Paper No. 130

WATER RESOURCES DEVELOPMENT AND MANAGEMENT IN POTHOHAR

Dr. Muhammad Nawaz Bhutta and Dr. Saleem Sarwar

WATER RESOURCES DEVELOPMENT AND MANAGEMENT IN POTHOHAR

By

Dr. Muhammad Nawaz Bhutta and Dr. Saleem Sarwar

ABSTRACT

Optimum utilization of every drop of available water is becoming increasingly important with the ever-increasing population to meet their food needs. In the Pothohar Region rainwater is wasted by flowing over steep slopes, rather causing soil erosion and damaging the water ways and dams. It has been estimated that annually 2.4 MAF water is lost as surface runoff from Pothohar Region. Rainwater harvesting structures (RHS) would contribute in enhancing the crop production and reducing the hazardous erosion. The Pothohar Region has a total command area of 5.5 million acres (2.2 Mha). Out of which about 86000 acres are being irrigated by existing rainwater harvesting structures. Since 1978, a number of interventions have been constructed and only 0.1 MAF rainfall runoff is being utilized out of potential of 2.5 MAF. Proper harvesting of this balance of 2.4 MAF is inevitably required for regional economic growth. A total of 8,707 sites for RHS have been identified for construction in four districts of Pothohar. The storage size of structures varies from 10 AF to 100 AF. A sample of 40 RHS sites were surveyed. The local geology of individual RHS sites suggests that 78 percent will be of earthen embankments and 22 percent will be stone masonry wall or concrete faced rock-fill structures. The catchment area for these sites will vary from 0.25 to 3 mile^2 and average annual water yield for 1 mile^2 is about 161 acre feet. The reservoir area varies from 1 acre to 16 acres. Sediment yield has been estimated as 1.5 AF per mile^2. For spillway design 25 years return period is proposed for all RHS. The structure heights vary from 20 to 35 ft and there exist reasonable agreement between reservoir area and storage capacity, and structure height. Crop water requirements of various crops assuming 140% annual future cropping intensity was calculated. There is sufficient water available to meet the crop water requirements. The overall estimated cost of 40 RHS is Rs.181.511 million including Rs. 115.963 million for component of RHS and Rs. 65.548 million for spillway. The incremental NVP values range from Rs. 413,000 to Rs. 5,042,000 depending upon the scale of CCA of each rainwater harvesting structure. Economic cash flow has been prepared at 12% discount rate. The life assumed as 25 years. All the RHSs sizes for their multipurpose usage are economically feasible even for sensitivity analysis. The EIRR for overall project is 19.15% and FIRR for overall project is 17.43%.

INTRODUCTION

The Pothohar Region lies between Indus and Jhelum rivers having a total command area of 5.5 million acres (2.2 Mha). Out of which about 86,740 acres is being irrigated by existing rain water harvesting structures. The topography of Pothohar area is undulating and the altitude varies from 300 to 600 m above mean Sea Level. In the Pothohar Region rain water is wasted by flowing over steep slopes, rather causing soil erosion and damaging the water ways and dams.

Since 1978 in the Pothohar region the construction of rainwater harvesting structures has been completed under various multi-sectoral development projects. It included construction of RHS (mini dams and ponds) dugwells and tubewells etc. Key achievements upto date are given in **Table 1**.

Table 1: Key Achievements in Pothohar

	RHS (mini dams & ponds)	Dug Wells	Tube well	Turbines	Total
Number	2154	4,112	399	187	-
Area irrigated (ac)	54460	20,560	7,980	3,740	86,740

A total of 8707 new potential sites for RHS have been identified for construction in four districts of Pothohar (**Table 2**). Out of these Attock district contains maximum number of potential sites (2,596) while Rawalpindi district contains minimum number of potential sites (1,431).

Table 2: Tehsil wise Summary of Potential RHS Sites

District	No. of Rural UC	Total
Rawalpindi	119	1,431
Chakwal	59	2,313
Attock	61	2,596
Total	42	2,367
Grand Total	**281**	**8,707**

SAMPLE SURVEY

A sample survey of 40 potential sites in Pothohar area using ASTER DEM data (30-meter resolution satellite imageries) was conducted. **Figure 1** shows the map containing these potential sites of RHS. RHS upto 10 AF are not considered feasible. RHS from 10 to 30 AF are small, 30 to 60 AF are medium and from 60 to 100 AF are large. Design criteria for RHS are likely to involve following:

I. Mark the potential RHS sites in the Pothohar Region. The criteria of selection will be based upon imagery / topographic survey of the Pothohar area.

