Hill Torrent Management in Southern Punjab of Pakistan: Historic Perspective and New Trends

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***Abstract*-**Hill torrents (locally known as Rodh Kohi) are distinct type of waterways in which water drains from the mountains and hit the localities and infrastructure in its way with enormous speed. More than 200 hill torrents originate from the west of Suleiman Range and hit Taunsa, Dera Ghazi (D.G.) Khan and Rajanpur Districts of Punjab in Pakistan. Among these, 13 hill torrents are having large catchment areas and flood potential. These Hill Torrents after crossing fan area locally named as "Pachad area" crosses D.G. Khan Canal through 22 numbers cross drainage structures and frequently creates disaster up to River Indus. Hill Torrents generally associated with uncertain flood flows have kept D.G. Khan and Rajanpur Districts Hill Torrent fan area socio economically very weak. Most often catastrophic flood events cause loss of billions of rupees to infrastructure, houses and irrigated lands. Conversely huge area, about 2.02 hectares, cultivable piedmont (Pachad) area fails to receive valuable irrigation water. Since the ancient times, diversion embankments of small size have been utilized by local people for diverting flood flows to their irrigation fields. These earthen embankments usually fail for high flow events but effectively divert low floods. A number of studies and plans were suggested to manage the Hill Torrent Floods since 1929 to date. It has been noted that these projects have shown some improvements in terms of utilization of Hill Torrent water for irrigation to uplift the economy of the area. It has been observed that piedmont area of the hill torrents is very fertile but due to erratic nature of floods land utilization is very low. The flood water due to its erratic nature one side destroys the infrastructure while on the other side barren land in piedmont area (Pachad area) is deprived off water for agriculture. This situation demands that there is a lot of space to improve the management of Hill Torrent floods. In this study existing management practices and appraisal of previous studies for Hill Torrents management in southern Punjab have been discussed with focus on additional prospective for sustainability of initiatives to gain full benefits of Hill Torrent water with an improved protection against flood vulnerabilities.

***Keywords*-**Hill Torrents, Catastrophic Floods, Flood Water Management, Piedmont Area Irrigation

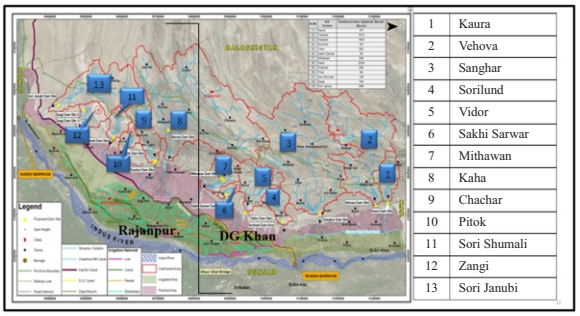
I. Introduction

The term torrent is utilized for water carrier channels carrying flash water flows; the term is mostly utilized for steep mountainous rivers generating rapid runoff. Locally these types of channels are termed as "Rodh Kohi". The torrential area of Dera Ghazi (D.G.) Khan and Rajanpur Districts of Punjab province is situated between the Indus River and the Suleman range surrounded by province of Sindh, Baluchistan in the west and Khyber Pakhtunkhwa (KPK) in the North. About forty five percent of the total catchment areas lie in the two districts and the remaining 55% in the province of Baluchistan. The area in the west (on the right side of the Indus River) which is unirrigated by local canal Irrigation network is piedmont area locally known as "Pachad" area and is fertile due to unexploited sediment deposits of the mountains brought down with flood water. Pachad area is considered to be an area between darrah (the point after which torrent enters the plains) and the right bank of Indus River. The torrential area of the two districts consists of thirteen (13) major Hill torrents extending from Kaura and ending at Sori Janubi as shown in Figure 1. These torrents after crossing the piedmont area hits the cross drainage structures constructed across the Chashma Right Bank, D.G. Khan under construction Kacchi canals and ultimately enters to Indus River. The piedmont area of these torrents is situated in the arid zone of the country and only source of agriculture water is floods and rains. The rainfall pattern is such that it causes erratic and uncontrolled floods during Monsoon months (June to August). The flood water in monsoon at one side destroys the infrastructure in D.G. Khan Canal / Chashma Right Bank Canal command area due to erratic nature of flows while on the other side barren land in piedmont area are deprived off water for agriculture [i].

