PLANNING AND ESTIMATION OF WATER GRID IN SUB BASIN OF GUNDLAKAMMA RIVER, ANDHRA PRADESH, INDIA: A MODEL STUDY

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ABSTRACT

Water is an essential element for survival of human lives and other purposes. In current situation, every person needs purified water for survival of human beings, crop production, public uses and for activities of industries. It is helpful to the irrigation engineers who face problem in designing an efficient water grid system in countryside regions. Water grid helps us to make sure that supply of water to the users at a specified demand. The foremost objective of this paper is to study the watershed and groundwater conditions, land use and land cover and surface run – off which will greatly help in designing a water delivery system by using smart sensors and Information and Communication Technology (ICT) which reduces the drips and monitors the water quality. With the support of Arc GIS and EPANET software, watershed is delineated and run – off is estimated by using SCS curve number method and plan of water delivery system has been carried out.

Key words: Water Network, funding, enactment, EPANET, Arc GIS, SCS-CN, Run – off.


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1. INTRODUCTION

Water is a vital natural resource for survival of humanity, species, agricultural and industrial activity on earth and it’s also one of the most under listed but over abused commodity. Today most of the industries use water to produce products which in turn results in improvement of monetary growth in India. Scientific management of water resources is very essential in order to meet the growing needs of the future generation.

Usage of traditional irrigation techniques in India are causing water scarcity for irrigation. Water is getting depleted over the years due to increased activities of industries, increased land to be irrigated, increase in population and other environmental conditions like low rainfall and global warming. In India, as an effect of growth in population and socio economic development, the ultimatum for water is growing equally in urban and rural areas. In 1951, the per capita water accessibility was about 5177 m³ which is drastically reduced to 1545 m³ in 2011 in India as presented in Figure - 1. Absence of water competent administration and conveyance of water between purchaser's outcomes in incredible loss of water assets.

![Figure 1 Per capita water availability in India from 1951 - 2011](image)

Half of the population around the globe will face high scarcity of water and developing countries have more chances of water scarcity in future and almost 75% of the population will live in urban part of India by 2050 (Aditya Gupta et al, 2016). Seong won Lee, et al (2014) have proposed to integrate two platforms namely water grid and Information and Communication Technology (ICT) and they are hooked on a single water management scheme and are designed for supervision of bi-directional water and data flow in accordance with the consumer demand and supply distribution schemes in both incorporated and decentralized grids. Michele Mutchek and Eric Williams (2014) state that the present day urban water distribution systems face viability and resiliency issues due to increase in population, old designs and aging pipelines which in turn increases water leaks, quality issues. Use of ICT could help the challenges that are developed through the implementation of smart water grids that automates the devices with the inputs of real time hydraulic data. When acute shortage of water was faced in Gujarat in 2002, Gujarat state government has drawn the plan of providing water grid that connects 48 million people to overcome such shortage of water (Andrea Biswas, 2014). Government of Telangana State has proposed to build a massive water grid with the integration of smart systems to provide drinking water to all of the towns and villages in Telangana with an investment of Rs.42000 crores (Ramesh,2016).
2. RESEARCH SIGNIFICANCE

States like Andhra Pradesh, Telangana, Tamil Nadu and Maharashtra in India are witnessing the frequent failure of crops due to acute shortage of water for agriculture resulting debit trap of farmers in turn migration to urban areas in search of livelihood or suicides. Over 12,000 farmers committed suicide every year since 2013 due to failure of crops and debit traps. In the year 2015, Maharashtra topped the list with 4921 suicides followed by Karnataka with 1569, Telangana with 1400, Madhya Pradesh with 1290, Chattisgarh with 954, Andhra Pradesh with 916 and Tamil Nadu with 606. In order to address such critical social, agricultural and rural employment issues, it is necessary to evolve a comprehensive water network model for meeting the water requirements of growing population in water scarce areas.

3. DESCRIPTION OF STUDY AREA

The study area forms part of Gundlakamma river basin, covers an area of 1846 km² and falls in Survey of India topo sheets 57 M/2, 57 M/3, 57 M/6, 57 M/7, 57 I/14, 57 I/15. Geographically this area lies between the latitude 15°11´ - 15°48´N and longitude 78°42´ - 79°22´E and located in the eastern coastal plain of Indian sub-continent with an average elevation of about 91m above the sea level. The Gundlakamma River passes through the east central portion of prakasam district, Andhra Pradesh. The average annual rainfall of the study area is around 895mm and receives rainfall during south west as well as north east monsoon. The Cumbum Lake also known as Gundlakamma Lake, which irrigates about 11,000 acres of land in prakasam district. It is the major source for drinking purpose as well as for irrigation needs. The stream network of Gundlakamma sub basin is presented in Figure – 2.

