OPTIMAL UTILIZATION OF IRRIGATION WATER BY USE OF PIPE DISTRIBUTION NETWORK (PDN) INSTEAD OF CANAL DISTRIBUTION NETWORK (CDN) IN COMMAND AREA

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ABSTRACT

Water, which is a vital valuable, finite, renewable and shared resource demanded by several sectors, should be managed optimally. The stress due to unavailability or limited availability of water is growing at alarming rate. To cater this, construction of new water resources projects, improving water use efficiency of existing projects, use of advanced technology for water application and recycling of water are some of the solutions.

Focusing on irrigation sector of India, particularly after independence, more than half of all public expenditures on agriculture have been spent on irrigation alone. As a result, land area under irrigation expanded from 22.6 Mha in 1950 to 59 Mha in 1990, which is about 161% increase in four decades. But, this increase was just about 33% of the estimated potential. To irrigate remaining 67% land, and to fulfil all demands by several developmental sectors simultaneously, new water resources projects may be planned. But this involves huge investments in construction and maintenance of projects, issues of water availability and social problems associated with land acquisition and rehabilitation. Therefore, there is an urgent need to search innovative alternatives to efficiently use the water stored in existing reservoirs.

Irrigation sector is the biggest consumer of water as more than 80% of available water resources in India are being presently utilized for irrigation purpose, serving at just 25 to 40 % water use efficiency. Thus, there is large scope for improving efficiency in this sector to avoid loss of 60 to 75 % water.

The objective of this paper is to emphasis on the use of Pipe Distribution Network (PDN) instead of Canal Distribution Network (CDN) in command area of irrigation project to improve efficiency of water use. By virtue of PDN the water use efficiency can be improved to 70 to 80 % from existing efficiency of 25 to 40 %. Thus there is about two to three times increase in the water use efficiency for irrigation, which means that there will be 55 to 65 % improvement in overall water use efficiency as irrigation itself is 80% shareholder in water use. In other words, from the same reservoir, double the command areas could be irrigated, or additional equal volume of water is made available which can be distributed to another purposes. To backup above statements, this paper is based on the design of PDN of Nagthana-2 Minor Irrigation (MI) project, located at Amravati district of Maharashtra state, which was initially designed to irrigate Culturable Command Area (CCA) of 600 Ha by conventional CDN, and now planned for gravity PDN and result implies that same volume of water could irrigate CCA of 1200.

In this paper, focus is placed on the use of PDN instead of CDN in command area of irrigation project to improve efficiency of water use. By virtue of PDN the water use efficiency can be improved to 70 to 80 % from existing efficiency of 25 to 40 %.

1) WATER STATISTICS

According to United Nations Environment Programme (UNEP), it was estimated that the total volume of water on Earth is about 1400 million km^3, which is enough to cover the earth with a layer of 3 km depth of water. Freshwater resources are estimated around 35 million km^3, or in other words, it is about 2.5 percent of the total volume. Of these freshwater resources, about 24 million km^3 or 67 percent is in the form of ice and permanent snow cover in mountainous regions, the Antarctic and Arctic regions. Further, around 10.5 million km^3 or 30 percent of the world's freshwater is stored underground in the form of groundwater (shallow and deep groundwater basins up to 2000 metres, soil moisture, swamp water and permafrost). This constitutes about 97 percent of all the freshwater that is potentially available for human use. Freshwater lakes and rivers contain an estimated 0.105 million km^3or around 0.3 percent of the world's freshwater.

If the next world war happens; it may well be triggered by water scarcity across the continents. It has been already found that the one third of the world is suffering from water shortages. Increasing demand for water with rapidly growing rate of population, industrial growth, inadequate rainfall, uncontrolled use of water and climate change are some of the reasons behind it. As per the United Nation's estimate, water scarcity already affects every continent. Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage.