II. Determine height and storage capacity of the RHS on the basis of satellite imagery/ topographical survey.

III. Identify the command area in the adjoining vicinity of the rainwater harvesting structures.

IV. Recheck design of the RHS on the basis of general geology of the area assuming that rock will be available approximately 5 meter from the surface. Moreover availability of impervious material within 5 Km lead be looked into.

V. Design of spillway will be done on the basis of 25 year return period inflow.

HYDROLOGICAL & HYDRAULIC STUDIES

In order to study the effect of the climatological factors in Pothohar area, rainfall data of Gujjar Khan, Islamabad, Jhelum, Chakwal and Cherat station operated by Water and Power Development Authority was used. The span of available data is from 1954 to 2009 (1954-1970 monthly data, 1971-2009 daily data). The normal annual rainfall in Pothohar region varies from 400 mm to 1200 mm (15.7 to 47.2 inch) depending upon location, the maximum being the northeastern area and the minimum in the southeastern. About 45 % of the rainfall occurs in the months of July, August and September. The maximum mean monthly rainfall (350 mm) occurs in Murree in the month of July while minimum rainfall (1.81mm) occurs in the Chakwal in the month of November.

There is an appreciable variation in the summer and winter temperatures. January is the coldest month, while June is the hottest month. The absolute mean monthly temperature in the valley ranges from 1°C in January to 46°C in June. The temperature analyses for the Jhelum gauging station were carried out to determine the inter-seasonal and annual changes in this region.

The daily maximum and minimum data of Jhelum from 1980 to 2013 was collected to assess variations in the temperature of the region. The results indicated that mean temperature over the period of 34 years is 30.68°C, whereas, average maximum temperature was recorded in 2003 with a value of 33.07°C. The average minimum temperature recorded over the same period was 16.77°C with minimum temperature of 11.74°C recorded in 2003. The results indicated that minimum temperature is 5.58°C that occurs during the month of January and maximum temperature occurs during the month of June with value of 39.73°C.