Various studies conducted on optimum use of flash flood water for irrigation purpose and minimize the drought effect for Hill Torrent's concluded that the

provision of storage reservoirs, diversion structures and cross drainage structures utmost important [ii-iv]. Conventionally agriculture growers in hill torrents regions use low flows of torrents by building small embankments locally named "Gandaz". It has been noted that flash floods break small embankments and not allow the farmers to use this precious water. 80 % agriculture contribution of Pakistan is supported from Punjab therefore it has a key role in Pakistan's economic life. More than 90% agronomic production in Punjab is through irrigated land exploiting a major part of its conventional water resources and land. Now with increasing population and reducing land resources, demands utilization of barren lands that only rely on the flood water irrigation. It has been noted that cropping intensity in piedmont area of hill torrents fluctuates significantly according to the level and frequency of inundating. Sorghum and Millets are sown on maximum of the cropped area on flood dampness and afterwards oil seeds are grown. For the occasions when flood period ends, late and optimal soil dampness is there in the soil from previous inundating, wheat is cultivated in the month of November. The flood water and silt of Pitok and Sori Shumali is brackish so injurious for plant growth. The piedmont area of remaining eleven hill torrents is very fertile because it has been developed by the continuous silt accumulation carried out by flood water. It has been noted that the yields per unit area are low which may be attributed to erratic and insufficient water availability and poor management practices [v].

The use of GIS was found effective for integrated way of conserving the excess water to minimize the flash flood risk and its use for irrigation purposes. Earthen reservoirs were proposed using GIS to achieve both the objectives [vi]. In order to uplift the quality of life for the people inhabiting the piedmont areas of these torrents and to avoid destruction of valuable infrastructure due to sudden floods, this research work investigated existing water management practices, various previous studies and implementation programs, conducted various site visits to the piedmont area to evaluate the outcome of existing management efforts and proposed new development strategies. Previous reports have been discussed keeping in view the management of floods of all 13 torrents and due to limited space, scope of evaluation for existing management practices and proposed development strategies have been discussed only for Kaha hill torrent. Kaha hill torrent has been selected for discussion as this torrent bring maximum discharge (Q_{100} = 6440 m^3/s at darrah) among the 13 torrents and has maximum potential of agricultural growth.



1	Kaura
2	Vehova
3	Sanghar
4	Sorilund
5	Vidor
6	Sakhi Sarwar
7	Mithawan
8	Kaha
9	Chachar
10	Pitok
11	Sori Shumali
12	Zangi
13	Sori Janubi

Fig. 1. Location of Hill Torrents of Rajanpur and D.G. Khan Area of Punjab, Pakistan

II. Existing Water Management of Hill Torrents

For cultivating the seasonal crops flood Irrigation is conventionally utilized for diverting flow of hill torrent into areas to be irrigated. The agricultural practices are developed keeping in view the extreme occasions of inundations and droughts and a unique irrigation system for hill torrent area is being practiced, known locally as “Kamara Irrigation”. In this system sequential water rights are enforced and irrigation pattern are dictated starting higher to lower riparian, without concern of the period and amount of flows generated through storms. Due to this arrangement distant lower riparian's could not get irrigation water throughout a year of low flow. For utilizing the flood water generally embankments of earthen material are constructed through the stream with big water passage on one or both sides of the stream. Traditionally earthen embankments and arrangement of water delivery were built by the local peoples on their own by utilizing their customary expertise. It has been noted that locals, prepare field by constructing embankments of about 1.8 m high to store the water by keeping in view the soil type, share in water and various other local factors. As soon as water dried up in the field, crops are sown which flourish due to the moisture stored in the soil. No further irrigation is possible except rain if it occurs.

