Government of the People's Republic of Bangladesh

Ministry of Local Government, Rural Development and Cooperatives
Local Government Division
Local Government Engineering Department

Exhibit G6-L: Criteria and Design of Command Area Development Subproject

November 2017

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GLOSSARY

Aman	Rice grown during the wet season (Kharif), and harvested late (Nov-December). Yields: (i) Broadcast, deep water 1.5t/ha; (ii) Transplanted, local variety 2.2t/ha; (iii) Transplanted, high yielding variety, 3.25t/ha
Aus	Rice grown during the wet season (Kharif), and harvested early (July-August). Yields: (i) Broadcast 1.25t/ha; (ii) Transplanted, high yielding variety, 2.5t/ha
Beel	Saucer shaped low-lying area with pond of static water as opposed to moving water in rivers and canals.
Boro	Irrigated rice grown in the dry season (Rabi). Transplanted in December/January and harvested in April / May. Yield: (i) Transplanted, high yielding variety, 4.25t/ha
District	Second administrative unit of the government comprising 6-9 Upazilas. There are 64 districts in Bangladesh.
Haor	Haor is a wetland ecosystem in the north eastern part of Bangladesh. Physically a bowl or saucer shaped shallow depression, also known as a back-swamp
Integrated Water Resources Management Unit	Unit comprising two sections: (i) planning & design, and (ii) operation & maintenance, with a mandate to guide LGED's activities in the water sector.
Khal	Natural or man-made water channel (canal)
Kharif	Wet (monsoon) season
Local Stakeholder	Local Stakeholders are inhabitants of an area directly or indirectly affected by water management, be it as beneficiaries or as "project affected people".
Rabi	Dry / winter cropping season (November to March)
Stakeholder Groups	Stakeholder groups are collections of individuals who have similar interests concerning water.
Union	Subdivision of Upazila. There are 4,889 unions in Bangladesh.
Union Parishad	Local government institution at Union level. The Union Parishad consists of an elected council & chairman, and is the oldest government institution in Bangladesh
Upazila	Administrative unit, sub-division of District and lowest administrative tier of the government. In all, there are 482 upazilas in Bangladesh.
Upazila Parishad	2^{nd} tier of local government institution at Upazila.

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
AE	Assistant Engineer
CA	Community Assistant (Project Based – Subproject Level)
CO	Community Organizer
CPO	Community Participation Officer (Project based, district level)
CS	Construction Supervisor (Project Based – Upazila Level)
DAE	Department of Agricultural Extension
DLIAPEC	District Level Inter-Agency Project Evaluation Committee
DOC	Department of Cooperatives
DOF	Department of Fisheries
DWRA	District Water Resources Assessments
FMC	First Management Committee
FSDD	Feasibility Study & Detailed Design
GoB	Government of Bangladesh
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
ICM	Integrated Crop Management
IWRMU	Integrated Water Resources Management Unit (of LGED)
LCS	Labour Contracting Society
LGED	Local Government Engineering Department
MC	Management Committee (of WMCA)
MIS	Management Information System
NGO	Non-Governmental Organization
O&M	Operation and Maintenance
PM	Planning Meeting
PMO	Project Management Office
PRA	Participatory Rural Appraisal
QC	Quality Control
SAE	Sub-Assistant Engineer
SP	Subproject
SSWR	Small Scale Water Resources
SSW-1	SSWR Development Project Phase I (ADB), 1996-2002
SSW-2	SSWR Development Project Phase II (ADB), 2002-2009
SSW-3	SSWR Development Project (JBIC), 2009-2015
SSW-4	Participatory SSWR Project (ADB) 2010-2017
TA	Technical Assistance
TOR	Terms of Reference
UDCC	Upazila Development Coordination Committee
UE	Upazila Engineer
uPVC	Un-Plasticised Polyvinyl Chloride (or PVC"u")
UP	Union Parishad (local council)
UzP	Upazila Parishad
WCS	Water Conservation Structure
WMCA	Water Management Cooperative Association
XEN	Executive Engineer

UNIT CONVERSION TABLE

Length

1 inch (in)	0.0254 m
1 foot (ft)	0.3048 m
1 metre (m)	3.28 feet (ft)

Area

1 acre	4046.86 m^2
1 acre	0.4046 ha
1 square metre (m^2)	0.00024 acres
1 hectare (ha)	2.47 acres

Volume

1 cubic foot (ft^3)	0.0283 m^3
1 cubic metre (m^3)	35.315 cubic feet (ft^3)

Capacity

1. imperial gallon	0.0045 m^3
1. US gallon	0.0037 m^3
1 pint	0.5681 l
1 US gallon (dry)	0.0044 m^3
1 litre (l)	0.22 imp. gallon
1 litre (l)	0.264 U.S. gallon
1 hectolitre (hl)	100 litres
1 litre (l)	1.760 pints
1 cubic metre (m^3)	1000 l

Mass

1 ounce	28.3286 g
1 pound	0.4535 kg
1 long ton	1016.05 kg
1 short ton	907.185 kg
1 gram (g)	0.0353 ounces (oz)
1 kilogram (kg) 1000 g	2.20462 pounds
1 ton 1000 kg	0.984 long ton 1.102 short ton

Pressure

1 pound force/in^2	6894.76 N/m^2
1 pound force/in^2	51.7 mm Hg
1 Pascal (PA)	1 N/m^2
1 atmosphere	760 mm Hg 14.7 pound force/in^2 (lbf/in2)
1 atmosphere	1 bar
1 bar	10 metres
1 bar	100 kpa

Energy

1 B.t.u.	1055.966 J
1 foot pound-force	1.3559 J
1 B.t.u.	0.25188 Kcalorie
1 B.t.u.	0.0002930 KWh
1 Joule (J)	0.000947 B.t.u.
1 Joule (J)	0.7375 foot pound-force (ft.lbf)
1 kilocalorie (Kcal)	4185.5 J = 3.97 B.t.u.
1 kilowatte-hour (kWh)	3600000 J = 3412 B.t.u.

Power

1 Joule/sec	0.7376 foot pound/sec
1 foot pound/sec	1.3557 watt
1 Kcal/h	0.001162 kW
1 watt (W)	1 Joule/sec = 0.7376 foot pound/sec (ft lbf/s)
1 horsepower (hp)	745.7 watt 550 ft lbf/s
1 kilowatt (kW)	860 Kcal/h = 1.34 horsepower

Temperature

^{0}C (Celsius or centigrade-degree) ^{0}C	= 5/9 x (^{0}F - 32)
^{0}F (Fahrenheit degree) ^{0}F	= 1.8 x 0C + 0F
K (Kelvin) K	= ^{0}C + 273.15

SECTION-1: INTRODUCTION

A. Background

One CAD subproject was developed under SSW-1 (1996-2002), SP11004 Agrani Irrigation project. This was considered successful with farmers choosing to switch from cultivation of winter Boro rice to vegetables and potato. Under SSW-2 (2002-2009) 29 CAD subprojects were developed and three CAD & IRR subprojects. The cost of these at 2013/14 prices (assuming 5% annual inflation in US$ terms) varied from about US$ 460 to 1,160 / ha, averaging US$ 745 / ha.

These were usually designed for boro rice cropping with water pumped from a permanent water body, small river or khal into a concrete header tank. Water distribution from the header tank to farmers' fields usually comprised: (i) either a buried concrete pipe or an open (lined) canal system constructed by the project supplying flow to outlets; and (ii) open earthen ditches from the outlets to the fields dug by farmers. Where buried concrete pipes were adopted joints were sealed using bitumen impregnated hessian / jute cloth and a concrete / mortar surround. Spigot and socket joints are only features of the larger (600 mm or more) concrete pipes. Associated structures included: (i) simple header tanks for sedimentation of coarse sediment and to allow driving head through pipeline – ie no regulatory or flow measurement function; (ii) air-vent standpipes to release trapped air; and (iii) riser outlets for surface irrigation. Any sediment that entered the pipe system was expected to wash out through the riser outlets.

Figure I-1: Photos of CAD Irrigation System

Header Tank, Kharia Nadi

Production of Spun Concrete Pipes, Rouha

Air vent Standpipe & Outlet Box, Kharia Nadi

Locked cover to prevent tampering to Alfalfa Vale of Outlet

Unfortunately many of these early CAD schemes are not working well, and the main reasons included: (i) failure to provide equitable coverage over the proposed benefit (command) area; (ii) leaking concrete pipeline joints; (iii) no regulatory structures except for the alfalfa valves at the outlets; and (iv) inability of farmers to procure suitable sized pumps and manage operation including distribution of water and collection of fees from users.

In 2011 a guideline was adopted for CAD subprojects constructed by LGED and significant improvements included: (i) adoption of uPVC pipes up to 550 mm diameter; (ii) improved layout and flow control with large systems broken up into independent smaller rotation units, 80-120 ha in size. A single pipeline to supply each flow control unit, and flows controlled at the head each rotation unit – usually at the header tank. This guideline was used for design of CAD subprojects under SSW-3 and SSW-4, and forms the basis of this current guideline.

From May 2014, to ensure immediate benefits result from new schemes, a pump house and two pumps along with steel pipe connections are being provided by LGED. Unless an electric connection can be quickly provided then diesel pumps are adopted. Overtime farmers / WMCAs are expected to arrange for addition pumps to meet peak water demand.

B. Criteria for Selection of CAD Subprojects

CAD subprojects are relatively expensive[1], therefore criteria should be used to screen proposals during reconnaissance, see below.

Table I-1: Criteria for Selection of CAD Subprojects

Nr	Criteria	
1	Water source	The water source must be perennial with sufficient water in an adjacent river / khal even in a dry year to meet demand. Highly unstable rivers should also be avoided.
2	Other Users	Increased pumping from the water source must not adversely impact on other users (whether for domestic, agricultural or fishery use)
3	Existing irrigation system	There should be an existing low lift irrigation system (open channel / pipe) in the subproject area demonstrating community interest and ability to manage an irrigation system
4	Community Interest	The local community must give high priority to provision of an irrigation system (CAD type SP)
5	Groundwater pumping	If the command area is already irrigated by either: (i) small privately (household) owned shallow wells; or (ii) a few number of deep tubewells it should not be developed as a CAD SP
6	Flooding / land elevation	Irrigation facilities should not extend over land which is extensively flooded in the monsoon. If the proposed SP contains extensive (say >40%) of such land it should not be developed as a CAD SP.
7	Power source	Reliable power supply must be available – assuming electric pumps this implies that a suitable power line is available within (say) 3km
8	Soils	The soils should be suited to irrigation – sandy soils with high infiltration rates are not suited to surface irrigation. Also note that a high variation of soil types within the subproject would pose challenges to operators.
9	Topography	If the proposed command area is highly fragmented / broken (eg bisected by khals) then irrigation development is not likely to be viable. For example undulating & irregular narrow ridges broken by low-lying land are not suitable.
10	Unit Cost / Economic Viability	The CAD subproject must be viable. While high value crops may be proposed for Rabi, it is suggested that the SP should at least break even for padi cropping. This means that the existing rabi cropping intensity should be quite low (ie less than say 60%).
11	O&M	The CAD subproject should benefit equitably all farmers within the subproject area to facilitate collection of O&M fees

[1] EME study 2013/14 in US$: (i) CAD 806/ha; (iii) Regulatory 300-600/ha; and (iii) Non-regulatory 160-200/ha.

C. Design Guideline for CAD Subprojects

This Guideline is intended for use by those responsible for the detailed design of the CAD subprojects developed by LGED. It is intended to synthesize best international practice and ensure sound design, standardization and adoption of efficient and cost effective buried pipe irrigation systems.

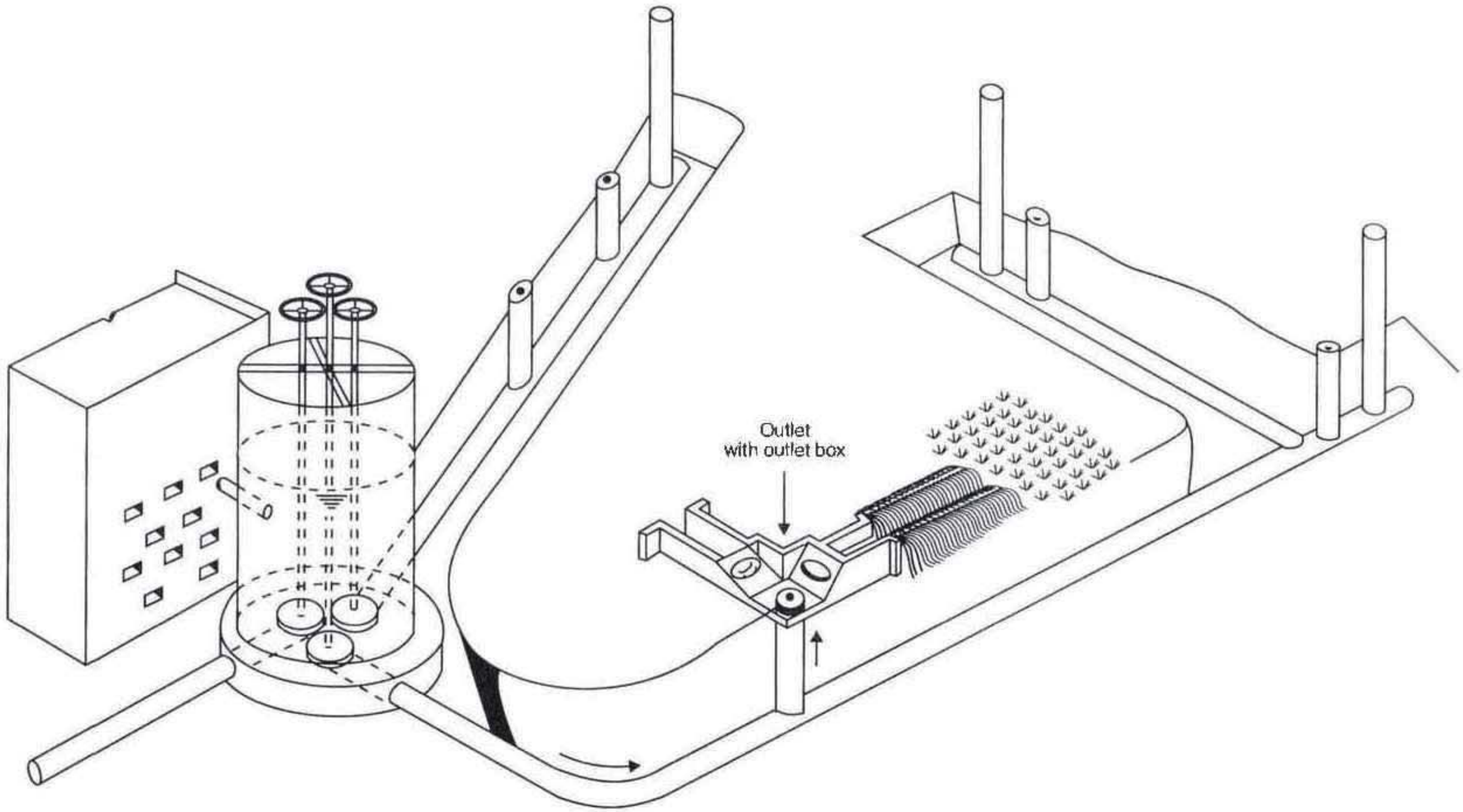
Following this Introductory Chapter, the rainfall and climatic variation in Bangladesh are presented in **Chapter II**, and irrigation water requirements in **Chapter III**. This chapter also observes that crop water requirements vary through the lean season, only peaking for a few weeks, and that in design optimisation whole life (capital and pumping) costs should be considered.

In **Chapter IV** pipe system options are discussed and guidelines given for pipeline layout and achieving cost effective design. This is followed by design guidance in **Chapter V** for the pipe line, and in **Chapter VI** for the associated pipe system structures.

The adoption of appropriate pumps able to deliver the required discharge against the pumping head efficiently is important to operators / farmers to minimise operation costs, and pump selection and power requirements are discussed in **Chapter VII**.

Construction is discussed in **Chapter VIII**. Finally operation and maintenance requirements are described in **Chapter IX.**

Figure I-2: Schematic Illustration of Buried Pipe System



SECTION-2: CLIMATIC DATA

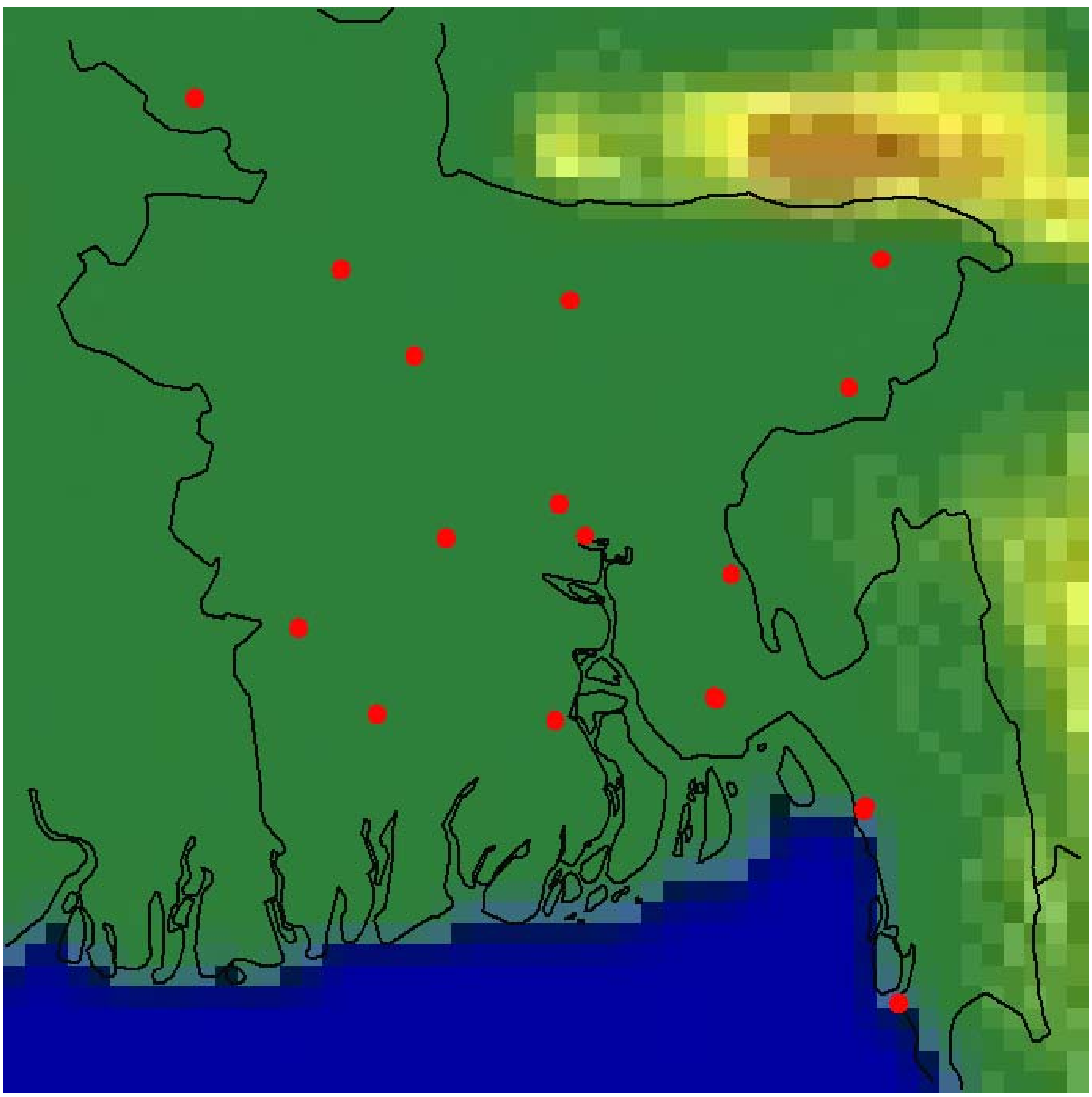
I. Rainfall and Climatic Data

A. Introduction

Reference crop evapotranspiration may be calculated using climatic data for any one of 16 main climatic stations in Bangladesh using the FAO program CROPWAT (version 8). Data in a format ready for use in CROPWAT are available from the FAO CLIMWAT database. Details of these programmes are given in **Appendix B1**.

However several institutes and agencies keep climatic records including the Bangladesh Meteorological Department (BMD) and the Bangladesh Water Development Board (BWDB). A hydrological station network map is given at the end of this Chapter and shows locations for 252 rainfall / climatic stations. Using data from several stations close to the subproject is is likely to result in greater accuracy of evapotranspiration estimates.

