CHALLENGES IN PLANNING DESIGN AND IMPLEMENTATION OF PIPE IRRIGATION NETWORK AT COMMAND LEVEL

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ABSTRACT

Irrigation conveyance facilities consist primarily of natural channels, man-made canals and pipelines. Natural Channels are used in their natural state or they may have been improved by man to increase their efficiency to convey water for irrigation use. Canals are designed hydraulically to provide the most efficient cross section for the conveyance of irrigation water. The overall efficiency that can be achieved for most efficient lined canal system has reached the upper limit which is about 35-60%. The Pipe Irrigation Network (PIN) will aim at making the efficiency about double (ie 70-80%) that of conventional Canal Irrigation Network (CIN). The PIN coupled with Micro Irrigation System (MIS) will further improve the efficiency. Planning, Design and Implementation of PIN at command level have certain challenges/problems such as siltation and clogging of pipes, heterogeneous land ownership, pumping cost, maintaining of minimum pressures, velocities; minimum and maximum; Chak/Sub-chak size, access problem etc have been discussed and addressed to the extent the extent possible in this paper.

1 Introduction

Historically Irrigation development in the country has been undertaken as Canal Distribution Network emanating from rivers, dams and reservoirs for the purpose of carrying water mostly through gravity up to outlets and from outlets to agricultural field through water courses or field channels. In earlier times canals were unlined; later on these unlined canals have been improved by lining to increase their water carrying efficiency which led to extend water deliveries to additional fields which had not been irrigated previously. Canals are designed hydraulically to provide the most efficient cross section for the transportation of irrigation water. There is no further scope in improving the efficiency of the hydraulically most efficient canals section with most efficient lining. The delivery efficiency of the canal is limited. Therefore the overall efficiency that can be achieved by canal conveyance and distribution has reached the upper limit which is about 35-60%.

With the increasingly greater demand on limited water supplies in many parts of country, there is an urgent need for its efficient utilization by reducing losses at various reaches in the irrigation system. Replacement of existing canals with pipe lines or new schemes with pipe lines wherever feasible in order to improve irrigation efficiency or to further extend the area of irrigated agriculture is the need of the hour. Field application of water through micro irrigation methods improves overall efficiency of the project to a great extent. Piped irrigation can be accomplished many a times through gravity and/or use of pumps to lift the water into the distribution network.

With rising population, demand for commodities and change in life style, more and more demand for water resources from other sectors is projected, leaving less water for irrigation as the availability is finite in nature. With rising population, per capita water availability has reduced drastically from 5177 cum in the year 1951 to 1567 cum in the year 2011. As per international standards, now India is already in water stress zone (if water availability is between 1000 to 1700 cum per year) with threats of climate change may further
aggravate the problem. By the year 2050, with projected population of the order of 1.6 Billion, the water availability will further reduce to 1140 cum nearing to water scarce situation. India as a country has to adopt itself to this changed scenario. Efficiency has to be brought in each water use activity including irrigation for sustaining the food, water, shelter and employment requirement of the human and animal population.

Piped Irrigation System provides one of such options which if implemented properly can curtail irrigation water demand without compromising with net irrigation requirement (NIR) but by improving the water use efficiency.

Piped Irrigation System consists mainly two distinct divisions; 1) Pipe Network for conveyance from source to outlet (This includes primary and secondary system as shown in Figure 1) and 2) Pipe network for application for micro irrigation. The two divisions together with collections chamber at outlet form a complete Piped Irrigation Network (PIN) from source to root while the two parts in isolation form a partial PIN.

2 Applications of Pipe Irrigation Systems

Pipe systems especially are to be preferred over open channel alternatives in the following situations.

(1) where poorly cohesive soils would result in high seepage losses from open channels,
(2) where variations in ground level mean that irrigable land cannot be reached by an open canal system.
(3) where water is both valuable in terms of the crops which can be grown and limited as evidenced by low reservoir capacity or restrictive controls on water abstraction from river or groundwater sources.

Because of shorter transit times for water from source to field, lower conveyance losses and the smaller volumes of water in the conveyance system, pipe systems can deliver a supply which is more flexible in both duration and timing, in a way not possible with open channel systems, so enabling intensification and diversification into higher value crops.

With most of a piped distribution system underground, rights of way problems are significantly reduced, allowing more direct and rational layouts to be chosen. Because outlet
location is not limited by topography, pipe systems are better able to accommodate existing patterns of land ownership with the minimum of disruption compared with new irrigation development using surface channel systems.

