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IMPACTS OF PLANNING AND DESIGN CHANGES ON CHANNEL BEHAVIOUR AND ENVIRONMENT : A CASE STUDY OF FALL AT RD. 64+537 MUZAFFARGARH CANAL

BY

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IMPACTS OF PLANNING AND DESIGN CHANGES ON CHANNEL BEHAVIOR AND ENVIRONMENT: A CASE STUDY OF FALL AT RD 64357 MUZAFFARGARH CANAL

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ABSTRACT

Muzaffargarh Canal offtakes from left side of Taunsa barrage and irrigates 0.845 million acres of land. Soon after its commissioning in 1958, vast area on both sides of the canal in its head and middle reaches got severely waterlogged. In order to provide relief to the area, 5.3 feet fall at RD 127300 was knocked down in 1960-61. Over the long run, knocking down of the fall at RD 127300 resulted in retrogression of the Canal bed and lowering of water levels upto the next upstream fall structure located at RD 64357.

This paper describes and critically reviews various remedial measures undertaken at the fall RD 64357 from time to time. It attempts to identify the reasons for continuous D/S bed scour and side erosion. Remedial measures for addressing the problems have also been proposed.

Extending the case study, the paper discusses some broader issues which have had a bearing on the channel behavior and environment. These include planning stage decision making, effect of increase in water allowance of Muzaffargarh Canal and role of external influences on technical decision making. The paper concludes that lack of adequate technical considerations in planning and design of major irrigation projects may have serious repercussions on their operation and subsequent performance.

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A. INTRODUCTION

Muzaffargarh Canal off-takes from left side of Taunsa Barrage on River Indus. Previously area in D.G. Khan and Muzaffargarh Districts used to receive Irrigation Supplies from the inundation canals. Taunsa Barrage Project was commissioned in 1958 to provide weir controlled irrigation facilities to the area. Original Design capacity of Muzaffargarh Canal was 8285 Cusecs. The Irrigation System of this canal comprises 123 channels in all; a main canal, 4 branch canals, and 118 distributaries and minors with cultivable command area of 845,000 acres. The canal system had originally been designed as non-perennial. But over the years, the main canal is being increasingly run during winter season also with partial supplies to feed the areas having brackish groundwater. The existing annual cropping intensity (1993-1994) is around 114%, against annual designed cropping intensity of 65% (NESPAK 1995).

Figure-1(a) shows the project location, while Figure-1(b) shows the general alignment of the Muzaffargarh Canal and its command area. The area is bounded by River Chenab on its east and River Indus on its west. The confluence of these two rivers is in the south at Panjnad. The area is characterized by the alluvium deposited by the two rivers in recent geological time. This alluvium consists of loose to medium dense, fine to silty sand. The surface deposits are exposed to eoline processes, as such sand dunes are a distinct surface feature in the area.

There are a number of hydraulic structures along Muzaffargarh Canal. Table 1 summarizes the details of falls/regulator structures, originally provided in the head and middle reaches of the main canal.

TABLE-1

Falls/Regulator Structures on Muzaffargarh Canal RD 0-206700 (Original Design)

S.No.	Site	Fall	Remarks
1.	RD 0	3.0 ft.	Head Regulator of the Canal.
2.	RD 64357	4.0 ft.	Fall and regulator. Thal branch off-takes from left.
3.	RD 127300	5.3 ft.	No channel off-takes in the reach from RD 64357 to RD 127300.
4.	RD 147500	3.0 ft.	Fall and regulator.
5.	RD 177093	1.1 ft.	Fall and regulator.
6.	RD 206700	1.5 ft.	Fall and regulator.

The structure built across Muzaffargarh Canal at RD 64357 serves two purposes in the canal system. First, it is an essential component providing a fall of 4 ft. as originally anticipated in the design and a cross Regulator for Thal Branch, Rafique minor and a newly built intake structure for Thermal Power Station Kot Adu.

B. EXCESSIVE WATERLOGGING AFTER COMMISSIONING OF MUZAFFARGARH CANAL

Muzaffargarh Canal was commissioned in 1958 with a discharge capacity of 8285 Cusecs. This channel was designed as alluvial channel based on Lacey's approach having a silt factor of 0.93. The estimated seepage loss through the wetted perimeter of the main canal was about 1043 cfs. along a canal length of 74 canal miles. Due to the coarse nature of soil having high permeability, the area quickly started showing signs of the emerging menace of water-logging. This had an alarming impact on the environment within one year of operation of Muzaffargarh Canal. The other factor which contributed to the high seepage rate was the alignment of the canal making a concave shape in the head and middle reaches providing large volume of water body in an area having coarse-grained soils and a natural constraint in respect of subsurface drainage. The open drains within the Muzaffargarh Canal Irrigation System were unable to cater for proper drainage of infiltrating water from Muzaffargarh Canal System and the irrigation fields. The area thus got heavily water logged resulting in the decline of crops yields and build up of soil salinity in the root zone. An area of 5.3 lac acres came under the grip of serious waterlogging conditions by the year 1960. This seriously hampered agriculture of the area as vast tracts of land were driven out of cultivation. The gravity of the problem gave rise to strong socio-political pressures which alarmed the Government (PID Syndicate Report, 1986).

C. KNOCKING DOWN OF FALL AT RD. 127300 AND ITS IMPACT ON CHANNEL BEHAVIOR

In 1960-61 Additional Chief Engineer Operation decided to lower the full supply levels in Muzaffargarh Canal, in the reaches where feeding of channels was not effected, by lowering the crest level of fall at RD 127300. There is no record available which may show that the effect of this decision on the canal system was ascertained before executing it at the site. Redistribution of Residual head of 3 ft. in the form

of kinetic energy resulted in steep water surface profiles along the U/S reach RD 127300 to RD 64357 and in the canal reach down-stream of fall RD 127300 up to the next fall at RD 147500. This resulted in serious bed scour in these reaches causing excessive settlement of two left piers of D.R. Bridge at RD 132500. The canal was immediately closed and the crest of Fall at RD 127300 was raised by 1.5 ft. during the same flow season. The crest was again lowered by 1.5 ft. prior to the flow season of 1964. Lowering of the crest of fall RD 127300 continued in the following seasons, and the 5.3 ft. fall was completely eliminated in five flow seasons.

