J. Ind. Geophys. Union (January 2011)
Vol.15, No.1, pp.1-8

Hydrogeomorphological Mapping at Village Level Using High Resolution Satellite Data and Impact Analysis of Check Dams in Part of Akuledu Vanka Watershed, Anantapur District, Andhra Pradesh

V.Raghu and K.Mruthyunjaya Reddy
A.P. State Remote Sensing Applications Centre (APSRAC)
8th Floor 'B' and 'C' Blocks, Swarnajayanthi Complex, Besides Maithrivanam, Ameerpet, Hyderabad – 500 038
E.mail: raghuvangeepuram@rediffmail.com

ABSTRACT
Anantapur District is a hot and arid District, falls in rain shadow zone with a very low annual rainfall of 520mm. The recurrence of drought increased considerably and unless collective measures are initiated on a permanent basis the situation will become grim in future. Akuledu Vanka watershed in Anantapur District is selected to demonstrate the capability of high resolution satellite data in ground water mapping at village level. This watershed is located in Survey of India toposheet Nos. 57F/5 and F/9. This watershed with an area of about 54 sq.km is underlined by hornblende-biotite gneiss and metabasalt traversed by dolerite dykes. Hydrogeomorphological mapping was carried out on 1:10,000 scale using IRS-P6 LISS-IV satellite data. The satellite data facilitates to update the extent of built-up area, road and drainage network. Further, the revenue villages enclosed in the watershed are digitized, mosaiced and superimposed on hydrogeomorphology map. This helps to give site specific recommendation on ground water prospects survey number wise i.e. for individual farmers. In addition, the impact analysis of check dams constructed in the watershed is also discussed. Studies showed that after construction of check dams the water levels in wells increased, abandoned wells got rejuvenated, new bore wells came up resulting increased irrigated area.

INTRODUCTION

The synoptic view provided by satellite remote sensing offers technologically the appropriate method for studying land and water resources, characterizing the coherent agricultural zones, and identifying the constraints/ecological problems at micro level. Effective use of space based remote sensing data suitably merged with collateral, socio-economic and meteorological data in GIS helps arriving at locale specific prescriptions to achieve sustainable development of natural resources of any drought affected region. Remote sensing data in conjunction with sufficient ground truth data provides information on geology, geomorphology, structural pattern and recharge conditions which ultimately define ground water regime.

Anantapur is a hot and arid District, falls in rain shadow zone with a very low annual rainfall of 520 mm which is second lowest in the country after Jaisalmer in Rajasthan (APSRAC 1997). Monsoon evades Anantapur District due to its location in the rain shadow region. South-West monsoon is prevented by the high altitudes of Western Ghats, making Anantapur District a rain shadow area and hence, agricultural conditions are more often precarious. Being far away from the East Coast, it does not also enjoy the rainfall benefit of the North-East monsoon. The recurrence of droughts increased considerably and unless collective measures are initiated on a permanent basis the situation will become grim in future. In order to demonstrate the capability of high resolution satellite data in ground water mapping at village level part of Akuledu Vanka watershed in Anantapur District is selected. The objective of the study is to demonstrate the capability of high resolution Indian Remote Sensing satellite data in ground water mapping with specific reference to find scientific and lasting solutions to mitigate recurring droughts at micro level. Further, the impact analysis of check dams were discussed to study augmented recharge of ground water which ultimately resulted in sustainable development of watershed.

STUDY AREA

The area of the Akuledu vanka watershed (Lat.14° 47′ 01" to 14° 47′ 29" N; Long. 77° 29′ 35" to 77° 37′ 30" E) is 54.06 sq.km included in Survey of India toposheet Nos. 57F/5 and 57F/9 of Anantapur District, Andhra Pradesh (Fig.1). The watershed encompasses part of eight villages namely Kotanka, Martadu (Garladinne mandal), Loluru, Akuledu (Singanamala mandal), Gotukur, Kammuru (Kudair mandal) Podaralla (Bukkarayasamudram mandal), and Taticherla (Anantapur mandal). About 75% of the watershed area is included in Garladinne mandal. A canal from Penna Ahobilam Balancing Reservoir (PABR) passes through the mandal providing irrigation to about 1100 ha in the watershed. The normal annual rainfall of Garladinne mandal is 568 mm and the cumulative departure from normal rainfall from 2000 to 2005 is -108% (CGWB 2007).