Figure I-1: Climatic Stations in Bangladesh, FAO



B. Rainfall Data

1. Variation in Average Rainfall

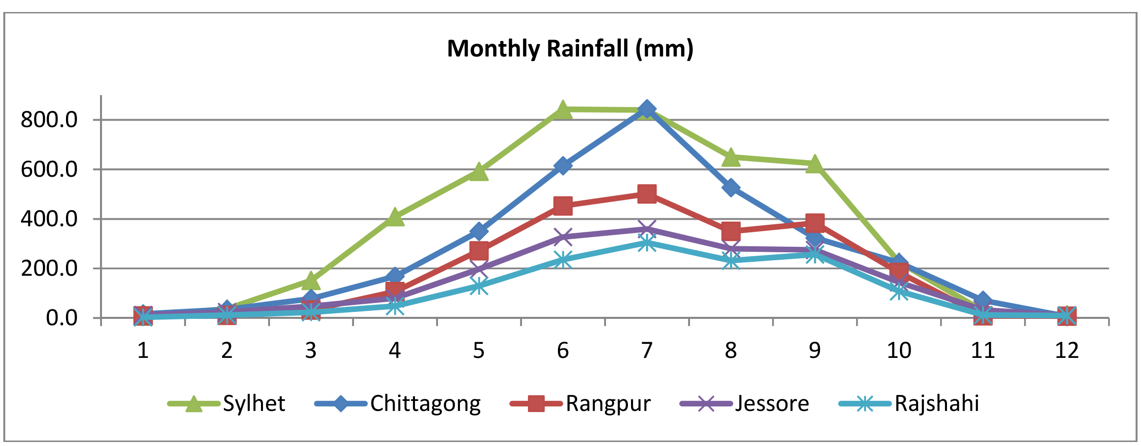
To indicate country wide variation in rainfall, data have been analysed and compiled for the following 13 stations.

Table I-1: Selected Climate Data Stations & Average Annual Rainfall

Nr	Station	Latitude,N	Longitude,E	Elevation (m)	Average Annual Rainfall (mm)	Rainfall as percentage of average
1	Barisal	22⁰ 41'59.99"	90⁰ 22'00.08"	10	2,120	83%
2	Chittagong*	22⁰ 19'49.53"	91⁰ 49'30.59"	10	3,259	127%
3	Comilla	23⁰ 27'21.45"	91⁰ 10'55.33"	17	2,202	86%
4	Cox's Bazar	21⁰ 26'21.96"	92⁰ 00'27.91"	3	3,936	153%
5	Dhaka	23⁰ 42'35.97"	90⁰ 24'25.55"	19	2,149	84%
6	Faridpur	23⁰ 36'00.02"	89⁰ 51'00.00"	15	1,881	73%
7	Jessore*	23⁰ 10'00.00"	89⁰ 13'00.01"	13	1,789	70%
8	Madaripur	23⁰ 10'23.09"	90⁰ 12'16.65"	10	2,012	78%
9	Maijdee / Noakhali	22⁰ 52'20.02"	91⁰ 06'06.11"	9	3,372	131%
10	Mymensingh	24⁰ 44'56.49"	90⁰ 24'10.12"	18	2,563	100%
11	Rajshahi*	24⁰ 22'06.80"	88⁰ 36'00.09"	26	1,375	54%
12	Rangpur*	25⁰ 45'01.53"	89⁰ 15'22.10"	38	2,318	90%
13	Sylhet*	24⁰ 53'51.23"	91⁰ 52'17.85"	24	4,422	172%
				Average	**2,569**	

The data shows a large range in annual rainfall. The districts to the east are the driest with rainfall 50-75% of the average for the country – Rajshahi with just 1,375 mm falls in this area. Districts with 70-100% of the country average extend from the north-east to the south east and also the centre - centre-west of the country – Rangpur, Dhaka, Comilla, Madaripur and Barisal fall in this region. Districts wetter than the average lie in the east, with the wettest districts in the far north-east, Sylhet -172%, and the far south-east, Coxes Bazaar – 153% [2].

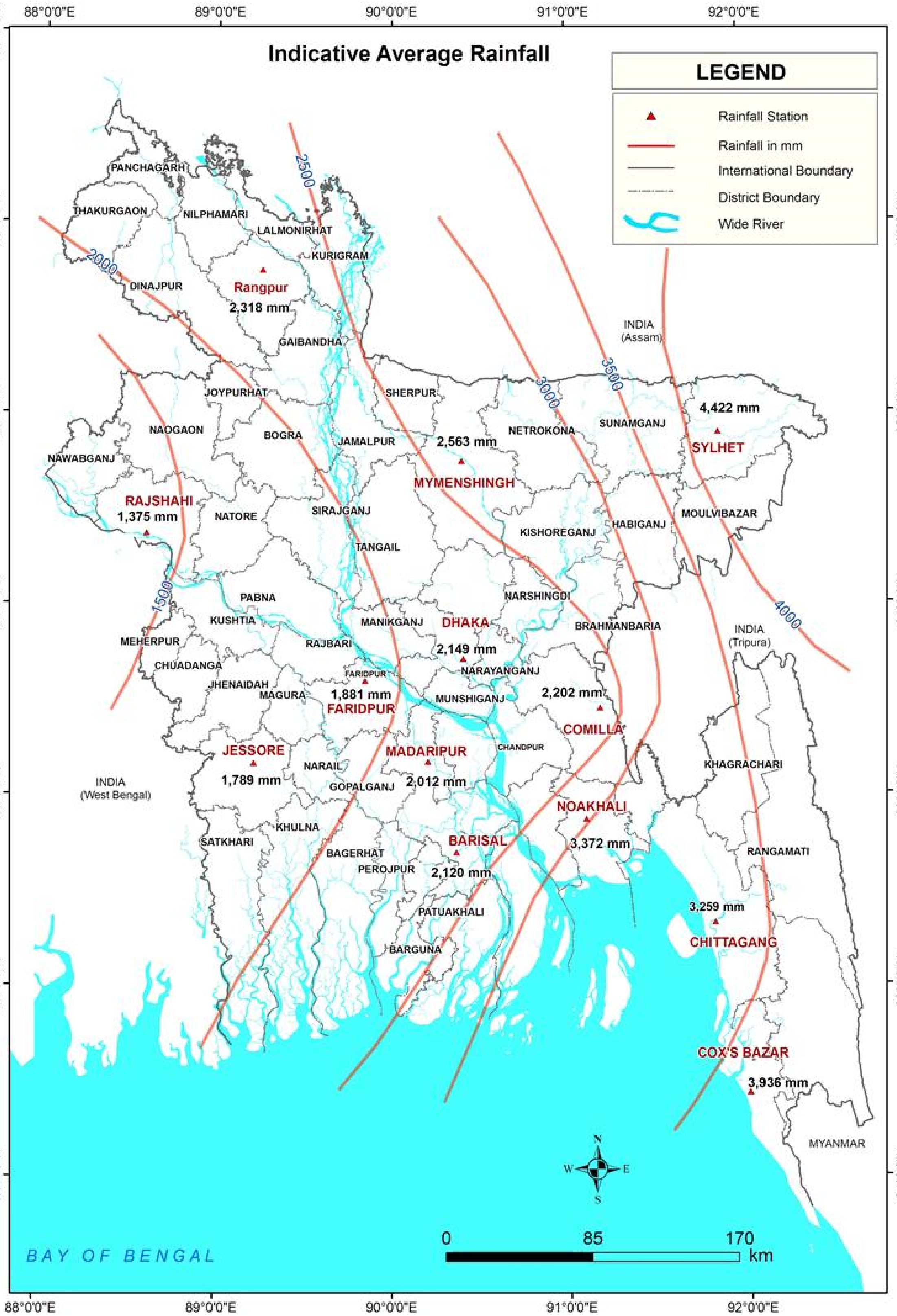
It is the uncertainty associated with monthly rainfall that impacts cropping, and the high variation in the amount and timing of rainfall from year to year can cause extensive crop loss due to flooding and/or water shortages. Monthly rainfall data are presented below for five stations, giving a reasonable representation of the average monthly rainfall variation in the country.



[2] Hill tract areas in the south east are not considered

Figure I-2: District Map

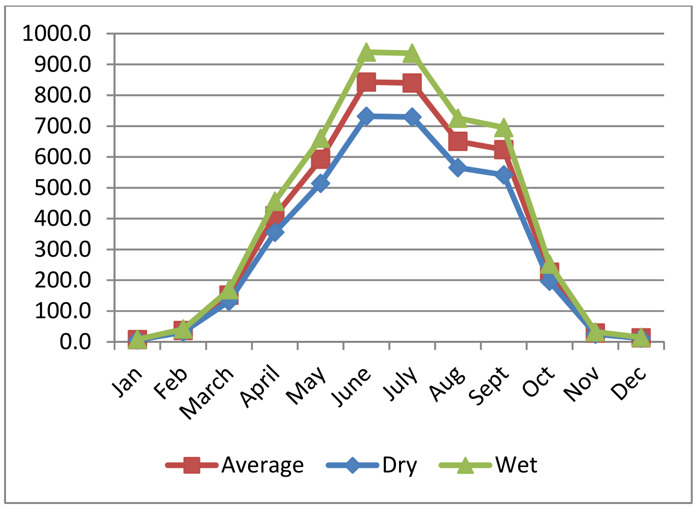
Figure I-3: Indicative Average Annual Rainfall

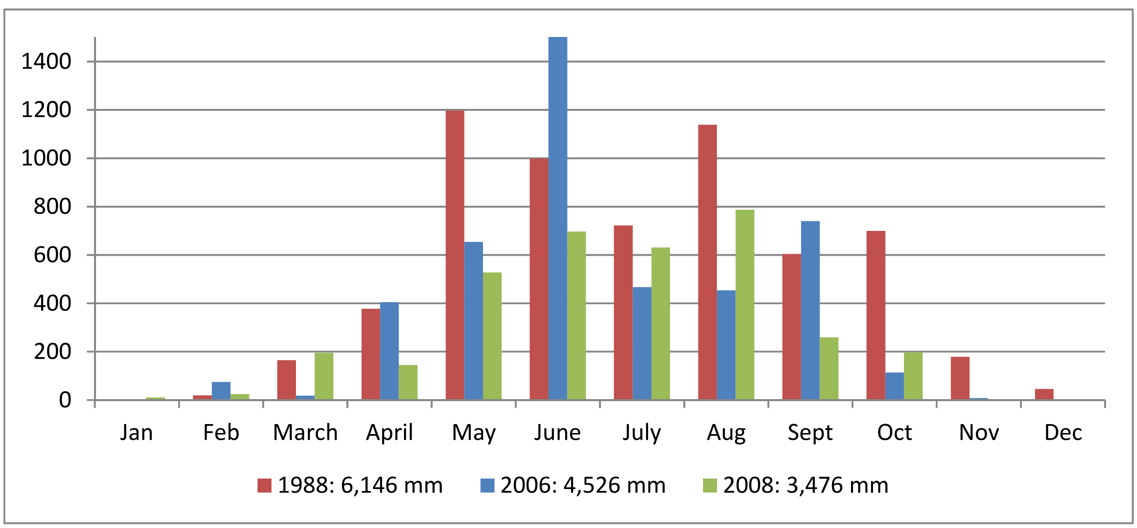


a. Sylhet – 4,422 mm

Sylhet represents the wettest part of the country, with an average annual rainfall of 4,422 mm, about 172% of the country average. Wet and dry year rainfall (5 year probability of occurrence) varies from 4,932 mm to 3,841 mm and large areas of the countryside are submerged during the monsoon for prolonged periods. The distribution of rainfall over the year impacts on crop losses / production. In the driest year of the 28 year data record, 2008, monthly rainfall was quite uniformly spread from July to August, with about 600 mm falling each month. This would not have posed significant difficulties for farmers, though with flooding much less than usual. In a near average year, in 2006, there was 4,526 mm of rainfall. However most of this “extra” rainfall fell in June, 1,589 mm, which would have caused severe flooding and Aus crop losses. The wettest year on record was in 1988 when there was 6,146 mm of rainfall. However the high rainfall was distributed over several months with peaks of 1,196 mm in May and 1,138 mm in August. Flood damage to transplanted Aus seedlings would have occurred in May, the Aman crop would also have suffered excessive depths of floodwater and the land would have been slow to dry out for a Rabi crop.

Month	Sylhet		
	Average X2.33	Dry X1.25	Wet X5
Jan	7.4	6.5	8.3
Feb	37.1	32.2	41.3
March	151.7	131.7	169.1
April	409.1	355.3	456.2
May	592.3	514.4	660.5
June	842.8	732.0	939.9
July	839.9	729.4	936.6
Aug	650.5	565.0	725.5
Sept	623.7	541.7	695.5
Oct	226.0	196.3	252.0
Nov	29.0	25.2	32.3
Dec	13.3	11.6	14.8
Annual	**4422.7**	**3841.2**	**4932.0**





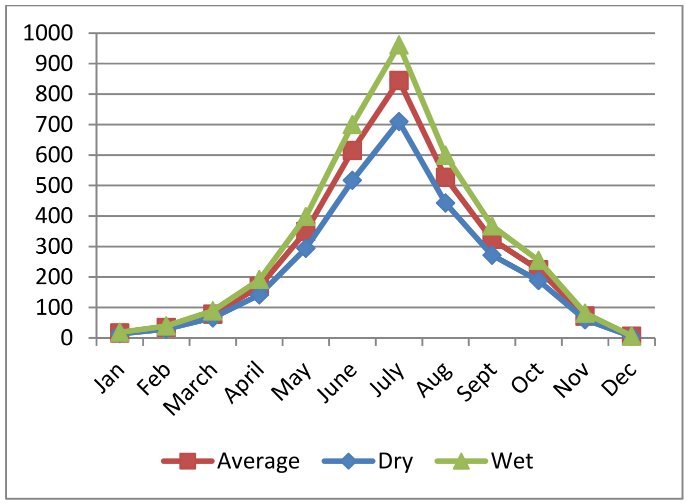
Sylhet Monthly rainfall – 4,423 mm in an average year
28 years of data, 1981 to 2010
(some years missing from record)

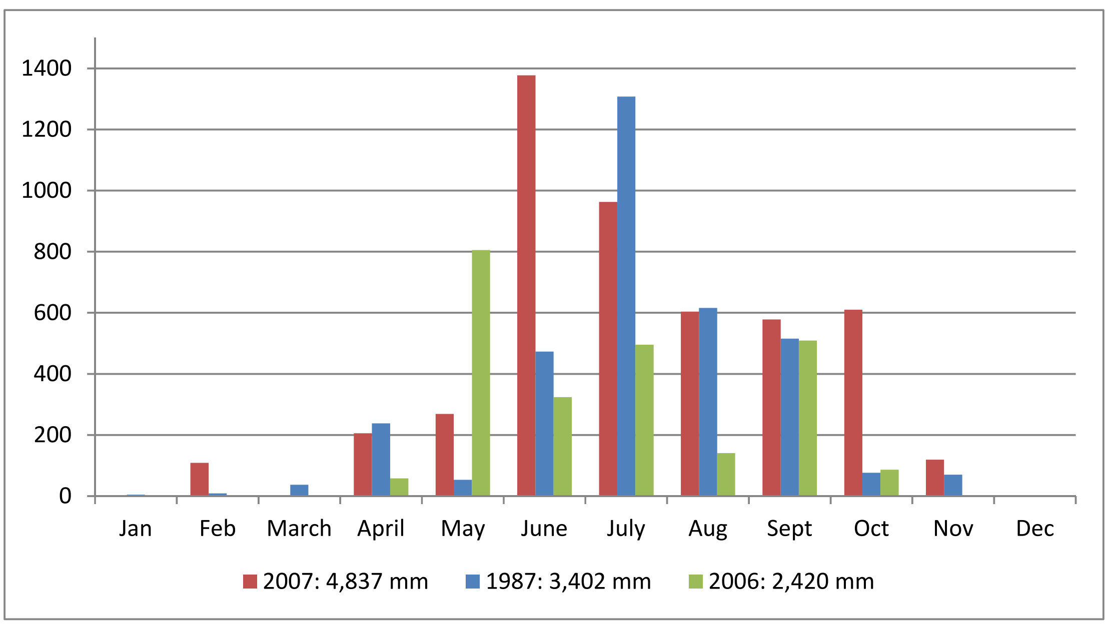
b. Chittagong – 3,259 mm

The south and south east of the county, represented by Chittagong data has rainfall 120-150% of average, and is the next wettest area after Sylhet. Wet and dry year rainfall (5 year probability of occurrence) varies from 3,709 mm to 2,739 mm.

In the driest year of the 25 year data record, 2006, rainfall was particularly light in June and August, and some (minor) supplementary pumping may have been required. In a near average year, in 1987, there was 3,402 mm of rainfall. However most of this "extra" rainfall fell in July, 1,308 mm, which would have caused severe flooding and Aus crop losses. The wettest year on record was in 2007 when there was 4,837 mm of rainfall. Most of this fell in June and July with peaks of 1,378 mm and 963 mm. Interestingly there was 106 mm of rainfall in February which would have helped meet rabi / boro crop water requirements.

Month	Chittagong		
	Average X2.33	Dry X1.25	Wet X5
Jan	16.5	13.9	18.8
Feb	34.6	29.1	39.4
March	78.2	65.8	89.0
April	168.2	141.4	191.4
May	350.1	294.3	398.5
June	615.2	517.1	700.1
July	844.8	710.1	961.5
Aug	526.9	442.9	599.7
Sept	323.3	271.7	367.9
Oct	223.8	188.1	254.7
Nov	71.5	60.1	81.4
Dec	6.0	5.1	6.8
Annual	**3,259.1**	**2,739.5**	**3,709.3**





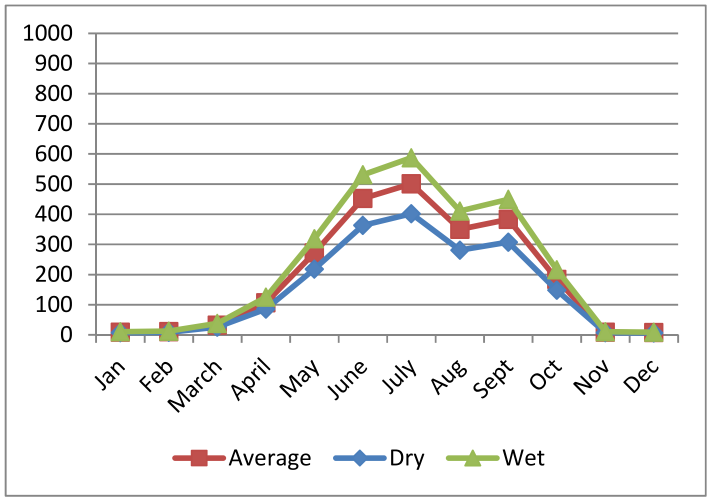
Chittagong Monthly rainfall – 3,259 mm in an average year
Based on 25 years of data, 1981 to 2009
(some years missing from record)

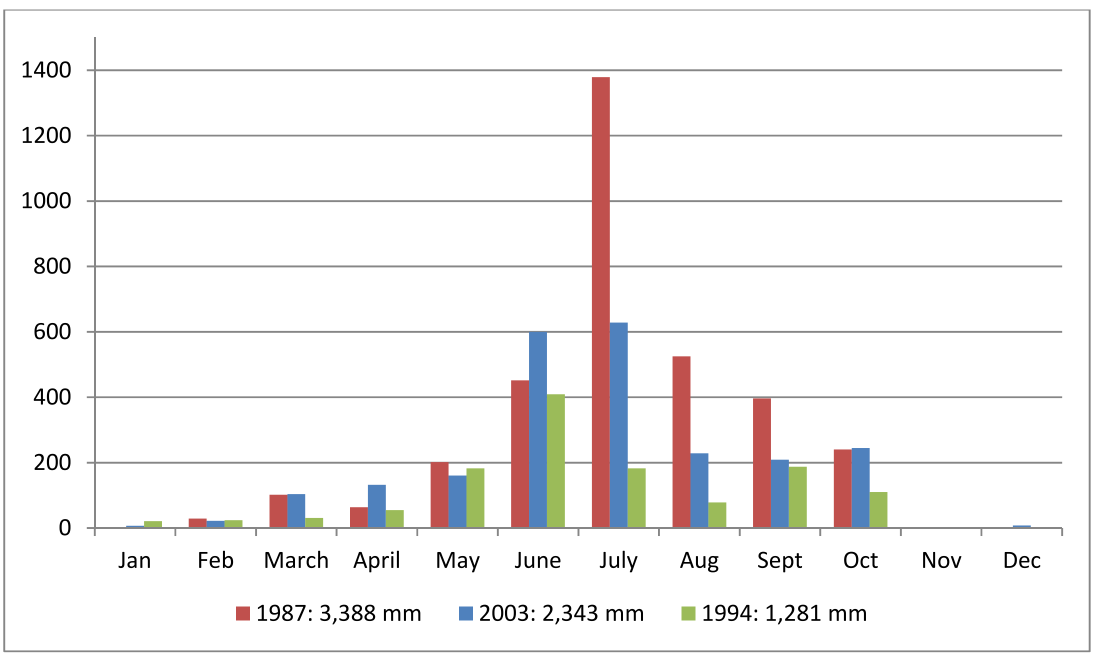
c. Rangpur – 2,318 mm

Rangpur district, lying in the northwest represents the drier part of the county with rainfall 75-100% of national average. Wet and dry year rainfall (5 year probability of occurrence) varies from 2,719 mm to 1,860 mm.