![Figure 2 Stream network of Gundlakamma sub basin](image)

4. OBJECTIVES

- To study the watershed conditions, ground conditions, land use/land cover and understand the condition of water resources in selected sub basin.
- To study the requirement of water for various needs.
- To design and estimate water grid system for selected study area.
5. METHODOLOGY
The methodology adopted in the present investigations is given below:

- Collection of literature
- Collection of topo sheets, satellite images & DEM files
- Delineating watershed by using ARC GIS software
- Preparation of land use / land cover maps of selected area
- Estimating runoff and water requirements for various purposes
- Collection of ground water availability & surface water resources
- Study of existing/ongoing water grid systems
- Designing of water grid systems
- Cost estimation of proposed water grid
- Collection of data on various finance schemes of state & central government & world bank
- Suggesting appropriate finance patterns

Stream network of the study area is traced from the topo sheets of Survey of India (Nakshe). Digital Elevation Model (DEM) files were used in delineating the watershed and identifying various elevation points for study area. Satellite images have been used in creating land use/land cover map with the help of Arc GIS Software. Reports of water grid systems in various parts of world as well as in India are gathered and studied to understand how well these structures are applicable to the selected area.

5.1. Data Collection
Topo sheets are gathered from Survey of India (Nakshe). DEM files are gathered from the United States Geological Survey (LISS III DEM) and Bhuvan National Remote Sensing Centre (NRSC). Data related to ground water, rainfall and crop water requirements have been collected from Sate Ground Water department, Indian Meteorological department, Hyderabad and Horticulture Department of Government of Andhra Pradesh respectively. Data regarding plans of Bhagiratha Mission undertaken by Telangana state government, Gujarat water grid and Satya Sai Baba water supply project in Anantapur district of Andhra Pradesh have been collected.

5.2. Data Analysis
5.2.1. Water Shed Delineation
First the fill tool is used to seal the imperfections in the digital elevation model. At that point, the stream flow and flow accumulation tools are utilized to decide the course of the stream and assembled water. A shapefile was made to store the pour point and afterwards by utilizing snap pour point to guarantee that point is situated on the higher upstream. Finally, the stream course network was chosen as info raster and pour point as direct information towards getting the yield raster.
5.2.2. Land Use/Land Cover (LU/LC) Map
First, the satellite image is geo referenced and to classify the features, training sample manager is used in classification toolbar. Samples are created and stored as signature file in GIS Database. Output raster is arrived by using maximum likelihood classification with the inputs of input raster and signature file.

5.2.3. Runoff Estimation by using SCS – CN Method
Soil Conservation Service (SCS) method of United States Department of Agriculture (USDA) is adopted to estimate the run-off for chosen sub basin. The equation for the SCS Curve number is as follows:

\[
Q = \frac{(P-I_a)^2}{(P-I_a)+S} 
\]  

(1)

Where Q is the runoff in mm, P is average rainfall in mm, I_a is the initial abstraction in mm, and S is the potential maximum retention. To obtain potential maximum retention, the Curve Number (CN) has been taken from SCS National Engineering Handbook, Section 4, 1972. The parameter CN has a range of values between 0 to 100. The curve number is assigned to each portion of watershed according to soil group, land use/land cover features and antecedent moisture conditions.

5.2.4. Determination of Water requirements
Requirement of water per person is 135 lpd as per IS 1172 – 1963. Population forecasting is done by using the arithmetic increase method and this method is based on the assumption that population increases at a constant rate and then the water requirement is estimated. Census data of 1991, 2001, 2011 is used for estimating population for the selected study area.

The water quantity required for human beings is calculated as follows:

\[
\text{Quantity} = \text{Per capita demand} \times \text{Population} 
\]  

Likewise the cattle needs are calculated based on their population and consumption of water per day. Fire demand is calculated by using the Freeman’s formula with inputs population in thousands. For 1 lakh population, there is need of 35050 litres/min. Water requirement for irrigation is arrived assuming that horticulture crops will be encouraged by adopting water conserving irrigation methods like drip irrigation system and allocating 20 - 25%, 10 %, and 15% for the industrial needs, public use and losses respectively. Crop water requirements are calculated on the basis of average daily pan evaporation (mm/day), spacing of plants by using the following formula.

\[
\text{Water requirement under drip irrigation (lpd/Plant)} = A \times B \times C \times D \times E 
\]  

Where, A is open pan evaporation (mm/day), B is pan factor (0.7), C is spacing of crops/plant (m²), D is crop factor (1), E is wet area (0.3 for widely spaced and 0.7 for closely spaced crops).