METHODOLOGY

High resolution Indian Remote Sensing satellite, IRS-P6 LISS-IV data of 11th April 2007 and 23rd January 2009 with a spatial resolution of 5.8m covering Akuledu vanka watershed is analyzed. Onscreen interpretation is carried out delineating different geomorphological units/landforms, lithological formations, geological structures and hydrogeomorphological map is prepared by integrating the above said parameters (NRSA 2008). Further, well inventory data collected during fieldwork is made use in finalizing hydrogeomorphological/ground water prospects map of the study area on 1:10,000 scale (Fig.2). By zooming the satellite data up to 1:4,000 scale, extent of built up area, drainage and road network is updated. Cadastral maps of the villages included in the watershed are digitized and mosaiced on 1: 10,000 scale. All the cadastral maps are rectified with IRS-P6 LISS-IV satellite data (Fig.3) as well as with hydrogeomorphology map. The cadastral layer is superimposed onto the hydrogeomorphological map to give locale-specific ground water locations for drilling.

STATUS OF GROUND WATER DEVELOPMENT

Majority of the area is underlain by hornblende-biotite gneiss and western periphery of the watershed is covered with metabasalt (GSI 2002). These lithological units are traversed by NW-SE trending dolerite dykes. Most of the lineaments are trending in NE-SW and NW-SE directions. The secondary porosity is of great significance in crystalline rocks. Ground water in these rock formations is being developed by means of dug wells, dug-cum-bore wells and bore wells. The