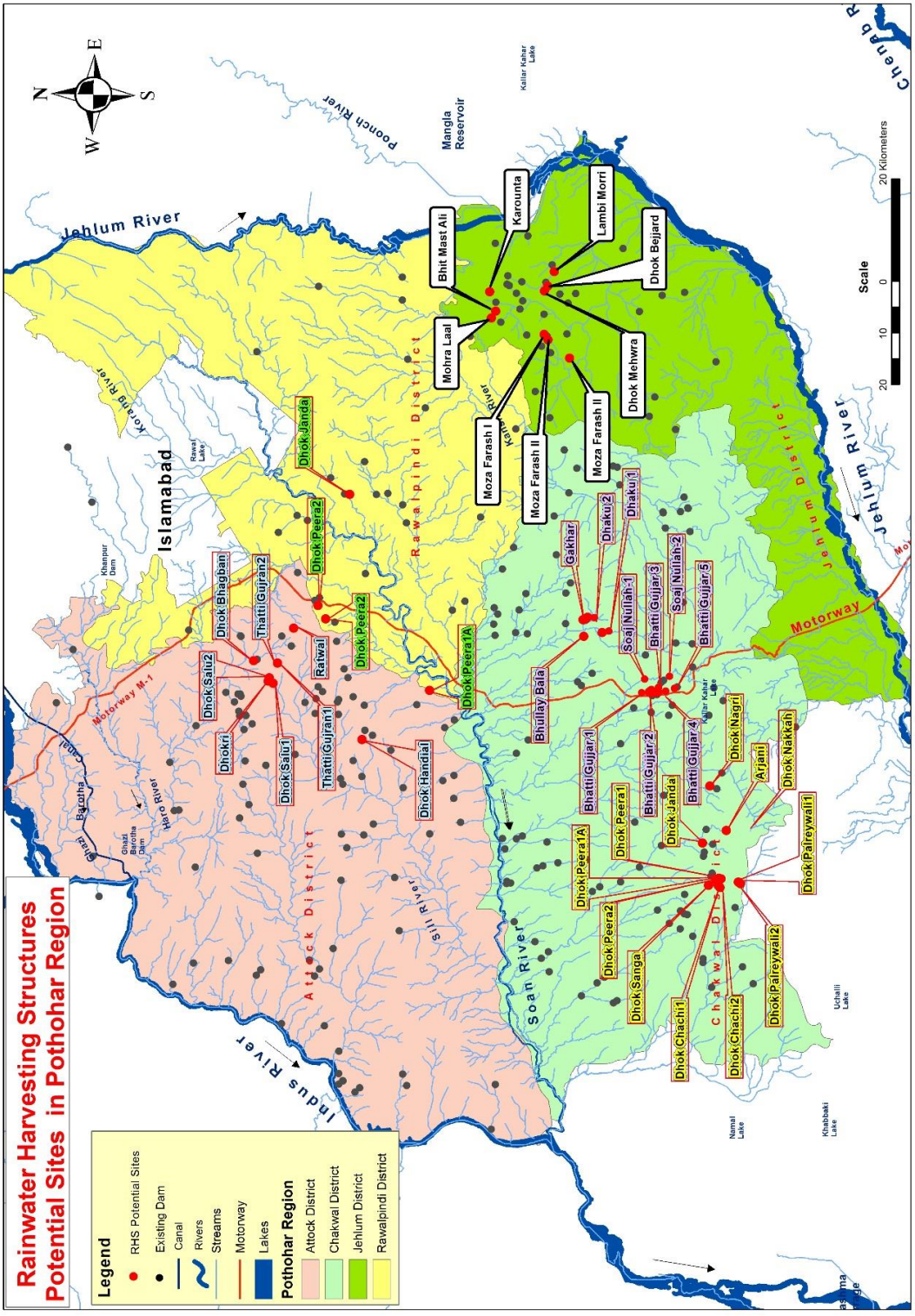


Figure 1: Potential Rainwater Harvesting Sites in Pothohar

Water Availability and Sediment Yield

Small Dams Organization (SDO) of Punjab Irrigation Department (PID) has carried out studies[1] on some of its existing dams and established monthly rainfall-runoff relationships as per observed rainfall-runoff recorded. Following regression equations for the three zones (see **Figure 2)** were developed:

Zone A: Bishan Daur River at Missa Runoff $= 0.983*10^{-7}*(\text{Rainfall}+112.6)^{3.5}$

Zone B: Sill River at Chahan Runoff $= 0.9222*10^{-2}*(\text{Rainfall}+21.3)^{1.6}$

Zone C: Ling River at Kahuta Runoff $= 0.428*10^{-2}*(\text{Rainfall}+32.5)^{1.5}$

Runoff Monthly in mm *Rainfall (monthly) in mm*



Water availability for 40 sample RHS is given in **Table 3**.

Table 3: Annual Water Yield of Selected Rainwater Harvesting Structures

Sr. No.	Total Sites	Total Catchment Area (miles^2)	Total Annual Water Yield (AF)
Chakwal	19	42.72	8296
Rawalpindi	4	4.99	1300
Attock	8	5.62	1172.8
Jhelum	9	4.74	834
Total	**40**	**58.07**	**11602.8**

Surface Water Hydrology Project (SWHP), WAPDA has some gauging stations in the vicinity of the catchment area that have long term sediment record. Sill River near Chahan that lies about 3.2 km upstream of Chahan village, about 27 km south west of Rawalpindi on Pindi Chakri Road (**Table 4**). The predicted sediment rate value of 0.59 AF/km^2 is estimated for the RHS. Catchment of these RHS are very small compared to

[1] Design Manual Volume 1 Hydrology and Hydraulics for small dams projects

Chahan, moreover, vegetation cover is also found on most part of these RHS compared to catchment area of Chahan, therefore, sediment rate will be far less.

Table 4: Sediment Yield for Various Catchments in the Pothohar Region

Sr No	River	Station	Catchment Area (km^2)	Data Record (years)	Mean Annual Runoff (AF /km^2)	Mean Annual Sediment Yield (AF /km^2)
1	Siran River	Phulra	1,057	36	470.3	1.5
2	Haro River	Garlia	3,056	37	225.4	1.0
3	Haro River	Khanpur	777	32	283.1	1.2
4	Soan River	Dhok Pathan	6,475	42	171.4	2.0

Design Flood

Design flood for each RHS is determined using Unit Hydrograph Method. Frequency analysis of the one-day annual maximum rainfall data of Gujar Khan station has been carried out to assess the rainfall of various return periods using Gumble Extreme Value Type I distribution as per normal practice in Pakistan. The results of frequency analysis as an example is given in **Table 5** and in **Figure 6**.