2) INDIAN WATER SCENARIO:-

a. Water Availability:-

Coming to the water resources of India, the main source of water is annual precipitation including snowfall and it was estimated to be of the order of 4000 km^3. The total water resource potential of the country, which occurs as natural run off in the rivers is estimated at 1869 km^3 considering both surface and groundwater into account. The distribution of water resources potential in the country shows that the national per capita annual availability of water at 1820 m^3 in 2001 is estimated at 1588 m^3 in 2010. There are various constraints, such as topography, uneven distribution of resource over space and time, therefore, it has been estimated that only about 1123 km^3 can be put to beneficial use, out of which only 690 km^3 is surface water and rest 433 km^3 is ground water. A total storage capacity of about 225 km^3 has been created in the country as a result of construction of major & medium projects. The Projects under construction will contribute to additional 64 km^3 while the contribution expected from projects under consideration is 107 km^3. Thus likely storage available will be 396 km^3 once the projects under construction or consideration are completed against the total water availability of 1869 km^3 in the river basins of the country. [1]

b. Irrigation Potential:-

It is estimated that the total ultimate irrigation potential (UIP) of India stands at about 140 Mha, out of total geographical area of 328.7 Mha. Till 2007, 123 Mha irrigation potential was created with the help of Major, Medium and Minor irrigation projects. But in fact, the utilised irrigation potential was just 91 Mha, due to various constraints, such as less storage, diverse use, losses etc. Thus, there is gap between irrigation potential created and utilised, and it is upmost important to minimise the gap. This can be achieved by use of pipe distribution network.

c. Financial Aspects:-

At constant prices (1993 - 94 = 100), the expenditure on irrigation sector is estimated to have increased from Rs. 6,840 Crore in 1st Plan to Rs. 55,489 Crore in the X Plan. It has been observed that the approximately Rs. 5 lakhs is cost of bringing 1 ha land under irrigation facility. Further, to store 1000 m^3 water, approximately expenditure of Rs. 50,000 is required, at 2011 price level. With this rough estimate, in order to irrigate 140 Mha area, Rs. 70,000 billion will be required. From storage point of view, to store 396 km^3 water, Rs. 20,000 billion will be required. In order to succeed in reaching to UIP of 140 Mha from current position of 123 Mha, additional financial burden will be about Rs. 8,500 billion. Thus, it is clear that to complete ongoing and proposed water resources projects, huge investment is needed. In order to minimize this huge expenditure, the efficient utilisation of the water available in existing projects is crucial issue. If instead of 40 percent overall project efficiency of existing CDN, irrigating 91 Mha, PDN is implemented, then overall project efficiency can be reached to 80 percent which can irrigate another 91 Mha. Thus, without spending in new construction, desired UIP could be achieved, with little expenditure in conversion of existing CDN in to PDN.

3) WATER CRISIS IN INDIA:-

The thirst of water for India's rapid development is growing day by day. In spite of adequate average rainfall in India, there is large area under the less water conditions/drought prone. There are lot of places, where the quality of groundwater is not good. Another issue lies in interstate distribution of rivers. Water supply of the 90% of India's territory is served by inter-state rivers. It has created growing number of conflicts across the states and to the whole country on water sharing issues. India's population is expected to increase from 1.13 billion in 2005 to 1.66 billion by 2050. Out of that the urban population is expected to grow from 29.2% of the total population in 2007 to 55.2% by 2050. First and foremost result of the increasing population is the growing demand for more food-grains and allied agricultural produce. This will add pressure on the existing allotment of water to various sectors, and may create water crisis in coming period.

Some of the major reasons behind water scarcity along with population growth are increasing construction/ infrastructure development activities, massive urbanization and industrialization throughout the country, climatic change and variability, lack of implementation of effective water management systems. All of this will result in increased consumption of water. That is why there is urgent need to address the issue of water scarcity in India to make better policy decisions which will affect its availability in future.

4) WATER DEMANDS IN 2050:-

The requirement of fresh water both for irrigation and other uses is growing continuously. The requirement of water for various sectors has been assessed by the National Commission on Integrated Water Resources Development(NCIWRD) in the year 2000.This requirement is based on the assumption that irrigation efficiency will increase to 60 % from the current level of 35 -40 %. The total water demand for all the uses is likely to be 1180 km^3 by 2050 as per NCIWRD. Though major share of this would be consumed for irrigation purposes, this in no way undermines importance of providing potable drinking water. In fact, it may be presumed that drinking water provision would have to be given an added thrust since the lack of such facility is likely to entail serious social, economic and health impact.

In order to fulfil demand in 2050 it is required to store 1180 Km^3 water. To achieve this, approximately total expenditure will be Rs. 60,000 billion at 2011 price level. Till now, projects having storage capacity of 225 km^3 are completed, projects having storage capacity 64 km^3 are under construction, and still 891 km^3 water needs to be stored. Assuming 433 km^3 as ground water, India needs water resources project construction activities for storing remaining 458 km^3 water, which will require Rs. 23,000 billion. If, PDN in existing and ongoing water resources project is implemented, then approximately 100 km^3 water could be saved from 289 km^3, which would otherwise need expenditure about Rs. 6,000 billion.