In many cases, social, environmental and institutional constraints will provide the boundaries for system design. Although system designs may be similar, operating systems often vary widely.

Under Ground pipe systems are most attractive where gravity supply is possible or where the water source requires pumping and the additional head necessary to overcome pipe and system friction losses can be satisfied without serious consequences of reduced discharge or increased costs.

3 Planning of PIN

The first step to plan piped irrigation is the identification; of source, water availability, proposed command area and finalization; of location of outlets and discharge cut-off schedule. Having done above, the next step is the fixation of layout of conveyance network (i.e. pipes layout) and optimization of diameters within the available head loss.

The type of PIN network based on the head difference among the outlets and source whether gravity or pump, based on the method of application whether low pressure or high pressure, based on the supply control whether Tree network or Looped network, based on the pressure control whether open network or closed network is decided.

A Piped Irrigation Network system consists mainly of buried pipes and is therefore relatively free from topographic constraints. The aim of the network is to connect all the hydrants to the source by the most economic and hydraulically efficient layout. The source can be a gravity reservoir, a pumping station on a river, a canal or well delivering water through an elevated reservoir or directly into the network.

Generally tree networks are adopted or considered since they cost less than looped networks. Loops are only introduced where it becomes necessary to reinforce existing networks or to guarantee the security of supply.

3.1 Principles of Network Planning

A method of arriving at the optimal network layout involves the following three step iterative process:

i. **Proximity Layout**: the source or the shortest connection of hydrants to source.

ii. **120° Layout**: where the proximity layout is shortened by introducing junctions (nodes) other than the hydrants.

iii. **Least Cost Layout**: where the cost is again reduced, this time by shortening the larger diameter pipes which convey the higher flows and lengthening the smaller ones.

![Figure 2: Proximity $120^\circ$ Layout - Case of 3 Hydrants](image)
3.2 Challenges in Planning

The main challenges in planning of PIN are;

- On-demand distribution imposes no specific constraints upon the layout of the network: where the land-ownership structure is heterogeneous, the plan of the hydrants represents an irregular pattern of points, each of which is to be connected to the source of water.
- Land pattern and ease of maintenance (accessibility of junctions, etc.) generally outweigh considerations of reduction of pipe costs/network costs.
- Siltation due to low velocity and discharge are main reasons for poor performance.
- Making the system, tampering proof and vandalism proof is a big challenge.
- Flat surface grade and huge discharge require larger diameter pipes. The pumping cost involved in such situation is a big burden.
- Pipeline layout should be parallel with ditch, trench and road, and avoid fill section segments and areas with possible landslide or flood. The land acquisition should be minimum to nil when laid parallel to existing communications lines. The Pipe network below the distributor off take should be entirely underground which results in little or no loss of farm land.
- Larger Chak size in PIN will lead to higher discharge and higher diameter pipes, while smaller chak size lead to longer lengths of small diameter pipes. A sub-chak size of 4-5ha shall be adopted in the conventional Chak size of 100 acres (40 hectares) for PIN.

4 Design of PIN

4.1 Hydraulic Design

In a simple Pipe Irrigation Network, the sub-networks are represented by an equivalent pipe. The network is categorized as pipes in series or parallel as shown in Figure 3(a) below.

![Figure 3- Simple and Complex Pipe Network](image)

A Piped Irrigation Network, where large number of branching loops and other inline elements such as control valves, pressure relief valves etc are there is called Complex Piped Irrigation Network. In the design of PDN, the objective is minimization of network cost, which is the sum of costs of pipelines. The principles of analysis of pipe network are:
i. The sum of the lengths of pipes in each link is equal to the length of the line.

ii. The algebraic sum of the head losses in a path from source to each demand node is not more than the permissible head loss in the path.

iii. The algebraic sum of the head losses in each loop is zero; and

iv. Principle of conservation of mass

v. All pipe lengths are non-negative

Minimize Cost = \[ \sum \sum C_{ij}L_{ij} \]

Subject to

\[ \sum L_{ij} = L_i \]

\[ \sum \sum S_{ij}L_{ij} = H_j - H_n^{\text{min}} \]

for all paths from Source Node (S) to Demand Node (n)

\[ \sum \sum S_{ij}L_{ij} = 0 \]

for all loops

\[ L_{ij} \geq 0 \]

for all \( i \) and \( j \)

The complex system pipe irrigation network as shown in Figure 3(b) can be solved with available software tools such as:

1) EPANET
2) KYPIPE
3) PIPE FLOW EXPERT
4) VADISO
5) LOOP
6) HARDY
7) LINGO/LIGDO
8) WATER GEMS

4.2 Structural Design

Pipe materials are generally considered to be rigid or flexible. A flexible pipe is one that will deflect at least 2% without structural distress. Metallic and thermoplastic pipes are considered flexible.

