Chapter 6
Geographical Site Suitability Analysis for the Gravitational Pipeline Canal Irrigation System

6.0 Introduction

The gravitational pipeline canal irrigation system is the most efficient and applied mean of water transport in various sectors (Dubey, 2005). A large amount of water pipeline network for drinking, industry and agriculture purpose has as experience in throughout the world (Dubey, 2009). The results of the pipeline canal depend largely on appropriate site selection for maximum utilization of available water resource (Nasir, 2001). It is a crucial task to determine the most suitable site for a pipeline canal with eco-friendly and environmentally safe (Kang, 2017). An assured irrigation water supply with sufficient volume and adequate quality are considered as the most significant factors while deciding the suitable site for the pipeline canal irrigation system. For the study of influences of multiple factors in the pipeline canal site determination, Geographical Information System (GIS) is an imperative tool (Church, 1992, Opara, 2013).
6.1 Literature Review

There is an enormous literature review dedicated to the use of multi
criterion decision analysis with GIS technic to the pipeline site suitability
analysis including different approaches and constraint. Dey and Gupta,
1999, illustrated the decision support system (DSS) for the pipeline route
selection with the help of GIS. Nonis, 2007 studied the most efficient, cost
effective and eco-friendly means of water transport based on the multi
criterion weighting scheme with GIS, he considered road proximity, forest,
slope, land use, and the settlement etc. are the affecting factors. Delisle,
Chalana and Grisson, 2012, used the GIS techniques for selection of the
best rout and network of pipeline in the Renton city with the Arc-GIS
toolbox of ESRI software. Adrina, 2012, studied the use of GIS in deciding
the location and the site of the pipeline with the geography, agricultural
pattern and settlement aspects. Liu Jianli, 2013, described various methods
for the procession of pipeline route selection with the distance,
constructability, environment and approachability factors in which, the GIS
is the best alternative. Gamurra Americo, 2015, used the GIS based
suitability modeling decision support system for the pipeline site selection
in Peru in which he discussed the terrain, geography, geophysical and
anthropological parameters. Huseyhil, 2015 pointed out, the GIS based
pipeline route analysis including various weighted overlay surfaces which
are influenced by the slope, geology and land use. Audubon, 2015
explained the use of RS and GIS in the avoiding the natural and man-made
terrain obstructions for the pipeline site selection. Anitha, 2017 explained
an optimum route for drinking water pipeline, considering the geography,
slope, population and road connectivity by using the RS and GIS.
Therefore, geographical information system have supported multi criterion
decision analysis (MCDA) used in the site suitability analysis of the left
bank canal of the Nilwande dam.
6.2 Analytic Hierarchy Process (AHP)

Pipeline canal is the most efficient and eco-friendly water conveys system (Dubey, 2005). The selection of the most suitable site for pipeline, different factors affect the route. Basically, pipeline canal site suitability analysis can be defined as the suitability of a particular location of the canal site based on the physical and socio-economic parameters. There are many multi criterion analysis techniques used for decision making in which, Analytic Hierarchy Process (AHP) is a popular technique (Malczewski, 2006). To address the influence of each parameter Analytic Hierarchy Process (AHP) method has been used.

The AHP methodological approach was developed by T.L. Saaty in 1970 to arrange information and judgment in choosing the most ideal alternative. It is a multi criterion analysis method which uses hierarchical structure and ranking to develop priorities based judgment on the problem (Saaty, 1980). This method gives flexibility in decision making process and consider the qualitative and quantitative aspect for analysis (Baric, 2014). It defines an average importance of components with involving structuring criterion of several options in to a system hierarchy (Kholil, 2014). It is, a weighted based method for multi criterion decision analysis (Banai, 1993, Basnet, 2001, Zhu and Dale, 2001). Several researchers have used AHP method for determining the most suitable site for pipeline canal and other water management issues. Feldman, 1995, Delavar, 2000, Luettinger, 2005 used MCDA based AHP method for determining the efficient route of water pipeline. Whereas Mulyawati, 2013 studied the determination of priorities in the operation and maintenance activities with AHP. The priority determination of irrigation network performance has been analyzed using the AHP method by Supriyono, 2013. Nosin, 2007, Azis, 2016, has also used the GIS based AHP weighted method for determining the suitable site in the cross country pipeline project. The AHP approach has been applied by Thangngern, 2015 in Thailand for water resource management. Therefore, GIS and MCDA based AHP method has been used to determine
the geographical site suitability (GSS) by using the weighting components for the left bank canal of the Nilwande Dam.

6.3 Selection of Affecting factors (Criterion) on Pipeline Site Suitability

As stated in the literature review each researcher has selected different parameters for the pipeline route selection according to their purposes. Effective gravitational pipeline site selection requires suspicious consideration of physical and socio-economic factors (Dey and Gupta, 1999, Balogum, 2012, Audubon, 2015). The physical factors include elevation, slope and soil depth while the socio-economic factors include the land use and land cover and road proximity (Gmarra, 2015). The geographical factors (elevation, slope, and soil) play a significant role in site suitability analysis for pipeline canal. While all factors are not creating the same impact on the pipeline canal site suitability. There are five major determining factors that have been taken into consideration during the site selection i.e. elevation, slope, soil depth, land use and land cover and road proximity. Determination of the level of influence of each component is important during the decision making process in the suitable site selection analysis.

6.4 Methodology

Geographical information system (GIS) supports multi criterion decision analysis (MCDA) based Analytic hierarchy process (AHP) applied for the site suitability analysis. The present pipeline canal site suitability analysis consists the nine stages as followed (figure 6.1).

