

PRE-QUALIFICATION DOCUMENT (POD)

PUNJAB IRRIGATED - AGRICULTURE PRODUCTIVITY IMPROVEMENT PROJECT (PIPIP)

Implementation Modalities for Precast Concrete Parabolic Lining of Watercourses

Background

Government of the Punjab is implementing World Bank financed “Punjab Irrigated-Agriculture Productivity Improvement Project (PIPIP)” in the entire province. The major physical activities related to improvement of water conveyance system, to be carried out under the PIPIP include the followings.

- **Upgrading Farm Level Irrigation Conveyance System through**
 - ✓ Improvement of unimproved canal irrigated watercourses
 - ✓ Completion of partially improved watercourses
 - ✓ Rehabilitation of irrigation conveyance systems in non-canal commanded areas

It is planned that 5,500 new un-improved watercourses would be improved and 1,500 partially improved watercourses would be completed in canal commanded areas while 2000 irrigation schemes (tubewell watercourses) would be rehabilitated in non-canal commands/barani tracts of the province under PIPIP. The scope of activities under watercourse improvement component is being extended under PIPIP-revised, which would be implemented till June 2021.

Watercourse Improvement

Watercourse improvement consists of:

- i) **Earthen improvement** involving complete demolishing of community channel and rebuilding according to engineering design with clean compacted soil.
- ii) **Installation of necessary water control structures** i.e. naccas, culverts, buffalo wallows, drop structures, siphon/aqueducts etc.
- iii) **Lining**- the most important part of watercourse improvement carried out in reaches prone to maximum water losses.

The standard lining executed under previous and ongoing OFWM projects has been a rectangular shaped channel constructed by using double brick masonry walls (23 cm) and a brick masonry floor (07 cm) plastered inside and on top of the walls. This type of lining has

been adopted since inception of OFWM program for being durable and easy to install. Moreover, the availability of construction materials (bricks, cement and sand) at local level coupled with easily available appropriate skilled labor supported brick lining. Consequently, this type of brick lining was preferred even over other low cost lining alternatives. However, under continuous rise in demand for bricks, no price control, and day by day dwindling quality of bricks, there is dire need to adopt an innovative approach in selecting alternate techniques for lining to overcome the multifarious problems being faced in the field. Following are the main factors to be kept in view while making choice for a specific lining technology among available alternatives:

- Technical suitability
- Economic feasibility
- Acceptability by the farming community

Alternate Lining Technologies

A particular watercourse may be designed in different shapes. Cross sectional area (A) and wetted perimeter (P) vary with shape. Presently, most of the watercourses are being improved using double brick lining with rectangular cross section (shape) in the Punjab. Besides this technology, many other lining techniques/shapes have also been developed and tested for their technical suitability, economic feasibility and acceptability by the farmers.

These lining options include:

- i) Brick lining with 11 cm thick walls in rectangular shape
- ii) Brick lining with 07 & 11 cm thick walls in trapezoidal shapes with sharp corners
- iii) Concrete lining in trapezoidal shape with sharp/round corners
- iv) Concrete lining in triangular shape with sharp/round corners
- v) Precast concrete lining in semi-circular shape
- vi) Precast concrete lining in parabolic shape

The semi-circular shape is hydraulically the most efficient cross section among all above mentioned lining techniques. However, this shape may not be practicable for watercourse improvement due to construction and fabrication/installation issues and poor acceptability by farmers because of its greater top widths. The next hydraulically most optimum cross section is the parabolic shape.

Watercourse Improvement with PCP Lining

The PIPIP envisages improvement of 3,400 watercourses using precast concrete parabolic lining (PCPL) out of total 5,500 new un-improved watercourses. Likewise, about 750 out of 1,500 partially improved watercourses in canal commands would be completed with PCPL. Similarly, 1,000 irrigation schemes would be lined with precast concrete parabolic sections/segments in non-canal commands/barani tracts of the province. The scope

of activities under watercourse improvement component is being extended under the revised project, which will be implemented till June 2021.