(a) Non-metallic pipes: The non-metallic pipe selection can be made based on the pressure rating and manufacturer specifications. However, if necessary, the checks for wall crushing and wall buckling may be carried out to ensure the structural stability depending upon the site and loading conditions.

(b) Metallic pipes: The design of metallic pipes involves; determination of wall thickness, check for deflection and check for buckling.

3.1 Challenges in Design

The design of PIN involves the following challenges;

i. Maximum permissible velocity: The higher the velocity, the greater the risk of damage through surges and water hammer. This risk particularly applies to pipes subject to uncontrolled starting and stopping. Anti surge devices shall be installed to control water hammer.

ii. Non silting velocity: When the water is silt rich, design velocity of Piped Irrigation Network should not be lower than non-silting velocity. Non silting velocity should be
determined by experiments. The maximum velocity may be limited to 3.0 m/s and minimum velocity shall not be lower than 0.6 m/s.

iii. Exit pressure at irrigation outlet/stand post for flow irrigation: A minimum effective head (i.e. H.G.L. – G.L.) of 0.6 m in normal cases and can take a minimum value not less than 0.3 m in exceptional cases should be provided at the most favourable location of the Chak.

iv. Exit pressure at irrigation outlet/stand post for Micro irrigation: In case of micro-irrigation, water will be delivered into Diggy or Ponds from which it is pressurized with pumps to suit micro irrigation pressures. Outlet pressure for micro irrigation systems with design working pressure between 0.2 MPa and 0.4 MPa shall be used.

To ensure equitable distribution, all outlets should have same residual head. In low lying areas if HG is more, it should be reduced by using lesser diameter pipes or valve

5 Implementation of micro irrigation at command level

The purpose of providing piped irrigation network is to provide timely and adequate supply of water to each holding by avoiding seepage and leakages through open channels. The benefits of piped irrigation can be achieved effectively when the PIN is clubbed with micro irrigation such as Drip or Sprinkler irrigation systems depending upon the type of crop.

5.1 Challenges in implementation of PIN & Micro Irrigation

Siltation and clogging of pipes: Main reasons for poor performance are – siltation due to low velocity and discharge. Piped Irrigation Network may not be suitable if the irrigation water contains large amount of sediments. Desilting arrangement would be necessary in such cases. Silt particle of size greater than 150 microns shall be removed to prevent clogging of nozzle of drip points in micro-irrigation.

Non uniform specifications of MIS by Formers: Where the choice of MIS is left to formers, they will not adopt MIS with uniform specifications (flow rate, discharge, and pressure). This will cause inequality in distribution. Water User Associations (WUA) must be formed and the system should be implemented to such non uniform specifications. One such project which is has good performance in irrigation management by WUAs is Guhai reservoir project, Gujarat

Pumping of water from the system by the farmers: Pumping of water in MIS system should be maintained by WUA. Pumping by individual formers will lead to stopping of flow to downstream formers. The system maintained by WUA will ensure uniform and timely supply.

Internal rivalry amongst farmers: Poor performance results from internal rivalry amongst farmers (viz Karjan Reservoir Project, Gujarat)

Vandalism: Breakage of scour valves and stealing of brass parts, chocking of pipes to stop the flow to downstream farmers, etc.
**Access problem:** Access for maintenance during standing crops is also a challenge which can be overcomed by introducing crop compensation into policy.

**Problems of Funds:** Partial implementation of MIS under a particular out will lead to skewed distribution within the outlet command. State governments & agriculture department should devote the limited funds to fully implement MIS outlet by outlet. In any new PDN project at least 10% area should be covered with MIS for demonstration to farmers

### 6 Conclusion

- The primary system of the PIN should be laid parallel to existing communications systems so that the land acquisition shall be minimum to nil.
- The secondary system to the extent possible shall be laid underground and the tertiary system which goes in farm lands shall be completely underground.
- The PIN networks coupled with MIS will yield maximum water efficiency.
- PIN having source directly from river/small reservoir will have large amount of sediment. Desilting chamber is necessary to remove sediments. Silt particle of size greater than 150 microns shall be removed to prevent clogging of nozzle of drip points in micro-irrigation.
- Water User Association formed must be formed from the beginning of planning and implementation.
- WUA should maintain the MIS with the support of qualified vendors for successful performance.

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