Table 5: Frequency Analysis of one Day Annual Maximum Rainfall

Return Period	K	Computed Rainfall Depth (inch)
500	4.395	9.36
100	3.137	7.64
50	2.592	6.90
25	2.044	6.15
20	1.866	5.91
15	1.635	5.59
10	1.305	5.14
5	0.719	4.34
2.33	0.001	3.36
1.02	-1.518	1.29

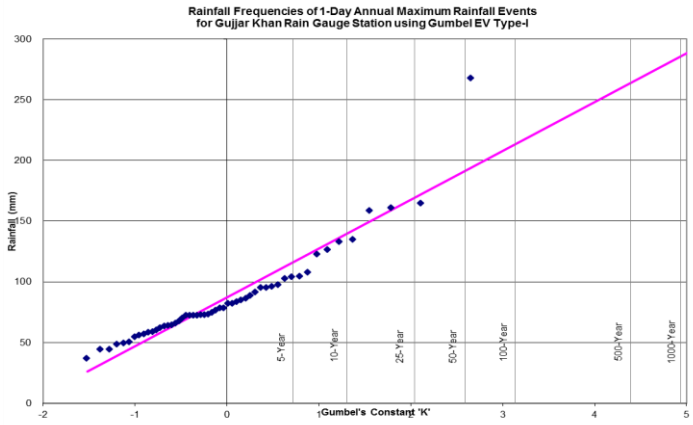


Figure 2: Plot of Gumble K Factor and Estimated Rainfall

US Soil Conservation Services (USSCS) approach has been adopted to estimate design flood for the RHS. For the spillway design 25 year return period is proposed for all RHSs.

Assessment Of RHS Height And Spillway Width

Area capacity curves for RHS were generated from 0.5 m contour interval topographical survey. Flood routing was carried out to determine the Normal Pool Level (NPL), Highest Flood Level (HFL) and Dam height for these RHS. The Muskingum-Cunge flood routing procedure has been adopted. HFL was computed by selecting appropriate spillway rating curve for each RHS. Freeboard of 3 ft. was added to compute structure height. The results show that storage of these sites varies from 11 AF to 100 AF and reservoir area varies from 2 ac to 16 ac.

Wave Run-up analysis was also carried out to determine the potential wave height for these RHSs. The topographical survey indicates that for these RHSs, average fetch length varies from 0.12 mile to 0.25 mile. USBR (2012) Design Standards No. 13 was used for calculation of wave run-up. The results show that maximum wave of 1.71 ft will be created for average fetch length.

Crop Water Requirement

The crop water requirements of various crops to be grown in command area were calculated by using Crop Coefficient (K_c) Approach. According to this approach, crop evapotranspiration (ET_c) is calculated by multiplying the reference crop evapotranspiration (ET_o) with K_c.

The Gross irrigation requirements at RHS outlet is computed by dividing net irrigation requirement over irrigation efficiency. Table 5 indicates monthly irrigation requirements at RHS outlet in Chakwal District which needs to be assured through RHS operation**.**

Table 6: Crop Water Requirements for 100 ac with 140% cropping for RHS in District Chakwal

Reaches	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	CWR (AF)	
													100 ac	Per ac
Rootzone	11.8	5.3	7.7	7.9	11.6	21.4	17.1	9.4	18.2	13.6	9.4	5.8	139.2	1.4
Nakka	16.4	7.4	9.9	9.2	12.9	24.4	20.8	11.5	23.4	17.3	12.9	7.9	174.1	1.7
RHS Outlet	17.3	7.8	10.4	9.7	13.6	25.7	21.9	12.1	24.7	18.2	13.6	8.4	183.3	1.8

There is sufficient water available to meet the crop water requirements in the various months of the year. The demands have been adjusted with spills and shortages such that maximum flow would be regulated and command area of 10 to 43 acre can be irrigated from these RHSs.

Hydraulic Design of Spillway

Design of spillways for 40 sample RHS is based on USBR guidelines for cut spillways and pressure flow principles for pipe spillways. The pipe spillways are provided in the RHS with spillway outflow capacity of less than 300 cusecs.