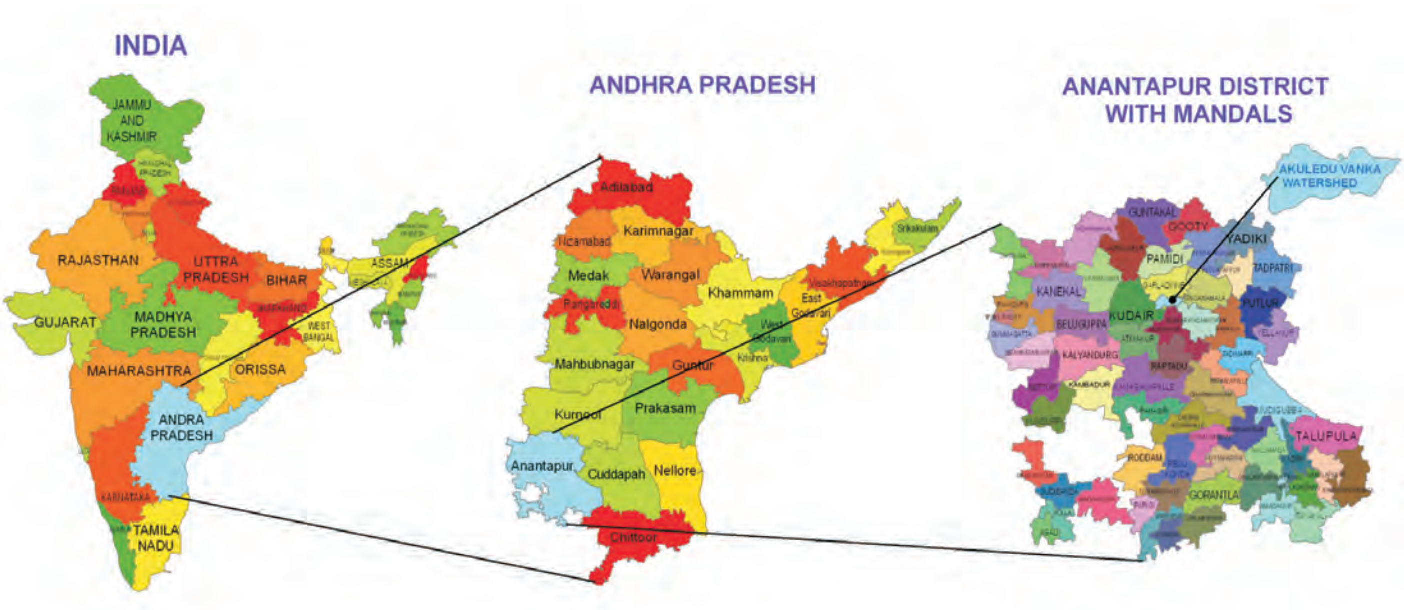

Figure 1. Location map

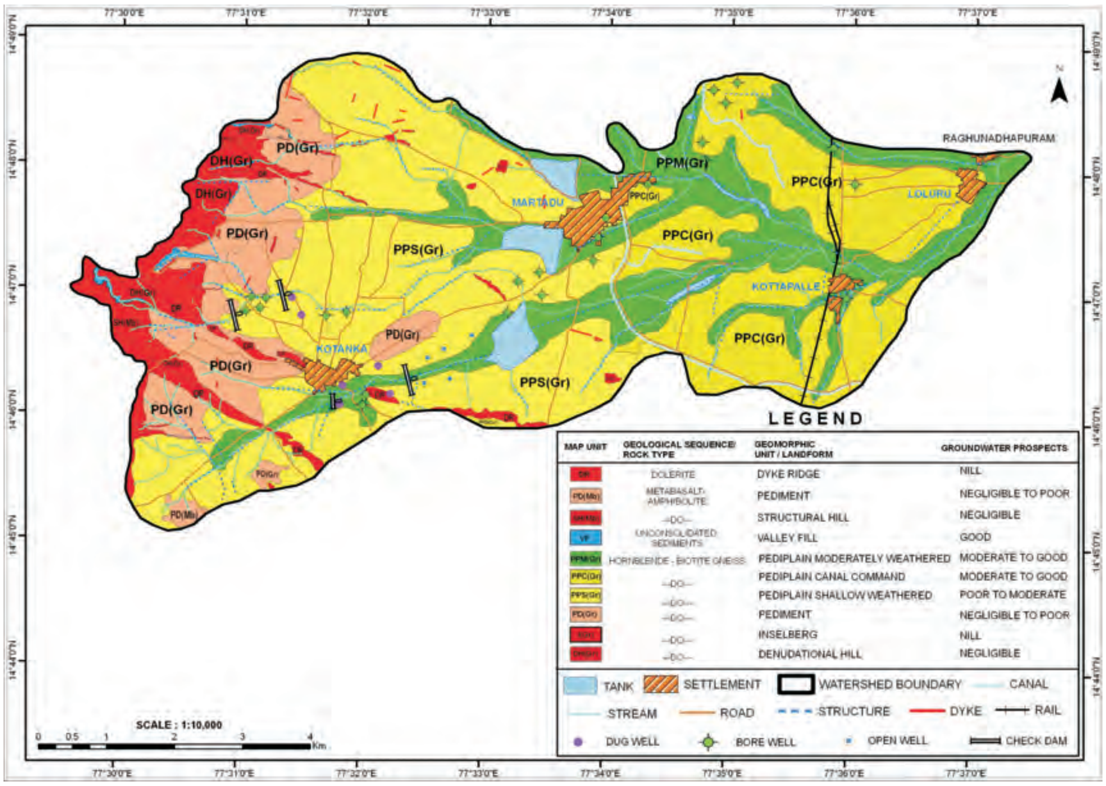

Figure 2. Groundwater prospects map of Akuledu Vanka Watershed, Anantapur District, A.P.