1. Define the problem
2. Data Collection
3. Determine the criterion
4. Create the criterion map
5. Rank assigned to criterion and determine the weight
6. Pairwise comparison matrix
7. Normalized pairwise comparison matrix
8. Weighed overlay analysis
9. Site suitability map
Figure 6.1
Schematic Representation of the Methodology

Determine Suitable Site for PCIS

SOI Topomap 1:50000 → Collection of data → Landsat8 Satellite

Image rectification, enhancement & Supervise

Determine the criterion/affecting

Produce the criterion

Physical

Socio-economic

Elevation → Slope → Soil

LULC → Road Proximity

Ranking and determine the

Pair wise Comparison Matrix

Normalized pairwise comparison matrix

Source determination to sub

Weighed Overlay Analysis → Site Suitability Map

Redetermination & Process

Accuracy Assessment

*Sustainable Modeling of Gravitational Pipeline Irrigation System: A Geographical Focus on Left Command Area of Nilwande Dam in Ahmednagar District*
6.5 Database and Source

The satellite imagery and topographic map of the area require for building decisions for the selection of the most suitable site for pipeline canal. The geo-spatial data related to the selected criterion is used for choosing the most suitable site for pipeline. In the present study elevation, slope, soil depth, LULC and road proximity criterion are used. The topomaps of the study area (47E/10, 47E/11, 47E/13, 47E/14, 47E/15, 47I/01, 47I/02, 47I/03, 47I/05, 47I/06, 47I/07, 47I/09, 47I/10, 47I/13 and 47I/14) have scanned, geo referenced and used for preparing the elevation and slope map. The satellite imagery data are used for preparing the land use and land cover, soil depth and road network GIS layers. The digital supervised categorization has been done in the Landsate-8 satellite Image with operational land imager (OLI) thermal infrared sensor (TIRS) with spatial resolution of 30x30 m. Landsat 8 satellite cloud free images of December 2013 have been used for procuring the soil depth, LULC and road proximity map in the analysis.

6.6 Software and Data Processing

Geographical information system (GIS) is an effective and an able technique to determine the thematic layers of criterion. Data collected from remote sensing, topomaps and surveyed data has been loaded in GIS software. ArcGIS 10 and Earth Resource Development Application System (ERDAS) software’s are used for processing data. The soil depth and LULC maps are generated using supervised classification method from landsate-8 satellite data. Thematic maps are generated by using the Inverse Distance Weighting (IDW) interpolation method in geographical information system. Super Decision Software (SDS) is used for calculations and comparison of the weights of the determine criterion.
6.7 Criterion

The gravitational pipeline canals are used to meet the drinking and irrigation water needs in the command area. An overall goal in selecting the most suitable site for pipeline canal is the connection between the water reservoirs in the command area with shortest route (Yildirim, 2007). Simultaneously, many important factors are existing in the site suitability and they also affect the time of site selection (Dey, 1999). Geophysical and socio-economic factors interrelated to define the suitable site possibilities (Yildirim, 2007). The factors like elevation, slope, soil depth, land use and land cover and road proximity are frequently used for choosing the most suitable site for pipeline canal. The impact of these factors is different according to the command area's physical and socio-economic characteristics. Therefore, the above said criterion has selected for deciding the most suitable site for the pipeline canal by using weighted overlay analysis.

6.7.1 Elevation

The physical characteristics of the geographical area have been examined to decide the weight of affecting factors (Chakhar and Mousseau, 2012). The elevation of the location of water source and the command area to which irrigation to be provided are most important to determine the most suitable site for pipeline canal (CWC, 2017). Elevation of catchment and the command area is the most important physical factor, when applying the gravitational pipeline in the command area (Gmarra, 2015). The pipeline water supply application system, requires more than the six meters of head to create the gravitational force (CWC, 2017). The pipeline canal site determines, after topographical evaluation of the command area. Therefore, the elevation criterion has been considered for determining the most suitable site for the pipeline canal.

The elevation of the dam site and the command area are of paramount importance, when constructing irrigation facilities in command
Figure 6.2: Suitable site of pipeline canal with elevation

Legend:
- Existing Canal
- Proposed Canal
- Elevation in meter
  - Above 510
  - Below 610

Source:
1) Survey of India (SOI) Topomaps Scale 1:50000
area. The scope of the command area depends on elevation of the source. Since the proposed pipeline canal from the Nilwande dam, considered as a gravitational canal, therefore, it is important to consider the elevation of the source and the command area as an affecting factor. Figure 6.2 shows, existing surface canal irrigation system and suitable elevation based route for the proposed pipeline canal irrigation system. Depending on the source elevation 610 m, the command area considered below 610 m elevation in the study area. Below 610 m elevation is a basic assumption to find out the probable command area of the pipeline canal, hence, the elevation has considered as an impacting factor in deciding the suitable site. The elevation map produced from the SOI topographic map with 20 m contour intervals.

6.7.2 Slope

The measurements of change between the two geographical locations in elevation are called as slope. It is expressed as a degree of slope and the degree of slope, calculated by analyzing the spacing within the contours on a contour map. As per reports of the Indian National Committee, on Irrigation and Drainage (INCID, 1998), the gravitational pipeline canal generally most feasible in sloping topographical command area. The gravitational pipeline canal is governed by the topography (slope angle) of the command area (WRD, 2015). Hamam, (1982) point out, the water pressure, alignment of the pipe, shape of pipe, flow velocity, material and outlets are depend on slope condition of the region. The discharge rate of water and quantity to be conveyed in the command area, can be varied by considering slope profiles of the ground (INCID, 1998, CWC, 2017). Slope is a most sensitive geographical factor in choosing the most suitable site for the pipeline canal (Gamarra, 2015). Figure 6.3 shows, suitable site for the LBC, according to slope in the command area.
Figure 6.3: Suitable site of pipeline canal with Slope

Legend:
- Existing Canal
- Proposed Canal

Slope Class
- Gentle
- Moderate

Source:
1) Survey of India (SOI) Topomaps Scale = 1:50000
Ongombe, (2013) point out, suitable site in the pipeline involves, consideration of slope of terrain as a geographical constraint. Iqbal, Sattar and Nawaz (2006), have considered slope criterion in the spatial decision support system (SDSS) for analyzing a suitable site for pipeline in the North India. The steep slope is very perilous and complicated to construct the large pipeline in the command area (Rees, 2004). Yildirim (2007), studied the pipeline site analysis in the sea region of Turkey, with RS and GIS techniques and considered the slope as a fundamental factor. Huseynli (2015) used slope criterion for the pipeline route analysis with geology and land use. As well as soil depth depends on the degree of slope (Date and Gupte, 1984) in the command area, whereas, the steep slope has a thin and gentle slope have deep soil cover. The land use depends on the soil depth, therefore, to determined site suitability in the command area, slope of terrain consider as an important factor. The slope of the command area is positively associated with the most suitable site for the pipeline canal irrigation system.