Watercourse Designing for PCPL

Having decided the design discharge on the basis of sanctioned/measured flow and longitudinal slope available from the field topography, appropriate segment size is selected amongst available ones to be installed for watercourse improvement. The project consultants have developed computer worksheet/spreadsheets to make complex calculations, involved in parabolic design, easier and time savings for preparation of watercourse design for PCPL. The design worksheet developed for the purpose is enclosed (**Annexure-A**).

Available Standard PCP Segments

Depending upon varying design capacities and available longitudinal slopes, a series of PCP segments (Segment No. 1 to 8) have been designed that can be manufactured and used for watercourse lining. Sanctioned discharges in various canal commands and available longitudinal slopes in different areas of the Punjab province generally allow use of Segment No. 3 to 7 for lining of watercourses in canal irrigated areas whereas Segment No. 1, 2 & 3 are feasible for tubewell watercourses in non-canal commands of the province. It is indicated that Segment No. 8 is rarely needed for exceptionally high flows. A summary of presently available different segment sizes alongwith their hydraulic dimensions is given in **Table 1** while the construction materials required for each size of segments are given in **Table 2**.

Table 1: Segment Sizes and their Hydraulic Dimensions

Segment Size		Top Width	Depth	X-Sectional Area	Perimeter	Equation Coefficient	
No.	Section (mm x	Length (mm)	T (mm)	D (mm)	A (sq.m)	P (mm)	(a)
1	360 x 225	1220	360	225	0.054	593	0.006944
2	457 x 305	920	457	305	0.093	783	0.005842
3	600 x 360	920	600	360	0.144	966	0.004000
4	640 x 460	920	640	460	0.196	1150	0.004492
5	675 x 480	920	675	480	0.216	1204	0.004214
6	760 x 530	920	760	530	0.269	1339	0.003670
7	920 x 610	920	920	610	0.374	1571	0.002883
8	1144x 686	920	1144	686	0.523	1841	0.002097

Table 2: Construction Materials Required for Various PCPS Sizes

Segment Size			Concrete Weight	Aggregate Volume	Quantities of Construction Material with Mix Ratio of 1 : 1 : 2		
					per seg	perseg.	Cement
No.	Section (mm x	Length (mm)	(kg.)	(cu.m)	(bags)	(cu.m)	(cu.m)
1	360 x 225	1220	86.93	0.0565	0.439	0.0170	0.034
2	457 x 305	920	103.03	0.0669	0.520	0.0200	0.040
3	600 x 360	920	123.09	0.0800	0.621	0.0240	0.048
4	640 x 460	920	162.73	0.1058	0.821	0.0320	0.063
5	675 x 480	920	173.28	0.1126	0.874	0.0340	0.068
6	760 x 530	920	228.49	0.1485	1.153	0.0445	0.089
7	920 x 610	920	286.00	0.1860	1.443	0.0555	0.111
8	1144x 686	920	308.64	0.2006	1.557	0.0600	0.120

Note: Materials include permissible wastage

Concrete Specifications

- i) Suggested mix ratio of 1:1:2
- ii) 28 days curing with cylinder compressive strength of 4500 psi
- iii) 70 percent of specified strength after 07 days and 85 to 90 percent after 14 days curing
- iv) Maximum 01inch slump
- v) Precasting under approved conditions only, with compaction by vibrating table, to be casted in only approved steel moulds
- vi) Recommended water cement ratio of 0.36
- vii) Minimum 5 days curing (water) or fully covered by steam.
- viii) Aggregate sizes vary from minimum 3/8” to maximum of 3/4”. Manufacturer will adjust proportions of aggregate size to achieve the specified strength. For Segment No. 1, 2 and 3, maximum recommended aggregate size is 1/2”.
- ix) The sand shall be obtained from an approved source. It shall be well graded. The whole sand should be passed through a No. 4 sieve (4.75 mm) and 2 to 10 percent shall pass through a No. 100 sieve (0.15mm)
- x) Sand and gravel bay be washed before use
- xi) SR cement is recommended for PCP segments to be installed in saline areas particularly in southern Punjab
- xii) Mortar of 1:3 cement sand ratio shall be applied in the joints

Pre-Qualification Criteria

The Agriculture Department is implementing the World Bank funded Punjab Irrigated-Agriculture Productivity Improvement Project (PIPIP) in the entire Punjab. Improvement of community watercourses is one of the key components of the project. The watercourses are improved by the Water Users Associations (WUAs) with financial

assistance of the government for construction materials under technical supervision of OFWM field staff. The construction materials including nakkas and precast concrete parabolic segments will be procured by WUAs from firms prequalified by the government for the purpose.