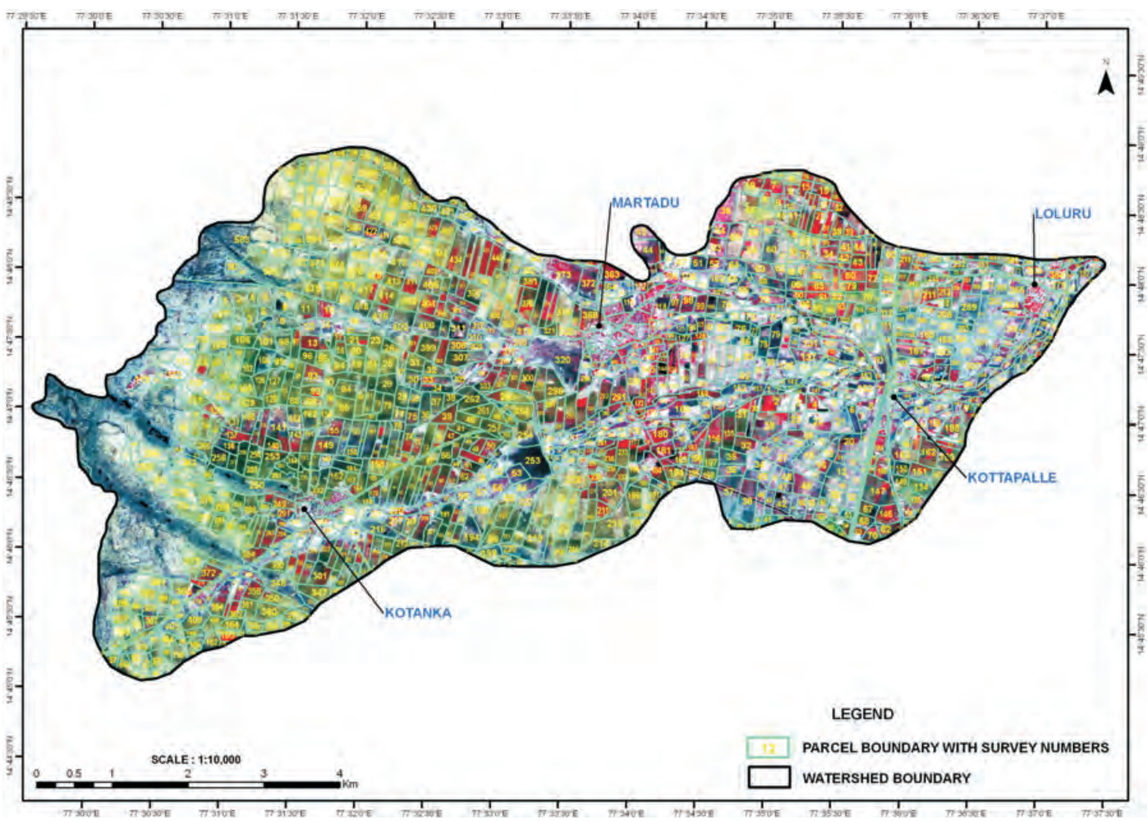

Figure 3. Satellite view (IRS-P6 LISS IV) of Akuledu Vanka Watershed with Cadastral boundaries, Anantapur District, A.P.

gradual decrease in rainfall and increase in ground water draft has resulted in depletion of ground water levels from the shallow depths resulted in forcing the farmers to go for deeper bore wells, tapping the static ground water resources which can otherwise be called as 'Ground water mining' from the non-replenishable resources. During the last few years the exploitation of ground water through bore wells increased enormously resulting in the decrease of ground water level drastically. There are 3977 wells in Garladinne mandal with a density of 13 wells per sq.km. against the district average of 7 wells per sq.km. (CGWB 2007). To improve the ground water levels construction of artificial recharge structures are essential to recharge the ground water in order to stabilize the ground water levels and sustain the yield of the wells.

HYDROGEOMORPHOLOGY

Aerial photographs and Landsat MSS data were widely used in India to study the landscape pattern and geomorphology during 1970s and 1980s in conjunction with Survey of India (SOI) toposheets. After the launch of IRS-1A satellite in 1988 and IRS- 1B in 1991, the availability of multi-date high resolution data and mapping on 1:50,000 scale became easier. The importance of hydrogeomorphological mapping to demarcate ground water potential areas was realised widely during early 1990s. The National Remote Sensing Centre (NRSC) carried out a nationwide hydrogeomorphological mapping on 1:2,50,000 scale using IRS data in conjunction with SOI topomaps during 1989 and 1993 under National Drinking Water Technology Mission project. This could be the major milestone in the use of remote sensing technology in targeting ground water potential sites in the drought affected districts in the country. With the technological breakthroughs, remote sensing opened new vistas in sensor technology and spatial resolution of satellite images have increased up to 1m in India. The availability of 5.8m multi-spectral IRS P6 LISS-IV satellite data enables the planners and resource managers to use them at micro level planning/ implementation especially in watershed development, village level planning etc.

Literature on thematic maps generated using high resolution satellite data is scarce and scanty. There are only few studies demonstrating the use of high resolution satellite data for ground water studies (Reddy, Vinod Kumar & Seshadri 1996; Mondal, Pandey & Garg 2008; Arindam Guha, Vinod Kumar & Lesslie 2009; Raghu & Venkata Swamy 2009). In the present study hydrogeomorphological mapping is carried out using IRS P6 LISS-IV satellite data. The landforms in the study area are broadly divided into three categories namely fluvial, denudational and structural landforms. As the depth of weathering and nature of soil cover plays a major role in the ground water prospecting, the pediplain is further sub-divided into pediplains with shallow and moderate weathering and thus ten geomorphic units are delineated. They are valley fill, dyke ridge, moderately and shallow weathered pediplains, pediplain under canal command, pediments, inselberg, denudational hill, structural hill. The description of each hydrogeomorphic unit occurring in this area is as follows.

