Sustainable and Cost-Effective Subsurface Dams on River Beds: A Case Study in the River Basins of YSR District, Rayalaseema, A.P., India

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ABSTRACT

World present scenario needs a multitasking technology that provides safety to living beings, environment and cost effective. One such technology attracting interest of Engineering scientists is construction of subsurface dams. Arid and semi-arid regions in general and YSR district of Rayalaseema region of Andhra Pradesh, India in particular have seasonal rivers which flow during monsoons and get dried during the other seasons. The salient principle behind the subsurface dams is that the flood water is trapped within the voids between the sand particles. Hence location having more coarse grained sand is suitable for the construction of such dams across the sand rivers. Subsurface dams trap water in the sand upstream of the dam wall, built across a sandy dry riverbed to a height of 0.4 m below the surface of the sand because, the sand beds have evaporation losses until the water sinks below 0.4 m below the sand surface. The coarse grained sand store more water than the fine grained sand, as the coarse sand could produce upto 350 litres of water per cubic meter space resulting an extraction rate of 35% of the total volume of the sand.In the present study dry river beds of Papaghni river near Gandi village, Penneru river near Siddavatam village and Cheyyeru river course between Rayachoti-Rajampeta villages were mapped to locate suitable location for the subsurface dams. These rivers contain dry river beds in all seasons and hence called sand rivers. Subsurface dams build in these sand rivers are most reliable and low cost.

Keywords: *Sub-surface dams, voids, coarse grain, flood water, seasonal river.*

I. INTRODUCTION

Subsurface dams are the structures that are built to obstruct the natural flow of groundwater through riverbed during rain and provide storage of water. They are practically suitable for water storage in arid and semi-arid regions, to rise groundwater levels, to minimise evaporation losses and to fight against desertification (Tsumuro, 1999; Prinz and Singh, 2000). Subsurface dams trap water in the sand upstream of the dam wall, built across a sandy dry riverbed to a height of 0.4 m below the surface of the sand (Fig.1) because, the sand beds have evaporation losses until the water sinks 0.4m below the sand surface (Yaanaka, T., et al 1994). An indispensable principle explaining the water storage in dry river beds is that the voids between sand particles will be filled with water during seasonal floods and it is pulled downstream by gravity when the river bed is dry (Fig.2). Coarse grained sand store more water than the fine grained sand, as the coarse sand could produce upto 350 litres of water per cubic meter space with an extraction rate of 35% of the total volume of the sand. The water trapped between the sand particles during seasonal floods can be retained with the construction of subsurface dam. The other important requirement of subsurface dams is narrow and high embankments with subsurface valley. The subsurface dams have been used in several parts of the world notably in arid and semi-arid regions where the flows of water in the rivers vary considerably during the year, from very high flow following rain to negligible flows during dry season. Suitable area to build subsurface dams must has narrowest point in the river coarse with low permeable basement rock, free of boulders, fractures and the sand in the river bed must be coarse grained. Dry river beds of Papaghni river near Gandi village of Vempalli, Penneru river near Siddavatam village and Cheyyeru river bed between Rajampeta and Rayachoti are few ideal places suitable for construction of subsurface dams in YSR district. Subsurface dams have many advantages. Soil erosion can be minimised. Since the water is stored within the sand water evaporation can be minimised. Siltation will not occur since there is no retaining structure over the sand surface. This kind of storage of water improves ground water levels in the vicinity. The subsurface dams built of impervious material like clay etc., it has proven less expensive than the construction of surface dams. This kind of structures minimise the floods and let flood water pass to the people living downstream. They do not require any maintenance.