Directorate General Agriculture, Water Management (DGA-WM) intends to expand list of pre-qualified supply companies/ firms for supply of pre-cast concrete parabolic segments (PCPS) during 2017-18 for lining of watercourses. The firm(s)/ joint venture(s) having the following strength/ background would be eligible for pre-qualification under the scheme for the project period, which will be renewed every year based on specified performance criteria.

- i) *Firm has an office in Pakistan.*
- ii) *Registration of Firm with GST Department (Valid STN registration certificate).*
- iii) *Registration with Income Tax Department (Valid NTN registration certificate).*
- iv) *Proven experience of at least one (1) year in precast business (list of completed assignments may be provided as proof of experience).*
- v) *Minimum average annual turnover of Rs. 1.00 million during last three (03) years to affirm firm's financial soundness (It will be evaluated from any of annual audit reports/ IT returns/ ST returns/ Bank statement, which will be submitted with prequalification application).*
- vi) *Availability of technical staff list (at least one (01) Sub-engineer having three years Diploma in Civil Engineering is required).*
- vii) *List of existing machinery (At least one each of vibrating table, mixture machine and measurement box etc. must be available).*
- viii) *Appropriate curing facilities (at least any one of the curing pond, overhead showering, compound curing, or steam curing) must be available.*
- ix) *A minimum of 50 moulds (of any two sizes) must be available or undertaking to prepare/ offer requisite number and sizes of moulds within three months (The prequalification will be effective only after verification of requisite moulds within specified timeframe).*
- x) *Availability of material testing equipment including at least one each of the followings.*
 - a. *Compression Testing Machine (Cube / Cylinder)*
 - b. *Cube / Cylinder Moulds*
 - c. *Slump Test*
 - d. *Sieve Analysis Set*
 - e. *Schmidt Hammer*
- xi) *The firm will submit Affidavit regarding undertakings for i) non-blacklisting by any government department, ii) supply of PCPS according to approved standards & specifications, iii) make addition of requisite number of moulds as per departmental advice, iv) availability of requisite number and sizes of moulds or willingness to fulfill the requirement within three months after conditional eligibility to make the prequalification effective v) availability of requisite material testing equipment or willingness to acquire the same before starting manufacturing of PCPS and vi) follow the instructions of department for adjustment of mould sizes for longer lengths.*
- xii) *Pay order/ bank draft amounting to Rs. 10,000/- in the name of Director General Agriculture (Water Management) Punjab, Lahore as non-refundable processing fee for prequalification.*

Procedure of Watercourse Improvement

Formation of WUA, Preparation of Design & Cost Estimates

OFWM staff will mobilize shareholders of the watercourses to organize Water Users Associations (WUA). The same will be registered under OFWM and WUAs Ordinance [Act] 1981 (Amended 2001). The WUA will open a joint account to be operated by its Chairman and Treasurer in a Commercial Bank. The WUA will provide bank statement alongwith specimen signatures of the Chairman and Treasurer to DDO (OFWM) who will forward the same to DO (OFWM). The WUA will execute an output-based agreement with District Officer (OFWM) wherein, roles and obligations of both the parties will be defined. The agreement will be based on lump-sum contracts with payments linked with achievement of physical milestones as defined in agreement.

OFWM staff in the respective tehsil will conduct engineering surveys of the watercourse command area and prepare design & cost estimates in consultation with WUA that will be checked/verified by PSC Field Engineer. As envisaged in the PC-I, the design will be prepared for earthen improvement of 70 percent of total length while remaining 30 percent length is lined. The competent authority will accord Technical Sanction of the watercourse.