Fluvial Landforms

Valley Fill (VF)

It constitutes unconsolidated sediments such as boulders, cobbles, pebbles, gravel, sand and silt deposited by streams/rivers normally in a narrow fluvial valley. It forms moderately productive shallow aquifers with very good ground water prospects. But, the ground water prospects vary depending upon the thickness of the fill material and its composition.

Denudational Landforms

Dyke Ridge (D)

It is a narrow linear ridge with heap of boulders of dolerite composition or steep massive ridge standing above the ground level or sometimes highly jointed. Negligible to poor yields are expected in this landform. Moderate yields are expected in the upstream direction.

Pediplain Moderately Weathered (PPM-Gr)

It is a generally flat and smooth surface of weathered pediplain of granite gneiss with more than 10m deep weathered material usually covered with red soil. In hard rocks, this landform forms very good recharge and storage zones depending upon the thickness of the weathering/ accumulated material and its composition. Moderate to good yields are expected in this geomorphic unit. Faults/ fracture zones passing through this unit act as conduits for movement and occurrence of ground water. Good yields are expected along fracture/lineament.

Pediplain Under Canal Command (PPC-Gr)

It is a gently sloping flat and smooth surface of weathered granite gneiss under canal command generally covered with red soil. Poor to moderate yields are expected in this unit. Moderate yields are expected along fracture/lineament and recharge due to canal. About 20% of the area is present under this category and is confined to eastern part of the watershed.

Pediplain Shallow Weathered (PPS-Gr)

It is a gently sloping flat and smooth surface of weathered granite gneiss with less than 10m of weathering generally covered with red soil. Poor to moderate yields are expected in this unit. Moderate yields are expected along fracture/lineament.

Pediment (PD-Gr)

It is a gently sloping smooth surface of erosional bedrock of granite gneiss between hill and plain with thin veneer of detritus. This unit forms runoff zones with limited prospects along favorable locales. In general, the ground water prospects in this landform are poor.

Inselberg (I-Gr)

It is a massive isolated hill of granite gneiss abruptly rising above surrounding plains. It forms run-off zone without any significant recharge potential and prospects.

Denudational Hill (DH-Gr)

It is a granitic hill formed due to differential erosion and weathering so that a more resistant formation stands and occupies a large area. The ground water prospects are negligible in this area as it acts as a runoff zone contributing very limited recharge to the narrow valleys within the hills and surrounding plains. Poor yields are expected along fracture/ lineament.

Pediment (PD-MB)

It is a gently sloping smooth surface of erosional bedrock of metabasalt between hill and plain with thin veneer of detritus. In general, the ground water prospects in this landform are poor.

Structural Landforms

Structural Hill (SH-MB)

These are linear to arcuate hills of metabasalt with narrow valleys showing definite trend lines. The ground water prospects are negligible. Moderate prospects are observed along valleys.

Impact Analysis of Check Dams

Several studies are carried out to examine the impact of check dams to augment ground water resources (Rao et al., 1993; Bhagavan & Raghu 1998; Bhagavan & Raghu 1999) and to dilute fluoride concentration in ground water (Rao et al., 1995, Rao & Tucker 1996; Bhagavan & Raghu 2005) in Anantapur District. As part of ground water investigations, the Ground Water Department, Govt. of A.P. carried out certain evaluation studies of check dams constructed by various government organizations in Anantapur District (GWD, 1998). The evaluation studies of check dams carried out by Ground Water Department, Govt. of A.P. located at four places in the watershed (Fig.4) are described.

A check dam was constructed on 3rd order stream by Panchayat Raj department, Govt. of A.P. in 1995, 0.3Km south of Kotanka village of Garladinne mandal. The storage capacity of check dam is 0.085 mcft. The area is covered with red loamy soils and thickness varies from 0.60 to 1.00 m. The rate of infiltration is medium. The depth of weathering of granite gneiss ranges from 8.0 to 12.0 m. The check dam is filled 4 to 5 times every year and duration of storage in the check dam is 10 to 20 days. There are 4 dug-cum-bore wells and 2 bore wells within the influence zone of the check dam. The influence zone extends 150 m transverse and 500 m downstream. Prior to the construction of the check dam, the wells used to irrigate 8.40 ha. and the ayacut increased to 13.80 ha after the construction of check dam. It is reported that prior to the check dam all dug wells are dried up in Rabi season. After the construction of check dam water column in dug wells ranges from 2.0 to 3.50 m in Rabi season also. The farmers expressed their satisfaction about the effect of the check dam in stabilizing the water levels in their wells and increasing the pumping hours by 3 to 4 hours (GWD 1998).

