Vol. 45, No. 1, pp 40-44, 2017
Indian Journal of Soil Conservation
Online URL:http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Design and development of gravity flow water conveyance system for irrigation in Himalayan foot hills

Ambrish Kumar[1], B.L. Dhyani, Bankey Bihari, D. Mandal, Charan Singh, Sujeet Desai[2], S.K. Shrama and Sweta Garg

ICAR-Indian Institute of Soil and Water Conservation, 218-Kaulagarh Road, Dehradun-248 195, Uttarakhand; [2]ICAR-Central Coastal Agricultural Research Institute, Goa.

[1]E-mail: aktswc@yahoo.com

ARTICLE INFO

Article history :
Received : September, 2016
Revised : December, 2016
Accepted : February, 2017

ABSTRACT

Increasing demand of water for industrial, domestic and power sectors necessitates urgent need for development of water saving technologies to ensure accessibility of water to every field (*Har khet ko pani*) through following the approach - "*per drop more crop*" in agriculture. Efficient water management in agriculture is the major challenge to ensure sustainable food production in India. While, the situation is more aggravating in mostly rainfed type of farming in hill and mountains. Low productivity and cropping intensity, subsistence level of farming is attributed to poor water resource development in the hilly areas. To enhance the productivity and livelihood in the Himalayan foothills, a participatory gravity-flow Irrigation System has been developed with major emphasis on the participation of beneficiary farmers in all activities starting from surveying, planning, implementation, monitoring and operation of the system. In this endeavor, 1830 m GI pipeline (100 mm diameter) from source to Distribution Tank (DT) as a water conveyance and 1500 m PVC pipeline (110 mm) as a water distribution are laid out in the command area (26.28 ha) in the adopted villages-Pasauli and Devthala of Dehradun district in Uttarakhand.

The conveyance efficiency was recorded >95% of the system starting from source to remotest riser in the command area. Discharge of randomly selected risers were taken in 2016 and found a 10-16% variation between designed (estimated) and observed data. Check basin border size for efficient irrigation were optimized using SIRMOD. Productivity of major crops increased by 48% with enhanced cropping intensity by 29% due to intervening crop of *Toria* in between Maize-Wheat sequence. Cultivation of *rabi* wheat on fallow land resulted increased additional net income of ₹ 17500/- ha.

Key words:
Gravity flow system,
Participatory irrigation,
Water conveyance system,
Underground PVC pipeline,
On-farm water managment

1. INTRODUCTION

Himalayas is environmentally sensitive, economically marginalized and densely populated in proximity of the arable lands is highly vulnerable to the impacts of these changes that may cause a substantial decrease in availability of water for drinking and food production, and consequently increase the vulnerability of food and agricultural systems in the entire region (Cline, 2008; ICMOD, 2007), that aggravate the situation of already existing Critically Diversified Risk prone Agriculture (CDRA). In the prevailing system under non-availability of irrigation water, farmers grow rain-fed cereals with very low yields. However, farmers use water of low-discharge springs (discharge <20 l/min) at very small scale in a unsystematic and scattered manner of vegetable production. Plant to plant hand watering is the most efficient water application method, but it requires a huge amount of labour.

The study area, comprising a village cluster-Gadoria, Devthala, Pasauli, and Dungakhet, is about 40 km away from Dehradun on Vikasnagar - Langha Road in Uttarakhand. The area represents a typical sub-tropical climate with high intensity storms during the rainy season and scanty rainfall there after. The area is drained by two torrents, namely Utmadi Rao (torrent) and Gauna torrent. Undulating topography, faulty land management practices coupled with high intensity storms result in high runoff and soil loss from the area during the rainy season while acute water shortage is experienced in the lean period. Preliminary survey conducted in 2005 indicated that out of total 321 farm families of these villages, 82% belonged to socially backward (SC, ST & OBC) and about 80% were economically poor. Total agricultural land of the four villages is 165.08 ha and major portion (about 85%) of it is rainfed. The irrigated area in Dungakhet, Pasauli, and Godaria was 20, 11 and 98%, respectively but Devthala had only rain dependant agriculture. Owing to meager irrigation facility, Pasauli and Devthala villages were selected for the intervention of water resource generation.