5) DISTRIBUTION NETWORK (DN) :-

A well planned, designed and constructed distribution network for irrigation purposes should deliver water in the right quantities, and rate, with the right pressure and at the right time without causing management and operational problems to the water authority or to the consumers. To this end, the distribution system has to incorporate all necessary structural and operational aspects such that the above requirements and any constraints imposed at the source or in other parts of the system are satisfied. Distribution systems vary greatly in size and complexity, from spreading of flood water over adjacent areas to the conveyance and distribution of surface water or groundwater to areas of intensive agricultural development. [2]

6) EFFICIENCY OF PROJECT :-

The efficiency of project can be estimated by multiplying the efficiencies of individual components of the irrigation project, such as main canal, branch canal, distributaries, minors, field channels, and field application efficiency etc. The field irrigation methods are the traditional surface gravity - furrow, basin, border etc., with field application efficiencies of 60–70 percent, i.e. additional water losses of about 20–27 percent of the total. Studies from many countries show an average of 33 percent water losses during conveyance through a 100 m conventional channel. It has been observed that the overall project efficiency of the project, at the stage of design itself turns out in the range of 40 to 50 percent. But, in fact, due to various constraints, it was assessed that the overall project efficiency during operation is only 20 to 35 percent.

7) PIPS DISTRIBUTION NETWOK (PDN) :-

A PDN system is a network installation consisting of pipes, fittings and other devices properly designed and installed to supply water under pressure from the source of the water to the irrigable area. The basic differences between CDN & PDN are [3]:

- The water flow regime:- In CDN, the size of the stream should be large, while in PDN very small flows, even 1 m^3/ha, can be utilized.
- The route direction of the flow:- In CDN, the irrigation water is conveyed from the source and distributed to the field through open canals and ditches by gravity following the field contours, whereas, in PDN, irrigation water is conveyed and distributed in closed pipes by pressure following the most convenient (shortest) route, regardless of the slope and topography of the area.
- The area irrigated simultaneously:- With CDN, the water is applied in large volumes per unit of area, while PDN systems distribute the water at small rates over a very large area.
- The external energy (pressure) required: Traditional surface gravity methods do not need external energy for operation, while piped irrigation systems require a certain pressure, 2-3 bars, which is provided from a pumping unit or from a supply tank situated at a high point.

8) EXPERIENCE IN PDN AND CASE STUDY

Several irrigation systems in southern USA, Canada and Spain are converting water transport from surface canals to rubber-gasketed jointed reinforced concrete pipes. The 20,000 ha irrigation system in Hidalgo County, Texas, has proven viable, with water and energy savings, reduced health risks and improved vector control. Spain has similarly retrofitted its 1,000-year-old Mula system, and so has Alberta in Canada with buried pipes in place of open canals. The motive for pipelining in these countries is to improve irrigation service, save water from evaporation and seepage, and provide pressurized irrigation. Many of these countries are land-abundant and have no need to save land. But in the Indian context where population pressure on farmland is high, PDN can reduce the need for much of the productive land that surface canal networks require.

In India, while CDN is commonly adopted, still, farmers have aggressively been using lifts and pipes to irrigate upland areas that have been written off as ‘non-command’. In the Upper Krishna Basin in Maharashtra, some 350,000 ha are irrigated by buried pipe distribution in lift irrigation systems established by individual farmers, farmer cooperatives and sugar cooperatives over several distributaries of the Krishna River. There are similar examples of the same in various part of the country.

The present paper is based on the outcome of PDN design for Nagthana-II MI Project, Tal-Warud, Dist-Amravati, Maharashtra. Originally it was proposed to have conventional CDN to irrigate CCA of 600 Ha area in command area. The PDN was designed for the same cropping pattern and it was observed that the same quantum of water could irrigate about 1200 Ha area. Thus, PDN carrying discharge under pressure would serve as a pilot scheme for switching over to this method for increasing efficiency of water conveyance. Water is planned to be supplied to farmers on volumetric basis by using closed conduit system. The farmers in command area have shown overwhelming response to the concept of volumetric basis, which would provide option of adopting cropping pattern to suit market demand.