In the driest year of the 23 year data record, 1994, there was 1,281 mm of rainfall, and monthly rainfall only exceeded 200 mm in June. Supplementary pumping would have been required for Aus and Aman cropping. In a near average year, in 2003, there was 2,343 mm of rainfall with most of this falling in June and July. The wettest year on record was in 1987 when there was 3,388 mm of rainfall. Much of this fell in July, 1,387mm and would have caused flooding and crop damage to the early Aman crop.

Month	Rangpur		
	Average X2.33	Dry X1.25	Wet X5
Jan	8.9	7.2	10.5
Feb	10.7	8.6	12.5
March	32.4	26.0	38.0
April	106.6	85.6	125.1
May	271.7	218.0	318.7
June	452.5	363.1	530.8
July	500.9	401.9	587.5
Aug	350.2	281.0	410.8
Sept	383.2	307.5	449.5
Oct	184.3	147.9	216.2
Nov	9.0	7.2	10.5
Dec	7.6	6.1	8.9
Annual	**2,318.0**	**1,860.0**	**2,719.1**





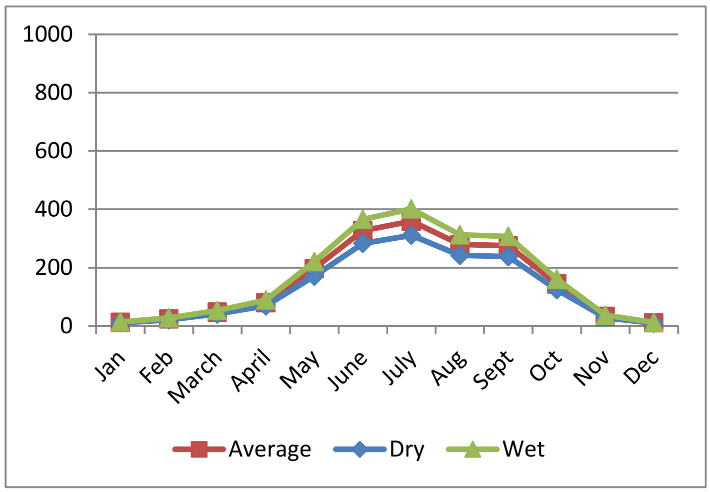
Rangpur Monthly rainfall – 2,318 mm in an average year
Based on 23 years of data, 1981 to 2010
(some years missing from record)

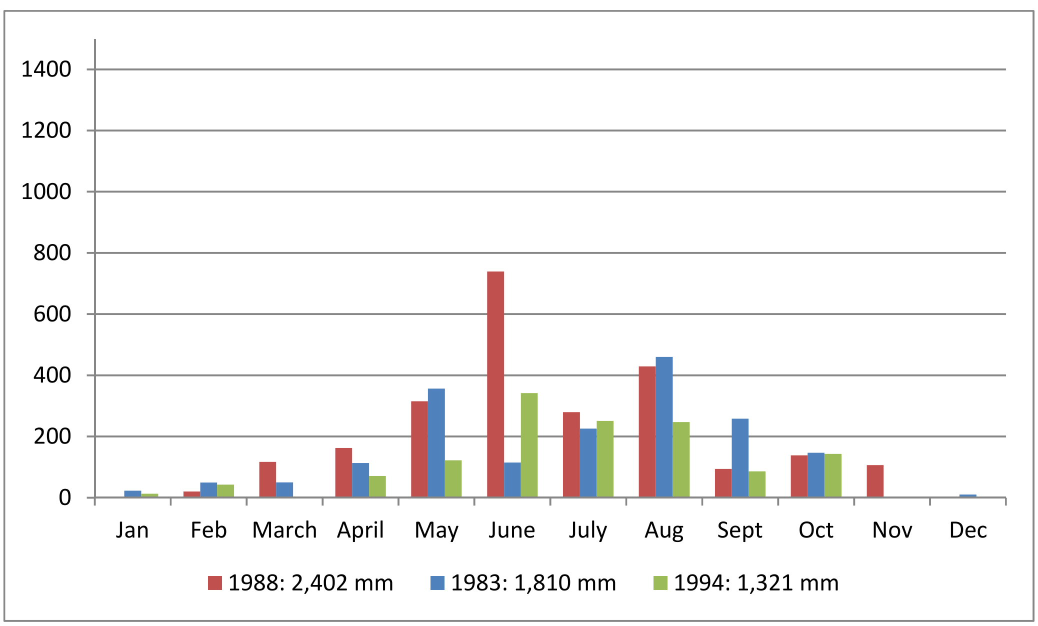
d. Jessore – 1,789 mm

Jessore district, lying in the south west northwest represents the drier part of the county with rainfall 50-75% of national average. Wet and dry year rainfall (5 year probability of occurrence) varies from 2,000 mm to 1,549 mm.

In the driest year of the 26 year data record, 1994, there was 1,321 mm of rainfall, though this was fairly evenly distributed over the monsoon months with monthly rainfall exceeding 200 mm in June, July and August. In a near average year, in 1983, there was 1,810 mm of rainfall with the highest rainfall occurring in May and August – supplementary pumped irrigation would probably have been needed in June and July. The wettest year on record was in 1988 when there was 2,402 mm of rainfall. Much of this fell in June, 740 mm and would have caused some flooding and crop damage to the early Aus crop.

Month	Jessore		
	Average X2.33	Dry X1.25	Wet X5
Jan	12.3	10.7	13.8
Feb	24.4	21.1	27.3
March	47.5	41.1	53.0
April	79.6	68.9	88.9
May	197.1	170.6	220.3
June	327.0	283.0	365.5
July	359.3	310.9	401.6
Aug	279.7	242.0	312.6
Sept	275.0	238.0	307.4
Oct	144.0	124.6	160.9
Nov	32.9	28.5	36.8
Dec	10.8	9.4	12.1
Annual	**1,789.4**	**1,548.7**	**2,000.3**





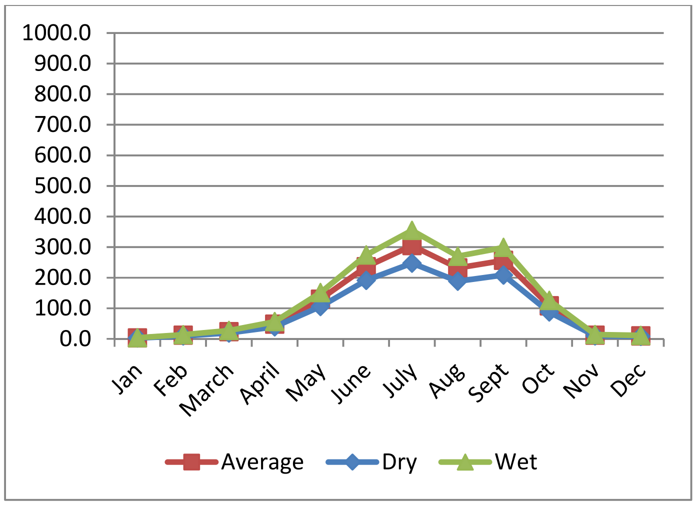
Jessore Monthly rainfall – 1,789 mm in an average year
Based on 26 years of data, 1981 to 2008
(some years missing from record)

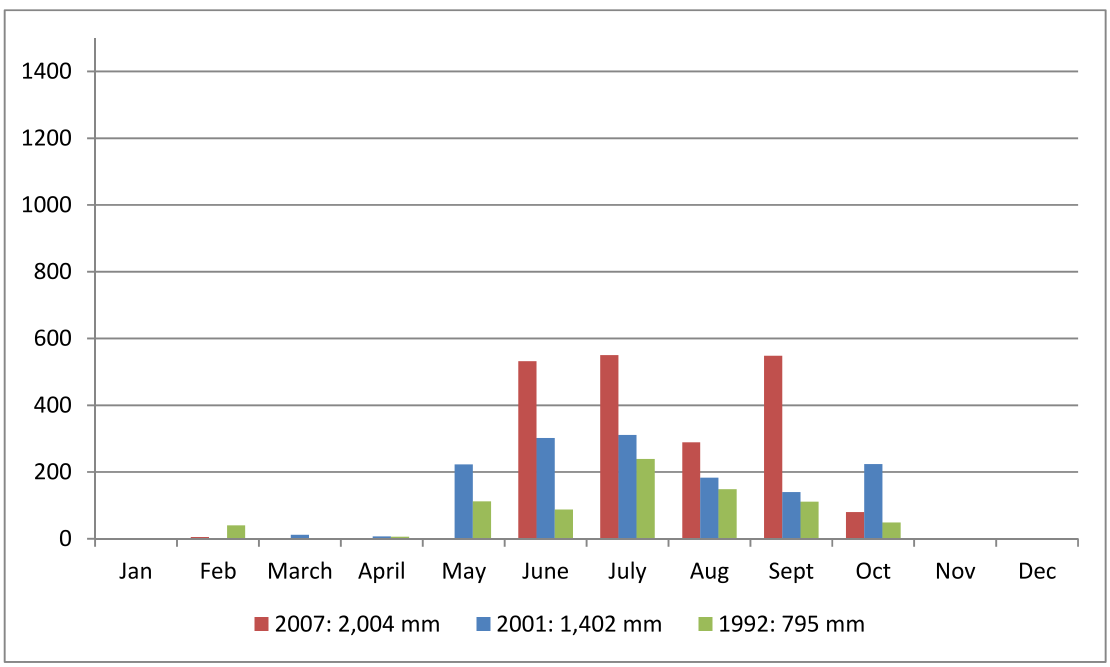
e. Rajshahi – 1,375 mm

Rashahi district, in centre-west represents the driest part of the county with rainfall only just over 50% of the national average. Wet and dry year rainfall (5 year probability of occurrence) varies from 1,601 mm to 1,117 mm.

In the driest year of the 26 year data record, 1992, there was just 795 mm of rainfall, mostly falling in July – September. Supplementary irrigation would have been required for both an Aus and Aman crop. In a near average year, in 2001, there was 1,402 mm of rainfall with more than 200 mm falling in May, June, July and October. Supplementary irrigation may have been needed in August and September. The wettest year on record was in 2007 when there was 2,004 mm of rainfall.

Month	Rajshahi		
	Average X2.33	Dry X1.25	Wet X5
Jan	3.1	2.5	3.6
Feb	11.8	9.6	13.8
March	23.4	19.0	27.3
April	48.2	39.2	56.1
May	129.8	105.4	151.1
June	235.6	191.4	274.3
July	304.6	247.5	354.7
Aug	231.9	188.4	270.0
Sept	256.6	208.4	298.8
Oct	108.2	87.9	125.9
Nov	12.1	9.8	14.1
Dec	9.7	7.9	11.3
Annual	**1375.0**	**1117.0**	**1601.0**





Rajshahi Monthly rainfall – 1,375 mm in an average year
Based on 26 years of data, 1981 to 2007
(some years missing from record)

2. Lean Season Rainfall

Although supplementary irrigation may be required from April to September, the main justification for a pumped irrigation CAD subproject is to enable Rabi/ lean season cropping.

What is interesting is that even in the wetter parts of the country the quantity of rainfall in the lean season, from November to February, is rarely "significant" (>50 mm rainfall in a month is adopted as being "significant").

Referring to *Table I-2* below, from November to February, the number of years in which rainfall in any month exceeded 50 mm showed little correlation with the volume of annual rainfall. The wetter eastern districts of the country have as little rainfall as the eastern districts during the lean season. For example, the likelihood of "significant" rainfall from November to February in any one month in Sylhet is 9% (ie about 1 year in 11), and is about 6% in Rajshahi. The district with the best chance of "significant" rain was Chittagong (16%), with Rangpur having the least chance (1%).

This indicates that there is a need for CAD subprojects and supplementary (pumped) irrigation for the lean season in all districts. However, the heavy monsoon rainfall in the eastern districts, particularly in the north-east, leads to prolonged flooding and high soil moisture – in this area only higher lying land may be suitable and fewer CAD subprojects are likely to be viable.

Table I-2: Lean Season Rainfall

District	Avg annual rainfall (mm)	Length of Record (yrs)	Nr of years with significant (> 50 mm / month) of rainfall					
			Oct	Nov	Dec	Jan	Feb	Mar
Sylhet	4,390	29	26	4	2	0	5	22
			90%	14%	7%	0%	17%	76%
		Average (Nov – Feb)		*9%*				
Chittagong	3,256	26	19	9	0	2	6	11
			73%	35%	0%	8%	23%	42%
		Average (Nov – Feb)		*16%*				
Rangpur	2,318	23	20	1	0	0	0	5
			87%	4%	0%	0%	0%	22%
		Average (Nov – Feb)		*1%*				
Jessore	1,789	27	20	6	2	1	4	9
			74%	22%	7%	4%	15%	33%
		Average (Nov – Feb)		*12%*				
Rajshahi	1,375	27	18	4	3	0	0	4
			67%	15%	11%	0%	0%	15%
		Average (Nov – Feb)		*6%*				

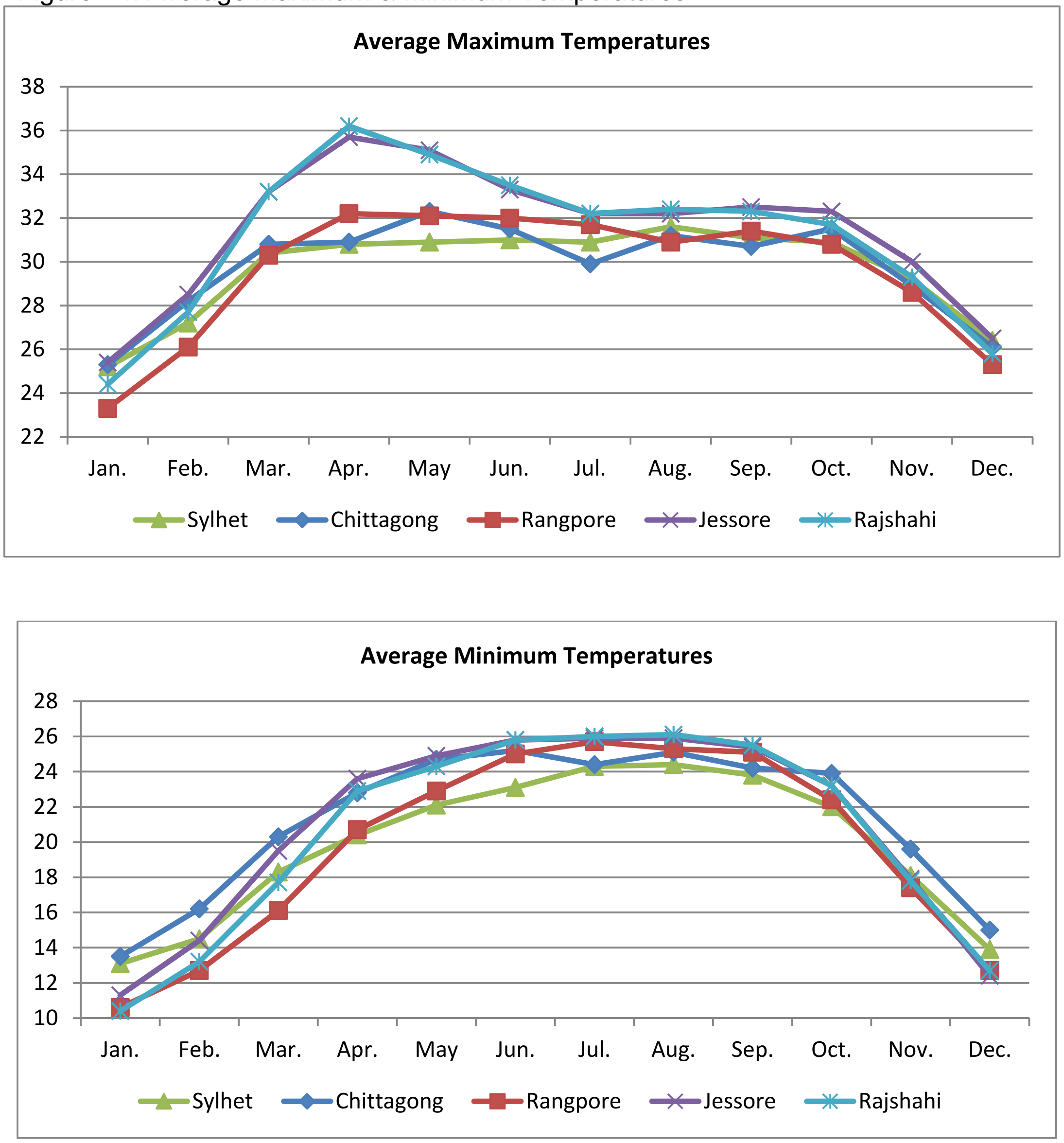
C. Climatic Data

Monthly temperature (minimum and maximum) ^{0}C, humidity %, wind speed km/day and sunshine hours data are required to calculate reference evapotranspiration, Temperature variation across the country is indicated by the data tabulated below in *Table I-3*.

Table I-3: Average Monthly Temperature Data

Month	Sylhet		Chittagong		Rangpore		Jessore		Rajshahi	
	Min Temp ^0C	Max Temp ^0C	Min Temp ^0C	Max Temp ^0C	Min Temp ^0C	Max Temp ^0C	Min Temp ^0C	Max Temp ^0C	Min Temp ^0C	Max Temp ^0C
Jan.	13.1	25.2	13.5	25.3	10.6	23.3	11.3	25.4	10.4	24.4
Feb.	14.5	27.2	16.2	28.2	12.7	26.1	14.4	28.5	13.2	27.7
Mar.	18.3	30.4	20.3	30.8	16.1	30.3	19.5	33.2	17.7	33.2
Apr.	20.4	30.8	22.8	30.9	20.7	32.2	23.6	35.7	22.9	36.2
May	22.1	30.9	24.7	32.3	22.9	32.1	24.9	35.1	24.3	34.9
Jun.	23.1	31.0	25.2	31.5	25.0	32.0	25.8	33.3	25.8	33.5
Jul.	24.3	30.9	24.4	29.9	25.7	31.7	25.9	32.2	26.0	32.2
Aug.	24.4	31.6	25.1	31.2	25.3	30.9	25.9	32.2	26.1	32.4
Sep.	23.8	31.1	24.2	30.7	25.1	31.4	25.4	32.5	25.5	32.3
Oct.	22.0	30.9	23.9	31.5	22.4	30.8	23.2	32.3	23.2	31.7
Nov.	18.1	29.2	19.6	28.9	17.4	28.6	17.9	30.0	17.8	29.3
Dec.	13.9	26.4	15.0	26.1	12.7	25.3	12.4	26.5	12.7	25.8
Average	**19.8**	**29.6**	**21.2**	**29.8**	**19.7**	**29.6**	**20.8**	**31.4**	**20.5**	**31.1**

Figure I-4: Average Maximum & Minimum Temperatures



Temperatures are higher for the dryer western districts, and lower for the wetter eastern districts. Temperatures peak in the pre-monsoon season, particularly in the drier districts. In Rajshahi for example, where there is just 1,375 mm of rainfall per year, temperatures reach 36^0C in April. In contrast in Sylhet temperatures peak at $31\text{-}32^0$C.