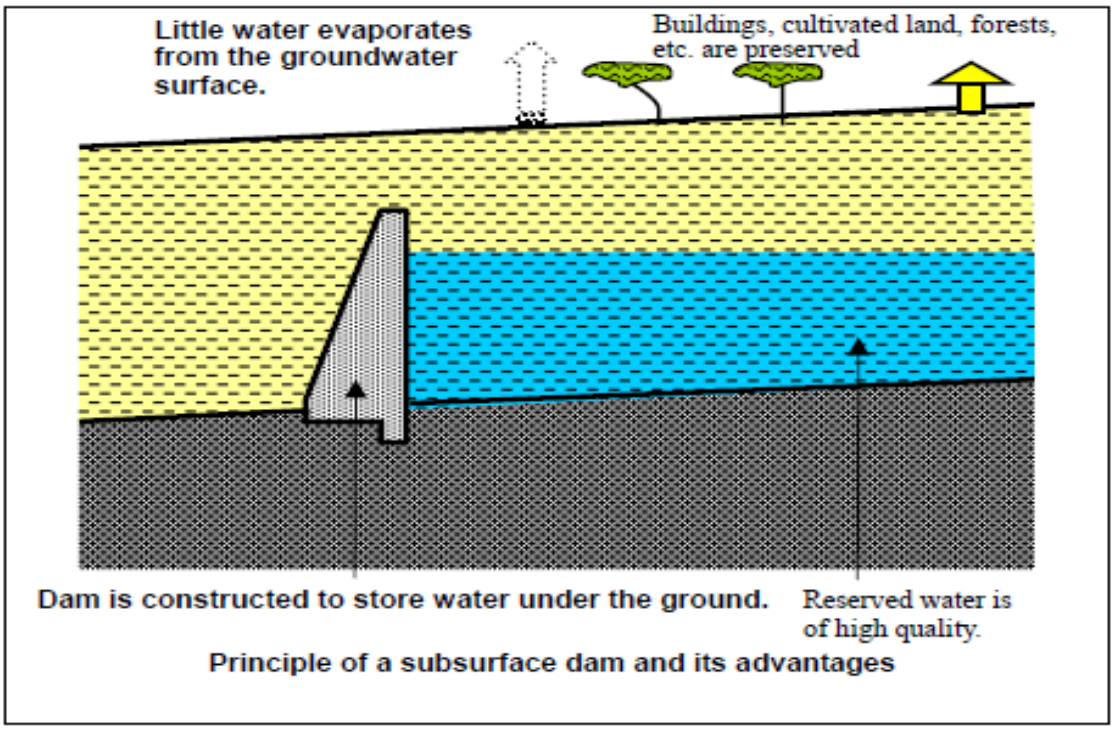

Fig.1 Principle of a Subsurface dam

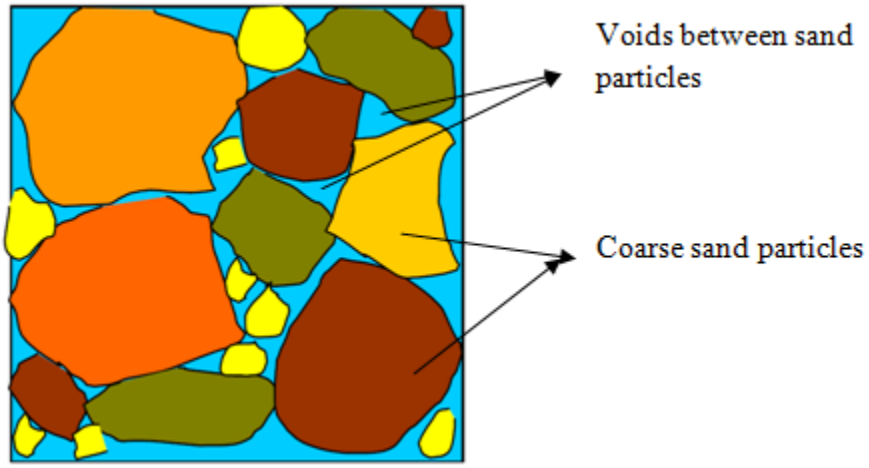

Fig.2 Principle of water storage in sand particles

II. RESULTS AND DISCUSSION

Considerable site for construction of subsurface dams are those where the riverbed consists of sand and gravel with an impermeable layer a few meters depth. The optimum zone for constructing a subsurface dam will be on gentle slopes in the transition zone between hills and plains. In general the gradient of the construction site should be between 0.2% to 4.0%, but slopes of 10% to 16% slopes can be considered in extreme cases (Nilsson, 1988). The reservoirs under sub surface dams are principally recharged by rainwater from flash floods in the catchment areas of higher elevation. A single and short lived flash flood may fully recharge the reservoir. Upon full saturation of the reservoir, the remaining flash floods will pass over the dam without further infiltration (Sans Frontieres, 2006). Three dry river beds taken for the present study which are seasonal and receives very less average rainfall of around 50-70cm per anum. They are mapped using satellite image and Geographical Information System software, analysed for selection of suitable area for the construction of Subsurface dams. Papaghni river flows through YSR District

for a length of 84.39Km before it meets the Pennar river. A dry river bed near Gandi village of Vempalli mandal has been taken for the study. Pennar river is the longest river flows in the district for a length of 178.55km. Dry river of Pennar river near Siddavatam village of Siddavatam mandal has been taken for the study. Cheyyer river is the other seasonal river flowing through the YSR district measuring a length of 87km before it meet the Pennar river. Dry river bed of Cheyyer river between Rajampet-Rayachoti near Balarasapalli village is taken for the present study.