This arrangement is barely proficient of handling the small flows, upon which moderate and large flows destroy the earthen embankments of farmers and frequently cause unprecedented damages to the local economy. These sudden floods are causing not only the wastage of irrigable flows but from centuries are causing loss of human lives, edible, potable and cashable agricultural production.

Cropping intensity is defined as the percentage ratio of the cultivable command area to the cropped area. For evaluating the existing system cropping data from revenue record from concerned offices of Rajanpur and Dera Ghazi Khan Districts has been collected (2010-2013) and average cropping intensity has been computed. The computed cropping intensities for each torrent are shown in Fig. 2 below.

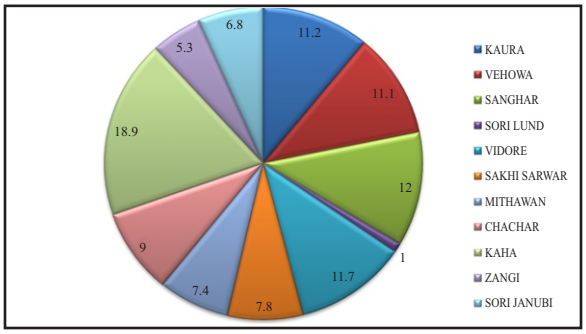


Fig. 2. Existing Cropping Intensity of Hill Torrents of Punjab Province, Pakistan

The analysis indicates the annual cropping intensity of the area is from 19% for Kaha to as low as 1 % for Sori lund. According to the amount and frequency of inundation in piedmont area, large variation in the cropping intensity has been noticed. Sorghum and Millets are sown on maximum of the cropped area on flood dampness and afterwards oil seeds are grown. Hill Torrent wise existing crop yields have also computed by analyzing field investigations and deliberations with officials of agriculture department functioning in the area. Published reports on Agricultural Statistics of Punjab for districts of Dera Ghazi Khan and Rajanpur were also consulted and compared for determining the existing crop yield levels. The crop yields estimated for Oil-Seeds, Pulses, Wheat, Bajra and Sorghum are 305, 280, 495, 242 and 293 kg/acre respectively. The overall yields are low that may be attributed to erratic and insufficient water supplies. Socio-economic situation of the agricultural community can be deteriorated without flood protection and proper management of water resources.

In order to improve the socio-economic condition of the local people of piedmont area various studies and implementation plans were initiated by various governmental agencies. In this research effort various previous reports have been studied and their recommendations are discussed below.

III. Review of Previous Reports

Following previous reports have been studied to review the previous development plans;

- NESPAK (1984), Flood Management of Dera Ghazi Khan Hill Torrents [vii]
- JICA (1992), Feasibility Study (FS) on Development of Irrigation based upon Flood Flows of Dera Ghazi Khan Hill Torrents [viii]
- NESPAK, (1998). Master Feasibility Studies for Flood Management of Hill Torrents of Pakistan, Flood Flows of D.G. Khan Hill Torrents, Federal Flood Commission, Ministary of Waters and Power, Govt. of Pakistan, [ix]
- NESPAK, (2005). Chashma Right Bank Irrigation Project (Stage-III) Updating Feasibility Study on Hill Torrents Management Plan in CRBC Area in Dera Ghazi Khan District, Irrigation & Power Department, Punjab, [x]

After reviewing the above reports following are the inferences;

- It was identified [vii] that recommended strategy should be, "utilizing the maximum quantities of floodwaters in areas where they are generated". For utilizing the flood waters gabion dispersion structures were proposed and no structure for storage or delay action dams was planned.
- It was proposed [viii] that catchment management techniques will cater sediment production of upper catchment for sustainable and long term solution for hill torrent management difficulties. The study proposed some dispersion structures for Vidore as case study.
- It was adopted [ix] to build suitable flood dispersion and diversion structures sustained by a system of surface drains to securely take the left over flow to the Indus River. In this study also no storage/delay action dam structure was proposed with the reason that dams may fill immediately due to heavy sediment loads.
- Six alternatives were evaluated [x] and finally recommended approach was Diversion /Distribution Options for attaining flood mitigation and irrigation purposes in the piedmont area. This study has also not considered dam structure in mountains with the same reason as mentioned above.