5.2.5. Design Criteria for Water distribution Network
Network is designed for supplying water for human needs, cattle needs, agriculture needs and industry needs. Entire selected study area is taken into consideration for estimating the head loss, pump capacities, diameters of the pipe and peak discharge. EPANET software is used for designing the water distribution networks. The maximum pressure is normally lies in the range of 6 – 7 kg/cm², minimum pressure during peak hours lies in between 3 – 4 kg/cm² and minimum pressure during fire flow is 1.5 kg/cm². A minimum velocity of 0.6m/s is maintained in all pipes. The recommended velocities in pipes of different diameters is
followed as per BIS: SP 35 -1987, are 0.9, 1.2, 1.5 and 1.8 m/sec for pipe diameters of 10, 15, 25 and 30 cm respectively.

Head loss in the water grid system is arrived by using the Darcy - Weisbach Equation, discharge equation is used to determine diameter of the pipes and pump capacities are arrived by using the following equation:

\[ P = wQh \]  

Where, \( P \) is Pump Capacity in hp, \( w \) is unit weight of water in N/m³, \( Q \) is Total Quantity of Water, and \( h \) is Total head loss in m.

6. RESULTS AND DISCUSSIONS

Digital Elevation Model Files are gathered and are analysed using Arc GIS Software. Columns and rows of the raster data are 7200 & 7200 respectively. Spatial extent of this DEM is 17° at top, 15° at bottom, 77.99° at left and 79.99° at right. Spatial reference of WGS_1984_World_Metacor with datum of D_WGS_1984 is used. Delineated watershed and its details are presented in Figure - 3 and Table - 1 respectively.

![Figure 3 Map showing delineated Gundlakamma sub - basin](image)

Based on the land use/land cover (LU/LC) map, the study area has been classified into five major land use classes viz; built up (9.96%), water bodies (0.002%), forest (32.70%), barren land (18.57%), agriculture land (38.60%) as shown in the Figure - 4. Using LU/LC map, run – off for the Gundlakamma sub – basin is estimated.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Area of Sub watershed</td>
<td>1846 Km²</td>
</tr>
<tr>
<td>2</td>
<td>Perimeter of Sub watershed</td>
<td>316 Km</td>
</tr>
<tr>
<td>3</td>
<td>Centroid of Sub watershed</td>
<td>79°0'00&quot; Longitude &amp; 15°30'00&quot; Latitude</td>
</tr>
</tbody>
</table>
Based on SCS – CN method, soils of the study area are classified into four hydrologic soil groups (HSG) to indicate the infiltration rate obtained for plain soil after persistent wetting. The soil classes thus arrived from HSG are A, B, C, D. Group A has low runoff and great infiltration rate, Group B has modest infiltration rate, Group C has low infiltration rate and Group D has high runoff potential. The area is comprising of black cotton soils which falls under sandy clay loam, accordingly HSG Group C has been taken for determination of curve number and estimation of run – off. (Figure - 5 & Table - 2)

The run-off for Forest, Water Bodies, Agriculture Land, Barren Land and Built Up Land are 150.85, 694.74, 338.78, 367.04 and 448.25mm respectively and total availability of surface water per year is 54312.05 ha.m or 543120.5 MLD and ground water availability is 20550 ha.m. Total availability of water in the sub basin is 74862.05 ha.m.

<table>
<thead>
<tr>
<th>Land Use Cover</th>
<th>Area in m²</th>
<th>Runoff in mm</th>
<th>Run-off Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest Land</td>
<td>604000000</td>
<td>150.85</td>
<td>91113400</td>
</tr>
<tr>
<td>Water Bodies</td>
<td>3000000</td>
<td>694.74</td>
<td>2084220</td>
</tr>
<tr>
<td>Agriculture Land</td>
<td>713000000</td>
<td>338.78</td>
<td>241550140</td>
</tr>
<tr>
<td>Barren Land</td>
<td>343000000</td>
<td>367.04</td>
<td>125894720</td>
</tr>
<tr>
<td>Built Up Land</td>
<td>184000000</td>
<td>448.25</td>
<td>82478000</td>
</tr>
<tr>
<td>Total</td>
<td>543120480</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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editor@iaeme.com
On an average there is an increase of 9.7% of population from 1991 – 2001 and there is an increase of 6.44% of population from 2001-2011 census and it is represented in graphical form as shown in Figure - 6.

