shows high resistivity i.e. greater than 50 Ohm m for cavities in the canal dry condition and a low resistivity value of less than 5 Ohm m in water filled condition. The red colour in the ERI images corresponds to high resistivity zone of cavities in dry condition and blue colour for low resistivity in saturated condition in the same area (Fig 9).

The anomalies in the GPR observations were attributed to the disturbance in the concrete lining (Fig 10). In view of this, the results were interpreted and concealed cavities present in the weak zone were identified all along the 39 to 41mile stretch. It was suggested to strengthen these weak zones so as to protect them from breaching and thereby ensuring the canal stability.

CONCLUSIONS

The various studies demonstrated the usefulness of geophysical methods for delineating the potential zones responsible for the seepage at dam sites. These geophysical investigations identified and confirmed the location of seepages in the area. The precise identification of these zones helped in adopting necessary remedial measures to protect them from failures and thereby ensuring the stability of the structure.

ACKNOWLEDGEMENT

Author is thankful to Dr.I.D.Gupta, Director, for according permission to publish this work.

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Manuscript received : June, 2012; accepted: Dec, 2012