District Chakwal RHS: There are 19 feasible RHSs sites in the district Chakwal. The storage capacity of these sites varies from 11 to 100 AF. Most of these site will be earthen having RHS with open cut spillway are 14 and RHS with pipe spillway are 5.

District Rawalpindi RHS: There are 4 feasible RHSs sites in the district Rawalpindi, the storage capacity of these sites varies from 14 to 68 AF. These sites will be earthen having open cut spillway.

District Attock RHS: There are 8 feasible RHSs sites in the district Attack, the storage capacity of these sites varies from 18 to 58 AF. Most of these sites will be earthen having open cut spillway however pipe spillway is provided in 2 RHSs.

District Jhelum RHS: There are 9 feasible RHSs sites in the district Jhelum, the storage capacity of these sites varies from 11 to 61 AF. Most of these site will be earthen having open cut spillway however pipe spillway is provided in 6 RHSs.

GEOLOGY AND GEOTECHNICAL STUDIES

The regional geology of this area is mainly represented by sandstones, siltstones, clay/ shale intercalated by conglomerate beds belonging to Murree & Kamlial Formations of Rawalpindi Group and Chinji, Nagri, Dhok Pathan and Soan Formations of Siwaliks Group. There are older formations of Paleocene and Eocene age southernmost part of the catchment which are mainly represented by limestone, marl and some fine laminated shale / argillaceous rocks in this part of Pothohar area. The rock mass outcropped of Pothohar Region, is mainly massive sandstone of Nagri Formation, while in the reservoir and in catchments of these RHS, Dhok Pathan Formation is predominant with a horizontal bed of Soan Formation at the top.

The Nagri Formation consists of sandstone with subordinate clay and conglomerate. The sandstone is greenish grey, medium to coarse grained, cross-bedded and massive. In places, the sandstone is bluish grey dull red with "salt and pepper" pattern, calcareous, and moderate to poor cemented. The clay is sandy or silty chocolate brown or reddish-grey and pale orange, the proportion of which varies from section to section.

The Dhok Pathan Formation is typically represented by monotonous cyclic alternations of sandstone, and clay beds. The sandstone is commonly grey, light grey, gleaming white or reddish brown occasionally buff or light brown in color, thick bedded, calcareous moderately cemented soft and cross–bedded. The clay / shale is orange, brown, dull red or reddish brown and occasionally rusty orange calcareous and sandy. Conglomerate in the form of lenses or layers is an essential character in the upper part.

AGRICULTURE DEVELOPMENT AND BENEFITS

Total reported area of Pothohar region is 5.55 Mac, out of which 2.56 Mac (46%) area is cultivated and 2.99 Mac; (54%) area is uncultivated. Under uncultivated category, 36% of total reported area is not available for cultivation, 11% is under forest and only 7% is culturable waste which can be brought under cultivation provided irrigation supplies are available. The percentage of cultivated area to total reported area is quite low (46%) as compared to 72% on Punjab basis. Sown area is 1.98 million acres, out of which 1.76 million acres are barani and 0.22 million acres are irrigated. The irrigated area is only 11% of the total sown area.

The proposed RHSs, will mostly supplement irrigation supplies to rainfed areas of Pothohar. According to land use statistics of Pothohar, about 13 percent of CCA under these proposed RHSs is culturable waste, barren and no agriculture is being practiced but it can be brought under cultivation provided irrigation facilities are available. The total CCA for these sample sites comes to about 994 acres.

Agriculture Under Without Project

The present agriculture in the command of 40 proposed rainwater harvesting structures is rainfed with poor per acre yields, no substantial improvement is anticipated. It is assumed that cropped area and yields will remain constant and hence no projection has been made for future without project.

To determine the bench mark agriculture development status in proposed RHSs, it is assumed that CCA under RHSs will comprise of about 87% of rainfed area and about 13% of culturable waste with no agriculture. The annual cropping intensity of matured crops under command of proposed RHS is assumed as 15%.

Agriculture Development Under With Project

Construction of rainwater harvesting structures in the Pothohar Region seems to be the viable option for storing runoff water and bringing barren lands under cultivation. Considering water and land resources as constraining factors, 25% of command area will be served with high efficiency irrigation system (HEIS). About 61% will receive surface / flood irrigation and 14% will be irrigated with bed and furrow method. The crop production is envisaged to be achieved through bringing barren / rainfed land under cultivation and practising of cropping pattern with high return crops including orchards and high value crops on 25% of the command area which is proposed to be served with HEIS. Irrigation water will be provided to field crops through improved water channel with minimum water losses. Cropping intensity of 140% has been proposed keeping in view the water availability, soil suitability and climate conditions.