The outcomes of previous reports suggested that almost all the studies have considered distribution/diversion of floods in piedmont area with gabion dispersion structures and have not considered dams - either delay action or storage option - in mountain area.

The probable reason of ignoring dam structures in mountain area may be techniques of reservoir flushing were not mature at the stage when these reports were prepared. Now, with the current engineering knowledge it is possible to flush reservoir by adopting suitable techniques. Therefore, in the present study, development plan is to consider flood management at two stages i.e.

- in mountains by constructing delay action/storage dams with suitable flushing arrangement and
- in the piedmont area by constructing dispersion structures/regular canal irrigation.

IV. Performance Evaluation of Existing Structures of Kaha Hill Torrent

Kaha Hill Torrent is one of the main hill torrents of Dera Ghazi Khan. It originates in the area lying within administrative territory of Balochistan Province and

drains an area of over 57, 00 sq km of Suleman Range. Kaha leaves mountains, upstream of Harand and fans out into numerous small channels known locally as wahs in downstream area. Flows of Kaha are managed with the help of 13 dispersion structures as shown in Figure 3. Recently under annual development program almost all the structures were modified from wire crate gabion structures to rigid PCC structures.

It has been noted that all the flood water dispersion structures across the flows are now rigid and constructed using PCC instead of conventionally used earthen embankments. It was informed by the local officials of the government agencies that, these rigid structures were constructed from year 2011 to 2013 under the annual development program and were according to the suggestions of various studies conducted in the past. These structures generally comprise of following components;

- Construction of a weir along whole width of hill torrent flow path which is a dispersion structure
- Upstream, downstream and central cut off walls on the basis of worst scour.
- Abutments, wing walls and retaining walls.
- Off taking channels on right and left side
- Protection bunds / embankments.
- Bed stabilizer on downstream of main weir.

For the purpose of performance evaluation of existing structures although several sites were visited as part of this study but in this paper two representative sites i.e. Muhammad Wah and Jindra Wah have been discussed and shown in Figures 4 and 5.

It has been noted that upstream side of the structures are filled with sediments after two flood seasons. This filling is as per design and will improve the water entry to the off-taking channel (wah). On the downstream side gabion crating is provided at glacis. It has been observed and reflected from the figure that gabion crates are damaged due to high velocity torrential flows. It has been noted that around downstream cutoff walls high speed flood water caused erosion as shown in the Figure 5. On the downstream side of the newly constructed structures these problems arise as energy dissipation phenomenon probably has not been considered in the design. It has been noted that no permanent structure has been provided for the off take of irrigation channels (Wahs). Drawback of this practice is that during high flows usually these earthen off takes could not perform properly and sometimes beds of wahs near off-take are subjected to heavy erosion and on other hand sediment accumulate at the mouth of wah and restrict the entry of water. It has been observed that upstream guide banks are constructed of local material and for preparing embankment it is not compacted as shown in Fig. 4. Disadvantage of this practice is that during high flows these embankments could not sustain the pressure of water and usually cause breaches. Due to breaches in guide bank water will disperse wildly instead of passing through the structures.

Although no data is available to compare the performance of these rigid dispersion structures to the historic earthen structures in terms of increase in cropping intensity or crop production. But from the discussions with local people it has been noted that these rigid structures are useful in improving the water diversion and reduced the annual efforts of the local people that they have to put after each flood in term of reconstruction of diversion weirs.