Average minimum temperatures peak at $24\text{-}26^0$C in July, and drop to $10\text{-}14^0$C in January, for all districts

Monthly climatic data are tabulated and discussed below for five selected districts, and given in **Appendix **** for 13 districts. As with rainfall there is significant variation in climatic data from year to year which is not apparent from the averages. This is illustrated by comparing monthly data for a single year, 1997, with the long term monthly averages.

a. Sylhet

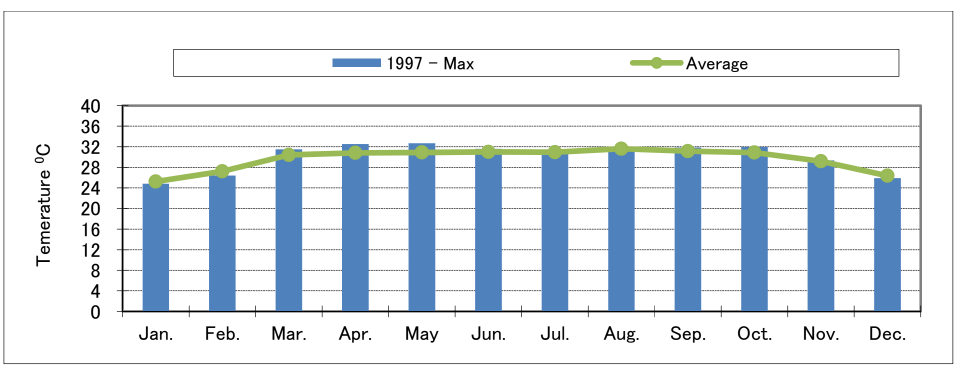
Table I-4: Climatic Data for Sylhet

Month	Min Temp ^0C	Max Temp ^0C	Humidity %	Wind km/day	Sunshine hours
Jan.	13.1	25.2	71	92	7.9
Feb.	14.5	27.2	67	116	8.2
Mar.	18.3	30.4	67	145	7.8
Apr.	20.4	30.8	76	143	6.8
May	22.1	30.9	81	127	5.7
Jun.	23.1	31.0	84	113	3.8
Jul.	24.3	30.9	88	105	3.5
Aug.	24.4	31.6	87	92	4.4
Sep.	23.8	31.1	87	77	4.7
Oct.	22.0	30.9	83	76	7.1
Nov.	18.1	29.2	77	86	8.3
Dec.	13.9	26.4	72	88	8.4
Average	19.8	29.6	78	105	6.4

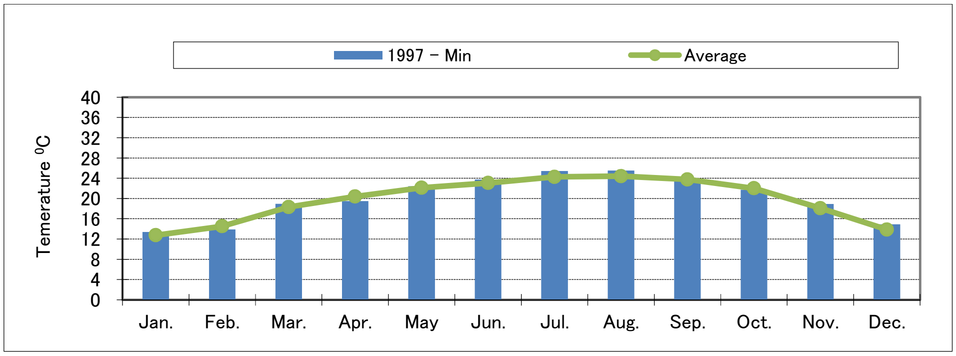
Maximum temperatures remain at about 32^{0}C from April to October, dropping to about 25^{0}C in January, the coolest month. Minimum temperatures show more variation, peaking at 24^{0}C in July-August, and falling to 13 ^{0}C in January. In 1997 monthly values were close to the long term average. Humidity remains high in the monsoon season at 80-90%, and falls to the lean season to about 72%. Wind speeds are typically “light”, between 60 and 216 km/day, and peak in March – April. Sunshine hours vary from about 8 in the drier lean season, reducing to about 4 in the monsoon.

Table I-5: Wind Speed Categories

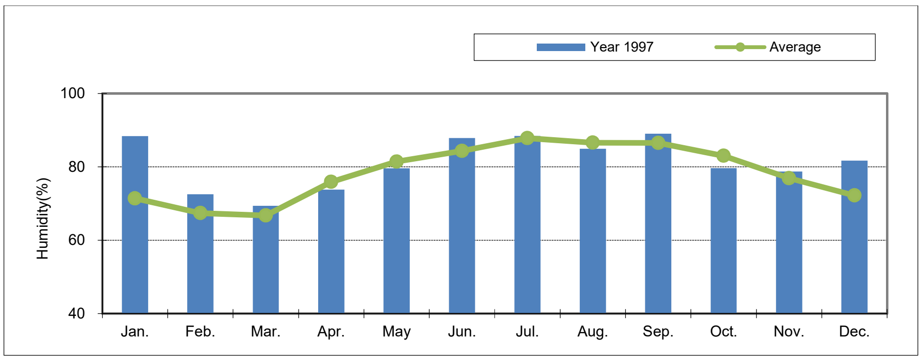
Nr	Wind Category	Wind Speed Range m/s		Wind Speed Range km/day	
1	No wind	0	0.7	0	60
2	Light	0.7	2.5	60	216
3	Moderate	2.5	3.5	216	302
4	Strong	3.5		302	



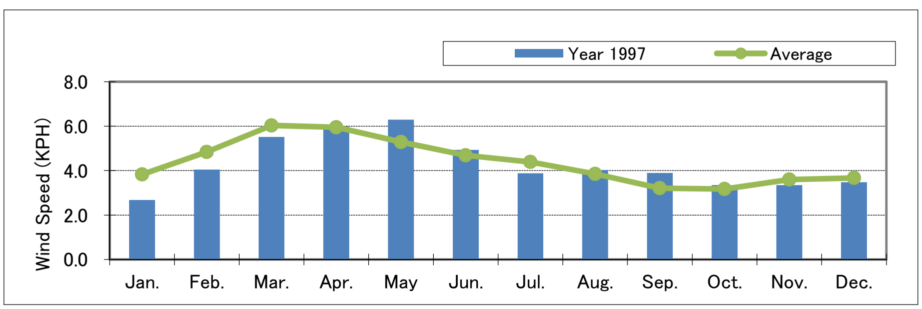
Monthly Average Maximum Temp



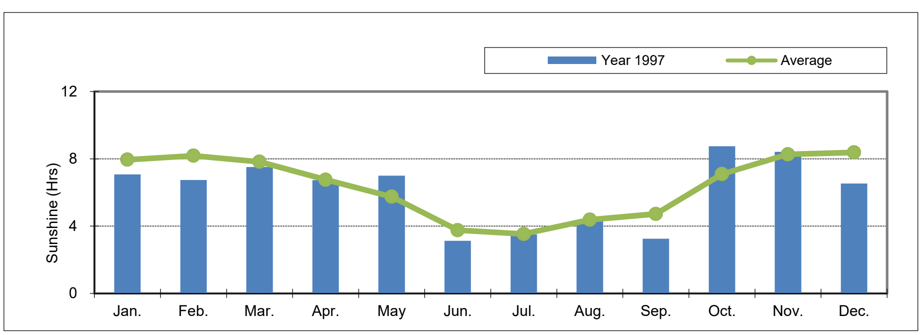
Monthly
Average
Minimum
Temp



Monthly
Average
Humidity



Monthly
Average
Wind Speed



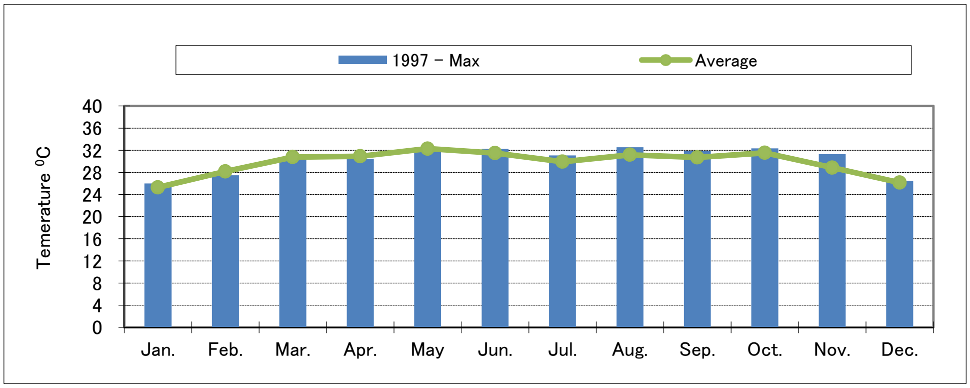
Monthly
Average
Sunshine
Hours

b. Chittagong

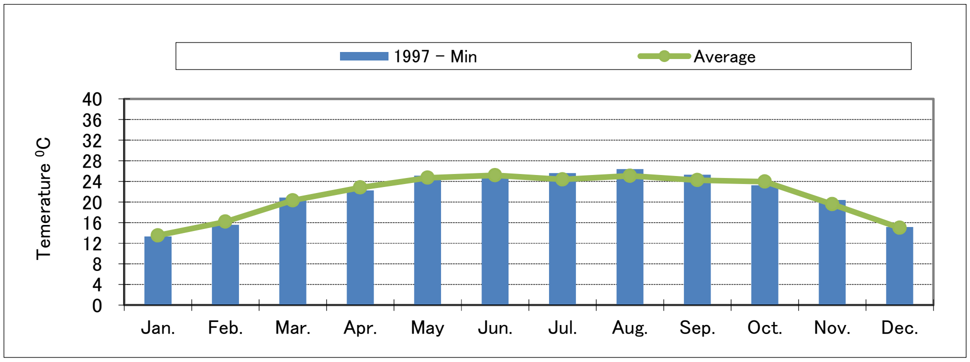
Table I-6: Climatic Data for Chittagong

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	13.5	25.3	72	110	8.6
Feb.	16.2	28.2	70	146	8.9
Mar.	20.3	30.8	74	233	8.7
Apr.	22.8	30.9	75	350	8.5
May	24.7	32.3	79	344	7.1
Jun.	25.2	31.5	84	411	4.1
Jul.	24.4	29.9	83	426	4.3
Aug.	25.1	31.2	86	378	5.1
Sep.	24.2	30.7	84	257	6.4
Oct.	23.9	31.5	82	140	7.4
Nov.	19.6	28.9	76	96	8.1
Dec.	15.0	26.1	73	94	8.2
Average	21.2	29.8	78	249	7.1

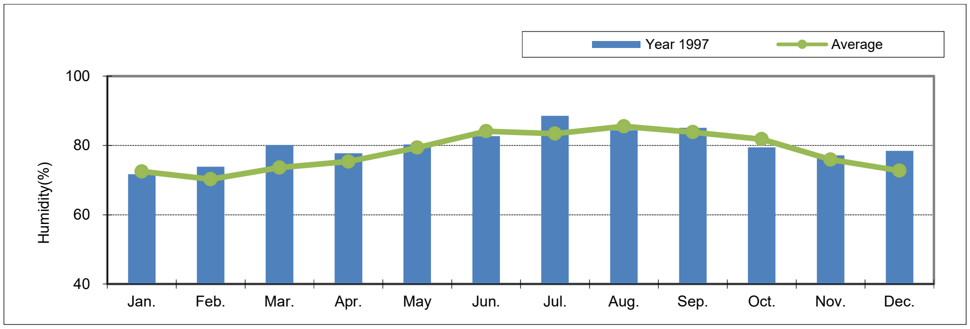
Maximum temperatures remain at about 31^{0}C from April to October, dropping to about 25^{0}C in January, the coolest month. Minimum temperatures show more variation, peaking at 25^{0}C in June, and falling to 13 ^{0}C in January. In 1997 monthly values were close to the long term average. Humidity remains high in the monsoon season at about 85%, and falls in the lean season to about 72%. Wind speeds are typically "light", between 60 and 216 km/day, from October to February, and "moderate", between 216 and 302 km/day, or "strong", greater than 302 km/day, from March to September. Sunshine hours vary from 8-9 in the drier lean season, reducing to 4-6 in the monsoon.



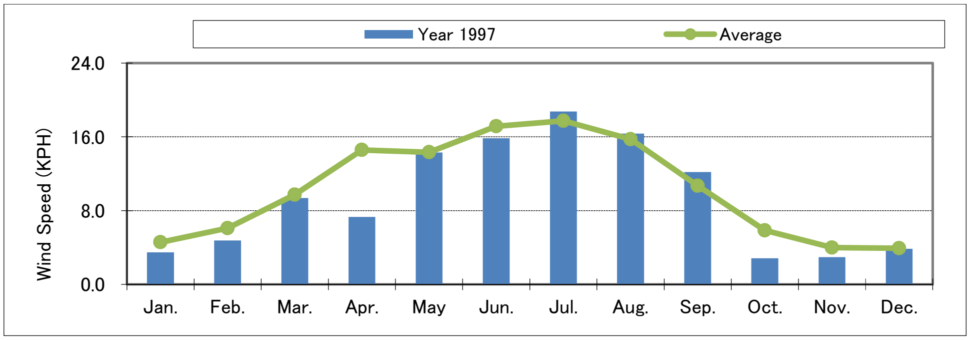
Monthly Average Maximum Temp



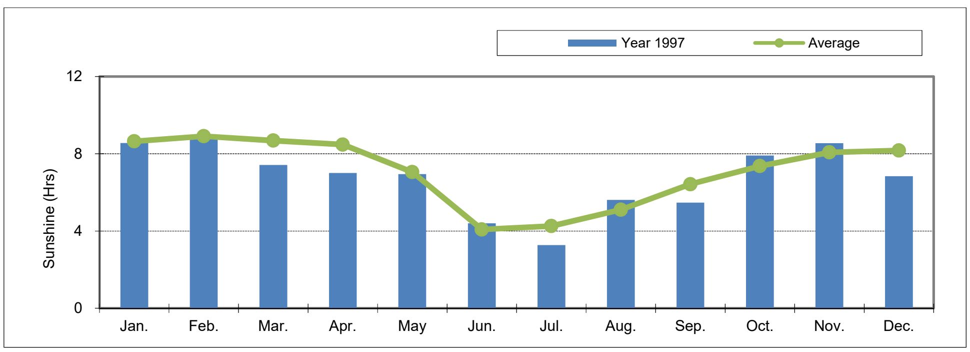
Monthly Average Minimum Temp



Monthly Average Humidity



Monthly Average Wind Speed



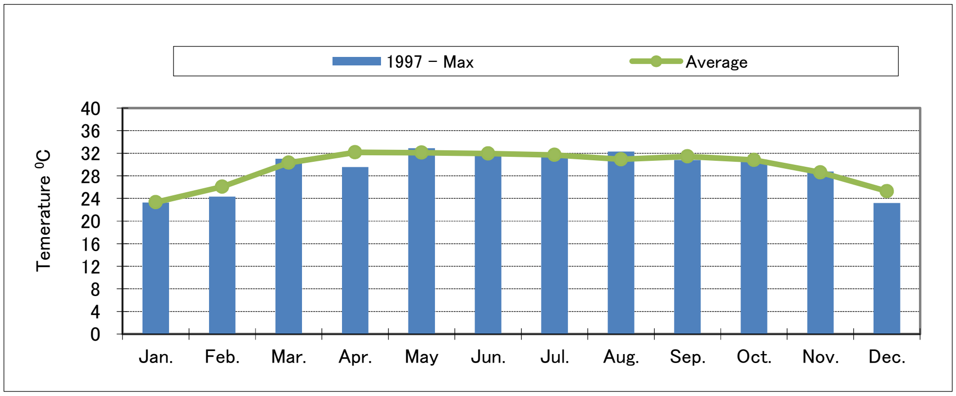
Monthly Average Sunshine Hours

c. Rangpur

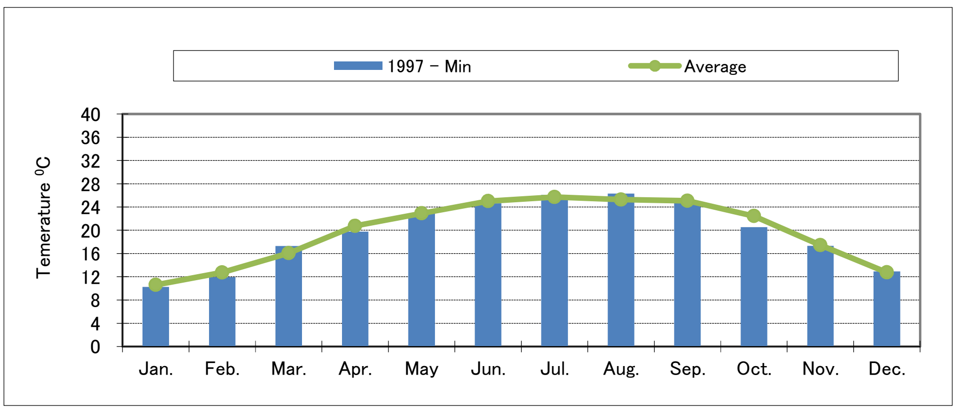
Table I-7: Climatic Data for Rangpur

Month	Min Temp ⁰C	Max Temp ⁰C	Humidity %	Wind km/day	Sunshine hours
Jan.	10.6	23.3	82	53	6.8
Feb.	12.7	26.1	76	71	7.8
Mar.	16.1	30.3	68	113	8.0
Apr.	20.7	32.2	73	153	7.4
May	22.9	32.1	81	131	6.6
Jun.	25.0	32.0	85	128	5.1
Jul.	25.7	31.7	84	124	4.3
Aug.	25.3	30.9	85	115	5.2
Sep.	25.1	31.4	87	95	5.2
Oct.	22.4	30.8	85	70	7.3
Nov.	17.4	28.6	79	69	8.3
Dec.	12.7	25.3	82	53	7.5
Average	19.7	29.6	81	98	6.6

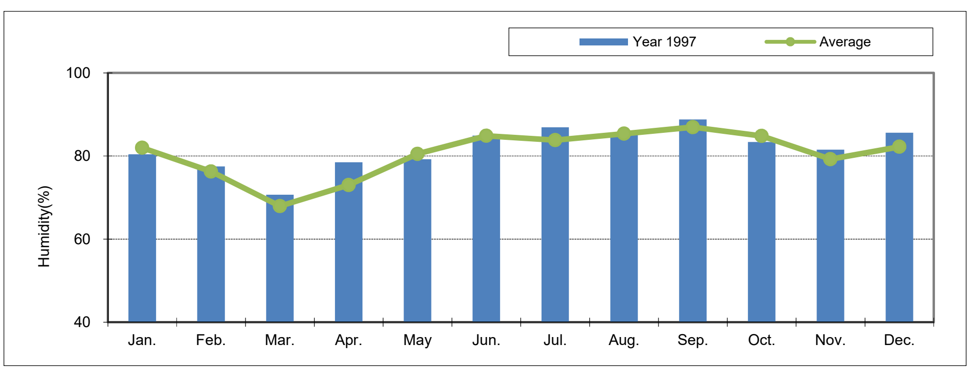
Maximum temperatures remain at about 31-32^{0}C from April to October, dropping to about 23^{0}C in January, the coolest month. Minimum temperatures show more variation, peaking at 25-26^{0}C from June to September, and falling to 11 ^{0}C in January. In 1997 monthly values were close to the long term average, except for April which was slightly cooler than usual. Humidity remains high in the monsoon season at about 85%, and falls in about 70% in March. Wind speeds are usually "light", between 60 and 216 km/day. Sunshine hours vary from 7-8 in the drier lean season, reducing to 4-6 in the monsoon.