Keeping all these in view, a major activity on water conveyance and water resource generation under the project- 'Participatory Dissemination and Assessment of Land and Water Management Technologies for Livelihood Security in Rainfed Areas of North Western Himalayas, which was funded by the Ministry of Rural development, was envisaged. In this endeavor, rain-fed cultivable lands of the villages - Pasauli and Devthala were selected for setting up a water conveyance system towards developing irrigation facility following the participatory approach.

2. MATERIALS AND METHODS

Location and Plan of the Water Conveyance System

In participatory rural appraisal and subsequent topographical engineering survey, a site situated at latitude - $30^0$27'40.16"N, longitude -$77^0$53'59.77" E and altitude - 745 m amsl in a Serukhala perennial stream, was identified to tap the surplus water for creating an irrigation facility in Pasauli and part of Devthala villages located down the water source. The minimum lean flow recorded during the study period (2005-2010) was 11.4 Litre/Second (LPS). An elevation difference of 36.5 m between water source and delivery point at the head of command area indicated technical feasibility for smooth gravity flow. The plan consisting of water conveyance, water distribution and water appliction sub-systems is depicted in Fig. 1.

Conveyance sub-system: It covers the part of system from source to distribution tank which is constructed at the head of the command area, and consists of intake structure, GI pipeline and distribution tank.

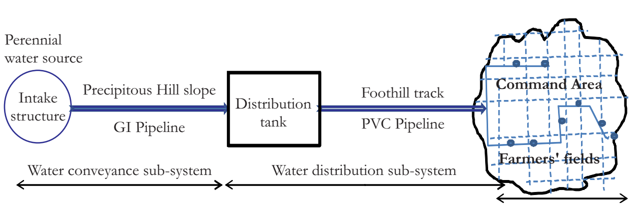

Fig. 1. End to end approach of the water conveyance system

Distribution sub-system: In order to minimize the cost of the system, PVC pipes of 110 mm ϕ with pressure 8 kg sq^{-2} cm was planned to lay out from the distribution tank to the command area with an objective to distribute the water to the each beneficiary farmer field spread in the command area (26.5 ha) with required 10-12 LPS discharge.

Application sub-system: For effective water management, the command area was divided into 19 Unit Command Areas (UCA), and a UCA covers about 1.5 ha. At the head of each UCA, one riser (outlet) was devised to be fitted on the PVC pipeline to deliver water uniformly.

Design Discharge of the Conveyance System

For the design of discharge and dia, the following equations were used.

i) Computaion of the flow velocity using Hazen-William equation: $V=0.849 \times C \times R^{0.63} \times S^{0.54}$ ...(1)

V=Velocity of flow (m/s); C= Hazen-William coefficient; R= Hydraulic radius (m); S= Energy slope (m/m).

ii) Computaion of flow velocity using Darcy-Weisbach equation: $H_f = 2f\,Lv^2/gd$; or $V=\sqrt{Hgd/2fL}$ ...(2)

h_f - head loss (m); f - friction factor; L - length of pipe (m); d - inner diameter of pipe (m); and g - acceleration due to gravity (m/s^2).

For turbulent flow through smooth pipes, f value was calculated using Blasius equation:

$f = 0.079/(Re)^{1/4}$ and $Re = dV/\nu$ ...(3)

Re- Renolds number; v- Kinematic viscosity of water (m^2/s)

i) Discharge, $Q = A \times V$ ...(4)

Where, A - Cross-sectional area of pipe.

3. RESULTS AND DISCUSSION

Water Conveyance

Water conveyance sub-system from water source to the distribution tank, connected by GI pipeline with hydraulic control measures is shown in the Fig. 2.

Discharge at Distribution Tank

By using Hazen-William equation mentioned above and considering C = 120, d = 0.1 m, L = 1900 m; the velocity arrives as 1.17 m s^{-1} and discharge as 9.5 LPS. While applying Darcy-Weisbach equation with f value as 0.0045 (calculated by using Blasius equation); discharge was found to be 10 LPS.