Another check dam is located 0.75 km north-west of Kotanka village. The check dam was constructed by Irrigation Department, Govt. of A.P. in 1995. The area

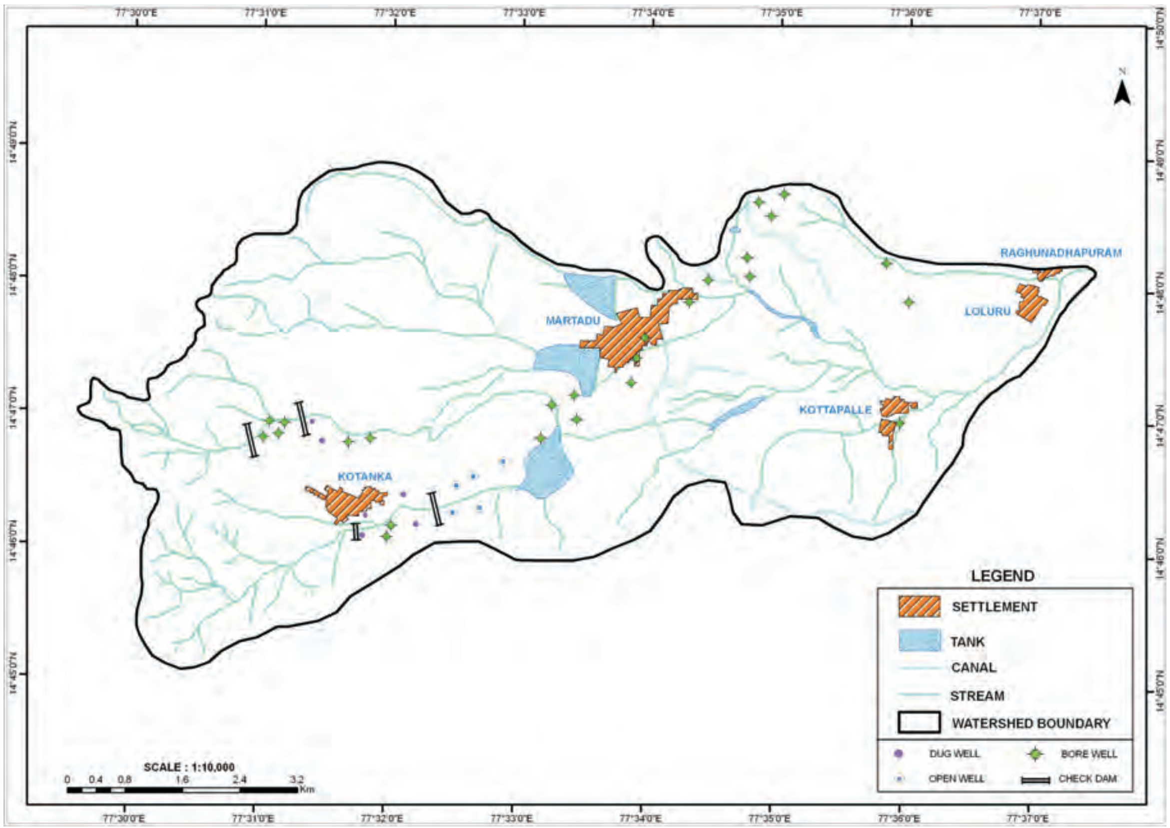

Figure 4. Drainage and Surface waterbodies map of Akuledu Vanka Watershed, Anantapur District, A.P.

is covered with red sandy soils of 0.45 to 0.75 m thickness with moderate rate of infiltration. The check dam was constructed on second order stream with a storage capacity of 0.05 mcft. The influence zone of check dam is 150 m transverse, 450 m downstream. The check dam is filled 4 to 6 times and duration of water retention in check dam ranges from 7 to 9 days. There are two dug-cum-bore wells and three bore wells within the influence zone of the check dam. The depth of dug well ranges from 12 to 18 m. The in-well bores were drilled from the bottom of the dug well to a depth ranges from 22 to 30 m. The depth of bore wells ranges from 60 to 75 m. Prior to construction of the check dam, the wells irrigate 6.50 ha and the ayacut is increased 10.20 ha after the construction. The dug-cum-bore wells and one bore well went dry and were abandoned prior to the construction of check dam. The construction of check dam helped to rejuvenate the wells within the influence zone (GWD 1998).