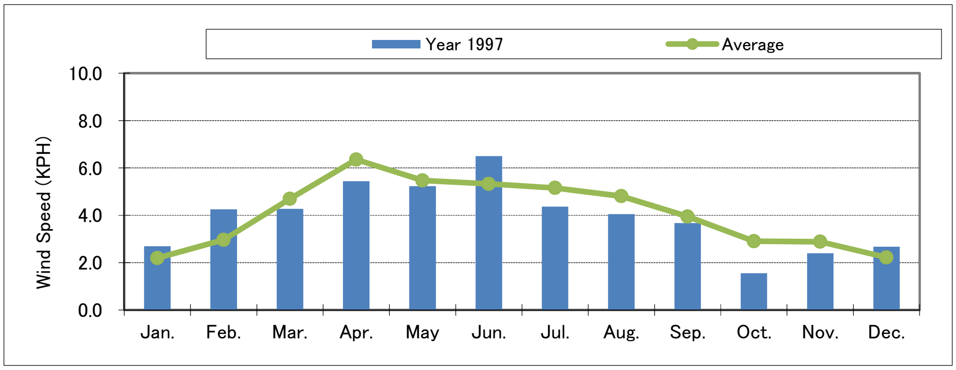
Monthly Average Maximum Temp



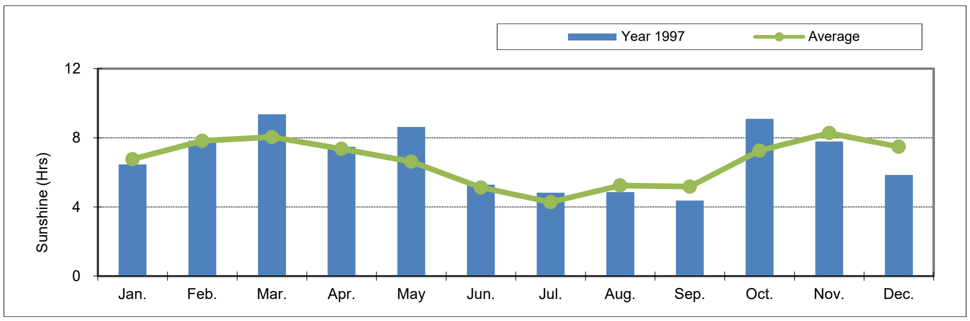
Monthly Average Minimum Temp



Monthly Average Humidity



Monthly Average Wind Speed



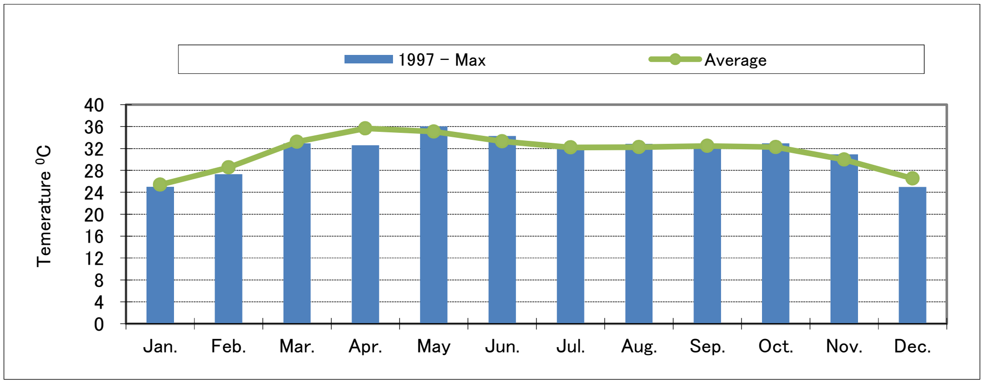
Monthly Average Sunshine Hours

d. Jessore

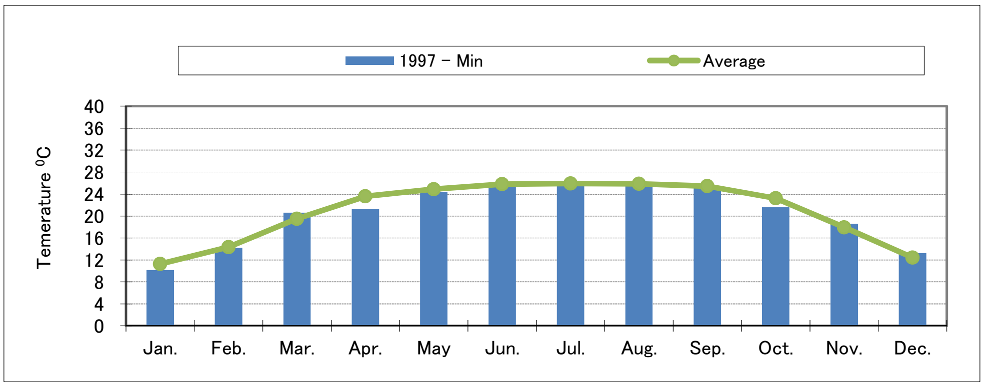
Table I-8: Climatic Data for Jessore

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	11.3	25.4	73	65	7.3
Feb.	14.4	28.5	69	95	7.8
Mar.	19.5	33.2	65	173	7.9
Apr.	23.6	35.7	69	318	8.1
May	24.9	35.1	76	320	7.3
Jun.	25.8	33.3	84	279	4.8
Jul.	25.9	32.2	87	245	3.9
Aug.	25.9	32.2	87	225	4.6
Sep.	25.4	32.5	86	176	4.8
Oct.	23.2	32.3	82	88	6.7
Nov.	17.9	30.0	77	61	7.4
Dec.	12.4	26.5	75	51	7.2
Average	20.8	31.4	77	175	6.5

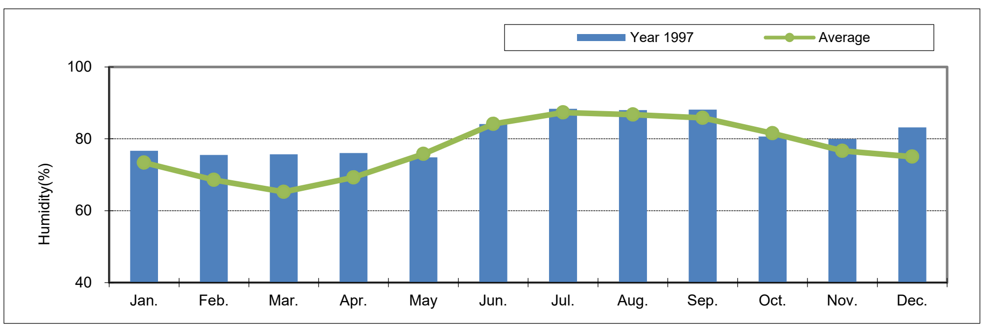
Maximum temperatures peak at about 35^{0}C in April and May, dropping to about 25^{0}C in January, the coolest month. Minimum temperatures show a bit more variation, being about 25^{0}C from May to September, and falling to 11^{0}C in January. In 1997 monthly values were close to the long term average, except for April which was rather cooler than usual. Humidity remains high in the monsoon season at about 87%, and falls in the lean season to about 73%. Wind speeds are typically “light”, between 60 and 216 km/day, from September to March, and “moderate”, between 216 and 302 km/day, in the pre-monsoon and monsoon months. Sunshine hours vary from 6-8 most of the year, reducing to just 3-4 from June to September.



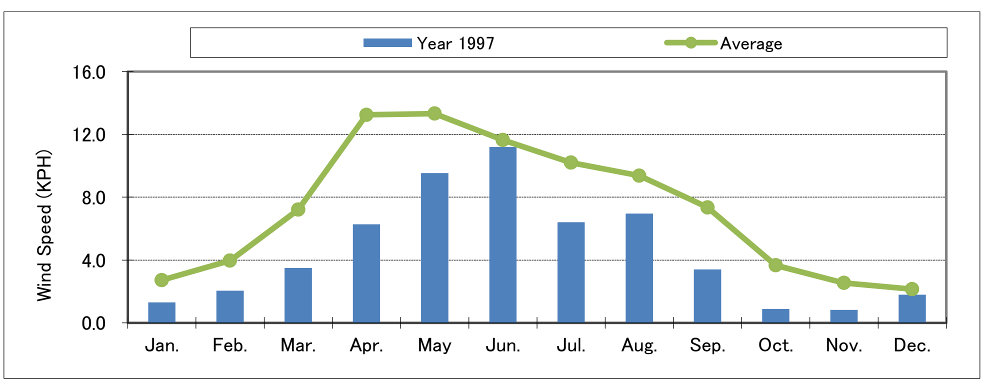
Monthly Average Maximum Temp



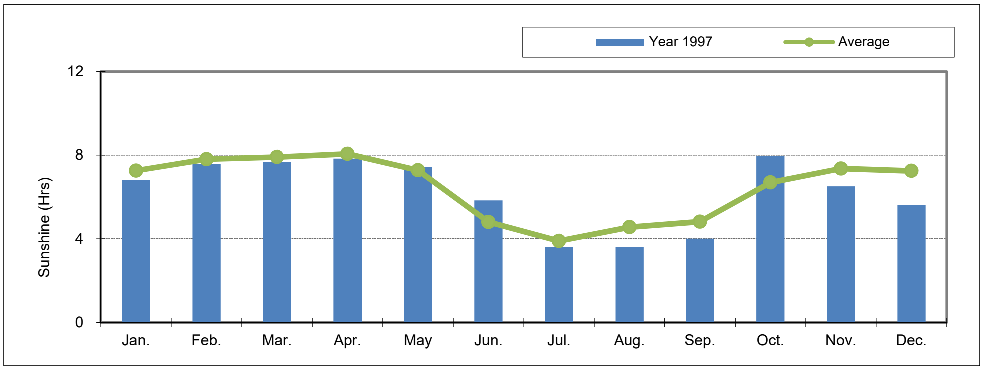
Monthly Average Minimum Temp



Monthly Average Humidity



Monthly Average Wind Speed



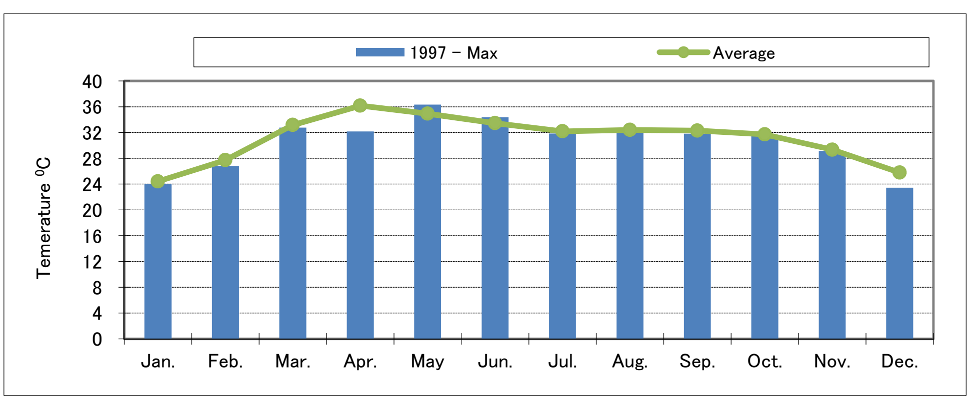
Monthly Average Sunshine Hours

e. Rajshahi

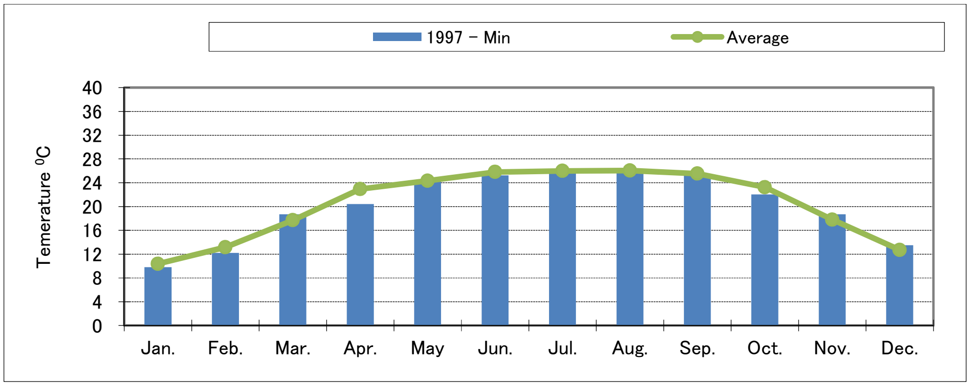
Table I-9: Climatic Data for Rajshahi

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	10.4	24.4	74	74	7.2
Feb.	13.2	27.7	67	81	8.2
Mar.	17.7	33.2	59	103	8.5
Apr.	22.9	36.2	62	158	8.4
May	24.3	34.9	74	173	7.5
Jun.	25.8	33.5	83	163	5.6
Jul.	26.0	32.2	87	148	4.5
Aug.	26.1	32.4	86	133	5.1
Sep.	25.5	32.3	85	111	5.4
Oct.	23.2	31.7	81	70	7.4
Nov.	17.8	29.3	77	68	8.1
Dec.	12.7	25.8	75	76	7.7
Average	20.5	31.1	76	113	7.0

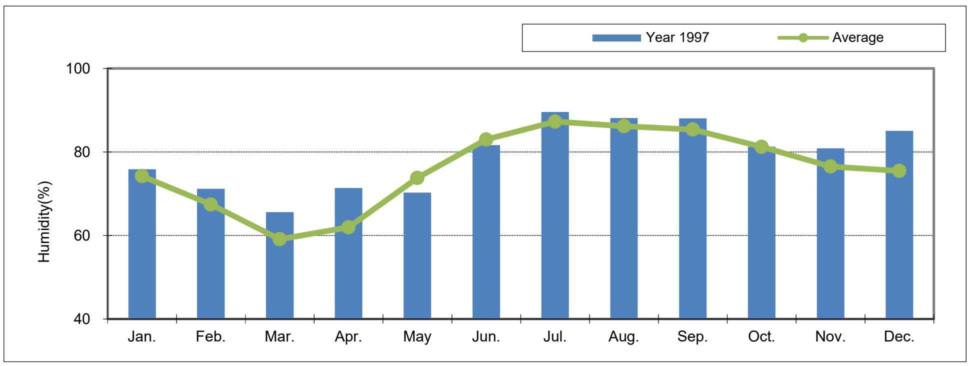
Maximum temperatures peak at about 36^{0}C in April, dropping to about 24^{0}C in January, the coolest month. Minimum temperatures vary from about 25^{0}C from May to September, falling to 10^{0}C in January. In 1997 monthly values were close to the long term average, except for April which was cooler. Humidity remains high in the monsoon season at 85-87%, and falls in the lean season to about 56% - lower than for most of Bangladesh. Wind speeds are typically “light”, between 60 and 216 km/day throughout the year. Sunshine hours are 7-8 most of the year, reducing to 4-6 from June to September.



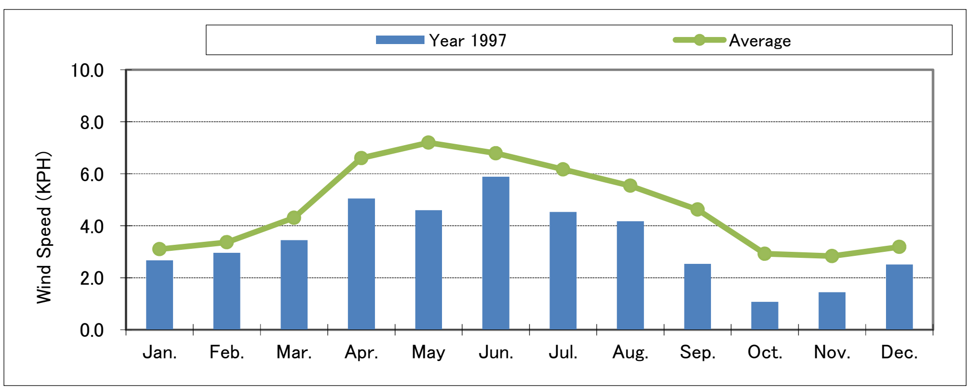
Monthly Average Maximum Temp



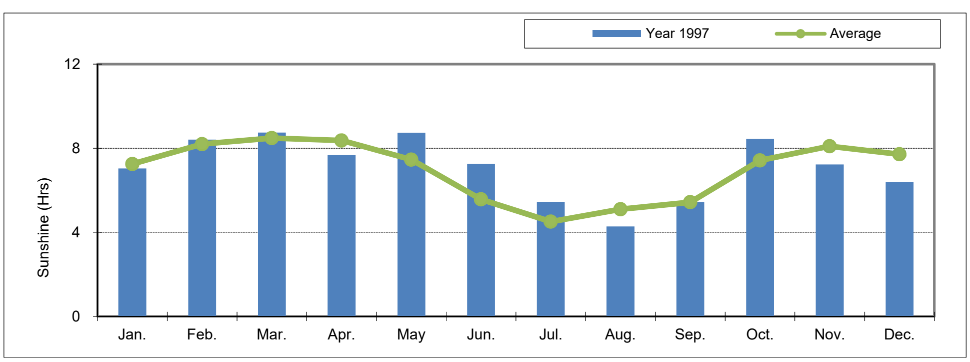
Monthly Average Minimum Temp



Monthly Average Humidity

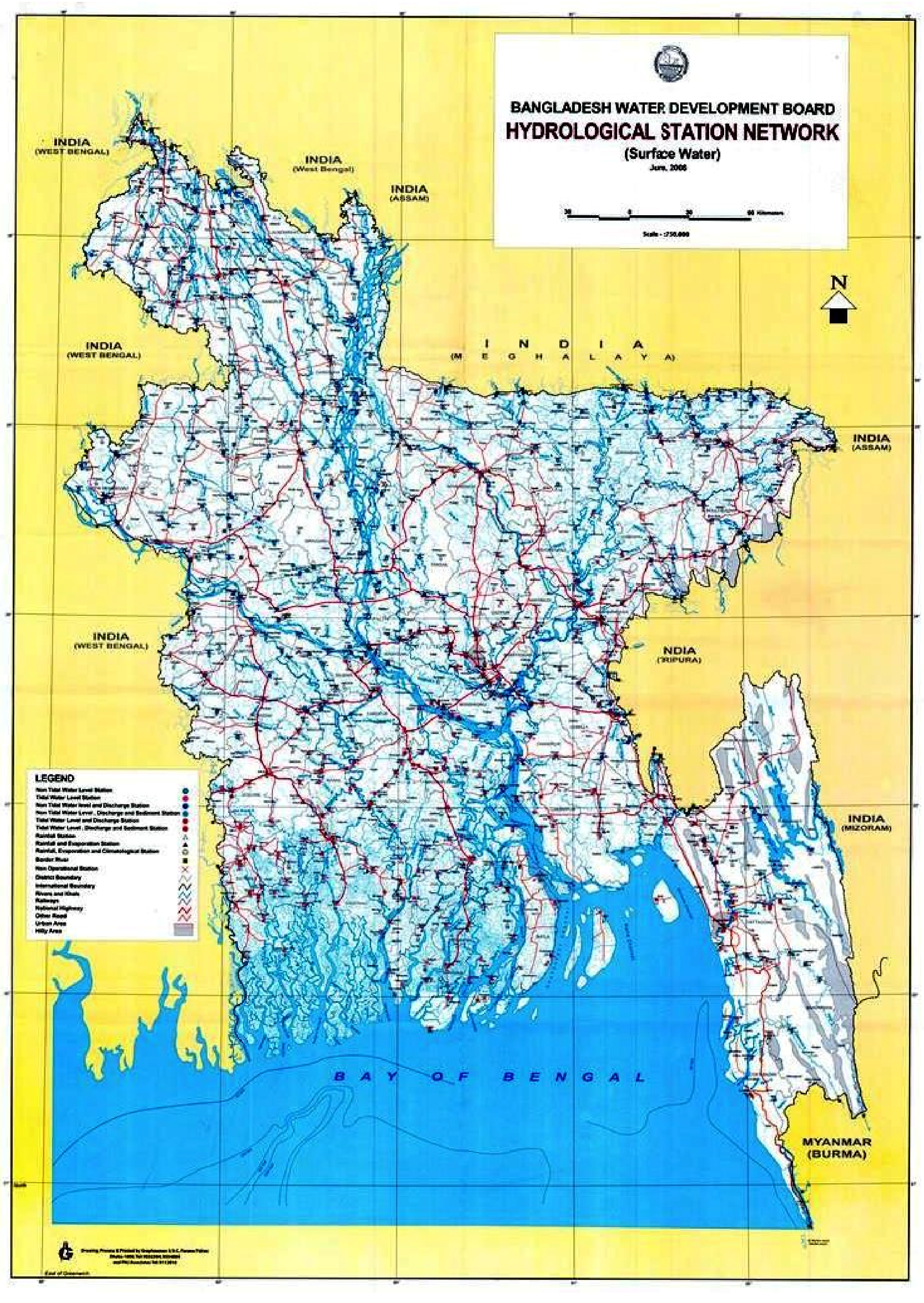


Monthly Average Wind Speed



Monthly Average Sunshine Hours

Figure I-5: Hydrological Station Network



II. Irrigation Water Requirements

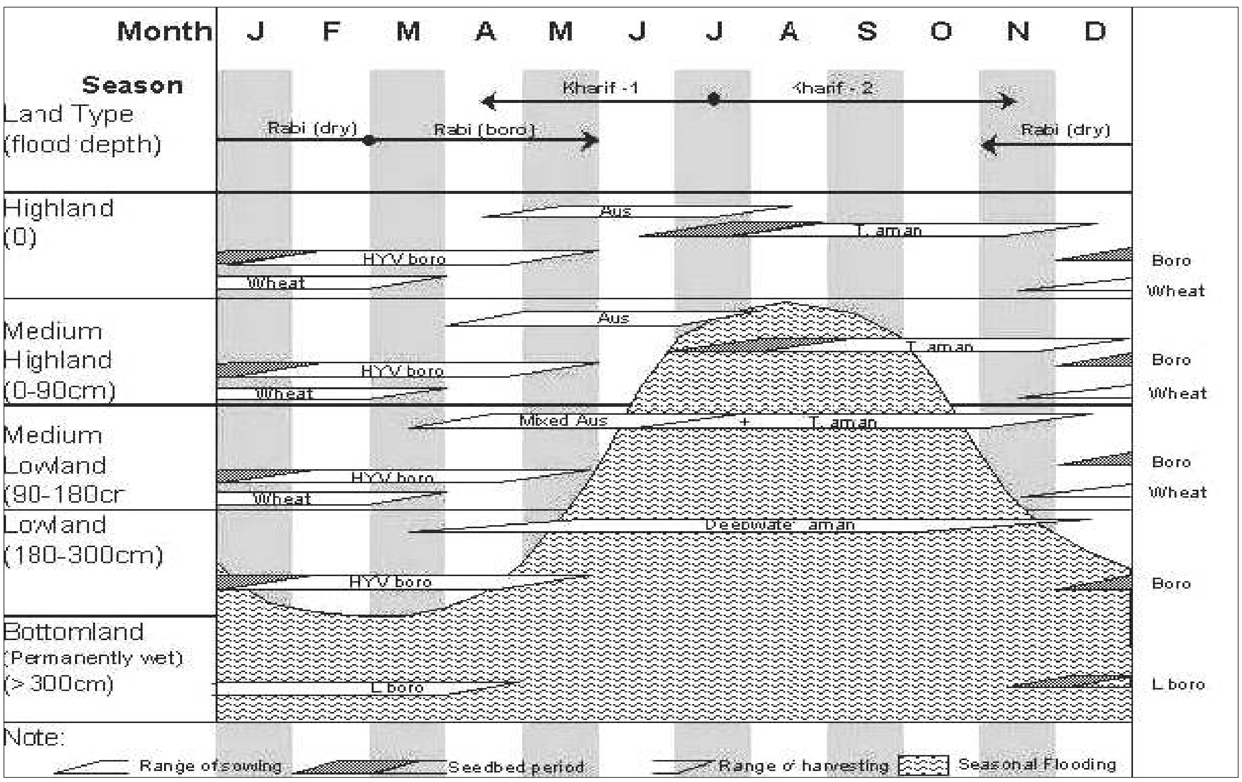
A. Introduction

Peak irrigation requirements occur in the lean season/ Rabi (December to April) with further supplementary irrigation depending on the crop and rainfall in subsequent months. Irrigation requirements will be greatest for the drier and hotter western districts, and lower for the wetter eastern districts.