Earthen Improvements and Installation of Water Control Structures

The WUA will carry out earthen improvements on planned length in the design under the supervision of OFWM field staff. This will involve removal of shrubs, bushes, and vegetation as well as other natural or man-made obstructions from the right of way. This will be followed by demolishing of existing channel, constructing a well compacted pad, and excavation of new channel as per design. After earthen improvement is completed, necessary water control structures such as naccas at major diversion/control points, culverts on farm roads, drops, buffalo bath etc. are constructed as per project standards & specifications.

Lining

Purchase Committee of the WUA shall be at liberty to purchase PCP segments from any prequalified firm at cost lower than ceilings fixed by the District Rate Committee (DRC) without any compromise on quality. The WUA may also make contract with the PCPS supplier firm to install the PCPS for lining as per approved standards & specifications. Lining will be carried out on remaining 30% reach(s) of the watercourse starting preferably from the

outlet and partially on the critical reach(s), if any. WUA will make choice of the environment friendly lining technology keeping in view its technical suitability and economic feasibility.

Installation/ Jointing of PCPSs

To facilitate the installation of PCP lining, about 07 cm thick layer of compacted sand is laid over an already prepared firm bed (of desired compaction). The PCP segments are then placed on this sand bed by following proper alignment and ensuring designed longitudinal slope. Segments are also checked by mason's hand level for their horizontal position to ensure proper jointing of male and female ends of each segment. The joints are then properly filled with mortar and cured for a minimum period of seven days. The required quantities of sand for the bed and that of cement & sand for mortar to be placed in jointing for each segment size are given in **Table 3**. The sand requirements in bed and details of joints have been prepared (**Annexure-A**).

Table 3 Materials Required for Jointing and Sand Bed Preparation

Segment Size			Material Required Per Joint With Cement Sand Ratio of 1:3		Sand Required Per Segment for Bed Preparation
			Cement	Sand	
	Section	Length	(bags)	(cu.m)	(cu.m)
1	360 x 225	1220	0.0022	0.00024	0.053
2	457 x 305	920	0.0037	0.00039	0.044
3	600 x 360	920	0.00445	0.00047	0.044
4	640 x 460	920	0.0062	0.00065	0.047
5	675 x 480	920	0.0065	0.00069	0.044
6	760 x 530	920	0.0089	0.00094	0.046
7	920 x 610	920	0.0115	0.00121	0.049
8	1144x 686	920	0.0121	0.00128	0.051

Note: Materials for jointing include permissible wastage

The supply and installation of PCPS would be carried out by the PCPS manufacturers/firms under an Agreement with WUA. Payment mechanism both for PCPS supply and labor charges for their installation would also be mutually agreed by the firm and WUA as part of this Agreement. As such, the payment to the firm contracted by WUA for supply and installation of PCPS will be made by the WUA as per agreed milestones.

Release of Government Funds

The Government funds shall be transferred from Account-I at provincial level to Account-IV at district level. The requisite funds from Account-IV will be released into joint account of the respective Water Users Association by District Officer (OFWM) in three

installments on recommendations of the Field Engineers of project consultants as per following criteria.

Improvement of Unimproved Canal Irrigated Watercourses

First Installment

Release of 40 percent of the estimated cost of civil works on receipt of First Intermediate Completion Report (ICR-I) from the consultants certifying following requirements.

- Issuance of Technical Sanction by the competent authority.
- Deposit of 50 percent farmers' share on account of labour charges for lining and installation of water control structures.
- Renovation of at least 50 percent of designed earthen sections.

Second Installment

Release of 30 percent of the estimated cost of civil works on receipt of Second Intermediate Completion Report (ICR-II) from consultants verifying followings.

- Deposit of remaining 50 percent labour charges of farmers' share on account of lining/installation of water control structures etc.
- Renovation of entire designed earthen sections.
- Completion of at least 30 percent planned lining and other works (volumetric basis).

Third Installment

Release of remaining 30 percent of the estimated cost of civil works on receipt of Final Completion Report (FCR) from consultants certifying following factors.

- Completion of all planned works.
- Rectification of any pending discrepancy.

Completion of Partially Improved Watercourses

First Installment

Release of 40 percent of the estimated cost of civil works on receipt of First Intermediate Completion Report (ICR-I) from the consultants certifying following requirements.