6.7.3 Soil Depth

Soil depth is conceded as an important physical criterion which is affected on deciding the pipeline canal location (Matthews, 1970, CWC, 2017). Yildirim (2007), Ongombe (2008), Shahabi (2015), Kulavmode (2017) and CWC (2017) etc. used soil depth criterion in spatial decision support system for examining site of the pipeline canal. The cropping patterns, of the region mainly depend on the soil depth (Zolekar, 2016). The specific characteristics of soil, like water holding capacity (Bhagat, 2014), Infiltration rate of the soil (Rabia, 2012), intensity of moisture (Zolekar, 2014), agricultural productivity (Yu, 2011), ground water level (Kulavmode, 2017) and soil nutrients (Jobbagy, 2001, Dar, 2012) depending on soil depth. According to the CWC (2017) guideline, it is a prime stage in the pipeline site determination, that to consider crop water requirement and irrigation schedules in the command area, while it depends on soil depth. As per engineering consideration, soil depth is important to protect the pipeline from various hazards take place by the temperature, like soil cracking (Kulavmode,
The durability and choice of pipeline materials also depend on the type of soil and soil types are depending on the depth of soil. Therefore, to locate the agricultural land in the command area deep soil depth, moderate soil depth, shallow soil, and thin soil classes are used in the AHP weighted overlay analysis. Figure 6.4 shows the pipeline canal layout suitable with the soil depth in the command area.
6.7.4 LULC

Land use and land cover are important socio-economic affecting factors in determining the pipeline canal location. The classification of LULC of command area gives an idea about the present utilization of land. Several researchers, like Ongombe (2008), Abramovich (2012), Liu (2013), Ahmed (2015), Kennelly (2015), Seynil (2015), Yildirim (2016) and Anitha (2017) have used land use and land cover to decide the pipeline route. The command area to be irrigated by the pipeline canal irrigation system, shall be considered with the help of LULC map. The dominant crops of the region and their water requirement has been calculated as per the proposed cropping pattern.

The LULC classification helps to understand the native characteristics, existing use and production capacity of the land (Siddiqi, 1971). LULC classification specifies the spatial distribution and uniqueness of land, i.e. agricultural land (13.99%), barren land (19.91%), dense vegetation (21.60%), fallow land (5.92%), open scrub (11.48%), rocky land (13.77%), settlement (2.51%), sparse vegetation (9.49%), and water bodies (1.33%) (Figure 4.2). The supervised classification technique has used for classification of the land use, and land cover in the nine dominant classes. Out of the nine classes Rocky land, dense vegetation, sparse vegetation, settlement, and water bodies are not suitable for agricultural utilization (Bangyopadhyay, 2009), therefore these classes have assign low scores in weighed overlay analysis.

The land use and land cover map of the study area has used to work out the agricultural land under the various crops, where the irrigation facilities will be provided. Figure 6.5 shows the most suitable path, based on the land use and land cover for the pipeline canal.
Figure 6.5: Suitable site of pipeline canal with LULC
6.7.5 Road Proximity

The road proximity is one of the important criteria in the multi criteria site suitability analysis method. It is considered as socio-economic factor, which is significantly responsible for the agricultural development (Mujumdar, 2002). According to CWC (2017), guidelines for the pipeline irrigation network, pipeline route should be analogous with linear features like as roads. Road construction avoids the probable landslide area, flood line and fill section segments, therefore it is feasible to construct pipeline parallel to roads. It will be economically affordable, when, pipeline arranges parallel to present communication lines as a road, because of the minimum land acquisition. The high road proximity should be useful for the inspection of the pipeline canal. Nonis (2007), point out, roads are considered one of the important criteria in the pipeline route analysis. He recommended that, pipelines should avoid road crossing, but the proximity of roads should be high. The pipeline site location problem consists of a strong spatial dimension, as a huge number of spatial factors are involved like, road (Yildirim et al, 2016). Gamarra (2015), considered accessibility or roads as a variable when identifying the pipeline route, he points out, according to the engineering requirement pipeline should avoid distance twenty km away from the road and preferred distance of five km to existing roads. Euclidean distance means the straight line distance within two spots is suitable for the determination of pipeline location (Ahmad, 2015). Several researchers have considered road proximity as criterion in the pipeline site suitability analysis, i.e. Ghaderi (2007), Ongombe (2008), Opara (2013), and Huseynli (2015).

Therefore, proximity of the road network has been considered as socio-economic factors in the pipeline canal site suitability analysis. Figure 6.6 describes the suitable route, with the road network connectivity.
Figure 6.6: Suitable site of pipeline canal with Rpad Proximity
6.8 Determination of Rank

Analytic Hierarchy Process (AHP) has used as a quantitative method for determining the rank of affecting criterion (Nonis, 2007). The first stage in AHP is to make a hierarchy of judgment for that selected criteria arrange according to their rank. The correlation analysis and expert opinions have been used for deciding the rank for the criterion (1 to 5). In the AHP analysis, the maximum value of the rank indicates best ranked or importance of the criterion (Thungngern, 2015). Fifteen experts from various sectors have responded and allotted the rank within the asked criterion. Elevation and slope have more importance in the determination of pipeline canal site suitability and ranked 1 and 2 respectively. The other criterion like land use and land cover assigned third rank, soil depth fourth rank, and road proximity fifth ranks have assigned. The last three criteria are shown comparatively less influence in the site determination. The table 6.1 shows the assigned rank for criterion.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Elevation</th>
<th>Slope</th>
<th>LULC</th>
<th>Soil Depth</th>
<th>Road Proximity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank assigned</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

6.9 Pairwise Comparison Matrix

The second stage of analysis contains relative priority analysis, for making a judgment of the decision (Nataraj, 2005). In the Analytic hierarchy process, define criterion, were evaluated with the pairwise comparison matrix (Azis, 2016). This method was introduced by Saaty (1980) for
deciding criterion wise relative priorities in AHP. In this process researcher compares each criterion with others to obtain scale of the measurement (Table 6.2). To make decisions about the preference of criterion, it requires comparison within the set of criteria. In more than two criteria, it is difficult to decide the important level of each, in this situation pairwise comparison matrix (PCM) helps to assign different priorities in the total criteria (Saaty, 1997). The PCM analysis helps to researcher to allocate the different positions of the importance of various criterion concerned with pipeline site suitability analysis (Thungngern, 2015). Normally, the PCM analysis converts qualitative comparison of factors into the quantitative number by using a scale of the range from 1 to 9. The factor comparing itself in the matrix always indicates one association and a reciprocal association observed for all comparisons. Therefore, a diagonal of one is always observed in the PCM. According to Saaty's comparison scale, the range between 1 to 9 decides different weights of criterion. Whereas, 1 value indicates equal importance, 2 and 3 values specify moderately more importance, strongly more importance denoted by 4 and 5, where, 6 and 7 values use for very strongly more importance, and finally, 8 and 9 values indicate the extreme importance (Mu and Rojas, 2017). The advantage of the AHP is that, it includes tangible components like elevation, slope, soil depth as well as intangible like LULC and road proximity as a criteria in the judgment making process (Mu and Rojas, 2017). Finally, individual weight of criterion has been considered based on the numbers given to the criterion in comparison to others. The PCM analysis shows the strength of criteria with one component dominates over another (Raghunath, 2006). Therefore, for calculating the weights of criterion, the pairwise relative comparison matrix has been used in the present research work.
**Table 6.2**
Pairwise comparison matrix