Cropping depends to a great extent on land elevation. Lower lying areas are vulnerable to flooding for much of the year limiting cropping while supporting fish-based livelihoods. Higher areas have the potential for 250-300% cropping.

Land categories and seasonal cropping are illustrated and described below.

Figure II-1: Typical Cropping Pattern by Land Category



For land of the same category all farmers are likely to want water at the same time – conversely if a subproject comprises several land categories water demand will be attenuated. Farmers on higher land will plant first, with farmers on lower land planting some weeks later after their fields have dried out and the monsoon crops harvested.

Of importance for design engineers of CAD subprojects is on the type and extent of lean season (Rabi) cropping, and the period over which irrigation water will be required by farmers. These lean season crops may include a variety of dry-foot crops (wheat, vegetables – onion & garlic, potato, etc) as well as boro paddy.

In this Chapter crop water requirements for the lean season are estimated using the climatic data summarised in Chapter 0 for five districts that represent the broad range found in Bangladesh (outside the hill tracts). Reference crop evaportranspiration is calculated from monthly average climatic data using the FAO program CROPWAT (version 8). Details of this program are given in **Appendix B1**.

Table II-1: Cropping by Land Category and Season

Land Category	Land Type	Nature of Flooding	Cropping			Cropping Intensity (%)	
			Kharif- I (summer)	Kharif-II (monsoon)	Rabi	Typical Current	Typical Potential
Non-cultivated high land	High	Not flooded	**(Housing area, roads & other infrastructure)**				
F0 (< 0.3m flooding)	High	Intermittent	HYV & B. Aus, Jute	T. & HYV Aman	HYV Boro, Oilseed, Wheat, vegetables (onion, garlic, etc)	210%	300%
F1 (0.3m - <0.9m)	Medium -high	Seasonal (3-6 months)				190%	280%
F2 (0.9 - <1.8m)	Medium-low		DW Amam		HYV Boro, Oilseed, (Wheat)	160%	220%
F3 (>1.8m)	Low	Seasonal (less than 9 months)	hyv Boro (cont.)	-	hyv Boro	100%	100%
Non-cultivated low land	Very low	Permanent	(Fishing & navigation)				
					Totals	**179%**	**220%**

T – Transplanted; HVY – high yielding variety; DW – Deep water; B – broadcast

B. Adopted Parameters for Calculation of Crop Water Requirements

1. Rice Crops

a. General

For transplanted boro (winter rice) the calculation of crop water requirements requires consideration of:

- Rice evapotranspiration as well as evaporation from ponded basins;
- Nursery requirements;
- Puddling requirements to break soil structure and reduce deep percolation; and
- Bund seepage and deep percolation losses.
- Effective Rainfall

b. Crop Coefficients

Rice is usually grown in levelled basins which are flooded with water throughout most of the growing season. For rice two crop coefficients per growing stage are required. The first one Kc *wet* is used when there is ponding water on the soil surface while Kc *dry* is used when there is no ponded water, which is a common situation towards the end of the late season during the drying out of the soil profile.

Kc is influenced mostly by crop type and to a minor extent by climate and soil evaporation. Kc for a given crop varies over the crop growing stages as ground cover, crop height and leaf area change as the crop develops.

For upland crops four growth stages are usual, namely initial, development, mid-season and late season. In wetland rice this is extended to six stages to include the nursery and land preparation periods. The different stages are described below and Kc dry and Kc wet values are given in *Table II-2*:

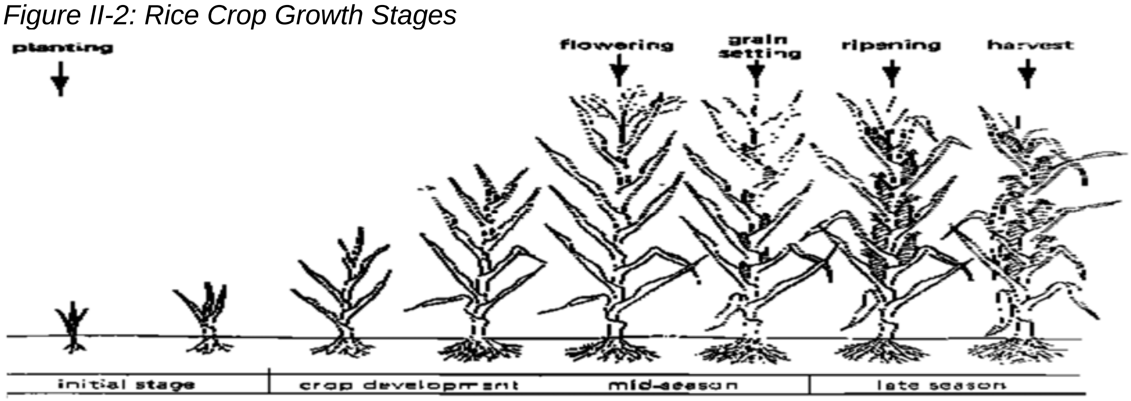
i. *Nursery stage*: starting from preparation of the nursery area to transplanting of rice seedlings.
ii. *Land preparation stage:* for land preparation and inundation prior to transplantation. Often land preparation will fall totally within the nursery period. If puddling is used for rice cultivation it is part of land preparation. Water requirements for land preparation depend on the amount required for soil soaking, water losses during (puddling) operations and on the amount of water used to maintain standing water in the field. Water requirements for soaking the land and puddling depend on the initial soil moisture content, soil surface conditions, soil texture and depth of puddling.
iii. *Initial growth stage*: during this period under optimal conditions for lowland rice, there is water standing permanently. During this period the leaf area is small, and for lowland rice evapotranspiration is predominately in the form of evaporation of the standing water. Kc wet during the initial period is large and Kc dry relatively low.
iv. *Development stage*: as the crop develops and shades more and more the ground and water standing, evaporation becomes more restricted and transpiration gradually becomes more important.
v. *Mid-season stage*: at this stage the Kc dry reaches its maximum value as maximum canopy cover is achieved.
vi. *Late season stage*: the Kc wet and Kc dry values at the end of the late season stage reflect crop and water management practices. Kc wet will be used only when there is ponding water. However, it is normal practice to drain the field in this grain filling and maturation stage with the crop drawing on water stored in the soil profile.

Table II-2: Growth Stages, Crop Coefficients, Rooting and Puddling Depths

	Nursery	Land Preparation*	Growth Stage				Total
			Initial	Devel.	Mid-season	Late-season	
Length (days)	25-30	20	15-20	25-30	30-40	20-30	115 - 150
			90 – 120				
Kc dry	0.70	0.30	0.50	0.5-1.05	1.05	0.7	
Kc wet	1.20	1.05	1.10	1.1-1.2	1.2	1.05	
Rooting Depth (m)			0.10	0.1-0.6	0.60	0.60	
Puddling Depth (m)		0.3-0.6					
Nursery Area (%)	10%						
Critical Depletion	0.20		0.20	0.20	0.20	0.20	
Yield Response			1.0	1.09	1.09	1.09	

Note: Land preparation including puddling occurs within Nursery period

Figure II-2: Rice Crop Growth Stages



c. Rooting Depth

Initial and maximum rooting depths are required as for all crops. However, as long as puddling is effective, that is, as long as water is ponded over the soil surface with a limited controlled deep percolation, the maximum effective rooting depth is considered to be equal to the puddling depth, which assumes that no roots grow beyond it.

d. Land Preparation, Puddling and Percolation Losses

Land preparation for boro paddy typically includes (i) land soaking; (ii) ploughing; (iii) harrowing and puddling; and (iv) smoothing, see *Figure II-3*. Land preparation is carried out to:

- Remove / plough in stubble and remove any weeds;
- Break up soil structure to facilitate transplanting and reduce deep percolation water losses; and
- Establishment of reduced soil condition which improves soil fertility and fertilizer management.

Figure II-3: Land Preparation

Dry Field with cracks prior to soaking **Soaked field (left) & Puddled field (right)**

The amount of water required for soaking and puddling depends on the initial soil moisture depletion, the soaking depth and soil water holding capacity and farmer practices. In Bangladesh for Boro typically about 180 mm is required[3].

Puddling is only possible with heavy soils[4], with clay content of 20% or higher, and enables rice to be grown under ponded conditions where the water table depth is below the root zone and the soil under the puddled layer is at field capacity. Where rice is grown on light silty soils either percolation losses will be very high, or the water table is brought to the surface.

The depth of puddling is typically 0.3-0.5 m. The greater the depth the more water required but the more effective it becomes in reducing deep percolation losses. The maximum rooting depth of rice plants is 0.6 m so puddling beyond 0.6 m serves little purpose as well as being difficult with the 2W tractors commonly used. However if soils are puddled to just 0.15 - 0.25 m then percolation losses are likely to be considerably higher for several reasons:

- The rather thin impermeable (puddle) layer;

[3] Table 9.5, Principals and Practices of Rice Production, S K De Datta
[4] For some soils careful management is required and puddling may not be appropriate, for example the black cotton clay soils (vertisols).

- Cracking which will occur if the soil is allowed to dry between irrigations. Once cracks penetrate below the puddle layer it cannot be restored by adding water to the soil. *Critical depletion* represents the soil moisture level at which cracks penetrate below the puddle layer so that when irrigation resumes percolation losses may be (initially) high as water passes through these cracks; and
- In the developing growth stage the plant roots may penetrate below the puddle layer, and facilitate percolation losses.

The deep percolation rate after puddling to a reasonable depth, usually 0.4 to 0.5 m, is likely to be just 1 to 3 mm/day for clayey soils[5]. For calculations here 1.3 mm/day is adopted. Tractors (2W) are used for plowing, harrowing and puddling and their widespread use enable land preparation to be done quite quickly. Land preparation is therefore usually limited by the amount of water available, or that can be pumped, for land soaking.

e. Nursery area

The area covered by the rice nurseries usually occupies 5-10% of the total cultivated area and are established 25-30 days before transplanting is planned.

Figure II-4: Land Preparation

Oil seed crop (left) and Rice Nursery (right)

Transplanted Rice Seedling

f. Cropping Calendar

The cropping calendar will vary from subproject to subproject, depending on land category, climatic and soil factors, as well as farmer preferences / crop prices.

In general transplanting starts in December/ January and is completed in February/ March.

Late planting (and transplanting) usually results in higher yields, but increases the risk of crop damage from pre-monsoon rains and flooding. Broadly the optimum date for transplanting is early January in the wet beel areas in the north-west of the country, and early-mid February in the drier north-east.

Late transplanting may however reduce water demand as pre-monsoon rains meet water requirements later in the season.

[5] Field studies in the Philippines have shown mean percolation rates to be 1.3 mm/d on alluvial soils with water table between 0.5 and 2 m, and 2.6 mm/day when the water table is deeper, (Kampen 1970)

For the crop water calculations here, transplanting over 6-7 weeks is assumed which attenuates the high water demand of land preparation. Also, the area transplanted in successive decimals is gradually reduced so that the water demands of transplanted areas can be met as well as the demands for land preparation. E*arly* and *late* transplantation schedules by 10 day decimals are tabulated below so the implications of late / early transplanting may be assessed.

Table II-3: Proposed Planting / Transplanting Schedules

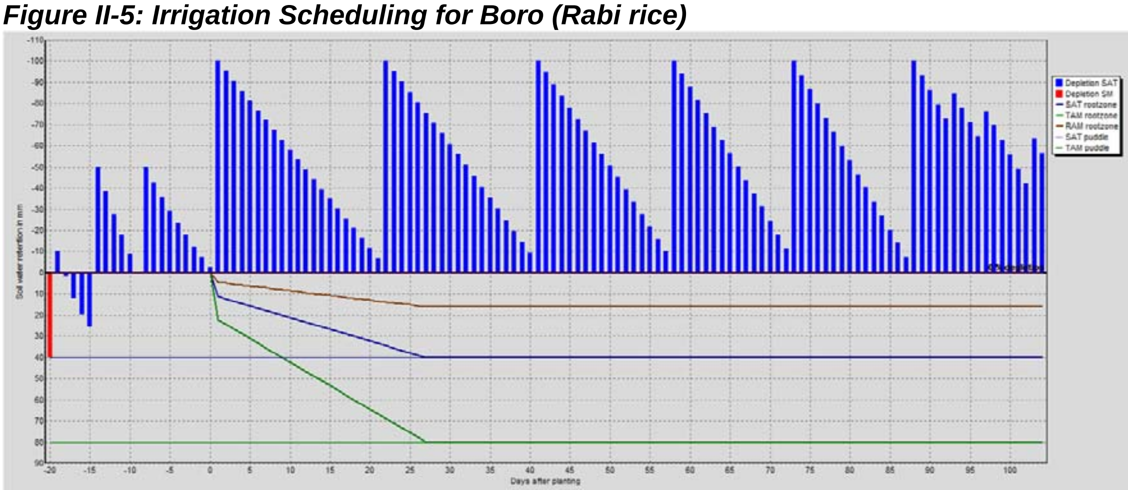
Decimal	Early Schedule		Late Schedule	
	Planting	Transplanting	Planting	Transplanting
December III	25%			
January I	20%	25%		
January II	20%	20%	25%	
January III	20%	20%	20%	25%
February I	15%	20%	20%	20%
February II		15%	20%	20%
February III			15%	20%
March I				15%

g. Irrigation Scheduling

Good on-farm water management with frequent irrigations increase yield. Experiments in the Philippines indicated that 4-8 day irrigations were appropriate, with yields dropping slightly when the irrigation interval was increased to 10 days[6].

Irrigation was scheduled to replenish ponded depths to 100 mm (max). This indicates that nine irrigations are required with an irrigation interval of 10-14 days, *Figure II-5*. Smaller more frequent irrigations may improve yields but should not require any more water.

Figure II-5: Irrigation Scheduling for Boro (Rabi rice)



[6] Principals and Practices of Rice Production, S K De Datta

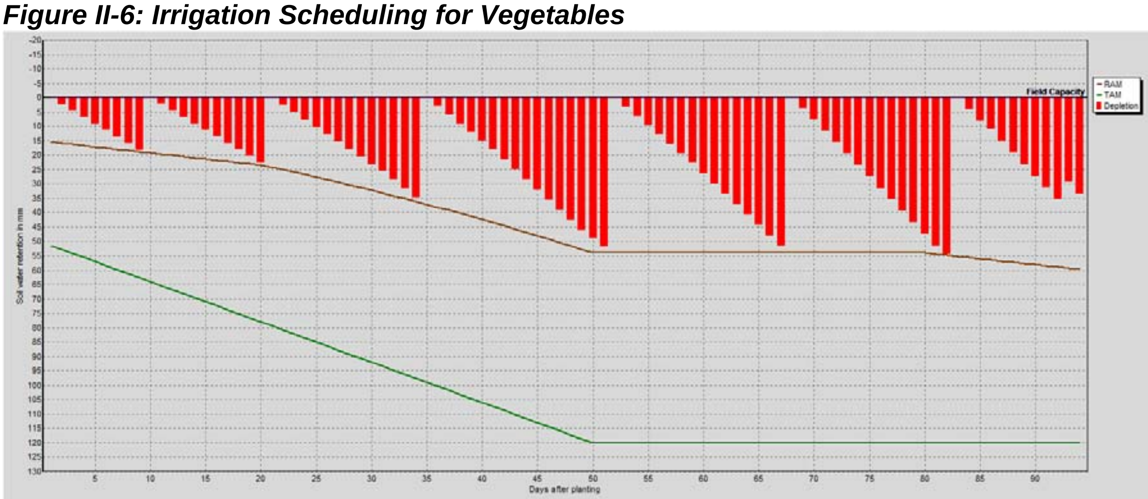
2. Vegetables and Pulses

For vegetables planting in early January is assumed with harvest in early April. Crop growth stages, crop coefficients and rooting depths are given in *Table II-4*. Irrigations were scheduled whenever readily available soil moisture is depleted (ie avoiding any loss in yield due to water stress). Typically (at least) 7 irrigations are required, *Figure II-6*.

Table II-4: Growth Stages, Crop Coefficients and Rooting Depths

	Growth Stage			
	Initial	**Development**	**Mid-season**	**Late-season**
Vegetables				
Length (days)	20	30	30	15
	90 days			
Kc	0.70	0.7-1.05	1.05	0.95
Rooting Depth (m)	0.25	0.25-0.6	0.60	0.60
Critical Depletion	0.30	0.30-0.45	0.45	0.50
Pulses				
Length (days)	20	30	40	20
	110 days			
Kc	0.40	0.4-1.15	1.15	0.35
Rooting Depth (m)	0.30	0.30-1.00	1.00	1.00
Critical Depletion	0.60	0.60	0.60	0.80

Figure II-6: Irrigation Scheduling for Vegetables



For pulses, planting in early January is assumed with harvest in mid/late April. Crop growth stages, crop coefficients and rooting depths are tabulated in *Table II-4*. Irrigations are scheduled to be when the readily available soil moisture is depleted (ie avoiding any loss in yield due to water stress). Typically (at least) 4 irrigations are required.

3. Rainfall Assumptions

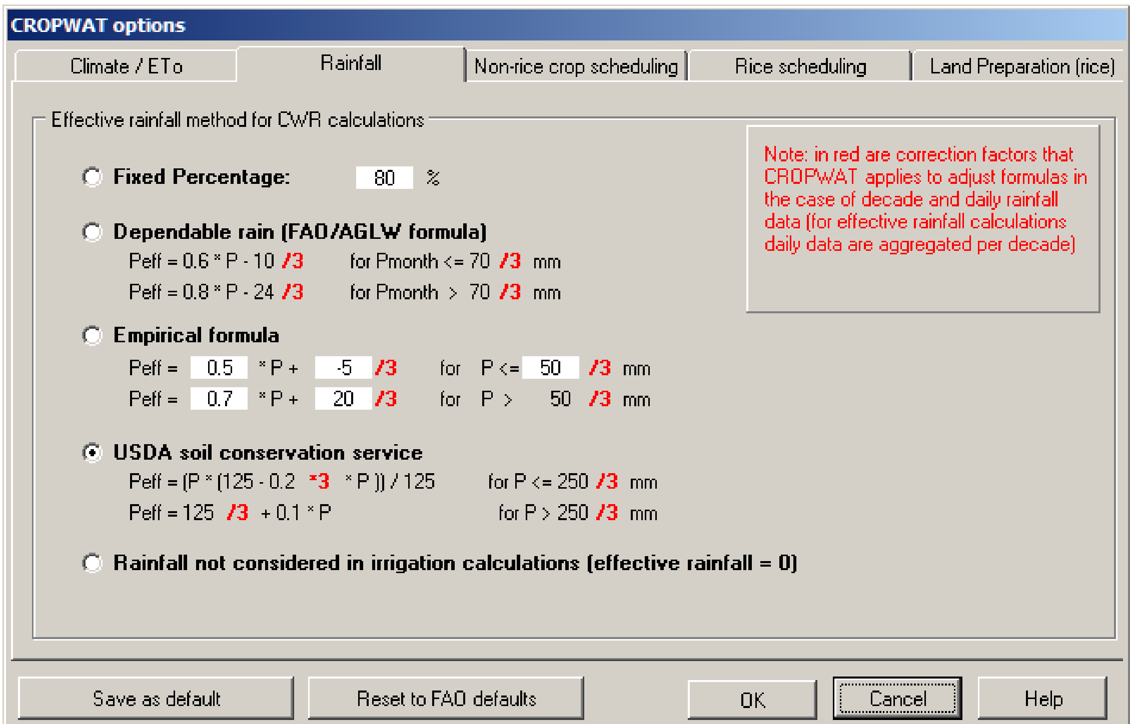
Usual convention for design of irrigation infrastructure is to use *dry* year data and this convention is adopted here, although it is recognised that it may be appropriate to use *average* rainfall data for the following reasons:

- Pumping costs based on the average crop water requirements should be used to determine scheme financial / economic viability; and
- For pipe systems additional flow capacity is easily provided by proving extra freeboard to the header tank and standpipes (air vents), and sizing of the pipelines

could arguable use average rainfall data to avoid over capacity and high construction costs.