The lowering of the crest meant higher than the designed velocities in the channel reach RD 64357-147500 due to additional energy gradient caused by lowering of the fall. These higher velocities started eroding the bed and banks of the canal. The retrogression traveled upto the next up-stream control point at RD 64357, progressively lowering the design bed level d/s of the structure and jeopardizing its safety. The temporal changes in design full supply levels upstream and downstream of fall at RD 64357 are given in Table-2.

TABLE-2

Temporal Changes in the Operating Parameters of Fall RD 64357

F.S.L. U/S (Ft)	F.S.L. D/S (Ft)	Discharge D/S Fall (Cusecs)	Fall (Ft)	Remarks
436.77	432.77	4567	4.00	Original Design, 1958
437.11	429.44	4800	7.67	Existing Condition 1975
437.39	428.98	4993	8.41	Existing Condition 1986
436.85	428.98	5100	7.14	Proposed Design 1986
438.29	429.28	6100(Max)	9.01	Max Operating Condition, 1995

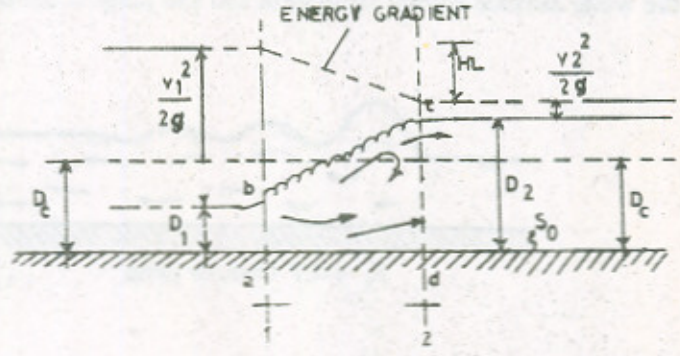
D. ANALYSIS OF FALL STRUCTURE RD 64357 MUZAFFARGARH CANAL

Phenomenon of Energy Dissipation through Hydraulic Jump

Effective energy dissipation in a hydraulic jump type basin takes place by designing the hydraulic structure in such a way that hydraulic jump is formed on the toe of the sloping glacis. The hydraulic jump is a sudden and turbulent passage of a flowing water from a lower than critical depth (Supercritical flow) to a higher than critical depth stage (Sub-critical flow). Like all expanding flows which produce an increased pressure downstream, the hydraulic jump is accompanied by large and violent eddies and loss of kinetic energy.(Dake,1983)

In a rectangular channel with the given discharge Q, width b and head loss H_L, the Conjugate depths d_1 and d_2 i.e. depth before and after hydraulic jump can be determined by the following equations which are based on momentum and energy principle.

OPEN CHANNEL FLOW



$$d_1 d_2 (d_1 + d_2) = 2\frac{q^2}{g} \qquad (1)$$

Where q is equal to Q/b.

$$\frac{d_2}{d_1} = \frac{1}{2}\left(\sqrt{1+8F_1^2}-1\right) \qquad (2)$$

Where F_1 is dimension-less number known as Froude number before jump which is given as Where V_1 is velocity of flow before jump and g is acceleration due to gravity.

$$F_1 = \frac{V_1}{\sqrt{g d_1}} \quad (3)$$

Energy loss or head loss is given by

$$H_L = \frac{(d_2 - d_1)^3}{4 d_1 d_2} \quad (4)$$

For hydraulic analysis of the fall structure, the solution of these equations has been obtained by iterative method and verified through the use of Blench and Crumps Curves.

Types and Characteristic of Hydraulic Jump

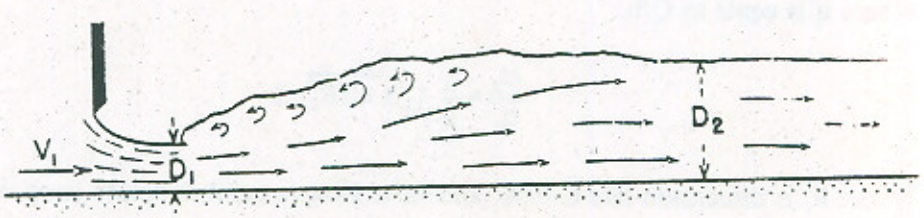
The characteristics of hydraulic jump and its performance has been studied by United States Bureau of Reclamation (USBR) through experimental flumes and model studies and its characteristics correlated with Froude number F_1 before jump (Petrika, 1984). For $F_1 = 1$, the flow is critical and hence no jump can form.

For $F_1 = 1$ to 1.7 the water surface shows undulation and the jump is called an undular jump.



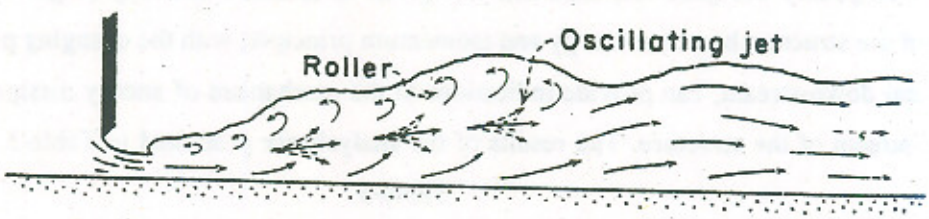
F_1 = 1-1.7 Undular jump

For $F_1 = 1.7$ to 2.5, a series of small rollers develop on the surface of the jump, but the downstream water surface remains smooth. The jump may be called a weak jump.



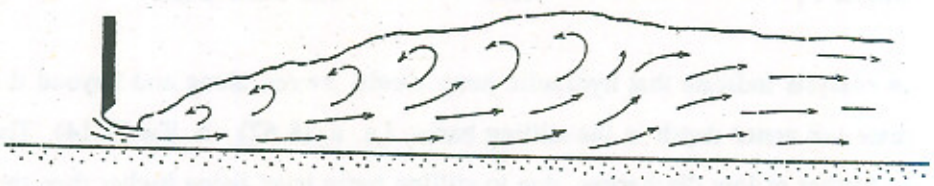
F_1=1.7 to 2.5

For F_1 = 2.5 to 4.5, there is an oscillating jet entering the jump bottom to surface and back again with no periodicity. Each oscillation produces a large wave of irregular period which, very commonly in canals, can travel for miles doing unlimited damage to earth banks and ripraps. This jump may be called an oscillating jump.