- Issuance of Technical Sanction by the competent authority.
- Deposit of 50 percent farmers' share on account of labour charges for lining and installation of water control structures.
- Renovation of at least 50 percent of designed earthen sections.

Second Installment

Release of 30 percent of the estimated cost of civil works on receipt of Second Intermediate Completion Report (ICR-II) from consultants verifying followings.

- Deposit of remaining 50 percent labour charges of farmers' share on account of lining/installation of water control structures etc.
- Renovation of entire designed earthen sections.
- Completion of at least 30 percent planned lining and other works (volumetric basis).

Third Installment

Release of remaining 30 percent of the estimated cost of civil works on receipt of Final Completion Report (FCR) from consultants certifying following factors.

- Completion of all planned works.
- Rectification of any pending discrepancy.

Rehabilitation of Irrigation Conveyance Systems in Non-canal Commanded Areas

First Installment

Release of 70 percent of the government share (maximum Rs. 250,000/-) for improvement/development costs on receipt of First Intermediate Completion Report (ICR-I) from the consultants certifying following requirements.

- Issuance of Technical Sanction by the competent authority.
- Excavation of at least 30 percent of designed sections.
- Deposit of 70 percent farmers' share for improvement/development of irrigation scheme.

Second Installment

Release of 20 percent of the remaining government share (maximum Rs. 250,000/-) for improvement/development costs after verification of Second Intermediate Completion Report (ICR-II) verifying the followings.

- Deposit of remaining 30 percent of farmers' share for improvement/development of irrigation scheme.
- Availability of entire construction materials/equipment at site.
- Excavation for entire planned length.
- Completion of at least 70 percent of planned works.

Third Installment

Release of remaining 10 percent of the government share (maximum Rs. 250,000/-) for improvement works on receipt of Final Completion Report (FCR) from consultants certifying following factors.

- Completion of all planned works.
- Rectification of any pending discrepancy.

In all above cases, WUA will procure the construction materials on the rates fixed by the District Rate Committee for the tehsil/cluster and carry out civil works under technical supervision of OFWM field staff. DO (OFWM) will make internal monitoring of improvement works while Deputy Project Director will undertake external monitoring to ensure quality of works. The Project-Implementation Supervision Consultants will carry out spot checking and third party validation/final verification of improvement works.

Procurements of PCP Segments

Following guidelines shall be observed during procurement process of PCP segments:

- Firms shall be pre-qualified at provincial level.
- Supply of PCPS would be acceptable from the prequalified firms only.
- All firms will ensure embossing the date, Lot No. and trade mark/name of firm on each segment at the time of fabrication.
- The computer spread sheets developed by project consultant shall be provided to all Field Engineers and District Officers (OFWM) to facilitate DRCs for assessment of rates of different sized PCP segments on monthly basis or on emergent basis, if required. Prevailing market rates of concrete ingredients (cement, sand & gravel) and transportation charges shall be the only variables to be incorporated in the spread sheets. Infrastructure and fixed & variable costs shall be assessed on need basis preferably on bi-annual or yearly basis.
- The rates assessed as above shall be the maximum ceilings, based on the prevailing market rates of materials. Rates shall be fixed in Rupees per segment rather than per foot or meter. Purchase committees of watercourses shall be at liberty to purchase PCP segments at cost lower than ceilings without any compromise on quality from any pre-qualified Firm.

Quality Assurance Mechanisms

To start with, Resident Supervision will be provided by the Project Consultants. One Field Engineer will be deployed at each pre-qualified yard. He will ensure observance of all approved specifications during fabrication of segments and their proper curing to produce segments of desired quality/strength before their shifting to the field.

Later on, with the passage of time, number of yards may increase covering the entire province/project area. At this stage, resident supervision by the Consultants through graduate engineer may not remain economically feasible and affordable under the existing provisions. And by that time, quality control mechanism at yard level would be adequately established/strengthened and, therefore, feasibility of shifting resident supervision from graduate to sub-engineer level or shifting of supervision level from resident to top one shall

be assessed and recommended. In addition, Directorate General Agriculture (WM) Punjab and Project Management Unit will continue to perform their supervision and monitoring role for proper performance of quality control mechanism.