<table>
<thead>
<tr>
<th>Factors</th>
<th>Elevation</th>
<th>Slope</th>
<th>LULC</th>
<th>Soil Depth</th>
<th>Road Proximity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>1/1</td>
<td>2/1</td>
<td>3/1</td>
<td>4/1</td>
<td>5/1</td>
</tr>
<tr>
<td>Slope</td>
<td>1/2</td>
<td>2/2</td>
<td>3/2</td>
<td>4/2</td>
<td>5/2</td>
</tr>
<tr>
<td>LULC</td>
<td>1/3</td>
<td>2/3</td>
<td>3/3</td>
<td>4/3</td>
<td>5/3</td>
</tr>
<tr>
<td>Soil Depth</td>
<td>1/4</td>
<td>2/4</td>
<td>3/4</td>
<td>4/4</td>
<td>5/4</td>
</tr>
<tr>
<td>Road Proximity</td>
<td>1/5</td>
<td>2/5</td>
<td>3/5</td>
<td>4/5</td>
<td>5/5</td>
</tr>
</tbody>
</table>

**6.10 Calculation of Weights**

The relative weights of each criterion are calculated with a mathematical process which is established by Saaty. The process consists of four steps i.e. formation of decision, assigned ranks to criterion, calculation of normalized pairwise comparison matrix (NPCM) and priorities or weight calculation. The rank assigned to criterion as per the expert opinions (Table 6.1) and compare in relative pairwise matrix (Table 6.2). For calculating the weights of individual criteria PCM require the normalization. It is a popular process that the PCM cell values are turned into more normal without changing their trends. In this process each cell of PCM is divided by the sum of the particular column. From the normalized relative pairwise matrix, final priority or weights have been calculated by the average value of each row (Akinci, 2013 and Mu, 2017). According to the weight in table 6.3, more importance given to the elevation (0.44), followed by a slope (0.21), LULC (0.15), soil depth (0.25). The road proximity has a minimum
weight (0.09) in most suitable site selection decision. The above weights have mathematical validity, while measurement values derived with ratio scale (Table 6.3), it means elevation and slope have 65 % influence and other factors (soil depth, LULC, road proximity) have only 35% influence on the pipeline canal site suitability.

After calculating weights in NPCM it is essential to ensure their consistency. The consistency ratio (CR) deals with logical inconsistencies in the final matrix of decision, it detects some possible errors. The acceptable consistency ratio is less than 0.10 in the decision making process (Saaty, 2012). Therefore, if the CR exceeds the minimum limit of 0.10 then PCM should change as per the improved decision (Akinci, 2013). Since the value of CR in the present analysis is 0.096, which is less than 0.10. Therefore, consistency ratio is acceptable for the process of determining the most suitable site for the pipeline canal by AHP.

### Table 6.3
Normalized pairwise comparison matrix

<table>
<thead>
<tr>
<th>Factors</th>
<th>Elevation</th>
<th>Slope</th>
<th>LULC</th>
<th>Soil Depth</th>
<th>Road Proximity</th>
<th>Priority or Weight</th>
<th>Influence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>1.00</td>
<td>2.00</td>
<td>3.00</td>
<td>4.00</td>
<td>5.00</td>
<td>0.44</td>
<td>44</td>
</tr>
<tr>
<td>Slope</td>
<td>0.50</td>
<td>1.00</td>
<td>1.50</td>
<td>2.00</td>
<td>2.50</td>
<td>0.21</td>
<td>21</td>
</tr>
<tr>
<td>LULC</td>
<td>0.33</td>
<td>0.67</td>
<td>1.00</td>
<td>1.33</td>
<td>1.67</td>
<td>0.15</td>
<td>15</td>
</tr>
<tr>
<td>Soil Depth</td>
<td>0.25</td>
<td>0.50</td>
<td>0.75</td>
<td>1.00</td>
<td>1.25</td>
<td>0.11</td>
<td>11</td>
</tr>
<tr>
<td>Road Proximity</td>
<td>0.20</td>
<td>0.40</td>
<td>0.60</td>
<td>0.80</td>
<td>1.00</td>
<td>0.09</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>2.28</td>
<td>4.57</td>
<td>6.85</td>
<td>9.13</td>
<td>11.42</td>
<td>1.00</td>
<td>100</td>
</tr>
</tbody>
</table>

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6.11 Determination of scores

Determination of score for sub criterion is the important step in AHP analysis. Table 6.4 shows the sub criterion score and the influence percentage of individual factor. Elevation is the most influenced (44%) physical factor in the determination of the most suitable site for pipeline canal (Gmarra, 2015). The first criteria elevation is divided into the two sub-categories. According to the source of canal water height, elevation criteria cell values have assigned. Elevation values greater than 610 m has assigned score 1 and it covered 14.30 per cent area, while less than 610m assigned score 9 and covered 85.70 per cent area.

Second criteria is slope, which is 21 percent influenced on the selection of a suitable site for the pipeline canal. The slope of the command area is also one of the significant physical factors in pipeline canal site suitability (WRD, 2015). In present study slope criteria further is divided into the seven categories from the DEM (figure 2.4). Gentle slope (0-1°) assigned a maximum score (9) and it covered 58.89 percent area, after that, moderate slope (1-3°) assigned 7 score which is covered 23.03 per cent area. Other classes stiff (3-6°), steep (6-2°), very steep (12-20°), extra steep (20-30°) and precipitous (30-90°) slope have not suitable for pipeline route so, they have assigned 1 score and they are covered 18.8 per cent area.