![Graph showing Population Vs Time](image)

Figure 6 Graph showing Population Vs Time

Based on 1991,2001, 2011 population data, the population is projected for 2021, 2031 and 2041 and the values are 368580, 397230 and 425880 respectively. The water consumption for domestic requirement for 2021,2031 and 2041 are 49.75, 53.62 and 57.49 MLD respectively. Like wise fire fighting demand has been arrived by using Freeman’s equation and the values for 2021,2031 and 2041 are 95143, 101655 and 108231 litres/min respectively. On an average, public utility uses 10% of the total demand of the study area and the values for 2021,2031 and 2041 are 4.97, 5.36 and 5.74 MLD respectively. Industrial demand constitutes upto 20% of the total demand of the study area and losses accounts nearly 15% of the total demand. The Cattle requirement is arrived as 15 MLD. The total water demand for the years 2021, 2031 and 2041 are 80.08, 86.23 and 92.49 MLD respectively for household, industrial demand, cattle needs and public utility. Like wise crop water requirements have been calculated by using the LU/LC Map. The total agricultural land is about 713sq.km, total barren land is 343 sq.km and in future these barren lands will also be converted into agricultural lands. By using the Eqn. 3 the water requirements for proposed horticulture crops under drip irrigation has been estimated and details are presented in Table 3.

<table>
<thead>
<tr>
<th>Description</th>
<th>Hectares</th>
<th>Number of plants per Hectare</th>
<th>LPD/Plant</th>
<th>Volume (MLD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables</td>
<td>52799</td>
<td>14000</td>
<td>1.5</td>
<td>1109</td>
</tr>
<tr>
<td>Guava</td>
<td>10560</td>
<td>625</td>
<td>14</td>
<td>92</td>
</tr>
<tr>
<td>Banana</td>
<td>5279</td>
<td>2500</td>
<td>8.1</td>
<td>107</td>
</tr>
<tr>
<td>Mango</td>
<td>5279</td>
<td>277</td>
<td>31</td>
<td>45</td>
</tr>
<tr>
<td>Amla</td>
<td>10560</td>
<td>277</td>
<td>31</td>
<td>91</td>
</tr>
<tr>
<td>Grapes</td>
<td>5279</td>
<td>2500</td>
<td>8.2</td>
<td>108</td>
</tr>
<tr>
<td>Sweet orange &amp; Acid Lime</td>
<td>10560</td>
<td>277</td>
<td>31</td>
<td>91</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>1643</strong></td>
</tr>
</tbody>
</table>

Cumbum Lake is selected as a main source for all essentials like household purpose, cattle needs, agriculture needs, industrial water needs situated at a distance of 3.5 km from starting node. Main pipe lines and laterals are designed based on the required discharge and assumed velocity of 0.6m/s. The diameter of the main pipe line is estimated by using discharge
equation and it is arrived as 800mm and diameter of distribution lines ranging from 30mm to 180mm. The pump capacities for main line is calculated as 40 hp and for other distribution lines it is found to be 2 hp. The capacities of each pump for pumping water from borewell to grid is 5 hp. The required discharge was estimated to be at 0.277 m³/sec. Tanks are placed at higher elevations so that there is no external power required to maintain the flow of water in pipelines and where ever necessary the pumping systems are used to maintain the water flow. The Layout of Water distribution network is shown in Figure - 7. Planning, designing and estimation of water grid system is confined to only 3 villages which are near to cumbum lake.

![Layout of Water distribution network](image)

**Figure 7** Layout of Water distribution network

7. CONCLUSIONS
The total area of Gundlakamma Sub basin is 1846 Km². Study has shown that there are five major land use classes viz., Agriculture land, forest, barren land, built – up land and water bodies. Soils are categorized into four hydrologic soil groups. Total run – off of the study area is 54312.05 ha.m, ground water availability is 20550 ha.m. Population projected for 2021, 2031, and 2041 are 3.68, 3.97 and 4.26 lakhs respectively. Water requirement for irrigation is 1643 MLD. The pipe diameter of main line is 800mm and distribution lines range from 30 – 180mm. Pump capacities required is arrived as 2 – 40hp. The power requirement is arrived as 10MW. Cost estimation of the grid system is arrived for three villages as Rs.40.89 Crores. The same data is extrapolated for the entire study area. Various schemes of the state government available for water grid are NTR Sujala Pathakam, Watershed development programme, Water harvesting schemes, Micro irrigation projects. Similarly various schemes available under central government assistance are Rashtriya Krishi Vikas Yojana (RKVY), National Watershed Development Programme for Rain fed Areas (NWDPRA), River Valley Project (RVP). The grid will be successful only when it is taken up by state government with the active participation of beneficiaries in conceptualization, installation and operation. It is suggested to take up such investment oriented projects on public private partnership mode.

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