F_1=2.5 to 4.5

For F_1 = 4.5 to 9.0, the downstream extremity of the surface roller and the point at which the high velocity jet tends to leave the flow occur at practically the same vertical section. The jump is well balanced and the performance is at its best. This jump may be called a steady jump (Vente-Chow 1983).



F_1=4.5 to 9.0—range of good jumps

The performance of hydraulic jump for energy dissipation depends on the downstream channel stage i.e. tail water depth. When Conjugate depth d_2 equals the tail water depth T_w the true hydraulic jump forms with its energy dissipation performance at its best. In case of Conjugate depth $d_2 > T_w$ the hydraulic jump sweeps along the stilling basin with increasing jump length and causing downstream erosion. On the other hand when $d_2 < T_w$ the hydraulic jump is submerged one in which case the weak jump forms and the energy dissipation is less efficient.

Hydraulic Performance of Fall RD 64357 in the Post Knocking Down Scenario:

The Fall structure at Rd 64357, also acting as a cross- regulator, had been designed for a discharge of 4567 Cfs. with 110 feet clear water way, fluming ratio of 0.61, and for providing a fall of 4 feet. The details of originally designed fall structure are given in attached drawing (Figure-2). The hydraulic analysis of the structure based on energy and momentum principle, with the changing physical parameters of the canal down-stream, can provide indications to the mechanism of energy dissipation and its effect on down-stream of the structure. The results of the analysis are presented in Table-3.

Table-3

Condition of Fall RD 64357, Year 1975.
Results of Analysis at Full Supply Discharge

Discharge Q	=	4800 Cfs.	Head Loss	=	7.67 ft.
Conjugate depth d_1	=	1.40 ft.	Clear water way	=	110 ft.
Conjugate depth d_2	=	8.52 ft.	Ef_2	=	8.94 ft.
Froude number F_1	=	4.64	Tail water depth	=	7.14 ft.

The above analysis indicate that hydraulic jump would sweep along and beyond the stilling basin due to inadequate tail water depth in the stilling basin, i.e. d_2 (8.52) > Tw (7.14). The conditions would deteriorate further at low discharges, due to stilling basin level being higher then the bed of canal. The sweeping of the jump beyond the stilling basin and the consequent turbulence and eddy formation caused severe downstream scour and side erosion of the earthen section.

E. REMEDIAL MEASURES UNDERTAKEN AT FALL RD 64357

Remedial Measures during 1975.

The Executive Engineer, Kot Adu referred the case to Central Design Office in 1975 for a permanent solution of the problem of inadequate energy dissipation at the fall structure. Upto 1975 the field staff was taking remedial measures on its own by pilchi pitching and stone dumping down-stream of the structure. The XEN reported that, due to elimination of the down-stream fall at RD 127300, the general

bed level d/s of the fall structure RD 64357 had retrogressed from 424.17 to 419.55, thus resulting in lowering of F.S.L. from 432.77 to 429.44. The field officers suggested the construction of a secondary fall in continuation of the existing d/s impervious floor. This secondary fall was to consist of a 25 ft long stilling basin at RL 414.15. The purpose of the secondary stilling basin was to dissipate the additional head over and above the original design values. The proposal also included a diversion channel for Muzaffargarh canal to afford longer construction period.

The C.D.O. reviewed the field proposal and identified the following options/ remedial measures for the safety of the structure :

1. Restoration of the original crest level of the Fall at RD 127300 may be considered, provided sub-soil water level has gone more than 10 ft. below the ground level.
2. To correct the side erosion, the end vanes (9" thick) in continuation of the abutments may be provided for a distance of 10 to 12 ft. with its top level about 0.5 ft. higher than the F.S.L. d/s. This device will avoid formation of the strong side rollers at the ends which usually cause heavy side erosion.
3. The d/s row of blocks at the end of the stilling basin may be converted into a sill so that minimum tail water level can be obtained in the basin for the formation of hydraulic jump.
4. The existing loose stone apron downstream may be replenished, if required at site.
5. If the wave action persists and is considered serious, some device to suppress the waves at their initial formation may have to be considered through extension of piers to accommodate some sort of breast wall immediately after the hydraulic jump.

Out of the above five recommendations, the recommendations at Sr. No:2, 3 & 4 were implemented at site in the year 1976, but the problem of bed and side erosion continued to persist.

Remedial Measures During 1986-87

Hydraulic Analysis

In order to identify the reasons for continued hydraulic problems, the working of fall structure RD 64357 has been analyzed based on momentum and energy principle for the condition existing during the year 1986-87. The results of hydraulic analysis for energy dissipation are summarized in Table-4.

Table-4

Condition of Fall RD 64357, the year 1986
Results of the Analysis at Full Supply Discharge

Discharge	=	4993 Cfs	Head Loss	=	8.41 ft.
Conjugate depth d_1	=	1.41 ft.	Clear water way	=	110 ft.
Conjugate depth d_2	=	8.85 ft.	Ef_2	=	9.27 ft.
Froude number before jump F_1	=	4.78 ft.	Tail water depth	=	6.68

The above results of hydraulic analysis based on energy and momentum principle indicate that hydraulic jump sweeps along the stilling basis as d_2 (8.85 ft.) > Tw (6.68 Ft). The turbulence and eddy currents still cause d/s scour and side embayment (erosion) due to inefficient energy dissipation within the stilling basin.

Measures Proposed by the Field Staff

The Executive Engineer Kot Adu, approached the Central Design Office in 1986. According to his report, hydraulic data observed during December 1985 showed that the head across the fall structure had increased to 8.41 feet against the design value of 4 ft. There was also serious bank erosion which had even swallowed the service road of main canal. A huge scour pit with a maximum depth of almost 38 ft. had formed just downstream of the structure as shown in the sounding plan (Figure-3). All these factors seriously endangered the safety of the structure. The Executive Engineer proposed that, starting from existing end of the d/s pucca floor filter, an additional 40 ft long stilling basin at RL 416.48 be provided, followed by 20 ft. inverted filter and 30 ft. stone apron with usual thickness. The field proposal is shown in Figure-4.