The LULC classification helps to understand the suitable site for canals (Siddiqi, 1971). This criterion divided into the nine classes for assigning the score. Within nine classes barren land and open scrub classes have 9 and 7 score and they have covered 27.43 and 15.36 percent area respectively. Because, these sites are highly suitable for irrigation and pipeline canal. Water bodies region is restricted for assigning score with aquairing 1.33 per cent, while other classes have limitations, so that they have assigned score 1 for each and covered 56.04 per cent area.
<table>
<thead>
<tr>
<th>Criteria Weight</th>
<th>Weight</th>
<th>Influence (%)</th>
<th>Sub-criterion (with ranges)</th>
<th>Area (%)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation (m.)</td>
<td>0.44</td>
<td>44</td>
<td>Below 610</td>
<td>85.70</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Above 610</td>
<td>14.30</td>
<td>1</td>
</tr>
<tr>
<td>Slope (Degree)</td>
<td>0.21</td>
<td>21</td>
<td>Gentle (0–1)</td>
<td>58.89</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Moderate (1–3)</td>
<td>23.03</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stiff (3–6)</td>
<td>7.06</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Steep (6–12)</td>
<td>4.74</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Very steep (12–20)</td>
<td>3.23</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extra steep (20–30)</td>
<td>2.11</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Precipitous (30–90)</td>
<td>0.94</td>
<td>1</td>
</tr>
<tr>
<td>LULC</td>
<td>0.15</td>
<td>15</td>
<td>Dense vegetation</td>
<td>14.37</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sparse vegetation</td>
<td>17.57</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Open Scrub</td>
<td>15.36</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Barren land</td>
<td>27.43</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rocky land</td>
<td>12.35</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fallow land</td>
<td>1.17</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Agriculture</td>
<td>2.21</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Settlement</td>
<td>8.37</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td>1.17</td>
<td>Restricted</td>
</tr>
<tr>
<td>Soil Depth</td>
<td>0.11</td>
<td>11</td>
<td>Deep soil depth</td>
<td>16.28</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Moderate soil depth</td>
<td>19.91</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Marginal soil depth</td>
<td>17.40</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Shallow soil depth</td>
<td>31.08</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thin soil depth</td>
<td>13.99</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td>1.33</td>
<td>Restricted</td>
</tr>
<tr>
<td>Euclidean Distance (meter)</td>
<td>0.09</td>
<td>9</td>
<td>200</td>
<td>82.60</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>250</td>
<td>17.40</td>
<td>7</td>
</tr>
</tbody>
</table>

*Sustainable Modeling of Gravitational Pipeline Irrigation System: A Geographical Focus on Left Command Area of Nilwande Dam in Ahmednagar District*
The score assigned to soil depth also depicts into the six subcategories. The deep soil, moderately and marginal deep soil have a negative impact on the pipeline canal site suitability, because of the more ground fracture are developed in dry season. In other hand shallow and thin soil cover has been noted positive influence on site suitability therefore, 9 score has been allotted to these classes (Table 6.4). About 45.07 per cent area out of the TGA has covered by these classes.

In case of Euclidean distance, Gamarra (2015), points out that, according to the engineering requirement pipeline should be avoided long distance from the road as well as not to prefer distance of 200 m to existing roads. Because of avoiding road crossing and accident, therefore distance up to 200 m assigned low score and it covered 82.60 per cent area are distance more than 250 m has been assigned 7 score in last criterion with aquairing 17.40 per cent area.

6.12 Weighted Overlay Analysis

The weighted overlay analysis is very effective method to answer the complex problems in site suitability analysis based on regular measurement of different inputs (Girvan et al., 2003, Kuria et al., 2011, Zolekar and Bhagat, 2014, Pramanik, 2016). Analytic hierarchy process has been exercised to decide the significant factors within given input to the weighted overlay analysis (Pramiala and Lopez, 2012). However, each thematic layer was overlaid with each other in geographical information system to use the WOL method (Girvan et al., 2003). Preferred raster layers were overlaid by changing their cell values to general scale, assigning a weight to individual criteria, and counting the weighted cell values collectively. The cell of every raster layer is multiplied with their weight value (Cengiz and Akbulak, 2009, Mojid et al., 2009).
\[ TSS = \sum_{i=1}^{n} WiXi \]  

Where,

\( TSS \) = total score of pipeline site suitability  
\( Wi \) = Weight of pipeline site suitability criteria  
\( Xi \) = sub-criteria score of i pipeline site suitability criteria  
\( n \) = total number of pipeline site suitability criteria

After that, the output raster map was produced and assigned scores were converted into the five classes according to average score. The classes were classified into the highly suitable site, moderate suitable, marginal suitable, low suitable and not suitable (figure 6.7).

### 6.13 Suitable Site for Pipeline canal

The selected criterion has been assigned the rank as per their influence on site suitability. The criterion wise weights have been calculated by AHP method and completed weights overlay analysis to produce the suitable site selection map of pipeline canal. Suitable sites for the pipeline canal were classified into the five classes.

The first class is a highly suitable site for pipeline canal covers 58.89 per cent area. Especially, plain region, which have gentle slopes and deep soil includes in this category (figure 6.7). Excluding the part of Godavari and Pravara canal command area remaining study area has a highly productive land, but the absence of the irrigation facilities. Second class is moderately suitable this class occupied about 23.03 percent area, it consists of moderate slope region of plain and plateau physiographic region. It is spread with the highly suitable class. Marginal suitability is the third class of site suitability, which is observed in the stiff and the steep slope region.
Figure 6.7: Suitable site of Left Bank Pipeline canal
The western Akole and Sangamner tehsils thin soil cover and the sloping area were included in this class. Fourth class is low suitability, it covers 5.34 percent area, which has very steep and extra steep slope in the study area. Lastly, not suitable class, it includes the water bodies and precipitous slope area, especially from Akole and Sangamner tehsils mountainous area.