Papaghni River bed near Gandi village

Papaghni river is one of the seasonal rivers flowing through YSR district, A.P., for a distance of 84.39 km before meeting the river Pennar near Kamalapuram village (Fig.3). The area falls in the SOI Toposheet No. 57j/7, between Latitude14° 22'N and Longitude 78°27'E.

Fig.3 Showing the Dry Papaghni river bed

The river basin receives an average of 60-80 cm rainfall annually and remains dry during other seasons. The dry sand bed of the river has been surveyed for the selection of suitable place to build subsurface dam. The river flowing through Gandi village is narrow down due to valley between two hills and hence with well defined high embankment and have a subsurface valley. An elevation map of the river bed has been prepared by using Google Earth satellite map and Geographical Information System software (Fig.4). From the elevation map a point has been selected between latitudes $14^0$33`N and $14^0$34`N and longitudes $78^0$47`E and $78^0$49`E. The subsurface dam in the selected area goes for a length of 193.92 m. The river bed in the selected region have 2% gradient. An alluvial gravel layer persists in the area. Mandals lying towards the upstream to the selected point for the subsurface dam are Veligallu, Garugupalle, Mukunda, Pandikunta, Talamudipi, Kuppam, Rajupalle, Chakrayapeta, Kumarakalva, Marellamadaka, Idupulapaya and all the villages coming under these mandals will be benefited by the construction of subsurface dam either directly or indirectly due to the recharge of the groundwater.