Proposals by the Senior PID Engineers

This problem was also taken up as a syndicate discussion at Punjab Engineering Academy and a panel of senior Engineers of the Punjab Irrigation & Power Department studied the following remedial options:-

a) Providing a stone boom d/s of the fall to reduce the working head. This proposal was dropped because it could not possibly dissipate the energy of the flow and heavy maintenance expenditure.

b) Providing adequate stilling basin in continuation of the existing d/s floor. This recommendation was in line with the proposal of Executive Engineer, Kot Adu. But the experts recommended that before implementing this proposal at site, it should be tested through model studies at Irrigation Research Institute.

c) Providing meter flume about 1000 feet d/s of existing Fall. The meter flume was to function as a subsidiary fall limiting the existing structure to its original designed drop as well as discharge measuring device.

The panel of experts recommended to adopt the alternative c. The alternative b was considered feasible subject to the results of physical model testing (PID-Syndicate Report, 1986).

CDO Recommendations

All the above three proposal were examined in C.D.O. and after considering the field conditions, comparative costs and practicability of construction, proposal 'b' was adopted. The conceptual approach of the design was based on the provision of a stepped fall structure in which the 2nd control point i.e. weir just downstream of existing stilling basin would control the water levels to such a level that existing fall would have to cater for 4 feet head loss as per original design. The stilling basin design for 2nd weir with an end sill was evolved to dissipate the balance energy of 3.87 Ft fall. An Inverted block filters and a downstream cutoff (sheet pile) were proposed to take care of the sub surface design requirements. Scour protection in the form of stone apron and stone pitching were provided to protect bed scour and side erosion of the banks.

Design Changes during Construction

The design proposals of CDO were not fully implemented reportedly due to field constraints and limitations of available funds. Inverted filter, downstream cut-off and extension of upstream floor were not constructed. Similarly changes were made by the field staff in the stilling basin design appurtenances with the provision of 2.5 ft. high baffle wall at about 15 ft. from the downstream glacis.

The analysis to evaluate the effect of design changes related to omission of downstream cut-off without extension of upstream floor indicates that the omission may endanger the safety of the structure due to excessive exit gradient under the extreme conditions. The calculations for exit hydraulic gradient indicate that exit gradient as per constructed lay out comes to around 1 in 3.3 under extreme conditions, which is beyond the recommended safe limits. The design details of the proposed structure are shown in Figure-5. The constructed layout of the structure is given in Figure-6 and can be seen through attached photographs.

F. THE PRESENT CONDITION OF FALL RD 64357

Hydraulic Analysis

The fall structure has been analyzed for effectiveness of energy dissipation under the present maximum operating conditions during the year 1994. The results of the analysis, based on energy and momentum principle, are given in Table-5.

Table-5

Condition of Fall RD 64357: Year 1994.
Results of Analysis at Maximum Operating Discharge

Fall (1)

Discharge Q	=	6100 Cfs	Head Loss	=	4.41 ft.
Conjugate depth d_1	=	2.02 ft.	Clear water way	=	110 ft.
Conjugate depth d_2	=	8.77 ft.	Ef_2	=	9.39 ft.
Froude number before jump F_1	=	3.40	Tail water depth	=	11.58 ft.

Fall (2)

Discharge Q	=	6100 Cfs	Head Loss	=	4.60 ft.
Conjugate depth d_1	=	1.45 ft.	Clearly water way	=	160 ft.
Conjugate depth d_2	=	7.21 ft.	Ef_2	=	7.64 ft.
Froude number before jumps F_1	=	3.85	Tail water depth	=	8.80 ft.

The above analysis shows that under the existing maximum operating conditions, the hydraulic jump is submerged as tail water depth in both the stilling basin is more than the required conjugate depth "d_2". The jump position has been further investigated for the discharge ranging from 10% to 120% of the design discharge. The results of this analysis indicate that jump in the stilling basin of main (first) fall remains submerged for all operating conditions. For the subsidiary fall, however tail water depth falls short of the required conjugate depth "d_2" at low flow stage. It means that jump would sweep out of the 2nd stilling basin at low discharges and cause d/s damage. This is depicted in Figure-7 which shows jump and tail water rating curve at various discharges for the subsidiary fall. At higher discharges the tail water rating curve is above the jump rating curve which indicates that the hydraulic jump would form on the glacis and would be of submerged type. For lower discharge range the jump rating curve is above the tail water rating curve which shows that the tail water depth is inadequate for formation of the jump on the sloping glacis, and therefore jump sweeps along the 2nd stilling basin. This causes downstream scouring of bed due to improper energy dissipation in the range of low discharges. The Froude number before jump indicates that the hydraulic jump falls in the range of unstable and oscillating jump (F_1 between 2.5 and 4.5) and the energy dissipation within the stilling basins is therefore inefficient.

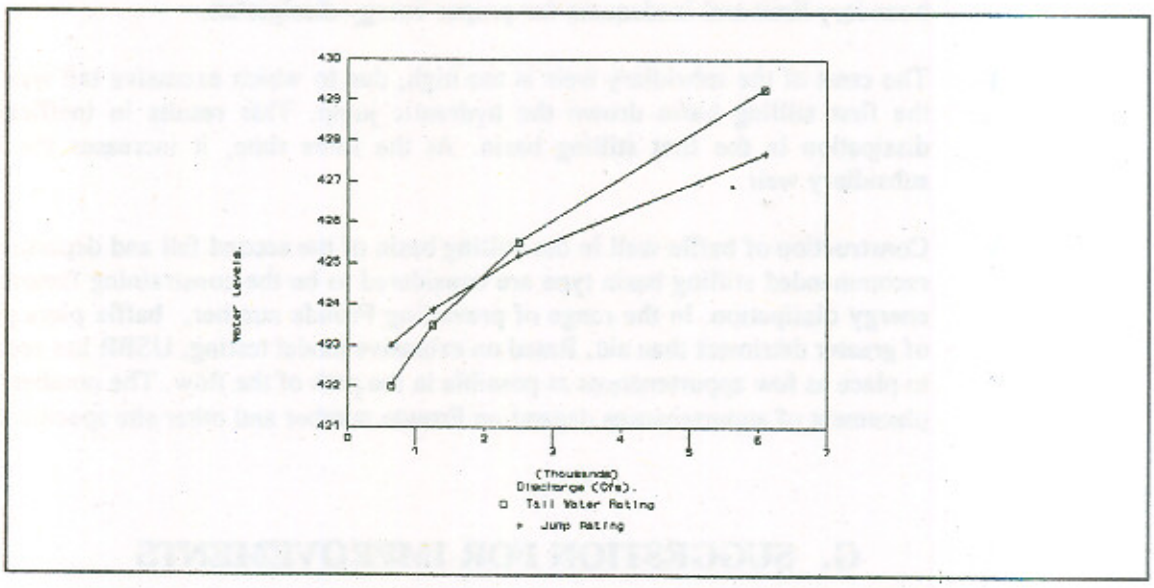


Fig.7 Jump and Tail Water Rating Curves for Subsidiary Weir.