A check dam is located 1 km north-west of Kotanka village constructed in 1995 by Irrigation Department, Govt. of A.P. The area is underlain by weathered and fractured granite gneiss with depth of weathering ranging from 8 to 12 m. The area is covered with red sandy soils and thickness ranges from 0.40 to 0.80 m. The rate of infiltration is medium. The check dam was constructed on second order stream with a storage capacity is 0.075 mcft. There are four bore wells within the influence zone of check dam. The influence zone extends 100 m transverse and 300 m downstream. The depth of bore well ranges from 60 to 75 m. The check dam is filled 4 to 5 times in a year and duration of storage in the check dam ranges from 8 to 10 days. Prior to the construction of the check dam, the area irrigated is 8.90 ha only and the ayacut is increased to 11.40 ha after the construction. After construction of check dam the cultivated land increased is 2.5 ha. The farmers reported that the check dams are very much helpful in recharging the wells.

A check dam was constructed by Irrigation Department, Govt. of A.P. in 1993. The check dam is located 0.50 km south-east of Kotanka village. The area is covered with red sandy and red loamy soils. The thickness of soils varies from 0.50 to 0.80 m. The rate of infiltration is moderate. The depth of weathering of granite gneiss ranges from 8.0 to 13.0 m. The storage capacity of check dam is 0.02 mcft. The check dam is filled 2 to 3 times every year and the water in the check dam retains 15 to 20 days. There are five wells within the influence zone of the check dam. The influence zone extends 180 m transverse and 600 m downstream. Prior to construction, all the wells are dried up and the area is irrigated under rainfed condition. After construction of check dam the area irrigated under the wells is 9 ha during Kharif and 10 ha during Rabi seasons. The construction of check dam combined with good rainfall helped to rejuvenate the wells within the influence zone.

CONCLUSIONS

The Indian Remote Sensing satellite (IRS P6 LISS-IV) data with a spatial resolution of 5.8m can be enlarged even up to 1:4,000 scale. With the help of high resolution data, expansion of rural settlements, drainage and road network is updated. The boundaries of all geomorphic units are drawn more precisely. With the advent of high resolution satellite data, site-specific recommendations for ground water exploration can be given at cadastral level for effective management of ground water resources at smallest possible revenue boundary i.e. in the individual fields of the farmers. The effect of check dams resulted in stabilizing the water levels in the wells, increasing the pumping hours, rejuvenating the abandoned wells, and resulting increase in irrigated area.

ACKNOWLEDGEMENTS

The authors thank the Deputy Director, Ground Water Department, Anantapur for providing the details of field investigations. Grateful thanks are also due to the reviewer for his excellent suggestions in improving the quality of the manuscript.

REFERENCES

APSRAC (A.P. State Remote Sensing Applications Centre) 1997. Integrated Study to Combat Drought, Anantapur District, Andhra Pradesh, Project Report, 102p.

Arindam Guha, Vinod Kumar,K. & Lesslie, A., 2009. Satellite based geomorphological mapping for urban planning and development- a case study for Korba city, Chhattisgarh, Current Science, 97 (12), 1760-1765.

Bhagavan, S.V.B.K. & Raghu, V., 1998. Implementation of remote sensing based action plan and impact analysis of check dams – A case study of Somagatta watershed, Anantapur District, Andhra Pradesh. Workshop on Watershed Management – Problems and Prospects, Jawaharlal Nehru Technological University, Hyderabad, 34-41.

Bhagavan, S.V.B.K & Raghu, V., 1999. Integrated remote sensing based watershed management programme in Anantapur District, A.P. – Glimpses of successful achievements. In: Proceedings of ISRS National Symposium on Remote Sensing Applications for Natural Resources: Retrospective and Perspective, Bangalore, 305-314.