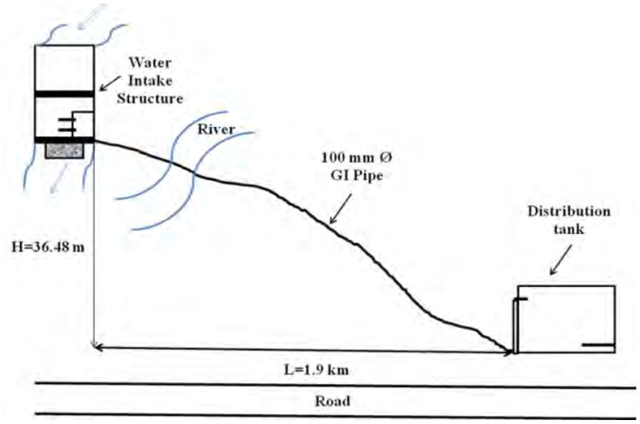

Fig. 2. Layout of water conveyance from intake structure to distribution tank

Intake Structure

The structure was constructed in the stream as 2-tier chambers in a cascading manner as upper and lower (Fig. 3). First, stone masonry cutoff wall, depth - 1.20 m, length - 8.50 m and thickness - 0.50 m, was constructed for setting up the upper chamber in order to make a bypass arrangement for uninterrupted flow with the adequate head to watermill lying just below the selected site. For this purpose, a low height (0.8 m) wall (cut-off wall) was raised above the bed surface towards maintaining the adequate head required for operating the watermill as owner of the watermill raised his concern about insufficient head for running the watermill. RCC headwall, height -2 m, length -7.4 m and wall thickness -0.50 m was constructed at a distance of 4m from the cutoff wall for the lower chamber as the capacity of water storage of lower chamber was comparatively large. Side walls, thickness -0.5 m, of both the chambers were made up with stone masonry. In order to check sub-surface water flow, the foundation of the wall was extended deeper to form an impervious barrier below the head wall. An inlet well, rectangular in shape and 1 x 1 x 2 m in size was set up at down, left end of the RCC headwall of the lower chamber (Fig. 3). It was connected with lower chamber by perforated GI pipe of 120 mm that acts as a filter. For smooth inflow to the inlet, two GI pipes of 3 m long each with 1.25 mm ф holes (as a perforation) were made. The opening space on each pipe was kept 40%, so that hydraulic friction by constriction of flow into the holes would not affect the smooth flow into the inlet well. Filter materials such as gravels, pebbles and stones were packed around the filter pipes in three layers, *viz.,* outer layer with 10-20 mm size of gravel, second layer with pebbles of size (>20 mm) and third inner layer around the perforated pipes with stones. The reason behind the arrangement of filter is to make the flow free from any blockage in the pipe. For water conveyance, the main GI pipeline was fixed at a height of 45 cm from the bottom of inlet well, so that the fine soil particles get settled on the bottom of inlet well (Dhyani *et al.,* 2015).