PCPS Compressive Strength Testing

Concrete can be tested by crushing the cubes/cylinders cast at the time of manufacturing and, by cutting cores of already manufactured/cast concrete and subjecting them to crushing test under laboratory controlled conditions.

However, another method, namely the Schmidt's Hammer testing can be employed for non-destructive testing. Schmidt' hammer test gives a good idea of strength, if homogeneity in concrete exists and the panel under testing is not supported. Schmidt's hammer test, if applied for comparative strength evaluation, is useful tool in testing of concrete. Its reliability can be improved by increasing the number of points tested in one panel/segment.

In view of the above, Schmidt's Hammer test with large no. of points would be applied as first-hand information about PCPS strength. However, in case of non-consensus, determination of exact quality of concrete conforming to the contract specifications, core testing would be recommended at the cost of manufacturers.

Quality Control Measures during Fabrication of PCPS at Yards

Following important measures along-with strict observance of agreed specifications for PCPS would be ensured at yards:

- Achieving inside surface finish of each segment shall be as equally important as its strength. Honey combing/cavities therefore, shall be controlled through proper water cement ratio and vibration time.
- Periodic inspections would be made to ensure regular repair & maintenance of moulds to keep each and every mould to produce segments of standard/designed dimensions. Any de-shaped mould shall be discarded immediately.
- Approved drawings (**Annexure-B**) shall be strictly followed during steel moulds fabrications to produce segments of true dimensions particularly the geometry of male and female ends of segments which counts a lot to produce leak proof joints between segments.
- The specifications for PCPS, as already approved by the committee constituted for the purpose, would be followed by the manufacturers at each yard.

Precast Concrete Parabolic Canalets in 8 Feet Length

World Bank Project Appraisal Document (PAD) envisages improvement of watercourses under PIPIP using precast concrete parabolic channel sections having unit

length of eight (08) feet called “canalets”. Presently, precast concrete parabolic sections called segments are available in eight various x-sectional sizes each having unit length of three feet. All PCPS yards in the province have moulds of these sizes. Some yards have hundreds of these moulds with millions of investment. As this technology is at infancy stage in the Punjab which has also been stalled for so many years, it would not be feasible to recommend an immediate shifting of unit length from 3 to 8 feet, thereby, converting all available mouldsto scrap and then persuade PCPS manufacturers to invest millions of rupees on fabrication of new moulds particularly without any field testing of 8 feet canalets on technical grounds and non-addressal of fabrication, transportation and installation issues associated with enhanced unit length.

Project-Implementation Supervision Consultants (PSC) have initiated working on technical aspects related to structural strength of 8 feet long canalets in existing sizes and concrete thickness along their perimeters. Structural stress analysis indicates strength of canalets having 8 feet length as sufficient. Various analyses are underway to reduce unit weight without affecting their structural strength under different options of unit length of each size.

Meanwhile, it has also been observed that wide gaps exist in discharge capacity of segment No 6 & 7 and 7 & 8 under the same field conditions. Segment No 6 has a discharge capacity of about 87 lps whereas segment No 7 allow passing of 144 lps under bed slope of 4×10^{-4} with a free board of 10cm in both cases. Similarly, segment No 7 has a discharge capacity of about 144 lps whereas segment No 8 passes 236 lps. It is, therefore, required to have new sizes introduced between segments No. 6 & 7 and 7 & 8 to accommodate discharges of about 115 and 186 lps respectively.

To begin with, project consultants have initiated shifting of segment No. 2 & 3 from 3 feet to 8 feet length as the unit weight of these segments with increased length remain within the brawn of a common man. As an experiment, moulds of these segments are being converted to 8 feet length. Segment produced with these moulds shall be fabricated at yard and installed in the field. Fabrication, transportation and installation issue, if any, faced shall be analyzed and addressed accordingly. Similarly a drawing of a new canalet with 2440mm length having x-sectional top width of 850mm & depth of 570mm to pass 115 lps discharge has been prepared (**Figure-1**) and handed over to PCPS manufacturer for fabrication of mould

to produce a canalet of 2440mm (8 feet) maximum length. Separate male & female ends shall be fabricated to facilitate production of canalets in different lengths varying from 1525mm (5 feet) to 2440mm (8 feet) length. Hollow pockets shall be provided to reduce unit weight to the possible extent and possibility of providing reinforcement shall be explored to supplement structural strength, if threatened, while reducing its unit weight.