9) EFFICIENCY OF CDN AND PDN:-

The major component of loss in the PDN is frictional loss, and it has been estimated that a well planned, carefully designed, properly constructed, and systematically operated PDN have the potential to operate at the efficiency of 70 to 80 percent. As operational efficiency of CDN is in the range of 20 to 35 percent, and about 80 percent water is utilised for the irrigation purpose, if this efficiency is increased to say 70 to 80 percent, it implies that there will be saving of more than 50 percent of water stored in the water resources project. Therefore, a greater surface may be irrigated with a fixed quantity of water. Further, PDN overcome the topographic constraints and make it easier to establish water fees based on volume of water consumed because it is easy to measure the volume of water delivered. Consequently, a large quantity of water may be saved since farmers tend to maximize the net income by making an economical balance between costs and profits. Thus, because the volume of water represents an important cost, farmers tend to be efficient with their irrigation. Operation, maintenance and management activities are more technical but easier to control to maintain a good service. The huge gap between the water wasteful in CDN and the highly efficient improved irrigation techniques can be eliminated with the implementation of the PDN.

10) BASIC LAYPUT OF PDN

The basic layout of the PDN consists of a simple control head, a pipe distribution network and the hydrants.

a) Control Head:-

The control head includes the necessary regulating valves (shut off, check valve, air valve) placed on a piece of galvanized steel threaded pipe, 60 cm above ground surface, with tee outlet for taps and pressure gauge. This arrangement, at a later stage, can easily be converted to a more sophisticated control unit, suitable for micro-irrigation systems.

b) Pipe Distribution Network:-

The main and sub-main pipelines (distribution network) can be of rigid PVC, buried underground. On hilly areas other kind of pipes are used on surface ground, such as the flexible black Polyethylene (HDPE), the Quick Coupler light steel or the galvanized steel threaded pipes. The latter is used only up to the 3 in size, because of the high cost.

c) Hydrants:-

The hydrants are rising on surface equipped with a shut off valve (gate valve) capable to deliver part of the systems flow or the whole of it to the manifold open ditches. At a later stage portable lightweight pipes (quick couplers aluminium, light steel, lay-flat hose, black polyethylene, etc.) can be attached to the hydrants, replacing the manifold open ditches, for the final delivery. From the hydrants the irrigation water is discharged directly to the manifold open earth channels for diversion to the furrows, the basins or the strip borders.

11) DESIGN PHYLOSOPHY OF PDN :-

The engineering design is the second stage in irrigation planning. The first stage is the consideration of the crop water requirements, the type of soil, the climate, the water quality and the irrigation scheduling. The water supply conditions, the availability of electricity and the field topography also need to be considered. The economic considerations, the labour and the know-how also need to be taken into account. The irrigation system is selected after a thorough evaluation of the above data and the computation of the system's flow, the irrigation dose, the duration of application and the irrigation interval.

The PDN combines both the features of the open surface methods and the pressurized closed pipe techniques. The design criteria and the parameters are too many as compared to the simplicity of the installation. The topography of the area (shape, slope, etc.), the type of soil, the size of flow and the method of water delivery to the crop (furrow, basin, border or other) should be carefully examined. The take-off hydrants must be placed at the highest points of the field plots and at the right distances to enable efficient practices of the gravity irrigation techniques through the manifold ditches or by drip or sprinkler techniques, if enough head is available at the delivery point.

The most important criterion to be considered during the design is the possibility for future extension of the network for the adoption of any other low-medium improved irrigation system, such as sprinkling, drip, spitters, etc., with the minimum expenses. Then the careful design of a flexible skeleton-piping network, suitable to serve all methods of irrigation and water delivery techniques is of major importance.

12) STEPS IN DESIGN OF PDN :-

The steps in designing water distribution networks are [4]

a) Conducting topographic surveys and preparation of maps.

The strip of land lying between the source of water supply and the distribution area is surveyed to obtain the levels for fixing up the alignment of the main pipe line. The distribution area is also surveyed and detailed maps are prepared showing the positions of roads, streets, lanes, residential areas, commercial locality, industrial areas, etc. A topographical map of the area is prepared to locate the high and low areas.

b) Preparation of tentative layout.