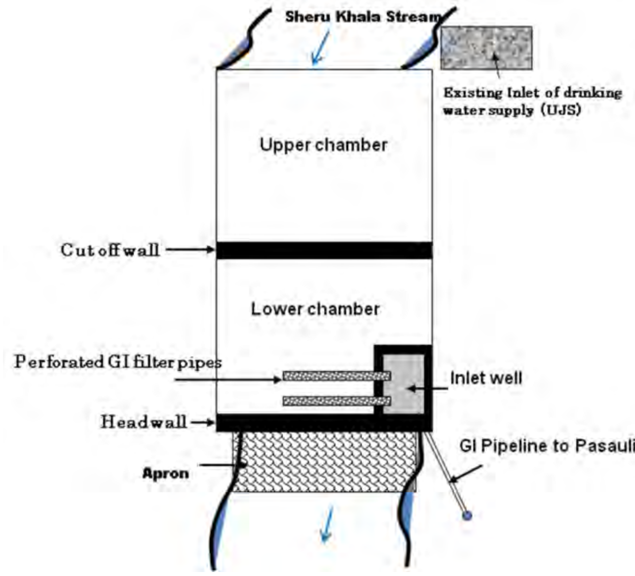

Fig. 3. Plan of the intake structure of the water conveyance system

Laying of GI pipeline

GI pipeline, 100 mm ф, was laid from inlet well to a distribution tank located at the head of the command area, covering a distance of 1.9 km. A sluice valve was fixed on the pipeline near the inlet well in order to control the flow or for the purpose of repair and maintenance of 1.9 km long pipeline laid on the unstable and precipitous slopes of Gauna river in Outer Himalaya. At 185 m from the source, the pipe was laid underground to cross the river which is 18 m wide. For protection of the pipe from flowing debris in the river, particularly in the monsoon, gabion barrier on the down side of the pipeline along the width of the river was erected. A perusal of Fig. 4 showing the longitudinal section of the proposed pipeline reveals the ground surface is 3-4 m above the hydraulic line, drawn with the data collected from surveying the line, in the segment between 1600 m and 2000 m. Thus, a trench with varying depth (3 to 4 m) in the elevated segment was dug befitting with the hydraulic gradient. The main conveyance GI pipeline was connected with the distribution tank which is located in a drop of 36.48 m with reference to the elevation of the water source.

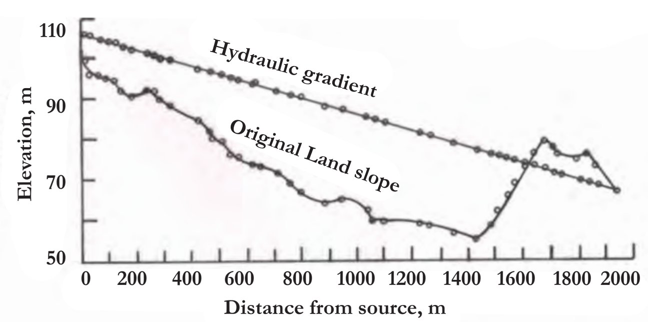

Fig. 4. L-section of line between source and distribution tank

Distribution sub-system

A masonry tank of size (Top: 7.4 x 5.5 x 1.8 m) with sloping inner sides and a capacity of 50,000 liters was constructed at an altitude of 709 m amsl and was fed with water conveying through the main GI pipe by gravity flow from the source. A gate valve was fixed to the main GI pipe before delivering the water into the tank with an objective to control the discharge of incoming pipeline.

Distribution pipeline (PVC)

In order to minimize the cost of the system, PVC pipes of 110 mm ф with pressure 8 kg cm^{-2} was laid out in the command area, instead of GI pipes. It was laid out from the distribution tank in the command area with an objective to distribute the water to each farm of the beneficiary farmers. A plan of the distribution underground PVC pipeline is shown in Fig. 5. A gate valve was fixed on the pipeline near the DT to control the flow into the distribution pipeline. A small segment (185 m) of distribution line was laid with GI pipeline (100 mm ф) from DT to Diversion Box as there is crossing of the road (Langha to Dehradun) at two places in this segment. For efficient management of irrigation, at the end of 185 m of GI pipe segment, a diversion box with gate valves were set up to regulate and distribute the flow either side of the road which divides the command area into two blocks, namely Pasauli-East and Pasauli-West. A network of underground PVC pipeline starting from diversion box was laid out in the entire command area. The gravity head between DT and end point of the distribution line in the Pasuali-west was registered 26.5 m and discharge recorded at that point was as much as 16 lps. For irrigation to the farmers' fields, risers (outlets) with complete assembly were fitted on underground PVC pipeline using Female Treaded Adapter (FTA). One riser in each 1.5 ha area was installed in order to maintain minimum discharge of 10 lps in the designed set up of risers. Control valve and locking device were also equipped with each riser for controlling the discharge and protecting riser from misuse by any other person. Keys of the locking device of all the risers were maintained by an operator appointed by the water user association. Operator of the system maintains the roster of turn of the irrigation to individual fields or follows the instruction of the association. Risers at the end points of the branches of the pipeline were fixed with pressure gauges to identify any low pressure/choking or any other problems by checking the pressure in the particular line (Kumar *et al.,* 2015).