The projections of future proposed cropping pattern and intensities and cropped area for rainwater harvesting structures were estimated. The ultimate annual cropping intensity of 140% will be achieved within a period of four years and will observe linear trend from base year to 4th year. In consistence with government policy, orchards and high value crops comprising of olive(2%), grapes(6%), citrus(6%), peaches(2%), guava(3%), fig(1%), vegetables tunnels(2%) and flowers consisting of rose petal(1%), rose cut flower(1%), gladiolus(0.5%) and tube rose cut flower(0.5%) have been included in the cropping pattern.

The crops will attain the ultimate yields during 5thyear and afterwards taking this level constant, no projection has been made upto project life. The growth rate will be higher in the first 2 years due to application of water and other non-water inputs and afterwards with some slower rate. The ultimate crop yields are almost at par with adjacent irrigated areas.

Incremental Production & Benefits

Though 140% cropping intensity is still less than intensity achieved in many irrigated areas in Pothohar, the major shift in cropping pattern with inclusion of orchards / high

value crops / flowers will have major impact on farm incomes. Similarly improvement in crop yields is proposed from one and half to about two folds in traditional crops.

Gross value of products (GVP) has been worked out by multiplying the crop production with per unit farm gate price of crop production. Per acre cost of crop production has been worked out by developing farm budgets and for future without and with project conditions for proposed RHS. Per acre cost of production of various crops has been multiplied with respective cropped area under with project conditions to compute gross cost of production (GCP). By subtracting the gross cost of production from GVP, net value of production (NVP) has been obtained for proposed RHS. Based on CCA, calculations of GVP, GCP, NVP and net agriculture benefits for surveyed 40 RHS are given in **Table 7**.

Table 7: GVP, GCP and NVP for 40 RHSs *(000 Rs.)*

Storage Category	Command Area (Acres)	GVP		GCP		NVP		Incremental NVP
		Without Project	With Project	Without Project	With Project	Without Project	With Project	
Small RHSTotal	251	853.40	26,656.20	652.60	10,893.40	200.80	15,762.80	15,562.00
Medium RHS Total	298	1,013.43	31,654.68	774.97	12,936.09	238.45	18,718.59	18,480.13
Sub-Total (3):-	445	1,513.00	47,259.00	1,157.00	19,313.00	356.00	27,946.00	27,590.00
Total:-	**994**	**3,379.60**	**105,562.80**	**2,584.40**	**43,139.60**	**795.20**	**62,423.20**	**61,628.00**

FINANCIAL AND ECONIMC EVALUATION

The financial cost includes all taxes and duties. The total cost includes management cost, environmental and social development, agriculture marketing support cost etc.

Financial and Economic Cost

Basic Cost of each RHS consists of two components: RHS and spillway. The overall estimated cost of 40 RHS's is rupees 181.511 Million (**Table 8**). Cost of HEIS, Social & Environmental Management, Agriculture Supports and Project Management Support has been added.

The Standard Conversion Factor (SCF) is used to convert financial cost of material into economic cost. For this study, the SCF of 0.90 has been adopted. SCF Cost per acre of CCA is also given to determine the threshold cost of a RHS being feasible.

Table 8: Financial Cost of Proposed RHS

Size	Command Area (ac)	RHS Cost (Rs.)			*Total Cost (M.Rs)	Cost Per Acre (Rs.)
		Embankment	Spillway	Total		
Small (20)	251	41,407,234	19,722,975	61,130,209	93.97	374,385
Medium (12)	298	36,188,720	22,378,980	58,567,701	90.03	302,051
Large (9)	445	38,367,163	23,446,243	61,813,407	95	213,483
Total (40)	**994**	**115,963,117**	**65,548,199**	**181,511,316**	**279.02**	**280,704**

* *Includes RHS cost, HEIS, Social & Environmental Management, Agriculture Supports, Project Management Support etc.*

Economic Analysis

The economic cost of the project is taken from financial cost for economic cash flow statement and operation and maintenance cost is calculated as 0.5% of total cost. The agriculture benefits have been taken from Section–5 (**Table 7**). Economic cash flow has been prepared at 12% discount rate. The life assumed as 25 years. Incremental benefits have been calculated by taking the difference of total benefits and total cost. Economic parameters have been worked out on incremental benefits to indicate the feasibility of investment.