Bhagavan, S.V.B.K. & Raghu, V., 2005. Utility of check dams in dilution of fluoride concentration in ground water and the resultant analysis of blood serum and urine of villagers, Anantapur District, Andhra Pradesh, India. Environmental Geochemistry and Health. 27, 97-108.

CGWB (Central Ground Water Board) 2007. Ground water information, Anantapur District, Andhra Pradesh, 34p.

GSI, (Geological Survey of India) 2002. District Resource Map, Anantapur District, Andhra Pradesh.

GWD (Ground Water Department, Govt. of A.P.) 1998. Note on evaluation studies carried out on water harvesting structures in Anantapur District, Technical report, 35p.

Mondal S. Md., Pandey, A.C. & Garg, R.D., 2008. Groundwater prospects evaluation based on hydrogeomorphological mapping using high resolution satellite images; A case study in Uttarakhand. Journal of Indian Society of Remote Sensing, 36 (1), 69-76.

NRSA (National Remote Sensing Agency) 2008. Ground Water Prospects Mapping Using Remote Sensing and Geographic Information System, Rajiv Gandhi National Drinking Water Mission Project, Manual, 256p.

Raghu,V. & Venkata Swamy, M., 2009. Remote sensing in ground water exploration for development of temple tourism in Vemulawada, Karimnagar District, Andhra Pradesh. J. Ind. Geophys. Union, 13 (4), 183-190.

Rao,R.S., Venkata Swamy, M., Mastan Rao,C. & Ramakrishna, G.V.A., 1993. Identification of overdeveloped zones of ground water and location of rain water harvesting structures using an integrated remote sensing based approach – A case study in part of Anantapur District, Andhra Pradesh, India. Intl.J. of Remote Sensing, 14 (17), 3231-3237.

Rao, R.S., Venkata Swamy, M., Rama Krishna, G.V.A. & Mastan Rao, C., 1995. Role of remote sensing in integrated fluorosis control programme in Anantapur district, Andhra Pradesh, India, pp.309-314. In: Proceedings of the International Conference on Remote Sensing and Geographical Information Systems for Environmental Planning (Ed.

I.V.Muralikrishna). Tata-McGraw-Hill Publishing Company, New Delhi, 765p.

Rao, R.S. & Tucker, S.P. 1996. Integrated remote sensing based approach to identify low fluoride drinking water sources – A case study of Nalgonda and Anantapur districts of Andhra Pradesh, India. In: National Workshop on Application of Remote Sensing and GIS Techniques to Integrated Rural Development. SIII.15 – SIII.38.

Reddy,P.R., Vinod Kumar,K. & Seshadri, K., 1996. Use of IRS-1C data in groundwater studies, Current Science, 70 (7), 600-605.

(Revised accepted 2011 January 12; Received 2010 November 12)

Dr.V.Raghu completed his M.Sc., Ph.D. in Geology from Sri Venkateswara University, Tirupati, Andhra Pradesh. He joined in A.P. State Remote Sensing Applications Centre (APSRAC) in 1992. Presently, he is working at APSRAC as a Senior Scientific officer. He is actively involved in the exploration of ground water, mineral resources, watershed development and disaster management using remote sensing, GIS and GPS techniques. He has thirty publications in various journals of national and international repute.

Dr.K.Mruthyunjaya Reddy completed his B.Tech. (Civil Engineering) from Sri Venkateswara University, Tirupati and M.Tech. (Remote Sensing) and Ph.D. (Remote Sensing & GIS) from Andhra University, Visakhapatnam. He joined in National Remote Sensing Centre (NRSC), Hyderabad during 1992 as Sci. / Eng. 'SC' and worked as Technical Secretary to the Director, NRSC and played a key role in Programme Planning and Evaluation Group (PPEG). He also headed Disaster Watch Team and worked as a member Flood Disaster Management, Remote Sensing and GIS Application Group, NRSC. Subsequently, he joined as the Director in A.P. State Remote Sensing Applications Centre (APSRAC), Planning Department, Govt. of A.P. on deputation basis during October 2004. At present, he is holding the post of Director General at APSRAC. As the Director (Technical), A.P. State Disaster Mitigation Society (APSDMS) since 2006, mathematical models are developed under his guidance for prediction and forewarning of natural disasters. He is a custodian for a repository of satellite data, spatial data on natural resources and infrastructure and models generated both at APSRAC and APSDMS. He is a member of several apex scientific bodies in the country. He has more than 50 publications to his credit published in Journals of National and International repute.