A tentative layout of the PDN is then marked, showing the location of the valves, distribution minors, sub-main laterals, and hydrants etc. The whole area is divided into smaller chaks of size 3 to 4 Ha. The length of pipelines should be kept as short as possible.

c) Calculation of pipe diameters.

The hydraulics of pipe flow have been studied for a long time and quite a number of empirical and more physically-based formulas have been developed e.g. to relate flow rates to pipe diameter, head loss and material properties. Although laminar flow occurs (e.g. in long path emitters in drip irrigation), most practical problems of irrigation water flow in pipes have turbulent flow conditions. For steady incompressible flow through pipes, expressions like the Weisbach-Darcy formula have been developed, in which a friction factor appears. For this factor often the Colebrook-White formula is used, for both smooth and rough pipes, and to ease its solution, the Moody diagram is often used.

The design of PDN is based on parameters such as, available head from distribution point to the outlet, length, area under outlet, cropping pattern etc. Using Darcy-Weisbach equation diameter of pipe required is computed. In order to keep equal discharge in all the outlets in the command, reducing diameter pipes are proposed in PDN.

13) ADVANTAGES OF PIPE NETWORK OVER CANAL NETWORK

Beside improved water use efficiency, other benefits of PDN can be listed as below-

1) Saving in cost of land acquisition, which is very sensitive issue in the India, as per capital land holding is very less.
2) The use of thermoplastic pipes and fittings, made of unplasticized polyvinyl chloride (rigid PVC), low density polyethylene (LDPE), high density polyethylene (HDPE), and polypropylene (PP), which are manufactured in almost every country in many sizes and classes, has reduced the cost of PDN installations to a relatively low level at a time when CDN are becoming increasingly expensive.
3) Saving in maintenance cost of canal structures and earthwork. In the CDN, expensive operations are carried out to prevent damage caused by roots; seepage through banks; the spread of weeds; siltation and sedimentation; clogging of outlets and gates; etc. Where as, in PDN, no maintenance or continuous repair of constructions are required. The basic component parts of the PDN require minimal maintenance during the first seven years. The complete PDN system requires a yearly maintenance costing about 5 percent of the initial investment.
4) Part of un-command area under CDN can be brought under irrigation.
5) The losses due to, evaporation, seepage, phreatophytes, and leakage in gates, spillways, etc. in the CDN can be avoided by PDN, in which, no such losses occur.
6) Water logging can be minimized.
7) PDN is feasible in any type of strata i.e. hard rock, BC soil, saline land etc.
8) Advanced technologies such as drip, sprinklers, sub-surface irrigation system of irrigation can be implemented.
9) May be operated 24x7x365 basis.
10) ‘Equitable water supply’ and ‘from tail to head’, irrigation principle may be achieved.
11) Accurate volumetric supply of water can be ensured.
12) Minimized manual control involved in operation of network.
13) The man-hours needed in the piped systems range from one-tenth to one-quarter of those required for open canals. Any person can easily operate the piped systems, while the open canals can require skilled labour.

14) LIMITATIONS OF PIPE NETWORK

1) Great care in design and construction of PDN in required.
2) Silt must be extracted from water before feeding to PDN.
3) Being recent topic in India, more study and experience in this field is required.

15) CONCLUSION

Implementing gravity based PDN improves overall water use efficiency to 70 to 80 % as against conventional CDN having water use efficiency as 25 to 40 %. In a view of above discussion, it is recommended to implement PDN to the ongoing Lift Irrigation Schemes (LIS) as pressure head is easily available and other ongoing irrigation projects as well in first phase. In second phase conversion of existing CDN in to PDN in part or whole command area, depending on techno-economic feasibility may be exercised.

16) REFERENCES

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BRIEF PROFILE OF THE AUTHORS

Er. Pravin Shivaji Kolhe, graduated in Civil Engineering from the University of Pune in 2004, with Gold Medal. He obtained a MTech. in Civil Engineering at the IIT Kanpur in 2007, and he is pursuing MBA in Finance and PG Diploma in Management of Resettlement and Rehabilitation from IGNOU, New Delhi. Since 2007, he is working as Assistant Executive Engineer at Water Resources Department, Government of Maharashtra, specialising in construction of irrigation projects. In Mar 2012, he was promoted as Executive Engineer at MI Division No.-2, Akola, Maharashtra holding charge of 7 under construction irrigation projects and 8 completed projects benefiting command area.