Present Site Conditions

The feed-back from the field staff and the site condition of Fall RD 64357 show that the downstream scour pit has reduced from 38 ft. to 9 ft. The condition of banks downstream has, however, aggravated due to excessive side erosion. The field staff has tried stone studs on the left and right bank downstream as a remedial measure to arrest bank erosion and regain channel section, but still this measure seems inadequate (Refer Photographs).

Main Reasons for Hydraulic Problems

i) The hydraulic analysis of present site conditions of the fall structure at maximum operating conditions indicates that both the stilling basins of fall RD 64357 operate in the Froude number range from 2.5 to 4.5. In this range, hydraulic jump has a pulsating action. Surface waves are generated which travel long distances and are the main source of difficulty and cause of erosion of banks down-stream of the fall structure.

ii) The level of 2nd stilling basin floor is higher than the existing bed level of the canal. This gives rise to serious inadequacies at low discharges. At low stages, the jump invariably sweeps out of the stilling basin due to tail water levels being lower than the required conjugate depth. The stilling basin length also appears to be on the lower boundary limit and inadequate for proper energy dissipation.

iii) The crest of the subsidiary weir is too high, due to which excessive tail water depth in the first stilling basin drown the hydraulic jump. This results in inefficient energy dissipation in the first stilling basin. At the same time, it increases the fall at the subsidiary weir.

iv) Construction of baffle wall in the stilling basin of the second fall and departure from the recommended stilling basin type are considered to be the constraining factors in proper energy dissipation. In the range of prevailing Froude number, baffle piers prove to be of greater detriment than aid. Based on extensive model testing, USBR has recommended to place as few appurtenances as possible in the path of the flow. The number, shape and placement of appurtenances depend on Froude number and other site specific conditions.

G. SUGGESTION FOR IMPROVEMENTS

Suggestions for improvement emanate from the diagnostic analysis of the present condition of the fall structure RD 64357 of Muzaffargarh Canal. The ideal solution would be to lower the level and extend the length of stilling basin of the second fall along-with provision of D/S cut-off, consistent with the

surface and sub-surface flow requirements under all operating conditions. This would however require reconstruction of the stilling basin of the second fall, which may pose practical difficulties in the field. The suggested improvement measures therefore basically aim at mitigating the identified hydraulic problems without resorting to extensive dismantling & reconstruction activities. The suggested measures include (Figure-8):

i) Lowering of the crest of 2nd fall (subsidiary weir), consistent with adequate tail water depth (Tail water depth = 1.1 d_2) to prevent sweeping of the jump. This would allow optimization of energy dissipation in the first stilling basin, thereby reducing the net fall at the subsidiary weir. The basic concept is that since the first stilling basin has more favourable characteristics (in terms of both length and level), so it should be utilized for dissipation of maximum possible head. Preliminary calculations indicate a possibility of lowering the crest by about 2 feet, which may be firmed up and refined. In this way the energy dissipation requirement at the subsidiary fall would reduce, thereby making it possible to improve the overall performance of the fall RD 64357.

ii) The appurtenances of 2nd stilling basin require modifications, consistent with the United State Bureau of Reclamation (USBR) stilling basin type IV recommended for the prevailing Froude number range of 2.5 to 4.5 (Figure-9). There is no need of baffle wall within the 2nd stilling basin, which may be removed. Deflector blocks at the toe of glaces would help to stabilize the jump and improve overall energy dissipation characteristics. These blocks therefore, need to be constructed as per standard design of USBR.

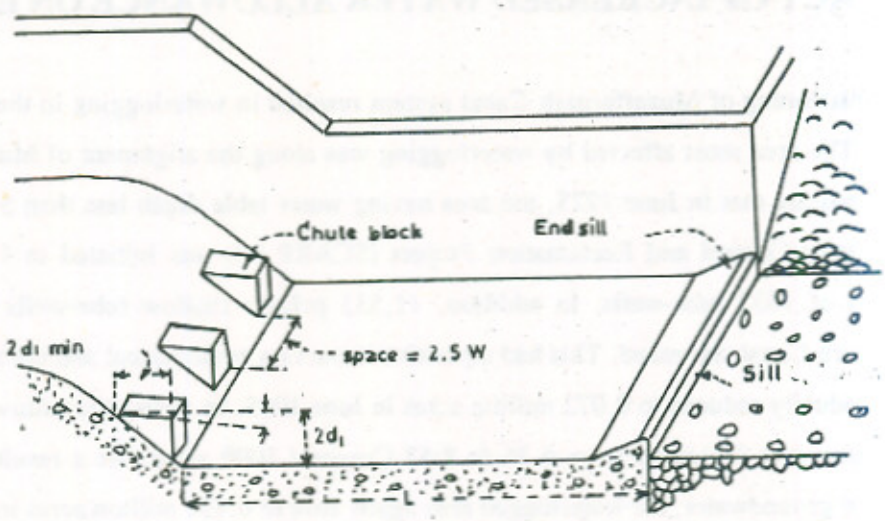


FIG.9 USBR TYPE IV BASIN

iii) The down-stream stone apron already existing at the site, may be converted into an improvised stilling basin with its top level below the D/S canal bed level (say at R.L.417). A standard end sill may be added at the D/S end for scour control. This would help to stabilize and contain the jump at low discharges.

iv) Performance of the structure with reference to the sub-surface flow conditions need to be monitored and evaluated, with special reference to omission of D/S sheet pile and U/S floor extension. The field officer should clearly understand the safe operational limits of the structure in the existing conditions. Remedial measures (D/S cut-off and U/S floor extension) may be implemented; keeping in view their need for constructiability and economics in the context of the prevailing site conditions.

v) Regulation pattern at the fall structure needs to be closely monitored in order to avoid isolated flow concentrations and head across the structure within the safe limits.

vi) Provision of smooth D/S transition with a splay of 1:5. The transition should extend to cover the existing dominant width of the canal, and to be curved back/embedded into the canal bank at its D/S end. This arrangement is expected to prevent flow separation and formation of side eddies, which cause bank erosion.

vii) The above suggestions may be tested on a physical model and the improvement measures fine-tuned and optimized in the light of the test results.