6.14 Accuracy Assessment

The accuracy assessment techniques apply to make the comparison between classified data and referenced data (Bhagat and More, 2013). The error matrix calculated as cross tabulation of classified data against referenced data (Comber et al, 2012). It is calculated at the three levels i.e. user’s accuracy, producer’s accuracy and overall accuracy. It is used to evaluate the output maps and measure the correlation between classified data and referenced data (Chabuk et al., 2017). Along with the accuracy level, it is also used for improving overall accuracy. Present analysis has 90.63 percent user’s accuracy, 96.67 percent producer's accuracy and 91.46 percent overall accuracy (table 6.5). About 196 ground reference positions were preferred from the LBC command area by using Global Positioning System (GPS) and confirmed using classified data.
## Table 6.5
### Error Matrix

<table>
<thead>
<tr>
<th>Classified Class</th>
<th>Reference Class</th>
<th>Highly suitable</th>
<th>Moderately suitable</th>
<th>Marginally suitable</th>
<th>Low suitable</th>
<th>Not suitable</th>
<th>Water bodies</th>
<th>Total Samples</th>
<th>User’s Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly suitable</td>
<td></td>
<td>33</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>36</td>
<td>91.67</td>
</tr>
<tr>
<td>Moderately suitable</td>
<td></td>
<td>1</td>
<td>29</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>32</td>
<td>90.63</td>
</tr>
<tr>
<td>Marginally suitable</td>
<td></td>
<td>0</td>
<td>1</td>
<td>28</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>32</td>
<td>87.50</td>
</tr>
<tr>
<td>Low suitable</td>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>93.33</td>
</tr>
<tr>
<td>Not suitable</td>
<td></td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>0</td>
<td>34</td>
<td>91.18</td>
</tr>
<tr>
<td>Water bodies</td>
<td></td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>32</td>
<td>90.63</td>
</tr>
<tr>
<td>Total Samples</td>
<td></td>
<td>37</td>
<td>33</td>
<td>32</td>
<td>30</td>
<td>34</td>
<td>30</td>
<td>196</td>
<td>91.46%</td>
</tr>
</tbody>
</table>

*Producer’s Accuracy (%) includes all classified and reference classes.*
6.15 Five Stages Pipeline Model

The water is the limited resource in many parts of the country. With the larger demand of water resource in various sectors, there is an insistent need to proficient consumption and reducing loss in the transport and irrigation system. In India generally, lined and unlined surface canal irrigation systems have in use. While, overall efficiency of the surface canals are not satisfied with the demand. In the perspective of improving the water efficiency in irrigation, water loss should be greatly reduced at various points. The gravitational pipeline canal irrigation system is a sustainable irrigation system. In which, many important objectives are obtained related to water efficiency, elimination of the problems substantially of evaporation losses, seepage losses, uneven distribution and malpractices. However, to install the pipeline canal irrigation system, huge capital investment and skilled workers should require initially. On the other hand, there are many incomplete irrigation projects in the country, because of lack of the capital. Under such circumstances, it is necessary to adopt the stage wise capital investment in the projects. On the other hand, all farmers are also not prepare to accept modern techniques of irrigation systems. The planners should also have the some space during the total implementation of any huge project to understand the ambiguities in the system.

The proposed left bank unlined canal of Nilwande dam should provide the irrigation facilities to 43866 hectares land of the command area. The transit losses of LBC unlined canal, considered as per the government norm and calculated 21 percent of the total requirement at all levels. As well as the field application efficiency is only 75 percent in the case of flow irrigation method (Table 5.1). Therefore, the five stage model has been suggested for applying pipeline canal instead of surface canal.
Table No.6.6
Stages in the Pipeline Canal Irrigation Model

<table>
<thead>
<tr>
<th>Stages</th>
<th>Pipeline Canal Irrigation System</th>
<th>Surface Canal Irrigation System</th>
<th>Efficiency Increase in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Main Canal</td>
<td>Branch canal, Minor Canal, Field Channel and field application</td>
<td>10</td>
</tr>
<tr>
<td>II</td>
<td>Main Canal and Branch canal</td>
<td>Minor Canal, Field Channel and field application</td>
<td>10</td>
</tr>
<tr>
<td>III</td>
<td>Main Canal, Branch canal and Minor</td>
<td>Field Channel and field application</td>
<td>10</td>
</tr>
<tr>
<td>IV</td>
<td>Main Canal, Branch canal, Minor and field channel</td>
<td>Field application</td>
<td>5</td>
</tr>
<tr>
<td>V</td>
<td>Main Canal, Branch canal, Minor, field channel and field application (Drip / Micro sprinkler)</td>
<td>Nil</td>
<td>20</td>
</tr>
</tbody>
</table>

6.15.1 Stage I

In the first stage only main canal would be converted into the pipeline canal irrigation system. The new pipeline canal would be constructed under the existing surface canal alignment. From the source point of the reservoir, water is laid down into the 85 km main pipeline canal by the gravitational force. The main pipeline provided by branch canal outlets, according to the irrigable land and topographical condition of the command area. Generally, the main pipeline and branch pipeline are feeder lines for the minor canal and no direct irrigation is made from them. The main canal shall be installed cross regulator valves for controlling the water.
flow. It is useful to stop water flow in emergency cases and maintain the pressure (Figure 6.8). There will be arranged in the main pipeline to measure the discharge. The branch canals, minor canals, and field channels will remain open surface canals. The field application also remains as it is conventional. In case of SCIS the main canal efficiency is 85 percent (Table 5.1), which will increase up to the 95 percent in PCIS that means the total water requirement at the main canal head is arriving with only 5% of the total demand. In case of LBC the total main surface canal head requirement is 7.16 TMC, however, the pipeline canal should be the 5.87 TMC considers 5% water loss. It is the first step to reduce the seepage and convey losses in the main canal irrigation system and to save 10 percent of water loss. In this stage it is easily possible to supply irrigation water to branch canals, according to the water demand from different pockets of the command area. As well as permanent drinking water supply also possible for the canal side villages through the main pipeline.

Figure 6.8
Stage I – Model of Pipeline Canal
6.15.2 Stage II

In the second stage the main pipeline is provided with branch canals along with the outlets to distribute the water in the command area. In this stage, branch canals shall be converted into the pipeline canal (Figure 6.9). The branch canals to be providing the cross regulator valves at the suitable distance to regulate the water flow. The branch canal shall have the suitable outlets, according the block of land to be irrigated with consideration of watershed and the drainages of the command area. In case of SCIS the branch canal efficiency is 85 percent (Table 5.1), which will increase up to the 95 percent in PCIS that means the total water requirement at the branch canal head is arriving with only 5% of the total demand, that's wherein open canal it is 15 % of the total demand. In case of the LBC command area there are total 45 km's three main branch canals (Figure 4.1) i.e. Talegaon Branch (14.5 km.), Kopargaon Branch (14 km) and tail branch (16.5 km).