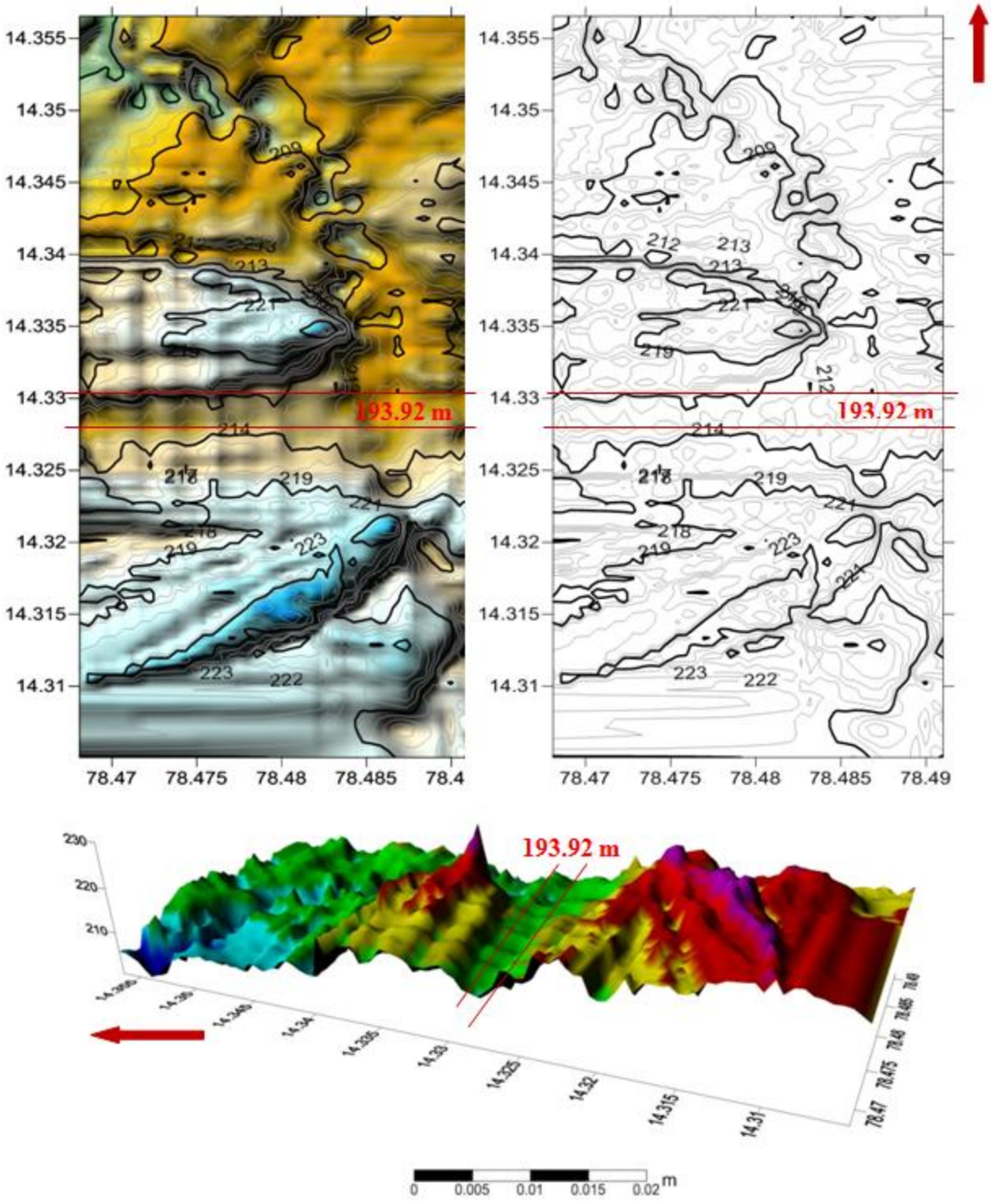

Fig.4 Elevation map with contours of dry Papaghni river bed near Gandi village

Pennar River bed near Siddavatam village

Pennar river flows through YSR district for a length of 178.55 km before it reaches Nellore district near Somasila. The Pennar river basin in YSR district receives an average rainfall of 60-70 cm per annum. A dry river bed of Pennar river course near Siddavatam village of YSR District is taken for the present study (Fig.5). The area falls within the latitude and longitude of 14.4667°N 78.9698°E. The area situated in SOI Toposheet No. 57j/15

Fig.5 Pennar dry river bed near Siddavatam village

The dry river bed in this area has high river banks covered on both sides by hills and with subsurface valley indicating suitability for the subsurface dams. The area is surveyed and mapped to select a suitable area for the construction of subsurface dam. An elevation map of the study area is prepared to from the Google Earth satellite image using Geographical Information System software (Fig.6). Location across the river bed is identified from the elevation map by selecting lower elevation point. The map shows that the area within the latitudes of $14^0465`N$-$14^0466`N$ and longitudes of $78^096`E$-$78^099`E$. The subsurface dam in the proposed area measures a length of 361.79m and showing slope of less than 4%. Villages like Gundalamulapalle, Jhothi, Machupalle, Siddavattam, Mulapalle lying towards the upstream of the proposed subsurface dam will be benefited by the construction.