H. IMPACT OF INCREASED WATER ALLOWANCE ON ENVIRONMENT

The commissioning of Muzaffargarh Canal system resulted in waterlogging in the command area of the channels. The area most affected by waterlogging was along the alignment of Muzaffargarh Canal. The statistics indicate that in June 1975, the area having water table depth less than 5 ft. was 0.127 million acres. Salinity Control and Reclamation Project (SCARP III) was initiated in 1971, which envisaged installation of 1632 tube-wells. In addition, 11,533 private shallow tube-wells were installed in the Muzaffargarh Canal command. This had a positive impact on environment and the area effected by water-logging gradually reduced to 0.072 million acres in June 1985. In 1986 water allowance of Muzaffargarh Canal System was increased from 6.36 to 8.57 Cusecs / 1000 acres. As a result of this and declining pumpage of groundwater, the waterlogged area again rose to 0.431 million acres in June 1991, indicating substantial build up of the waterlogging problem due to unplanned increase in surface supplies. The temporal variations in waterlogged area is presented in Figure-10.

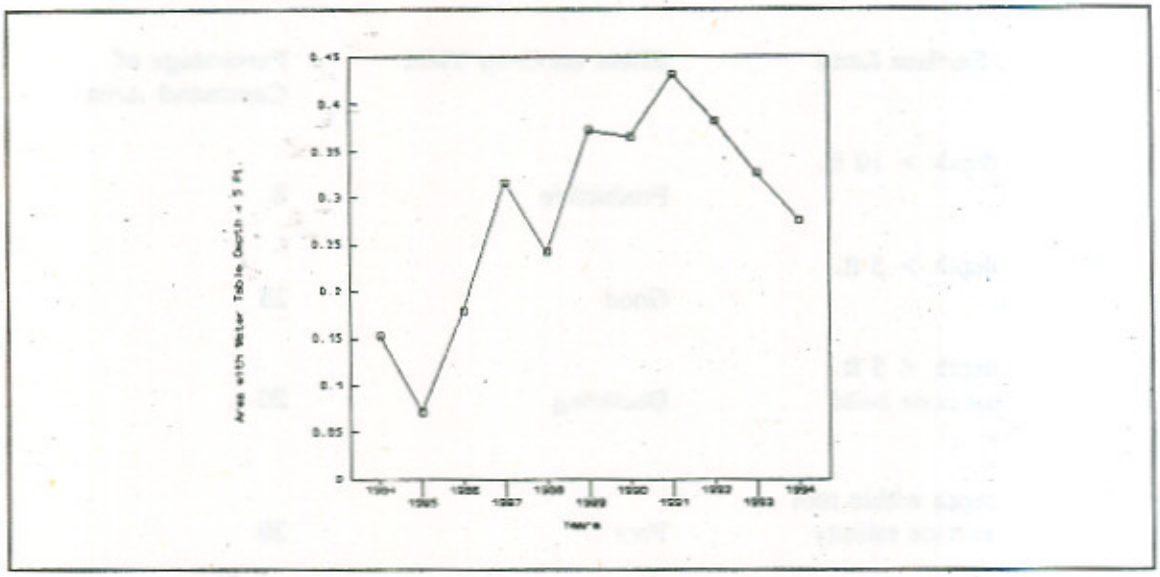


Fig.10 Extent of Waterlogging in Muzaffargarh Canal Command: Temporal Variations.

The build up of water-logging affects the productivity of land and triggers changes in the cropping pattern, growth of natural flora, quality of water and soil along-with changes in surface features. Lack of aeration affects the activities of soil bacteria, which in turn retards the plant growth. Continuous upward capillary flow of water from raised water-table results in deposition of salts in the root zone leading to increasing soil salinity. In saline area with pH > 8.5, the land becomes infertile. The farmers have to change their cropping patterns to respond to the changed environmental conditions.

At present, the area affected by water-logging in Muzaffargarh Canal command, based on the characteristics of water table depth, surface soil conditions and crop yield has been categorized and estimated by NESPAK (1995); which is presented in Table-6.

Table-6

Extent of Waterlogging in Muzaffargarh Canal Command

Subsurface, Surface Land Conditions	Effect on Crop Yield	Percentage of Command Area
Water table depth > 10 ft. Normal Soil	Productive	8
Water table depth > 5 ft. Normal Soil	Good	25
Water table depth < 5 ft. and below root zone build up of salinity	Declining	20
Water table depth within root zone visible surface salinity	Poor	20
Ponded Area Highly salinized	Nil	27

I. DISCUSSION OF BROADER ISSUES

Planning Stage Decision Making

In the initial stages of planning and design of Muzaffargarh Canal System, the effect of water seepage through the Irrigation System was not investigated in detail. The main Canal was aligned through an area having coarse gained soils and impeded drainage. An alignment along the present Magasson Branch was originally considered at the planning stage. This alignment was expected to be much more favorable than the existing alignment because of less permeable soil formations enroute and better drainage characteristics due to proximity of river Indus. This alignment, however, had to be dropped due to socio-political compulsions. This vital planning stage decision is visualized to have triggered far-reaching consequences on the subsequent problems of channel operation and environmental degradation.

Inadequate Technical Precautions in Implementing Design Changes

Knocking down of 5.3 ft. fall at RD 127300 Muzaffargarh Canal is a typical illustration of inadequate technical precautions in implementing field interventions by the operation staff. This emergency measure was ordered by the then Additional Chief Engineer (Operation) to provide relief from excessive waterlogging. This resulted in excessive retrogression and lowering of canal bed and full supply levels; steeper energy gradient; and higher than designed velocities causing excessive bank erosion in the reach between RD 64357 to 147,000. In addition, it reflected adversely on the working of canal structures in the above reach, especially the fall at RD 64357. The bridges at RD 88,000 and 111,000 of Muzaffargarh Canal also suffered serious problems with deep scour pits and excessive embayment d/s of the bridges. The situation is being managed with huge recurring expenditure ever since knocking down of the fall.