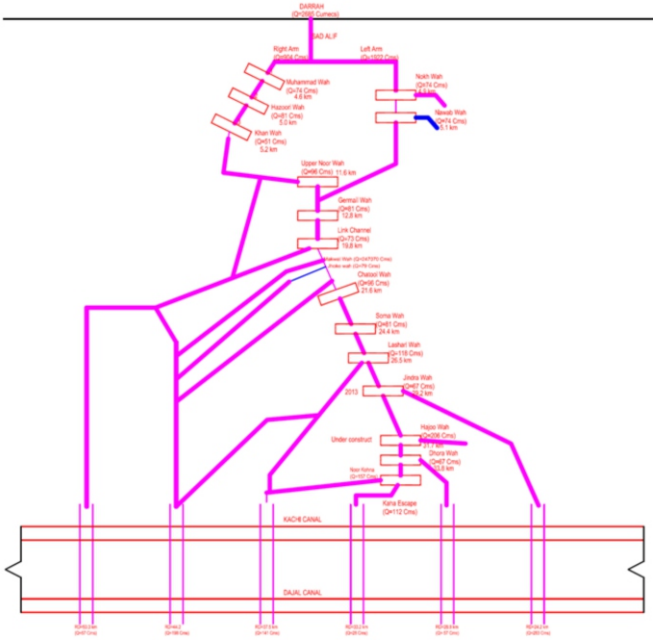


Fig. 3. Line Diagram of Kaha Hill Torrent

Fig. 4. Muhammad Wah (at 4.60 km) Kaha Hill Torrent

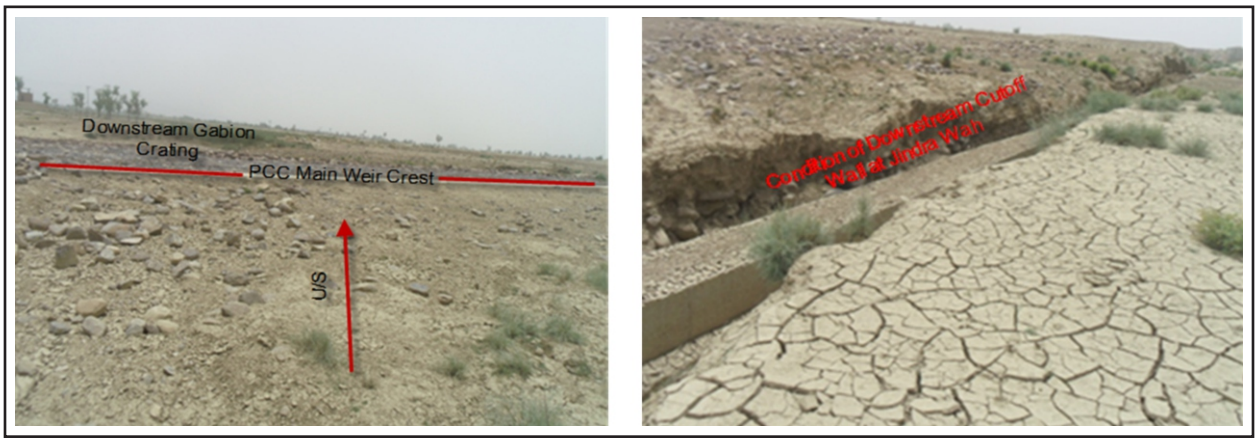


Fig. 5. Jindra Wah (at 29.20 km) Kaha Hill Torrent

V. Present Development Plan for Kaha Hill Torrent

Present development plan of the Kaha hill torrent has been proposed by keeping in view two issues i.e. to substantially reduce the flood peaks and to improve the irrigation agriculture of the area. For this purpose Kaha watershed was visited and identified a potential location for multipurpose dam near Nilakund village. The latitude and longitude of the site are 29º 33' 46" and 69º 48' 39" and it is about 18 miles upstream of Kaha darrah. For evaluating the storage potential of the site, freely available SRTM digital elevation data has been acquired and elevation area capacity curve prepared as shown in Fig. 6.

Hydrological studies at the dam site consist of computing the water availability and flood hydrographs. For this purpose rainfall runoff analysis has been done by utilizing the HEC-HMS computer software. The computed flood hydrographs at the dam site are shown in Fig. 7.