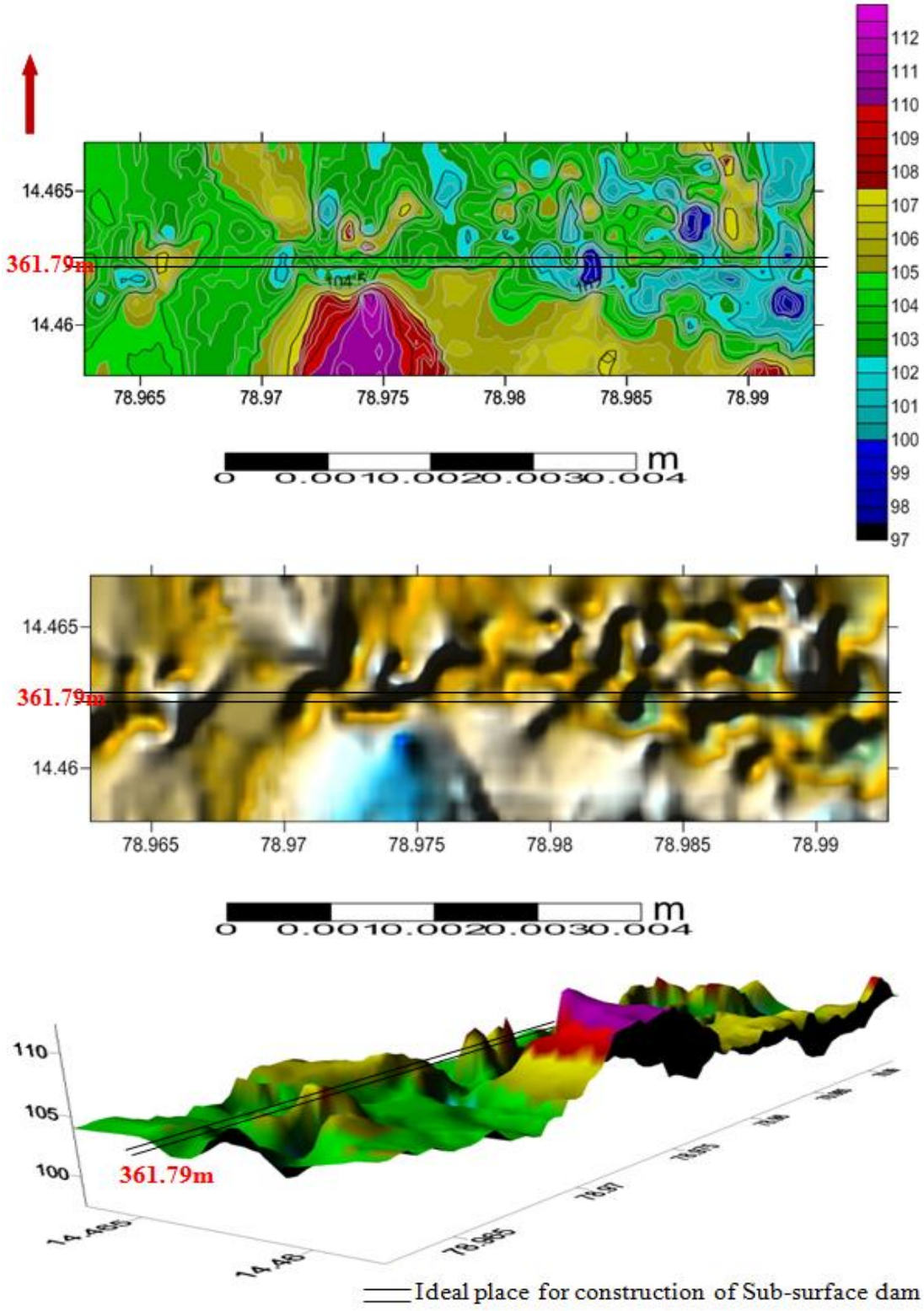

Fig.6 Elevation map with contours of dry Pennar river bed near Siddavatam village

Cheyyeru river bed between Rajampet-Rayachoti (Balarasapalli)

The dry Cheyyeru river bed running between Rajampet-Rayachoti near Balarasapalli village lies between latitude and longitude of $14^0$12`N; $79^0$01`E (Fig.7). The area fall within the SOI Toposeet No. 57n/4. It receives a average rainfall of 50-70cm per anum.

Fig.7 Dry Cheyyeru river bed between Rajampeta-Rayachoti (Balasarapalli)

The river banks of the Cheyyeru river in this area are well defined and covered in two sides by hill ranges. A subsurface valley exhibits suitability for the construction of subsurface dam. An elevation map of the area has been prepared using Google Earth satellite image and Geographical Information software (Fig.8). The map shows the low elevation areas suitable for the construction of subsurface dam. An area has been selected from the map lying between latitude of $14^0$32`N and $14^0$34`N and longitudes of $79^0$01`E to $79^0$02`E for a length of 331.92m. Brahmanapalli, Koilapuram, Kommurupothapi, Siriyavaram, Komaruniralla, Penagaluru, Tanguturu, Siddavaram, Singareddipalli, Obili, Nallatimmayapalli, Nagireddipalli, Adapuru, Narayananellore, Paturu, Kichamambapuram, Nandaluru, Gundluru, Paturu, Tallapaka, Pulapatturu, Mandapalle, Seshamambapuram villages around Rajampet are more benefited by the recharge of underground water.