Notwithstanding the above it should be noted that in the dry / lean season there is little rainfall and whether average or dry year rainfall is adopted is not too significant.

Effective rainfall is that which is received during the growing period of a crop and is available to help meet consumptive water requirements. It does not include rainfall that evaporates from the soil surface, runs off or percolates beyond the root zone. CROPWAT provides several options for calculating effective rainfall.



Lean season rainfall in Bangladesh arrives is often of short duration which reduce the rainfall effectiveness. The USDA SCS formula gives a lower proportion of effective rainfall than the FAO formula and is considered to be more appropriate.

C. Irrigation Efficiencies

1. Field Irrigation (Application) Efficiencies

Basin field irrigation efficiencies may be as high as 90%, are usually 50-80%, but may be as low as 30-40%, particularly for non-rice crops.

For rice, in addition to the deep percolation losses, there may be additional losses of water by basin runoff, lateral seepage to (drainage) channels (khals) or to field bunds and uneven deep percolation rates, often along small cracks that may develop due to drying of the soil, decay of roots or burrowing animals. These losses arise due to poor land preparation, soil variations and poor water management practices such as allowing very high ponded depths and runoff of water from rice basins.

Of these losses, lateral seepage to field bunds may be most significant and difficult to reduce unless puddling is done under the bunds which are then rebuilt – not a common practice among farmers due to additional labour required. Studies for seasonal water balance for Boro in Bangladesh[7] indicated the following:

- Irrigation supply: 1,200 – 1,350 mm
- Effective rainfall: 50 mm
- Evaportranspiration: 350 - 380 mm
- Deep percolation (vertical losses): 300-350 mm
- Lateral seepage and losses though bunds: 600 – 670 mm

These studies indicated that about half of water applied to puddle rice fields may be lost as lateral seepage to field bunds, and then percolation below these bunds though the soil matrix or cracks which are not sealed as puddling under the bunds is rarely done. The studies also noted that lateral seepage and bund losses vary hugely though the season, and are small whenever field ponded depths are small or the field surface dry, as well as being affected by field size – the smaller the field the greater the proportion of bund losses.

For dry-foot crops on-farm water management is more onerous than for rice, and over application leads to water loss below the root zone as well as runoff.

Application efficiencies will vary between subprojects but, for reasonably heavy soils, the following may be adopted in absence of other information: (i) 65% for rice; and (ii) 55% for dry-foot crops.

2. Conveyance Efficiencies

A conveyance efficiency of 80% is adopted to account for seepage and operational losses between the pipe outlets and farmers' fields. This assumes unlined open channel water distribution. If farmers adopt hose then losses would be reduced.

Within the buried pipe system losses would be small assuming joints are properly sealed - which may be assumed for uPVC pipes, and are generally ignored. However if concrete pipes are used with poor joint sealing arrangements, then an efficiency of 96% may be adopted within the buried pipe system from pumping point to outlet.

D. Irrigation Water Requirements for Selected Districts

Irrigation water requirements have been calculated for 13 districts for the following six cropping scenarios:

(i) 100% Rice: Early Planting (Dec to Feb)
(ii) 100% Rice: Late Planting (Jan to Feb)
(iii) 100% Vegetables
(iv) 100% Pulses
(v) 10% Vegetables, 10% Pulses & 80% Rice
(vi) 20% Vegetables, 20% Pulses & 60% Rice

Dry year data are adopted for calculation of effective rainfall, and heavy soils are assumed.

[7] Hydrology of a groundwater irrigated rice field in Bangladesh: seasonal and daily mechanisms of infiltration, Water Resources Research, Vol. 45, 2009

Irrigation water requirements are discussed below – monthly tabulated data are given for 13 districts in **Appendix B-2**.

1. Rice Cropping – early and late planting

Net and gross water requirements for 100% rice is summarised below for both early and late planting. The net requirements include for crop consumptive use, land preparation, deep percolation under the puddled part of the field and effective rainfall. The gross water requirements are the net requirements with efficiencies of 65% and 80% allowing for losses in the field (lateral seepage and deep percolation), and for conveyance of water from source to crop respectively. The gross requirements represent the volume of water to be pumped from the source (khal/ river/ etc).

Calculated crop water monthly requirements show considerable variation – for example monthly requirement for (early) rice are: Dec – 103 mm, Jan – 171 mm, Feb 73 mm, Mar - 45 mm. The irrigation system may be designed to meet the peak demand over a single month, or over a longer period up to about 3 months, particularly where there is considerable variation in land category and therefore attenuation in demand.

Adopting a longer 3-month period significantly reduces design duty, typically by about a factor of about 0.8, and therefore system costs. It is therefore recommended that buried pipes are sized using the *average* (3-month) duty, but that sufficient freeboard is provided to structures (header tank and standpipes) and enough pumps to meet a *peak* demand about 25% higher than this. This allows for the peak 1-month water demand to be met or load shedding to be accommodated where electric pumps are adopted.

Calculated boro water requirements (early planting) are lowest in the northeast of the country, in Sylhet, at 383 mm (net), 737 mm (gross), and increase to 673 mm (net), 1,294 mm (gross) in the west in Rajshahi. Requirements are also high in Cox's Bazar, largely due to higher wind speeds and sunshine hours. The calculated requirements were surprisingly low in Madaripur and Noahkhali / Maijdee and inspection of data indicates this is due to higher humidity, lower wind speeds and fewer sunshine hours in these two districts[8].

The 3-month average demand varies from 0.74-0.78 l/s/ha in Madaripur to 1.05-1.14 l/s/ha in Cox's Bazar. Duties for selection of pumping equipment and adoption of freeboard to associated structures should meet peak (1-month) demand and be 20-25% higher than this.

The areal variation for gross irrigation demand for boro is shown on *Figure II-7*.

[8] No (site) investigation has been done to check the accuracy of climatic data records – it may be that poor sites for these climatic stations is under reporting wind speeds / sunshine hours.

Figure II-7: Gross Irrigation Requirements for Boro Rice (early planting)

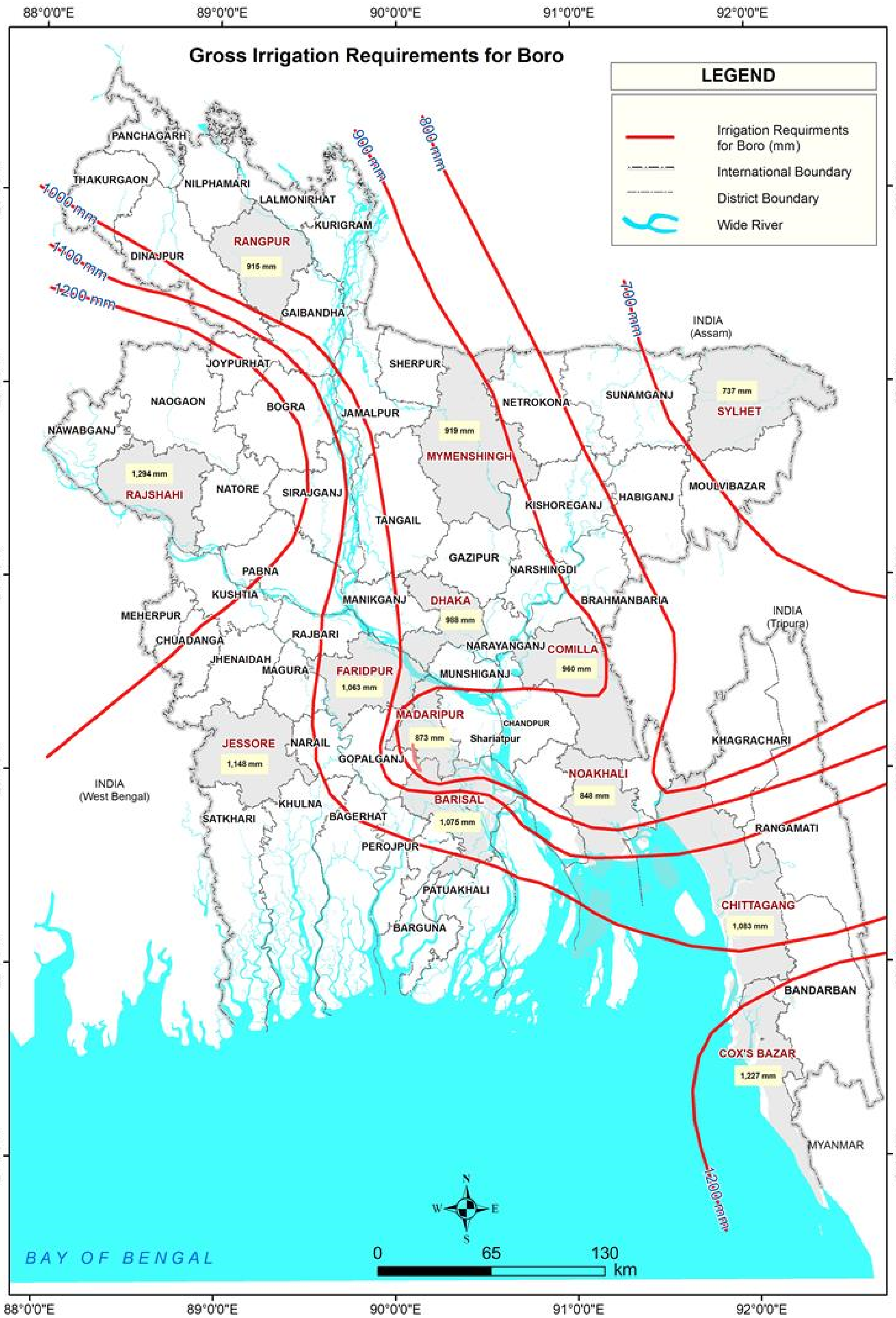
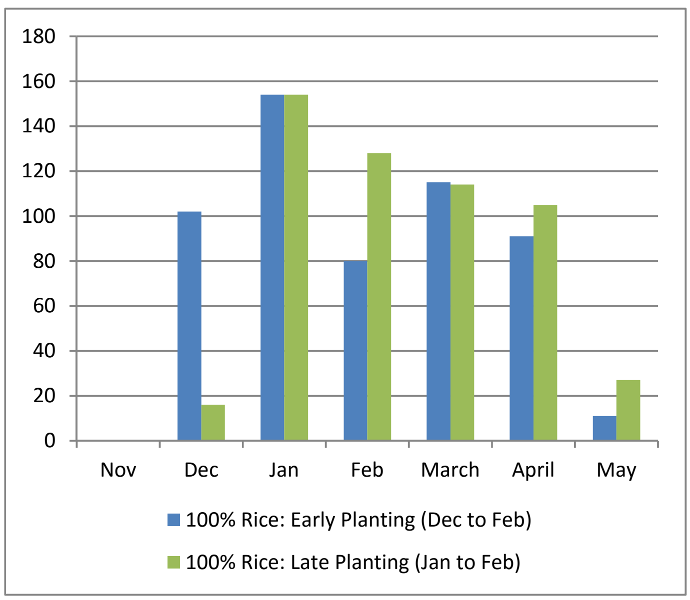


Table II-5: Irrigation Requirements for Boro

	District	Boro – Early Planting				Boro – Late Planting			
		Net	Gross	Design Duty (3-month)		Net	Gross	Design Duty (3 month)	
		mm	mm	mm/d	l/s/ha	mm	mm/d	mm/d	l/s/ha
1	Sylhet	383	737	7.2	0.83	339	652	6.9	0.80
2	Noakhali-Maijdee	441	848	6.9	0.79	379	729	6.6	0.77
3	Madaripur	454	873	6.4	0.74	407	783	6.8	0.78
4	Rangpur	476	915	6.6	0.76	464	892	7.5	0.87
5	Mymensingh	478	919	7.1	0.82	452	869	7.8	0.90
6	Comilla	499	960	7.3	0.84	462	888	8.1	0.93
7	Dhaka	514	988	7.4	0.85	513	987	8.4	0.97
8	Faridpur	553	1,063	7.5	0.86	544	1,046	8.5	0.98
9	Barisal	559	1,075	7.8	0.90	520	1,000	8.5	0.98
10	Chittagong	563	1,083	8.1	0.94	552	1,004	8.7	1.00
11	Jessore	597	1,148	7.7	0.89	620	1,192	9.2	1.06
12	Cox's Bazar	638	1,227	9.0	1.05	588	1,131	9.9	1.14
13	Rajshahi	673	1,294	8.2	0.94	683	1,313	9.4	1.09

Note: System design to accommodate 20-25% higher duties to meet peak (1-month) water demand / load shedding



For the adopted planting schedules, the variation in monthly net demand (ie field requirement) may show two peaks – the first peak is associated with land preparation / puddling, while the second is associated with peak crop evapotranspiration. Monthly net duties on the chart are for Faridpur District – the peak *net* water requirement is 154 mm in January.

The *gross* irrigation requirement, adopting conveyance and application efficiencies of 80% and 65% respectively, is 296 mm in January (9.6 mm/d, 1.1 l/s/ha).

The average 3-month gross requirement is 7.5 – 8.5 mm/d (0.87 – 0.98 l/s/ha) for early and late planting respectively, Table II-5.

The ratio between peak (1-month) and average (3-month) demand for boro rice is about 0.8 - 0.83.

2. Non-rice cropping

Water requirements are tabulated below for vegetables and pulses grown in lean season, and are typically slightly less than half the requirement for boro rice.

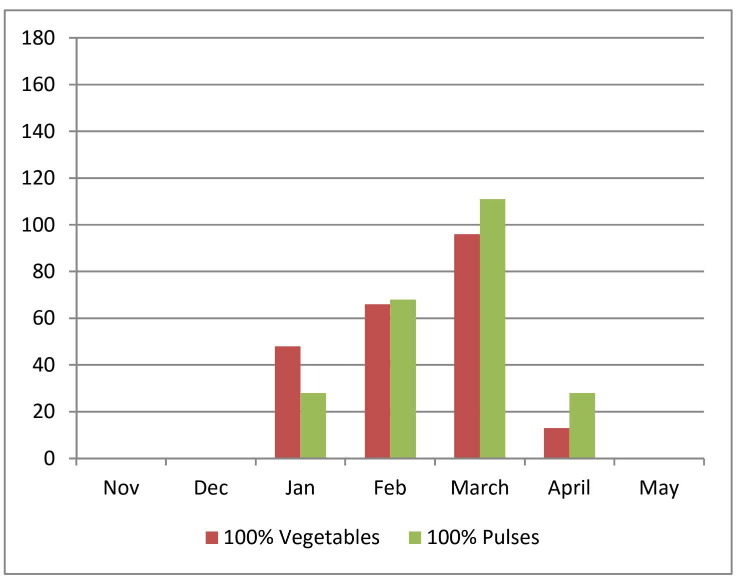
For vegetables, gross irrigation demand varies from 307 mm in Sylhet to 639 mm in Cox's Bazar. For pulses demand is similar.

Table II-6: Irrigation Requirements for Vegetables and Pulses

	District	Vegetables				Pulses			
		Net	Gross	Design Duty (3-month)		Net	Gross	Design Duty (3 month)	
		mm	mm	mm/d	l/s/ha	mm	mm/d	mm/d	l/s/ha
1	Sylhet	135	307	3.4	0.39	129	293	3.3	0.38
2	Noakhali-Maijdee	160	364	3.9	0.45	160	364	3.8	0.44
3	Madaripur	183	416	4.4	0.51	188	427	4.3	0.50
4	Rangpur	214	486	5.1	0.59	223	507	5.1	0.58
5	Mymensingh	214	486	5.2	0.60	219	498	5.1	0.59
6	Comilla	201	457	4.9	0.56	205	466	4.8	0.56
7	Dhaka	215	489	5.2	0.60	221	502	5.1	0.59
8	Faridpur	223	507	5.3	0.61	235	534	5.2	0.61
9	Barisal	219	498	5.2	0.61	225	511	5.1	0.58
10	Chittagong	222	505	5.4	0.62	226	514	5.3	0.61
11	Jessore	246	559	5.7	0.66	279	634	5.7	0.66
12	Cox's Bazar	281	639	6.8	0.78	283	643	6.5	0.75
13	Rajshahi	264	600	6.1	0.71	302	686	6.9	0.80

Note: System design to accommodate 20% higher duties to meet peak (1-month) water demand / load shedding

Adopting Faridpur district climatic data the monthly net demand of vegetables and pulses planted in January are shown on the adjacent chart. There is no land preparation / puddling requirement and irrigation demand increases with the stage of growth, peaking in March at about 100 mm.



The *gross* irrigation requirement, adopting conveyance and application efficiencies of 80% and 55% respectively, is 227 mm in March (7.3 mm/d, 0.84 l/s/ha). The average 3-month gross requirement is about 5.3 mm/d (0.61 l/s/ha).

In general the ratio between peak (1-month) and average (3-month) demand for vegetables and pulses is about 0.7.

3. Mix of rice and Non-rice cropping

A mix of rice and non-rice crops significantly reduces and attenuates irrigation demand, as shown below for a mix of: (i) 10% vegetables, 10% pulses and 80% boro rice (planted late); and (ii) 20% vegetables, 20% pulses and 60% boro rice (planted late).

For example, a gross requirement for 100% boro cropping of about 1,050 mm (Faridpur district data) reduces to about 950 mm and 860 mm respectively.

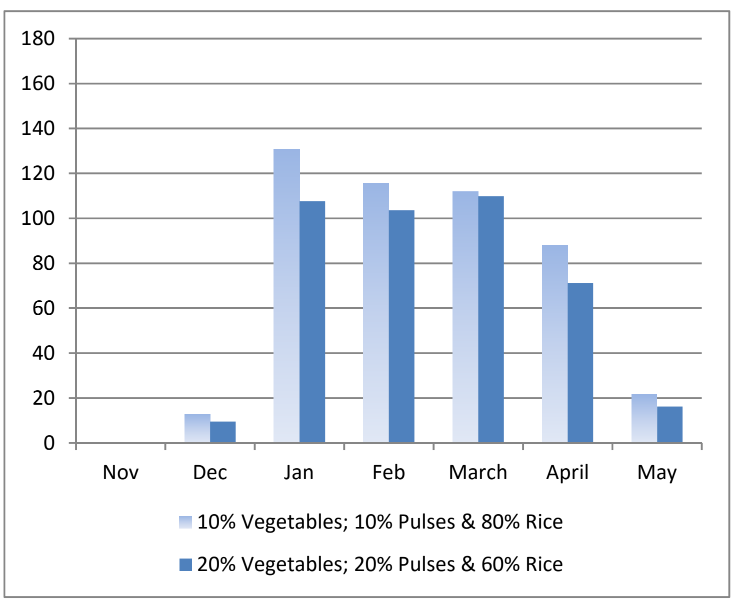
Table II-7: Irrigation Requirements for Mix of Rice and Non-rice Crops

	District	10% Vegetables, 10% Pulses & 80% Boro				20% Vegetables, 20% Pulses & 60% Boro			
		Net	Gross	Design Duty (3-month)		Net	Gross	Design Duty (3 month)	
		mm	mm	mm/d	l/s/ha	mm	mm/d	mm/d	l/s/ha
1	Sylhet	298	590	6.3	0.72	256	525	5.6	0.65
2	Noakhali-Maijdee	335	665	6.2	0.71	291	597	5.6	0.65
3	Madaripur	363	720	6.3	0.73	318	652	5.9	0.68
4	Rangpur	415	823	7.1	0.82	366	750	6.6	0.77
5	Mymensingh	405	803	7.3	0.85	358	733	6.8	0.79
6	Comilla	410	814	7.5	0.87	358	734	6.9	0.80
7	Dhaka	454	901	7.8	0.90	395	809	7.2	0.83
8	Faridpur	481	954	7.9	0.91	418	857	7.3	0.85
9	Barisal	460	913	7.9	0.91	401	821	7.2	0.84
10	Chittagong	462	917	8.1	0.94	403	825	7.5	0.86
11	Jessore	549	1,088	8.6	0.99	477	977	8.0	0.92
12	Cox's Bazar	527	1,045	9.3	1.08	466	954	8.7	1.01
13	Rajshahi	603	1,196	8.9	1.03	423	1,072	8.3	0.96

Note: System design to accommodate 20-25% higher duties to meet peak (1-month) water demand / load shedding

Significantly the peak demand also reduces as a mix of crop generally spreads irrigation demand more equally over several months. This is illustrated in the adjacent chart based on data for Faridpur district where monthly net irrigation requirements are sustained at about 105 - 130 mm from January to March.

The *gross* peak irrigation requirement, adopting efficiencies of 80% for conveyance and 55% (non-rice) and 65% (rice) for application is about 230 – 280 mm.



E. Design Duty for Subprojects

In determining the design duty to size a specific CAD subproject the following needs consideration:

i. Cropping pattern and intensity.
ii. Soil type, land preparation requirements including deep percolation and initial moisture condition.
iii. Application and conveyance efficiencies.
iv. Pumping hours / load shedding for electric power pumps.