Figure 6.9
Stage II – Model of Pipeline Canal
6.15.3 Stage III

The branch canals outlets will provided with minor pipeline canal to distribute the water for different parts of the branch canal command area in the third stage. The minor pipelines are provided with irrigation outlets or field canal off taking from minor. In this phase only field canal and field application have remained conventional. The desired discharge should be provided with the adequate sizes of the pipeline as well through the control valves. After studying the geographical characteristics of regions, minor pipeline shall be planned for pockets in the branch canal command area. The conventional unlined minor canal efficiency is 85 percent (Table 5.1), which will increase in pipeline canal up to the 95 percent. The minor canals should be prepared on the basis of clubbing of farmers due to the small land holders. In this stage, 10 percent of the water loss saves by the pipeline canal irrigation. At every outlet of minor a hydrant will be installed to make possible the field pipeline for individual farmer irrigation in the command area. The drinking water facility of the sectional villages also possible for throughout the year.

Figure 6.10
Stage III – Model of Pipeline Canal
6.15.4 Stage IV

The total water conveys system from the source to the farmer's field has been converted into the pipeline canal in the second last stage of the model. Every minor channel has installed the hydrant to assist an irrigation in the command area. From the hydrants individual farmers or landholders are provided the round lateral pipeline for irrigation. Each hydrant point has installed a gauge meter for volume metric measurement of irrigation water (Figure 6.11). The concept of water on demand shall be clear at this stage. In this stage general planning of an irrigated area has to designed. According to the land use maps irrigable area shall be planned by considering the cultivated land, soil types, drainage, contours, settlements and road of the command area.

The flexibility of cropping pattern shall be provided to farmers. The main crops in the command area and their water need to be determined in communication with the agricultural department and the agriculturist of the command area shall allow anticipated change in the present crop pattern. Individual farmer can demand water according to their crop pattern at any location in the command area. The equal distribution of water among the head, middle and tail locations shall be possible. At this level the conventional surface irrigation system efficiency is 90%, whereas the pipeline will get about 99 % of efficiency. The water distribution will be on a meter based so that government could collect precise revenue form the canal water. In future with the technological development it could be controlled by a computer program.
6.15.4 Stage V

The last stage is application efficiency. It defines the percentage of water used by the crop divided by the total water applied to the crop. Application efficiency includes evaporation loss, runoff, percolation, and other losses which are, more than at any point water loss. It has played a significant role in an overall project efficiency, because as per the United States Agency for International Development (USAID) the flow system of irrigation at farm level is 75 percent, that means on farm level water loss is 25 percent. In case of the pipeline and drip irrigation, the efficiency shall be at 90 percent (CWC, 2017). The conventional irrigation system causes for a huge water loss and assist soil degradation. It is very necessary to use a micro irrigation system like drip, sprinkle etc. Of course, it is not possible at a time to convert all cropland into the micro irrigation system, but in future,
the agricultural allocation of water will change and it will be diverted for other purposes then we must accept the micro irrigation at farm level.

**Figure 6.12**

**Stage V – Model of Pipeline canal**

With these stages the overall efficiency of the left bank canal irrigation will be increased by 45 percent at various levels. The saved water from loss would help, confirm water supply to command area or to increase the irrigated area and ensure that farmers can obtain their allocated water form the reservoir. Water loss, seepage loss, water logging problem, malpractices, social conflicts and uneven distribution of water problems shall be eliminated from this model rather than the most important is the priceless water resource shall be utilized appropriately and proportionally to all sectors. It is essential to adopt modern techniques likewise pipeline canal irrigation to eradicate drought in the drought prone areas.
6.16 Comparative Analysis between the SCIS and PCIS

6.16.1 Water loss

➢ The surface canal irrigation system (SCIS) has a huge water loss at various points such as evaporation, seepage and other convey. The unlined canal has 20-30 percent water loss through the seepage and convey systems. In case of the LBC there shall be 2.66 M. Cum water loss in water conveys systems.

➢ The pipeline canal irrigation system (PCIS) conveys water very efficiently, there is no evaporation loss, seepage loss. Therefore, water loss shall be minimized extremely. The PCIS shall increase convey efficiency up to 75-95 percent.

6.16.2 Overall Efficiency

➢ The overall project efficiency of the unlined LBC canal is very low (42 %).

➢ Whereas the overall project efficiency in case of PCIS shall be very high ( 75 - 95%).

Table 6.7
Comparative Overall Efficiency

<table>
<thead>
<tr>
<th>Stages of Conveyance</th>
<th>Type of Irrigation System &amp; Efficiency</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Surface Canal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Irrigation System (%)</td>
</tr>
<tr>
<td>Convey Efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Canal</td>
<td></td>
<td>85</td>
</tr>
<tr>
<td>Branch Canal</td>
<td></td>
<td>85</td>
</tr>
<tr>
<td>Minor Canal</td>
<td></td>
<td>85</td>
</tr>
<tr>
<td>Field Channel</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>Total Convey Efficiency</td>
<td></td>
<td>55.27</td>
</tr>
<tr>
<td>Field Application</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>Overall Efficiency</td>
<td></td>
<td>41.45</td>
</tr>
</tbody>
</table>
6.16.3 Land Acquisition

- The surface canal irrigation system faces the problem of the land acquisition. In the command area the agricultural and productive land endures the canal government have to pay more compensation to landowners and the cost of the project shall increase. In case of the LBC, project authority has acquired about 1212 hectare land from the command area as well as paid the compensation to 129 wells and 43 houses.
- In the pipeline canal no land acquisition is required, only during the construction phase authority need temporary land for installation of pipeline. In case of LBC new pipeline, it shall be constructed under an existing surface canal ditch and alignment.

6.16.4 Execution Time

- The earthen canal construction comparatively is more time consuming due to the land acquisition, farmers dispute, maintenance of the side and longitudinal slope. In case of the LBC the project duration was decided seven years from 1999-2000, but still date (April, 2018) it is under construction.
- The construction duration of pipeline canal is less compared to the SCIS due to the easy installation and place. The period can be minimized and the realization of the reimbursement from the investment can be materialized swiftly.

6.16.5 Water logging and soil degradation

- The unlined open canal degraded about 5.5 million hectares land in India, and 426.41 thousand hectares in Maharashtra due to the water logging problem. The Bhandardara major irrigation project also have
been the water logging problem and degraded 4.78 thousand hectares land from the command area.

- In case of PCIS there will not be the water logging problem and soil degradation.