This clearly brings out the need of proper planning and detailed technical analysis before implementing any design change on Irrigation Channels. In fact, a number of alternatives may be evaluated with a view to selecting technically most feasible and economically most viable option. Still better, a set of scenarios should be considered at the planning stage in order to bring out their likely impacts. The discounting techniques offer considerable promise in this behalf, as it provides a common base for comparing short and long-term costs/benefits of various alternatives.

Effect of Increased Water Allowance

The main factor which aggravated the environmental degradation due to water-logging was the decision taken in 1985 to increase the water allowance of the Muzaffargarh Canal System from 6.36 Cft. per 1000 acres to 8.57 Cfs. per 1000 acres. This decision was taken without technical analysis and estimation of crop water requirements under the prevailing agro-climatic conditions in Muzaffargarh Canal command area. The raising of water allowance was basically a socio-political decision. Although other factors may also have contributed to subsequent environmental degradation in the form of increased waterlogging, raising of water allowance appears to be the major factor which has aggravated the situation.

As such though well intentioned, raising of water allowance proved to be rather counter-productive in meeting the intended objectives of increased agricultural production.

Though widely acknowledged, the role of external influences on technical decision making in planning of irrigation projects has generally not been that well documented. Since irrigation projects are part of the broader context of the society, so it can be quite understandable that the external influences guide decision making related to socio-political aspects. For optimizing benefits from the Projects however, it would only be fair if technical decision making is left to the professionals.

As brought out in this paper, external influences can play a significant role in decision making on issues where technical considerations should have been the main determining factor. In most of the developing countries this situation prevails due to inadequate development of institutions, and lack of appreciation of the technical considerations by the politicians and decision-makers. The consequences of this state of affairs are not too difficult to comprehend. The point of concern, however, is that technical departments have been considerably weakened. The pitfalls and failures emanating from external influences either do not get reported or the failures get attributed to inefficient engineering skills. There is thus a need for the Engineering institutions to play a role in this behalf. A process needs to be set up for objective review of the completed and on going projects in order to learn from the experience and to optimize planning design decision making.

J. CONCLUDING COMMENTS AND RECOMMENDATIONS

1 The case study has brought out the following issues:

a) The hydraulic problems at the fall RD 64357 of Muzaffargarh Canal have been caused due to overstressing of the structure much beyond its design parameters. These problems have continued due to inadequate energy dissipation.

b) The existing fall structure is working in the Froude Number range of 2.5 to 4.5, which gives rise to oscillating hydraulic jump. In this range, the energy dissipation is inadequate and surface rollers and wave action persist downstream, resulting in considerable damage to canal banks.

c) The construction of second stilling basin is not in accordance with the type recommended by USBR for the above Froude number range. This hampers proper energy dissipation downstream of the fall structure.

2. Measures for improving performance of fall structure at RD 64357 have been identified. These include appropriate lowering of the crest of second fall, changes in the second stilling basin to make it more effective, and improvising the existing stone apron to act as additional stilling basin for improving energy dissipation. These measures may to be tested on a physical model for verification and incorporating necessary structural amendments / fine-tuning.

3. Lack of adequate technical considerations in Planning of large irrigation projects can reflect adversely on their subsequent performance. This case study vividly brings out the need for detailed technical, economic and environmental evaluation of various alternatives in order to optimize the planning decisions.

4. Design changes during the operation stage need to be carefully planned and analyzed in the context of system design. Implementation of design changes should ensure integration with the overall system. Isolated and ill-conceived changes can lead to serious problems.

5. Since Irrigation Projects are part of the overall context of the society, so external influences can have a considerable role in guiding decision making. While quite understandable for decisions making relating to the socio-economic considerations, there is a need to manage the external influences where purely technical considerations are involved. Engineering Institutions can play a substantial role in this regard.

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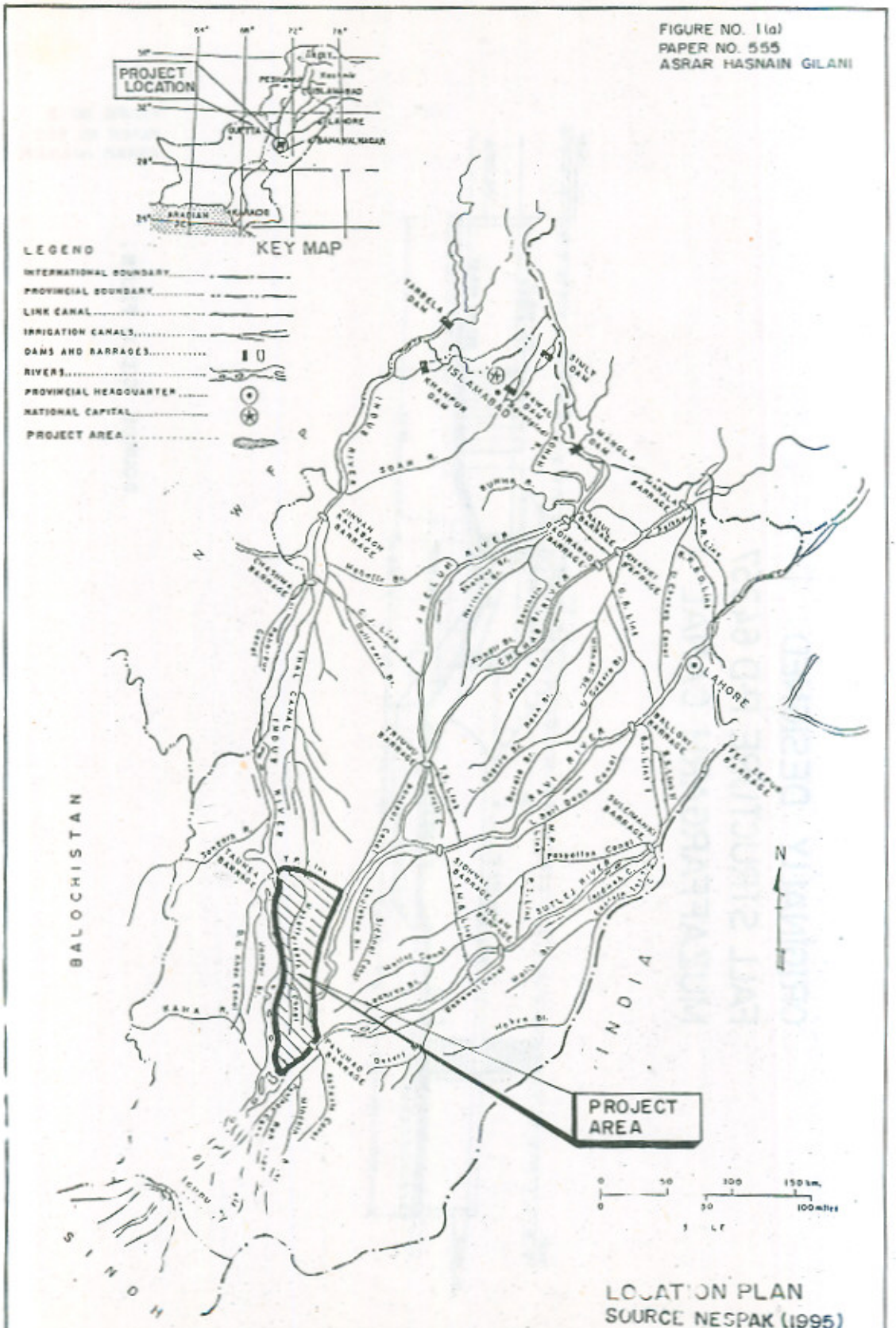
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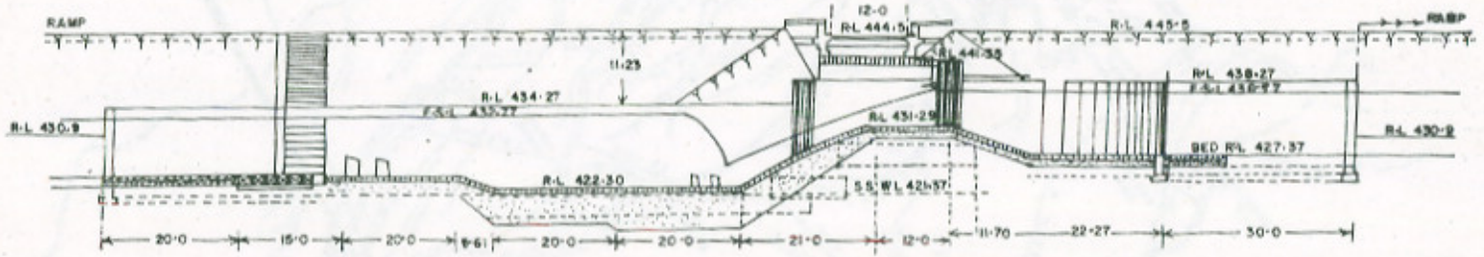
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FIGURE NO. 1(a)
PAPER NO. 555
ASRAR HASNAIN GILANI