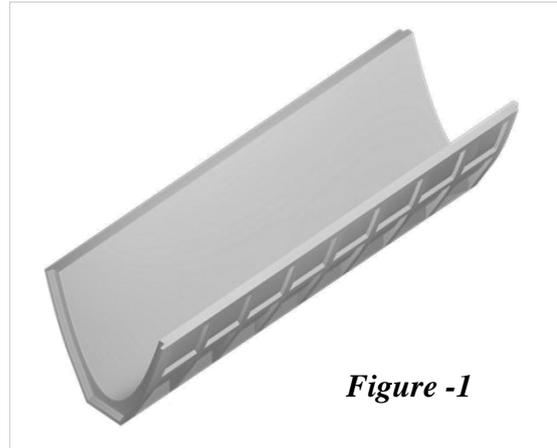


Figure -1

PUNJAB - IRRIGATED AGRICULTURE PRODUCTIVITY IMPROVEMENT PROJECT (PIPIP)

Design Work Sheet for Parabolic Shaped Watercourse

A. Identification

Watercourse No.		Fiscal Year	
Chak No./Village		Regular/Additional	
Minor/Disty.		Tehsil	
Name of Chairman		District	

B. Design Requirement

Watercourse Section	From (RD)	To (RD)	Length (m)
Main	0	450	450
Branch	0	0	0

Hydraulic Data

		cfs	cu.m	lps
Discharge	Q	4.080	0.116	115.50
Roughness Coefficient	n	0.0140		
Longitudinal Slope (m/m)	S	0.00040		

Segment Size Available

No.	Segment	Top Width (T) (mm)	Total Depth (D) (mm)	Free Board (FB) (mm)	Max. Flow Depth (d) (mm)	Flow Area (A) (sq.m)	Eq. Coefficient (a)
	Size (mm x mm)						
1	360 X 225	360	225	70	155	0.054	0.006944
2	457 X 305	457	305	70	235	0.093	0.005842
3	600 X 360	600	360	70	290	0.144	0.004000
4	640 X 460	640	460	70	390	0.196	0.004492
5	675 X 480	675	480	70	410	0.216	0.004214
6	760 X 530	760	530	70	460	0.269	0.003670
7	920 X 610	920	610	70	540	0.374	0.002883
8	1144 X 686	1144	686	70	616	0.523	0.002097

Select the Segment No. and Press "Ctrl P"

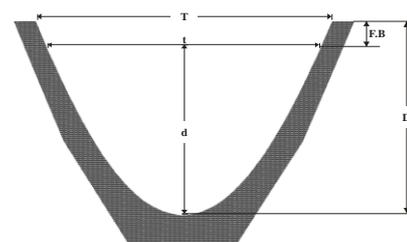
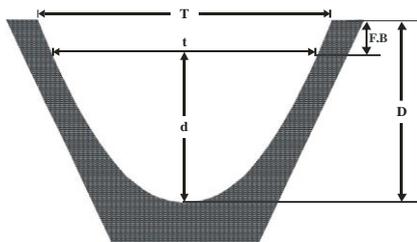
Segment No.	7
Constant "a"	0.002883
Maximum "d"	540.00

Select when "P" and "P_cal" are almost equal

d	t	A	V	R	P	P_cal	Ratio
(mm)	(mm)	(sq.m)	(m/sec)	(m)	(m)	(m)	(P_cal/P)
455.82	795.28	0.242	0.478	0.194	1.249	1.249	1.00

Select Flow Depth, d 455.8 mm
 Max. Allowed Flow Depth, Max. d 540 mm
 Difference 84 mm
 Free Board, FB 154 mm

Check for FB and Decide **FB is Sufficient. Select This Segment**



SEGMENT NO. 7

INPUT DATA