6.16.6 Drinking Water Facilities

- The conventional canal system provides the drinking water facility to the side villages during the rotation and after rotation from the water recharge. But most villages from the command area do not get sufficient and safe drinking water throughout the year.
- The PCIS shall provide drinking water facilities for the four months in 49 villages, eight month water facility for 38 villages and 14 villages and three urban centers shall facilitate throughout the year for safe, sufficient and a permanent drinking water facility in the command area.

6.16.7 Water on Demand

- It is not possible in the SCIS to provide an irrigation facilities as per demand of individual or group of farmers. The requirement of watering is different in the command area as per the soil types and cropping patterns.
- On demand water scheduling can be possible in the PCIS. Individual farmers or group of farmers shall obtain volumetric water as per their requirement, time and place. The main pipeline and branch canal will be fully charged, ultimately, farmers can avail irrigation water easily and quickly after registering the demand.

6.16.8 Scope and flexibility for crop diversification

- In the proposed surface canal irrigation system, the eighth month and two seasonal cropping pattern have considered. There is no any
scope for double and multiple cropping pattern due to an inadequate water in the storage. Even through the flexibility for fruit agriculture and cash crops are also very limited in the conventional system.

- The PCIS can make available water flexibly for multiple cropping pattern as well as various horticulture and cash crops on the condition of drip irrigation. It is possible from the saved water to provide an irrigation facilities for the perennial crops.

6.16.9 Capital Investment

- As compare to the PCIS the initial capital investment in SCIS is low.
- The PCIS require a huge initial investment in construction. The construction materials, skilled workers, adjusted pressure and other technical factors increase the cost of the project. The economic factors, construction cost, life of the pipeline, durability, and maintenance expenses require a huge capital investment in the pipeline canal irrigation system.

6.16.10 Operation and Maintenance

- The open canal system has to be maintained continuously, for that more skilled laborers should be engaged in maintenance. There are many costly operations need to carry out to avoid damage of canal banks likes roots controls, seepage control, siltation, blockage of gates and outlets.
- In the PCIS no continuous maintenance and required repairing. Due to the modern technics of flow control about 25-50 % are labor is saved in this system. So, the maintenance cost is very low. It is relatively trouble free operating system with an extensive benefits.
6.16.11 Economic Return or revenue per unit of water

- In the SCIS revenue is collected on the basis of an irrigated area, which is not appropriate as compared to huge investment in the construction and maintenance.
- The pipeline water supply assures and control, the high yielding in crop production and obviously, economic returns will be increased. The pricing of each unit of water is possible with the help of volumetric water distribution system in the PCIS. Therefore, the revenue per unit of water shall be improved.

6.16.12 Equality in Water Distribution

- It is confirmed that, the tail end, farmers have always faced an injustice in water distribution. Due to the long distance and seepage loss, and the dominance of the head and middle location farmers, the allocated water does not reach to the tail ended farmers.
- The PCIS is regulated by valve system, there is no option for illegal water trapping, hence tail command area farmers will also get their allocated water.

6.16.13 Weed or Plantation Problem

- On the embankment of unlined canal weeds and trees are developed vigorously, which blocks the canal or reduce the canal capacity. It's an obstacle in the flow and it is resulting in the over topping or canal burst. Weed seeds which are rowdy in the agriculture are transported to fields.
- In case of PCIS there are no weed's and plantation problem and blockages. There is no chance of an external interference in the pipeline.
6.16.14 Malpractices and Pilferage

- No measurement or volume metric scale to the water discharge on the farm in the SCIS that promotes malpractices in the administration and distribution system. Unaccounted water withdrawal, unauthorized water lifting, bid of black money and water pilferages are caused for low efficiency.
- The volume metric scale to the water discharge and transparency in the distribution results in higher efficiency in the PCIS.

6.16.15 Social Conflict

- Due to the low efficiency the allocated water does not reach to the tail location stakeholders, the head location farmers tap water in the scarcity period, consequently the social conflicts are raised between regions. In the field level farmers oppose to field canal due to the fear of water logging, soil erosion, and dehydration of fertilizers.
- The allocated water will be fairly distributed in all sectors and within the command area, so very little risk of conflict in PCIS. On farm level the field canal should be underground, so there will be no chance for quarrel.

6.16.16 Environmental Problems

- The biodiversity of flora and fauna is also affected by the construction of the surface canal irrigation system. Water pollution, over irrigation and soil salinization and break down small drainage systems are environmental problems created by the SCIS.
- The underground pipeline will not spoil the natural environment and not befall a barrier on biodiversity of flora and fauna.
6.16.17 Modernization in system

- It is very difficult to adopt modern techniques in a conventional canal system like automation of the canal. There is no scope of digital management and no possibility to introduce pressure irrigation methods.

- PCIS is flexible to adopt modernization techniques and the system can easily converted into the digital or computerized management. Pressurized irrigation methods like drip and sprinkler shall be introduced in PCIS.

6.16.18 Irrigable Command Area

- There is no scope to increase the irrigable command area (ICA) in the surface canal irrigation system. However, with passing time, efficiency will be decreased and proposed command area may be deprived from the water.

- The maximum water loss eliminated in SCIS and the conserved water will be used for irrigate extra area of the command. As well as acquired land for SCIS shall be used for agriculture in the PCIS and increase the culturable command area (CCA). In case of LBC, after use of the PCIS, the saved water will serve an irrigation purpose to the additional 10106 hectares in the command (Figure 6.13).
Figure 6.13: Comparative Irrigable Command Area by SCIS and PCIS

Legend:
- Existing Canal
- Proposed Canal

Area under irrigation
- Nilwande High Level Left Canal
- Nilwande Left Canal

Source:
1) Survey of India (SOI) Topomaps Scale = 1:50000
6.17 Resume

The Analytic hierarchy process (AHP) with the GIS techniques and MCDA have been used for the site suitability analysis. Pairwise comparison matrix, normalized pairwise matrix, determination of criterion, rank assigned to criterion and weighed overlay analysis conducted for the fixing the most suitable site for pipeline canal. Considering the social, political and economic situation of the command area a five stage pipeline sketch of the model has prepaid. The five stage model for applying pipeline in the canal command area has been introduced. The comparative study between the SCIS and PCIS has been carried out in this chapter.

The chapter wise overview of the research study, suggestions about implementation of the pipeline canal, scope for further study, and specific limitations have occurred during the research work and conclusions are discussed in the next chapter.

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