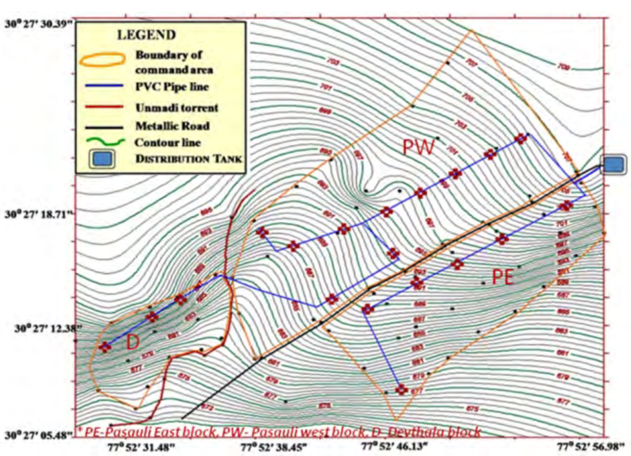

Fig. 5. Plan of PVC distribution pipeline in the command area

Water Application: on-farm Water Management

Command area of the irrigation project is divided into three blocks, *viz.,* Pasauli-East, Pasauli-West and Devthala (Fig. 5). Area of Pasauli-East, Pasauli-West and Devthala is 5.5, 16.28 and 4.5 ha, respectively.

In each block, one riser is provided at every 1.5 ha, this is termed as unit command area. A committee of beneficiary farmers of each unit command area was formed to decide turn to irrigate their fields. To enhance the application efficiency of irrigation, the farmers of unit command area use collapsible synthetic pipes. Even in the unit command area, water is delivered to the individual field head by a collapsible synthetic pipe. With continuous motivation to the farmers, adoption of the optimum size of border for irrigation in wheat crop and strengthening of field bunds for minimizing the seepage loss from the field bunds, particularly from downfield bund is popularized in the command area.

In order to avoid any conflict regarding the turn of irrigation to the farmers' fields; a mechanism is evolved with common consensus. In this mechanism, in one season, delivery of water follows the sequence from head to the tail riser and in next season delivery sequence gets reversed order to negate the clash among the farmers.

Surface irrigation system model SIRMOD developed by Utah State University was used for optimizing the size of border and check basin irrigation methods in the command area of the system for achieving maximum irrigation efficiency. The SIRMOD model (Walker, 1998) simulates the hydraulics of surface irrigation (border, basin and furrow) at the field level. The simulation method used in SIRMOD is based on the numerical solution of the Saint-Venant equations for conservation of mass and momentum as described by Walker and Skogerboe (1987). Since land slope of the command area varying 1-10% and characterized with soil texture-sandy loam to clayey loam, the irrigation methods were optimized for different situations prevailing in the command area. Check basin irrigation method in sandy loam and clayey loam was found most efficient in sizes - 20 x 15 m and 30 x 15 m, respectively. While the border size was best suited with dimension - 40 x 15 m and 50 x 15 m in sandy loam and clayey soils, respectively (Kumar *et al.,* 2016).

Estimated and Observed Discharge

In 2016, the system was evaluated in terms of discharge actually receiving at different risers (outlets) in comparison to designed discharge. Randomly some risers were selected for measuring the discharge. Lay out of the system and risers are shown in Fig. 6. Estimated and observed discharge is presented in Fig. 7. Observed discharge at Distribution Tank (DT) was matching with the discharge calculated using Darcy-Weisbach formula considering turbulence in pipeline flow. A variation between observed and estimated discharge was found in range of 10-16%.

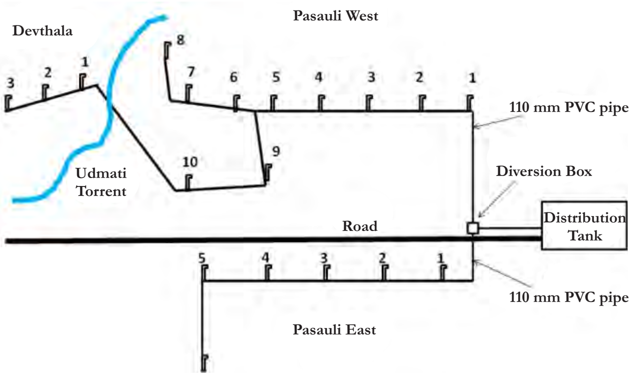

Fig. 6. Layout of system from distribution tank to risers (risers denoted by number)