For the economic analysis of RHS, following are the basic assumptions:

1. The RHS will be developed for both agriculture and fisheries. The small size RHS will be developed for agriculture plus fish farming. Whereas, medium size will be developed as 30% for agriculture + fish farming and rest 70% for agriculture only.
2. The large size RHS will be developed by allocating 50% of the RHS for each fisheries and agricultural crops and 50% for agriculture only.
3. Agricultural benefits will include development of conventional irrigation on 61 % of CCA, HEIS on 25 % of CCA and bed and furrow system on 14 % of CCA.
4. The useful life of civil structure is considered as 25 years for economic analysis.

Economic Analysis

The Economic Internal Rate of Return (EIRR), Benefits Cost Ratio (BCR) and Net Present Value (NPV) are calculated from the cash flow statement.

Based on the feasibility study of 40 surveyed sites as given in **Table 9**, it can be deduced that per acre cost of RHSs varies with location and size. This cost includes structures, spillway, HEIS, environmental and social management cost, agriculture marketing support and project management support etc.

The economic analysis has been carried out for multipurpose usage of RHS (agriculture + fish farming) to establish economic viability of each RHS category (small, medium, large) and then of overall project. The economic analysis given in **Table 9** reveals that all the three sizes of RHSs are economically feasible for multipurpose use (agriculture + fish farming) with EIRR as about 20.57% for small size, 17.70% for medium, 19.1% for large size and overall 19.15%.

Table 9: Summary of Economic Analysis Results

Sr. No.	Description	RHS			
		Small	Medium	Large	Overall
A	**Economic Indicators**				
	IRR %	20.57%	17.70%	19.1%	19.15%
	NPV (Million Rs.)	43.54	27.40	64.41	135.39

Sr. No.	Description	RHS			
		Small	Medium	Large	Overall
	BC Ratio	1.9	1.63	1.81	1.79
B	**Basic Project Costs (Million Rs.)**	59.1	52.36	95.0	206.49
C	**Total Command Area (ac)**	251	298	445	994
D	**Total Cost** Per Acre **(Rs.)**	281,571	239,087	213,483	236,259
E	**Benefits Rs/ac**	95,804	78,866	78,617	82,809

Financial Analysis

The financial value of project benefits has been estimated by using market prices and including taxes and duties. All other assumptions are same as for the economic analysis. The financial analysis is given in **Table 10**. The analysis reveals that small size RHSs are not financially feasible having FIRR as 11.8% which is less than 12%. The medium size has FIRR as 15.0% and large size as 17.1% and both are financially feasible. The projects financial rate of return (FIRR) is estimated as 15.1% and BC ratio as 1.30 to one. Financial cash flow for three categories of RHSs showing agriculture, fisheries and total benefits are given in **Table 10**.

Table 10: Summary of Financial Analysis Results

Sr. No.	Description	RHS			
		Small	Medium	Large	Overall
A	**Economic Indicators**				
	IRR %	17.75%	15.99%	18.0%	17.43%
	NPV (Million Rs.)	29.76	1.39	51.85	100.55
	BC Ratio	1.5	1.39	1.59	1.52
B	**Basic Project Costs (Million Rs.)**	59.1	52.36	95.0	206.5
C	**Total Command Area (ac)**	251	298	445	994
D	**Total Cost per ac (Rs.)**	281,571	239,087	213,483	236,259
E	**Benefits Rs/ac**	62,234	62,033	62,026	69,614

Economic and Financial Sensitivity Analysis

Economic analysis was carried out for overall project as base case and then repeated for following three scenarios:

a. Increase cost by 10%

b. Reduce benefits by 10%

c. Increase cost by 10% and reduce benefits by 10%

The values of economic parameters for base case and above three scenarios are given in **Table 11**. It indicates that project is feasible with BC ratio of 1.79 and EIRR as 19.15% and even under worse scenario, the project will be economically feasible.