ORIGINALLY DESIGNED
FALL STRUCTURE R·D 64357
MUZAFFARGARH CANAL



SOURCE C.D.O FILES.

FIGURE NO. 2
PAPER NO. 555
ASRAR HASNAIN GILANI.



Photo No.1 General Upstream View.

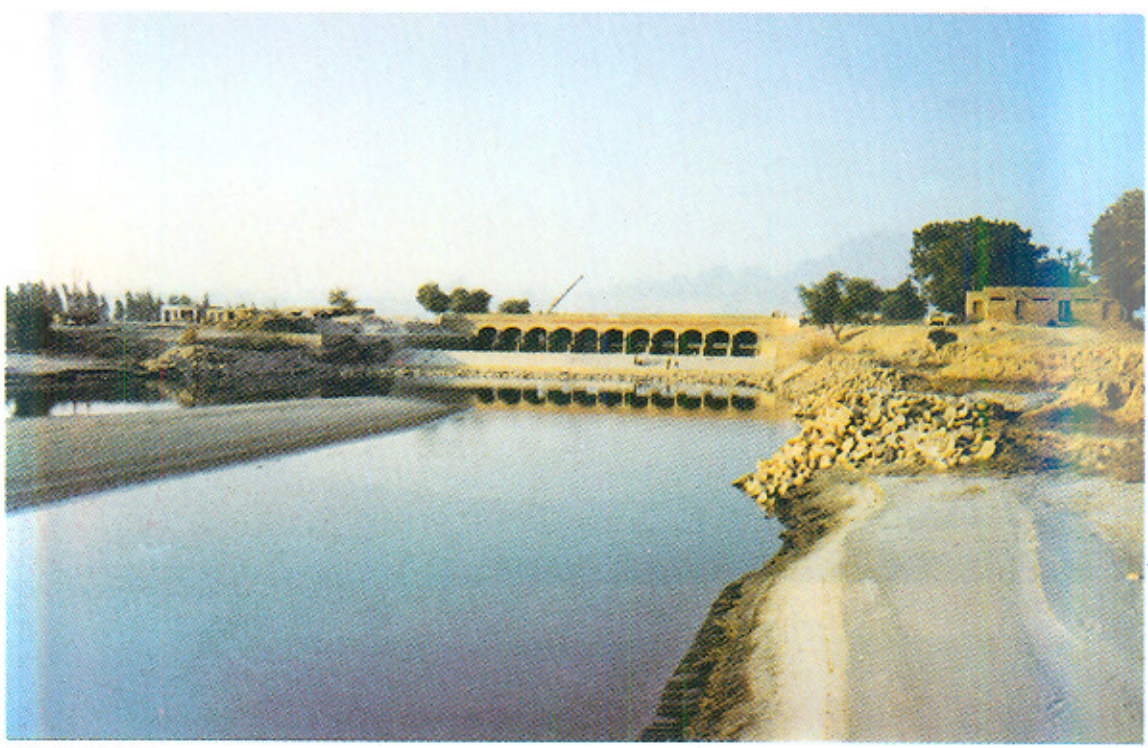


Photo No.2 General Downstream View.



Photo No.3 General View: Showing Excessive Side Erosion, Extending Large Distance D/S.



Photo No.4 General D/S View: Showing Stone Studs.



Photo No.5 General View of the Main and Subsidiary Fall.



Photo No.6 A Close-up View: Showing Stilling Basins and Crest of Subsidiary Fall (Note excessive crest height).



Photo No.7

A Close-up View of the Stilling Basin of Subsidiary Fall, Showing Baffle Wall and End Sill.



Photo No.8 General View of the Subsidiary Fall.
(Note that the stilling basin is above canal bed/standing water level)



Photo No.9 A Close-up View of the D/S Side Protection.



Photo No.10 General View of the Side Embayment.
(Note that even the canal road has been eroded)