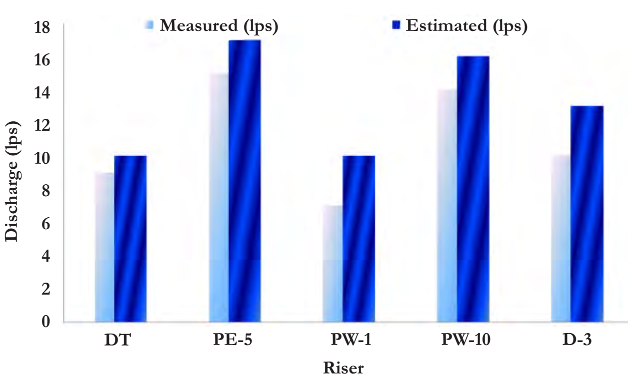

Fig. 7. Comparison between measured and estimated discharge

4. CONCLUSIONS

Himalayan hills have great potential to convert least an economic rainfed farming into the most profitable irrigated farming system through participatory water resource development for the purpose of irrigation. 1830 m GI pipeline (100 mm ɸ) from source to Distribution Tank (DT) as a water conveyance and 1500 m PVC pipeline (110 mm ɸ) as a water distribution are laid out in the command area; and 26.28 ha irrigated area is created in the adopted villages-Pasauli and Devthala. The conveyance efficiency was recorded >95% in the entire system in the command area. After completing the conveyance system in 2011, discharge of randomly selected risers were measured in 2016 and found 10-16% variation between designed (estimated) and observed data. Optimum dimension of irrigation methods were simulated using SIRMOD model. Optimum size of check basin irrigation in sandy loam and clayey loam was found as 20 x 15 m and 30 x15 m, respectively. While the border size was best suited with dimension - 40 x 15 m and 50 x 15 m in sandy loam and clayey soils, respectively. No repair and maintenance expenses was reported after commissioning of the system in 2011. This could be concluded that prevailing irrigation water course needs to be replaced by HDPE/PVC pipeline system in Hill and mountain agriculture, which requires less maintenance cost in comparison to small size cemented open channels.

Productivity of major crops *viz.,* Maize, Paddy, Wheat and *Toria* were increased by 48%. Enhanced cropping intensity by 29% due to intervening crop of *Toria* in between Maize-Wheat sequence and cultivation of *rabi* wheat on fallow land resulted increased additional net income of ₹ 17500/- ha. Crop diversification index improved from 0.84 (pre-project) to 0.96 at the end of the project, helped to minimize the negative impact of climatic aberrations.

REFERENCES

Dhyani, B.L., Bihari Bankey, Kumar, Ambrish, Mandal, Debashis, Singh, Charan and Muruganandan, M. 2015. Natural Resource management for livelihood security: project planning, monitoring and impact analysis; published by ICAR-IISWC, Dehradun (Uttarakhand) India, 175 p.

Cline, W.R. 2008. Global warming and agriculture Impact Estimates by country Peterson Institute for International Economics,Washington.

ICIMOD, 2007. Melting Himalayas: Regional challenges and local impacts of climate change on Mountain Ecosystems and Livelihood, Technical paper. pp 11-24.

Kumar, Ambrish, Dhyani, B.L, Bihari Bankey, Mandal, Debashis, Singh, Charan and Muruganandan, M. 2015. Participatory sustainable water resource managemenet for irrigation in Himalayan foothills. In: souvenir for All India Seminar on "Advances in Engineering and Technology for Sustainable Development organized by Institution of Engineers (India) at GBPUAT, Pantnagar, during 12-13 June 2015, pp 28-36.

Kumar, Ambrish, Dhyani, B. L., Mishra, P.K. 2016. Sustainable Water Resource Management for Efficient Irrigation System. In: Tradition irrigation systems in India (eds. N.R. Bandyopadhyay, Narendra Singh and Ambrish Kumar). Institution of Engineers (India) Gokhale Road, Kolkata: pp 117-123.

Walker, W. 1998. SIRMOD-Surface Irrigation Modeling Software. Utah State University.

Walker, W. and G. Skogerboe. 1987. Surface Irrigation Theory and Practice. Prentice-Hall, New York.