Table 11: Sensitivity Analysis Results (Economic)

Scenario	Net Present Worth (Millions Rs.)	Benefit Cost Ratio	EIRR (%)
Base Case	135.39	1.79	19.15
Sensitivity Analysis			
a. Increase cost by 10%	118.11	1.62	17.84
b. Reduce benefits by 10%	104.58	1.61	17.71
c. Increase cost by 10% and reduce benefits by 10%.	87.34	1.46	16.47

The financial value of project benefits has been estimated by using market prices and including taxes and duties. All other assumptions are the same as for the economic analysis. The projects financial rate of return (FIRR) is estimated as 17.43% and BC ratio as 1.52 (**Table 12**). Sensitivity analysis shows that project is robust and financially feasible under worse scenario.

Table 12: Sensitivity Analysis Results (Financial)

Scenario	Net Present Worth (Millions Rs.)	Benefit Cost Ratio	FIRR (%)
Base Case	100.55	1.52	17.43
Sensitivity Analysis			
a. Increase cost by 10%	81.40	1.39	16.11
b. Reduce benefits by 10%	71.34	1.37	15.97
c. Increase cost by 10% and reduce benefits by 10%.	52.19	1.25	14.72

CONCLUSIONS AND RECOMMENDATIONS

General: Pothohar region presents a good potential for construction of rainwater harvesting structures for storing runoff water and bringing barren lands under cultivation.

Criteria: Following criteria was adopted for analysis:

a) Mark the potential RHS sites utilizing imagery and general landuse map of the Pothohar area.

b) Determine height and storage capacity of the reservoir on the basis of topographical survey.

c) Identify command area in the vicinity of the rainwater harvesting structure.

d) Recheck design of the structure on the basis of general geology of the area assuming that rock will be available approximately at 10 ft depth from the surface. Moreover, availability of impervious material within 3 miles haulage distance shall be assumed.

e) Design of spillway will be assessed on the basis of 25 year return period inflow whereas highest flood level (HFL) of the RHS will be determined on return period.

f) Prepare BOQ and calculate base cost of the RHS and add 5% for physical contingencies.

g) Considering water and land resources as constraining factors, 25% of command area is proposed to be served with high efficiency irrigation system (HEIS) and Drip Irrigation is the option. The rest area will receive surface / flood irrigation and bed and furrow irrigation. The crop production is envisaged to be achieved through bringing barren land under cultivation and practising of cropping pattern and intensity of 140% with high return crops including orchards and high value crops on 25% of the command area proposed to be served with HEIS and traditional crops on 75% of area proposed to be served with conventional irrigation and bed furrow method of irrigation.

h) Calculate agriculture benefits per acre of command area.

i) Perform economic analysis of the RHS.

j) Structures having storage capacity less than 10 AF and above 100 AF will not be considered is recommended.

k) Solar system shall be installed for such RHSs with pumps ranging from 2Hp to 5Hp depending upon availability of command area and willingness of farmers to adopt HEIS as more than 90% RHSs would require lifting of water instead of gravitational flow.

Geological Studies: Mostly shale and clays predominate at the abutments while hard strata of sand stone is encountered in the nullah beds at shallow depths at most of the sites. Required construction material in adequate quantities and of suitable quality for the construction of these sites is available.

Hydrological Studies: The catchment area for these sites will vary from 0.25 to 3 mile^2 and average annual yield for 1 mile^2 is about 161 acre feet. The annual sediment yield is 2 AF/mile^2. The spillway will be designed to pass 100 year return period.

Sediment Control and other Benefits: With the construction of these RHSs, flows will be conserved for regulated flows for sustained irrigation in the Pothohar region. Moreover, these RHSs will be helpful in checking sediment in already constructed small dams in the Pothohar region.

Agricultural Studies: Command area is available in the vicinity of these sites. The present agriculture in the command area is meager and below subsistence level mainly due to slopping land and non-availability of regular supply of irrigation water. Because of assured irrigation supplies after the construction of these RHSs, annual cropping

intensity of 140% will be achieved within a period of 4 years after project commencement.

Project Cost & Economic Analysis: The basic cost of 40 sites including RHS and Spillway come to about Rs. 181.511 million. The average per acre of CCA cost is about Rs. 182,606. The overall project cost also includes HEIS, social and environmental management. Agriculture marketing support and project management cost etc. and it comes to about Rs. 279 million with average cost per acre of CCA as Rs. 280,824. A threshold limit of RHS cost in terms of its being economically feasible is about Rs. 375,000 per acre of CCA.