Dam height and its appurtenant structures like low level outlets and spillways at the selected site has been designed in such a way that created reservoir has enough volumes to store the discharges that attenuate the peak of 100 year return interval discharge to 50% and to increase the cropping area from existing 6854 ha to designed 36180 ha. The salient features of the dam and its appurtenant structures are presented below.

Inflow Flood

Inflow Design Flood = 6440 m^3/s (100 year Return Period)

Dam / Reservoir

Top of Dam Embankment = El. 684.4 m asl

Height of Dam = 124.0 m (El. 684.4 El. 560.4)

Reservoir Dead Storage (El. 575.7 m asl) = 0.11 Million m^3

Reservoir Gross Storage at MCL (El. 674.7 m asl) = 1227.62 Million m^3

Live Reservoir Storage = 1227.51 Million m^3

Spillway

Spillway width = 152.3 m

Crest Level = El. 674.7 m asl

Maximum Conservation Level (MCL) = El. 674.7 m asl

Low Level Outlets

Invert Level of LLOs = El. 575.7 m asl

Flushing Outlet
No. of Outlets = 4 No.
Size of Outlet = 2.74 m x 2.74 m
Total Discharge Capacity of Outlets at MCL = 924 m^3/s
Water Availability
Average Annual Availability = 250 Million m^3
Annual Agriculture Demand = 160 Million m^3
Proposed Cropping Period = Whole year
Total CCA = 36180 ha
Cropping Intensity = 70% per annum
Agricultural Shortages = 10.0%

By utilizing the elevation~area~capacity, outflow rating of the dam outlet works and the inflow hydrograph of 100 yr return Fig. 6. Elevation~Area~Capacity Curve at Selected Dam Site in Kaha Hill interval reservoir routing studies have been conducted by utilizing the MS Excel sheet program. The output of the reservoir routing study was an outflow ydrograph and is shown in Figure 8 below. It is evident from the figure that peak of the hydrograph is attenuated from 6440 m^3/s to 3216 m^3/s.

It is clear from the above analysis that if the development plan proposed as part of this study is implemented it will not only improve the irrigation agriculture of the area but also ensure safety of the downstream areas from the hazards of sudden floods.