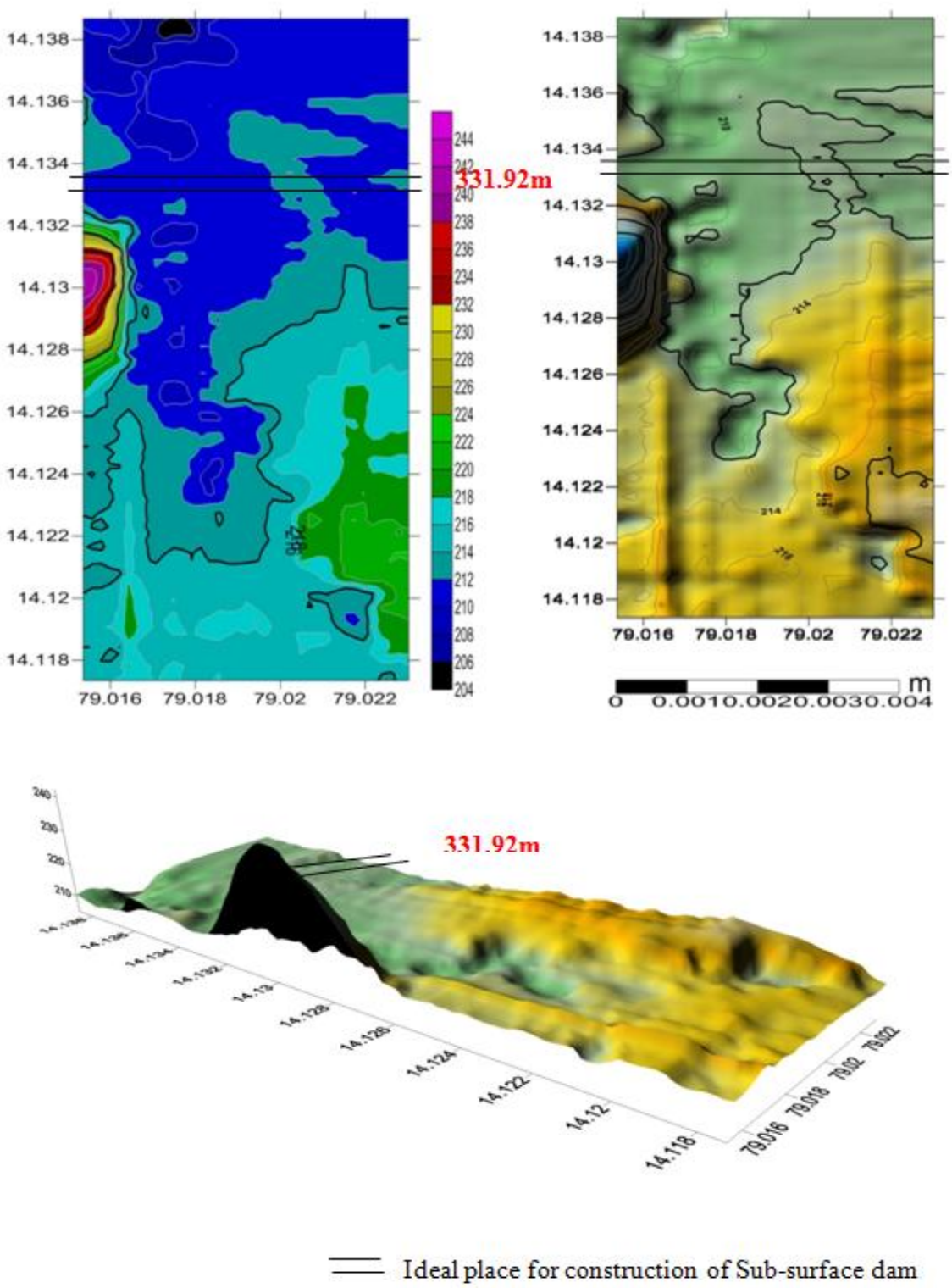

Fig.8 Elevation map with contours of dry Cheyyer river bed between Rajampeta-Rayachoti (Balarasapallivillage)

III. CONCLUSIONS

Major advantage of sub surface dams is that evaporation losses are highly minimised as the storage of water is underground. Intrusion of sea water is prevented. Problem of submergence of land, which is normally associated with surface dams is not present with the case of sub surface dams. There is no danger of dam breaching disasters and other environmental problems.

In the present study three dry river beds of Papaghni, Penneru and Cheyyeru are surveyed, mapped and analysed for the selection of site for building subsurface dams. All three river beds contain high river banks, subsurface valleys, impermeable quartzite bedrock basement with gradient of less than 4%, coarse grained beds and all are seasonal rivers having average rainfall around 50-70cm per anum. In the Papaghni river elevation map a point has been selected between latitudes $14^0$33`N and $14^0$34`N and longitudes $78^0$47`E and $78^0$49`E. The subsurface dam in the selected area goes for a length of 193.92 m. The river bed in the selected region have 2% gradient. An alluvial gravel layer persists in the area. Whereas in the Penneru river a point across the river bed is identified from the elevation map which is having lower elevation. The map shows that the area within the latitudes of $14^0$465`N-$14^0$466`N and longitudes of $78^0$96`E-$78^0$99`E is suitable site for the construction of subsurface dam. The length of the Subsurface dam in this point will be 361.79m. While the elevation map of Cheyyeru river bed shows the low elevation area suitable for the construction of subsurface, lying between latitude of $14^0$32`N and $14^0$34`N and longitudes of $79^0$01`E to $79^0$02`E for a length of 331.92m.

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