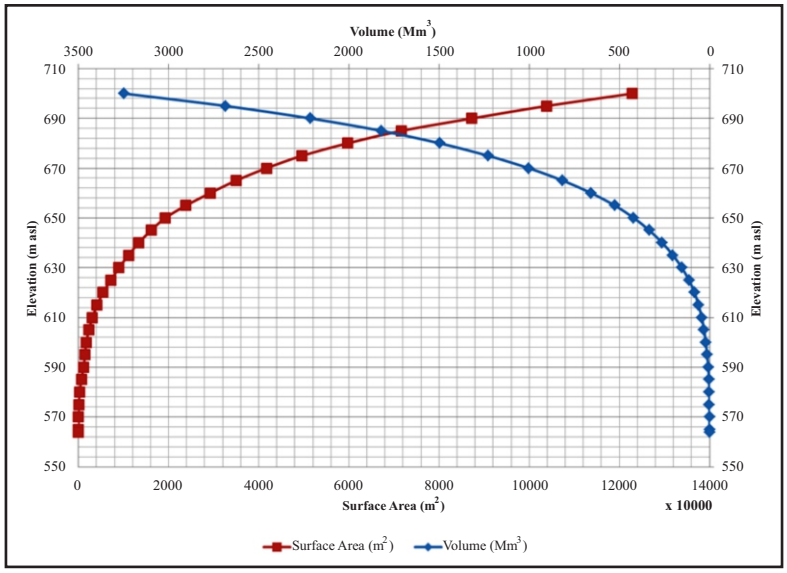


Fig. 6. Elevation~Area~Capacity Curve at Selected Dam Site in Kaha Hill Torrent

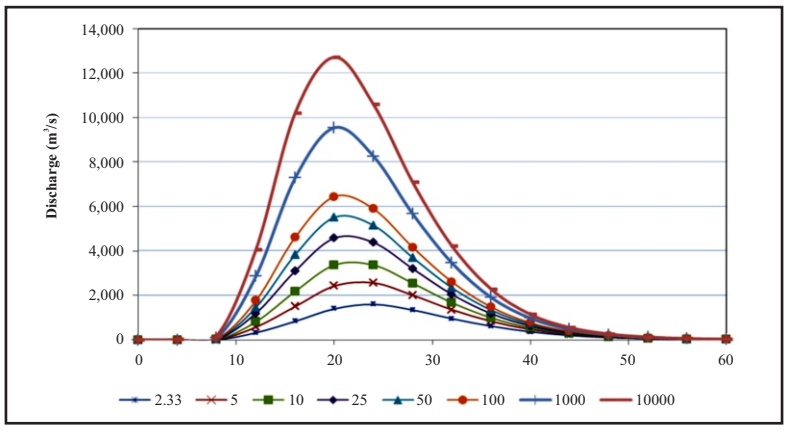


Fig. 7. Flood Hydrographs at Selected Dam Site in Kaha Hill Torrent

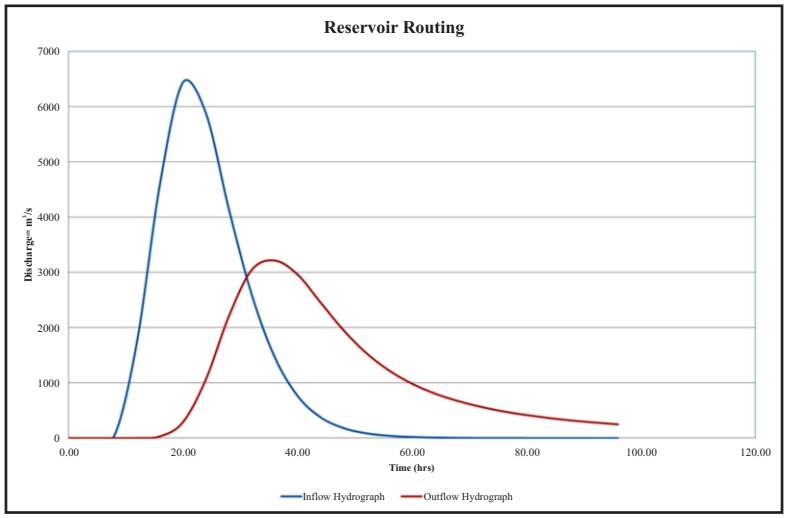


Fig. 8. Inflow and Outflow Hydrographs for Kaha Dam

VI. Conclusions and Recommendations

Following are the main conclusion and recommendations of the study;

- The piedmont area of the hill torrents despite of having fertile lands in general is producing low value crops. The land utilization per year varied from torrent to torrent. Maximum existing cropping intensity is 19% in Kaha to as low as 1% in Sori lund.
- Historically, flood waters of hill torrents were diverted by using earthen embankments that washed away in even low to medium floods. Now, due to intervention of governmental agencies there is trend of constructing rigid dispersion structures instead of old flexible embankments.
- Newly constructed rigid structures cause improvement in diverting the flood waters to irrigation fields. Beside this there is need to improve the design of downstream energy dissipation arrangements according to the state of the art engineering practices.
- Presently flexible structures have been provided for the off take of irrigation channels (Wahs). It is recommended that these off takes should be designed as rigid structures to withstand high floods.
- It is recommended to improve the existing rigid dispersion structure by keeping in view their present performance.
- Present development plan of the Kaha hill torrent involve construction of 124 m high dam. Implementation of this development plan can cause appreciable reduction in flood peaks and will increase the cropping area by 5 times as compared to existing.
- It is recommended to initiate a comprehensive feasibility study for the construction of dams in the mountain areas of the hill torrents.

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