The feasibility report for the subproject may provide some of the required data which may be supplemented by site visits. However the designer needs to be aware that cropping patterns may change over the design life of the subproject influenced by external factors such as crop profitability, marketing conditions and farmer preferences. Similarly there may be an improvement (or deterioration) in electric power supply.

Continuous pumping of water may be assumed provided that standby (diesel) pumps are provided to accommodate any load shedding. While farmers may not like irrigating at night it is assumed they will if they need the water. Also for rice grown in ponded basins irrigation is not difficult and stream flows may often be left unattended.

It is also advised that the trade off between operation or pumping cost and capital construction cost be considered. Whole life cost optimisation requires that both capital and pumping costs are considered for various pipe sizes – pumping head options. In practice this means a design resulting in a relatively low (2-4 m) water pressure in the header tank for most of the lean season, but with a higher pressure (5-7 m) acceptable for 3-6 weeks. This is discussed in Chapter 0.

As an example, a fairly typical subproject could adopt the following design parameters:

- Mixed cropping with 80% rice and 20% non-rice crops;
- Application efficiencies of 65% for rice and 55% for non-rice;
- 80% conveyance efficiency between the field and outlet from the buried pipe system (the small operational losses within the buried pipe system are ignored);
- Adoption of a *usual* (3-month average) duty to size the pipeline; and
- Adoption of *peak* (1 month) duty to determine the height of the header tank and standpipes.

For such a subproject in Faridpur district, the *usual* gross irrigation requirement or duty would be 7.9 mm/d (0.91 l/s/ha), while the *peak* duty would be 9.1 mm/d (1.05 l/s/ha). The total volume of water to be pumped would be 954 mm. The *usual* flow would be maintained for about 3 months.

SECTION-3: PIPE SYSTEM

I. Pipe System Options, Layout and Cost Effective Design

A. Pipe System Options

1. Introduction

Low-pressure (up to about 6 m operating head) pipeline conveyance systems enable delivery of irrigation water to farmers for surface application with minimal land-take, reduced water losses compared to open channel systems, and (depending on the control systems adopted) with increased flexibility of supply to meet a range of crop water demands. The pipe system supplies outlets (risers) which are spread equitably over the full command area, delivering water to irrigator groups for surface conveyance and application.

For the CAD subprojects developed by LGED the net irrigation command area typically varies from about 300-800 ha (with an upper limit of 1,000 ha), and the irrigator group areas from about 40-80 ha.

Options for the conveyance pipeline system require making choices for the following: (i) upstream versus downstream control; and (ii) choice of pipe types.

2. Upstream versus Downstream Control Systems

The characteristics and advantages / disadvantages of upstream and downstream control systems are tabulated below.

Table I-1: Upstream Versus Downstream Conveyance Systems

Option	Characteristic	Advantages / Disadvantages
Upstream Control (open pipeline system)	Water is released from a header tank into the pipeline system. Operating pressures within the pipeline are controlled by open standpipes located at the end of each reach, and often just upstream of each outlet (riser). If the outlets are closed water rises in the standpipes and if supply is not reduced overspills. When irrigation ceases the pipeline would usually drains empty.	Simple system to build but: (i) the standpipes are vulnerable to overtopping and possible damage; and (ii) good operation requires monitoring of irrigation demand and standpipe water levels to adjust the number of pumps operating.
Downstream Control (semi-closed or closed pipeline) system	In a downstream control system standpipes are replaced with pressure reducing valves so that when there is no irrigation demand pressure in the pipeline builds to the design static water level (SWL) and flow ceases. There is no spillage from the system and the operator turns on/off the pumps according to the water level in the header (discharge) tank. If required a water sensor (eg mercury float switch) can be used to turn the pumps on/off.	Usually a slightly more expensive system to build and with slightly higher pressures than for an upstream control system. However downstream control is beginning to find favour as a means of flexible water delivery (water is available at each outlet instantaneously) and for ease of operation which leads to increased efficiency of water use. These advantages are particularly felt if a range of different dry-foot crops are cultivated in the dry season. If mono-cropping of paddy rice is proposed then the advantage is minimal.

Initial LGED practice was to design pipeline conveyance systems for upstream control with open standpipes located just upstream of each outlet (riser). There are usually no other flow control or measurement structures. Costs were therefore minimized, but operational challenges were considerable. Pump houses and pumps were not provided and farmers were expected to source these themselves. CAD investments tended to be regarded as high risk as some subprojects such as Daripiapur, Chapai Nawabganj showing spectacular success while others have failed.

Improved designs were initiated from 2011, retaining upstream control but with improved layouts for rational operation and incorporating structures to control flows to each pipeline, as well as washout and escape structures.

3. Conveyance Pipes and Costs

a. Conveyance Pipe Characteristics

LGED practice prior to 2011 was to use precast concrete pipes with joints sealed by: (i) filling gaps with hessian cloth soaked with bitumen; and (ii) placement of a mortar / concrete surround. This remains the lowest cost option, particularly for larger pipes (> 300 mm).

Concrete pipes with spigot and socket joints can provide reasonable water tight joints for pressures up to about 6 m, particularly if rubber gaskets are used. However rubber gaskets are not currently used with concrete pipes and maintenance efforts to reseal leaking pipes is a recurring problem.

An alternative option is to use uPVC (and / or HDPE) pipes available for pipe diameters up to 600 mm. This is more expensive than concrete but would enable downstream control if this was desired, as well as addressing the joint leakage problem. uPVC pipes are manufactured in Bangladesh. GRP pipes are also a possibility but would have to be imported / are expensive.

For low-pressure pipe systems (less than 6 m head) with open water surface risers / outlets “water hammer” will not be an issue. Nonetheless flow velocities in uPVC pipes are limited to 1.7 m/s[9]. For concrete pipes flow velocities of about 2.4 m/s are allowed, though such high velocities may acerbate damage to, and leakage of, joints.

Table I-2: Conveyance Pipe Characteristics

Nr	Material	Typical Diameters (mm)	Jointing	Nominal Working Pressure, PN (bar)	Average Life (years)	Suggested Use
1	Rigid uPVC (6 m lengths)	50 to 600 mm	Solvent (small pipes); and spigot & socket (large)	4, 6, 10 & 16 bars (but any pressure can be specified)	50 years buried with proper trenching / bedding	Ideal for irrigation water conveyance for smaller pipes. Maximum flow velocity, 1.5 m/s
2	Precast spun concrete	300-900 mm	Rubber gaskets, mastic fill, filter fabric, mortar / concrete, external bands	Usually Low pressure	50 years buried with proper trenching / bedding	Free water surface flow or low pressure pipelines
3	GRP	300 to 2,000 mm	Couplings with elastometric seals	10 & 16 bar (other pressure classes possible)	50 years buried with proper trenching / bedding	Irrigation water conveyance where larger diameters are required. Careful handing necessary to avoid damage.

[9] FAO Handbook for pressurized irrigation techniques, 2007

b. Pipe Sizes and Wall Thicknesses

The base material from which the uPVC pipes are produced shall be un-plasticised Polyvinyl Chloride (uPVC) with additives as necessary for manufacture in accordance with ISO 4065: 1996(E).

All fittings having sockets shall comply with ISO 727-1985 and shall be compatible with the pipes supplied.

Pipes with a nominal pressure of 3.25 bar (32 m head) are to be used. Thinner wall pipes are difficult to produce, particularly for larger sizes, as they tend to deform.

Adopting a design norm for working (static) pressure of 70% gives a pressure rating of about 22 m, leaving 30% (10 m) for surge pressures (refer ASAE S261.7, 1989).

Wall thicknesses of uPVC pipes and pipe fittings shall be commensurate with the adopted pressure rating and determined in accordance with ISO 4065: 1996(E), having a SDR value of 81 (equivalent to PN 3.25).

For the recommended 3.25 bar (32 m head) pipe diameters and wall thickness are tabulated below for the range of pipes sizes likely to be used.

Table I-3: uPVC Pipes Diameters and Wall Thicknesses

Nr	External Diameter (mm)	Nominal Wall thickness (mm)	Internal Diameter (mm)	Length (m)
1	160	2.00	156	6.00
2	180	2.30	175	6.00
3	200	2.50	195	6.00
4	225	2.80	219	6.00
5	250	3.10	244	6.00
6	280	3.50	273	6.00
7	315	4.00	307	6.00
8	355	4.40	346	6.00
9	400	5.00	390	6.00
10	450	5.60	439	6.00
11	500	6.20	488	6.00
12	560	7.00	546	6.00

There are a number of manufacturers and suppliers of PVC pipe in Bangladesh including:

- Rangpur Foundry Limited (rfl@prangroup.com)
- Aziz pipes (info@azizpipes.com)
- PCL plastics (pclplasticsbd@yahoo.com)

c. Comparison between PVC and Concrete Pipe Costs

LGED 2011 rates for uPVC (3.25 bar pressure, 32 m head) pipes of various diameters are tabulated below and include for transport to site, placement in trench and jointing.

LGED 2011 rates for concrete pipes are also given. The "*fitted and fixed*" rates are the schedule rate increased by 10% for the reinforced concrete plinths which are to be placed under the pipes to prevent settlement and joint failure.

PVC pipes are available for a variety of sizes from 225 mm to 560 mm (outside diameter). Concrete pipes are usually *spun* for pipes from 300 to 550 mm (internal diameter), and cast using steel forms for diameters from 600 to 900 mm or even larger.

For 300 mm diameter pipes, uPVC is comparable in cost to a concrete alternative, about Tk 1,900 / m. For larger diameters concrete pipes are considerably cheaper, being half the cost of uPVC pipes for diameters of about 550 mm (Tk 3,075 /m compared to Tk 6,200 /m).

While the lower friction losses and greater range of available diameters of PVC pipes means that often a slightly smaller pipe can be used than its concrete alternative, designers should avoid using PVC pipes larger than (say) 500 mm. Also twinning of PVC pipes should be avoided as this would be very expensive. For large flows concrete pipes should be adopted.

Table I-4: Comparison between PVC & Concrete Pipe Costs (2011 rates)

PVC Pipe (3.25 bar)				Concrete Pipe			
External Diameter (mm)	**Pipe Wall Thickness (mm)**	**Internal Diameter (mm)**	**LGED Rate*1 (Tk/ m)**	**Internal Diameter & thickness (mm)**	**2011 Schedule of Rates**	**Fitted & Fixed Rate*2 (Tk/m)**	**%**
225	2.80	219	1,130				
250	3.10	244	1,184				
280	3.50	273	1,487				
315	4.00	307	1.900	300 x 50	1,719	1,891	0%
355	4.40	346	2,370	350 x 50	1,780	2,136	90%
400	5.00	390	3,016	400 x 50	2,044	2,248	75%
450	5.60	439	3.780	450 x 50	2,144	2,358	62%
500	6.20	488	4,667	500 x 50	2,185	2,404	52%
560	7.00	546	(6,200)	550 x 75	2,795	3,075	50%
				600 x 75	2,958	3,254	
				650 x 75	3,005	3,306	
				700 x 75	3,345	3,680	
				750 x 100	3,656	4,022	
				800 x 100	4,662	5,128	
				850 x 100	4,880	5,368	
				900 x 100	4,606	5,067	

‘1. PVC pipe fitted & fixed 2011 LGED rate includes for transport, placement & jointing
‘2. Concrete pipe fitted & fixed rate is taken from 2011 schedule of rates but increased by 10% for cost of RCC plinth bedding under pipe joints

d. Use of uPVC pipes in CAD Subprojects

The adoption of uPVC pipes for CAD subprojects has the following advantages:

i. Lengthy on-site manufacture of pipes is avoided – this often takes a year or longer.
ii. Quality control is easier and problems arising from poorly cast / spun pipes avoided.
iii. PVC pipes are light and handling, placement and jointing is both easier and quicker than for concrete pipes.
iv. With PVC pipes leaking joints are rare.

The main disadvantage is the higher cost. Prior to the manufacture of larger size uPVC pipes in Bangladesh the cost difference was prohibitive. This is no longer the case for smaller pipes, though larger diameter uPVC pipes are relatively expensive.

To avoid very high pipeline costs it is recommended that LGED CAD pipe irrigation systems adopt a mix of PVC pipes with diameters ranging from 225 to 500 mm and concrete pipes for diameters from 550 to 900 mm.

Figure I-1: Photographs of uPVC Pipe and T-fitting

uPVC pipe and T-fitting

B. Pipeline Layout

1. Introduction

The pipe system layout must provide complete and equitable coverage to the whole command area.

The first challenge is to identify the command area for the subproject. Prior to detailed survey this is best done using freely available *google earth* imagery. This allows the planner to identify:

i. Physical features (settlements, fields, roads, bunds, rivers, khals, wet land, etc).
ii. Drainage alignments / hydraulic boundaries, rotation units and a viable command area for the subproject.
iii. The best alignments for the pipelines and possible locations for irrigation outlets and for the header tank. Note: *google earth* imagery gives spot heights to the nearest meter.

2. Guidelines for Layout Preparation

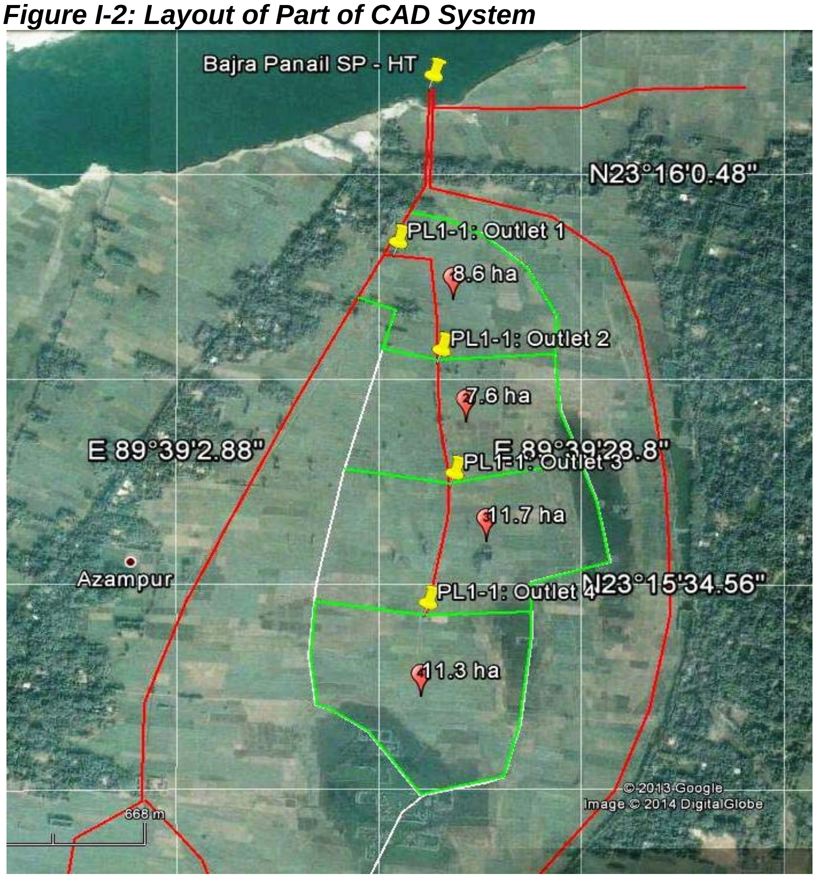
The process and guidelines for delineating the pipe system layout is as follows. As noted above this should be done using *google-earth, or a GIS program.* For those unfamiliar with these programs imagery may be printed out, joined and the layout done on a paper copy:

- Block out any land not to be commanded (eg village areas, permanent swamps – low land).
- Delineate natural drainage lines.
- Delineate physical features which affect the layout (eg roads, bunds, railway tracks);
- Finalise and delineate the subproject boundary and command area.

- Divide up the command area into roughly equal **rotation hydraulic units** each commanding about 80-130 ha. There should generally be a minimum of 2-3 rotation units in the subproject and as many as about six;
- Consider whether the subproject can efficiently be commanded from a single header tank – or whether the area should be divided up into two schemes each with its own header tank to reduce pipeline lengths and costs.
- Ensure complete coverage of the command area so that all beneficiaries have equitable access to water. As a rule of thumb no part of the irrigable area should be more than 200-400 m from a riser (outlet).
- Each rotation hydraulic unit should be supplied by a separate pipeline. The main – larger diameter pipelines should be as short as possible, and may be aligned up / down slopes. Branch spur lines should lead from each main pipeline so that there is a riser located at all high spots.
- Adopt the number of riser outlets so that each outlet commands a 10-15 ha **irrigator unit**. From each the outlet flow will be distributed by open channel / hose procured by farmers.
- Flow from the main or primary header tank to any secondary flow control tank would usually be through a (closed) pipeline without risers (outlets). The closed pipeline should be aligned along the most direct route to minimise costs.
- Consider the danger posed by pipeline floatation if a pipeline is aligned across low lying areas that may flood deeply in the monsoon months. If necessary the pipeline should be set lower in the ground with more than 1.0 m of cover and / or encased with concrete.

Examples of good layouts of constructed CAD subprojects are included as **Appendix C.**

Figure I-2: Layout of Part of CAD System



The figure shows four outlets located along branch pipeline PL1-1. Each outlet is located to supply an area of about 10 ha, and are located about 230 m apart

C. Costs of CAD Subprojects and Cost Effective Design

1. Costs of CAD Subprojects

Capital costs of CAD subprojects are typically about BDT 60-100,000 / ha (US$ 750-1,250/ha (2014 rates), and the uPVC pipes themselves typically comprises about 60-65% of the investment. The costs of major components of a CAD subproject are illustrated below for SP 33097 Mongalpur. This scheme has a net irrigable area of 313 ha, and its total as-built cost was BDT 28.04 million, US$ 350,525 (US$ US$ 1,120 / ha) at 2014 prices. The uPVC pipes made up 63.1% of the total cost.

Table I-5: Cost Breakdown for SP 33097, Mongalpur

Component	Cost BDT	%	US$	US$/ha
Header tank, 6.1 x 3.25	2,771,085	9.9%	34,639	111
Flow control structure (1 nr)	817,289	2.9%	10,216	33
Buried pipe system				
- uPVC pipes	17,702,503	63.1%	221,281	707
- uPVC pipe fittings	580,824	2.1%	7,260	23
- trench earthworks	1,966,253	7.0%	24,578	79
- sand bedding	667,847	2.4%	8,348	27
Standard structures	2,956,241	10.5%	36,953	118
Sub-total	**23,873,669**	**85.1%**	**298,421**	**953**
Pump house incl. steel pipes & pumps				
Pump house, 4.3 x 4.8	250,929	0.9%	3,137	10
Pump house accessories	83,203	0.3%	1,040	3
Pumps (2 provided)	225,331	0.8%	2,817	9
Sub-total	**559,463**	**2.0%**	**6,993**	**22**
Misc	20,500	0.1%	256	1
Total	**28,042,006**	**100.0%**	**350,525**	**1,120**

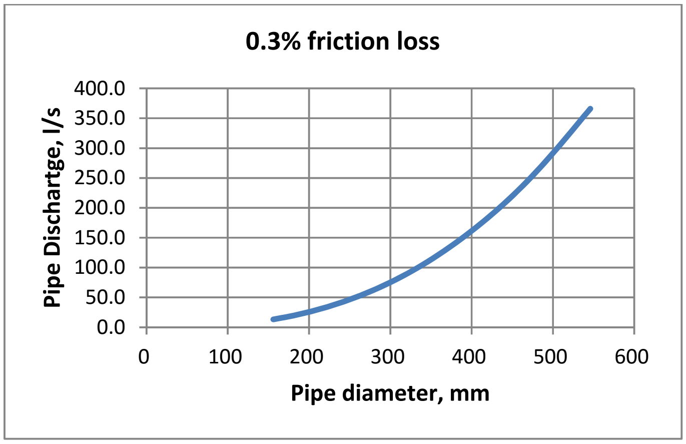
2. Cost Effective Design

Cost effective engineering design does not necessarily mean that construction costs should be low. Rather it requires that money be spent on engineering infrastructure which will enable the expected agricultural benefits to be obtained with minimal risk and for the lowest full-life (construction and operation) costs. In practice this requires:

- A buried pipe system layout which can provide water to the whole scheme area – not just part of it – and ensure a similar standard of service to all farmer beneficiaries.
- Quality infrastructure which will perform reliably / as expected – for example adoption of uPVC buried pipes instead of concrete pipes to address joint leaking / quality issues.
- Control structures which will facilitate water distribution by farmers – flow control should be provided at the head of each rotation and irrigator unit.
- Consideration of both capital (construction) costs as well as operating / pumping costs by consideration of various pipe sizes – pumping head options.
- Minimizing pumping costs through careful selection of suitable pumps that operate efficiently for the usual pumping heads.

Larger pipes (400 - 500 mm) are 5-7 times more expensive than the smaller pipes (160 – 200 mm) but of course carry higher flows. This is illustrated below for a pipe friction loss of 0.3%. In terms of pipe capacity / cost, the larger pipes are more cost effective.

Figure I-3: Pipe diameter and flow



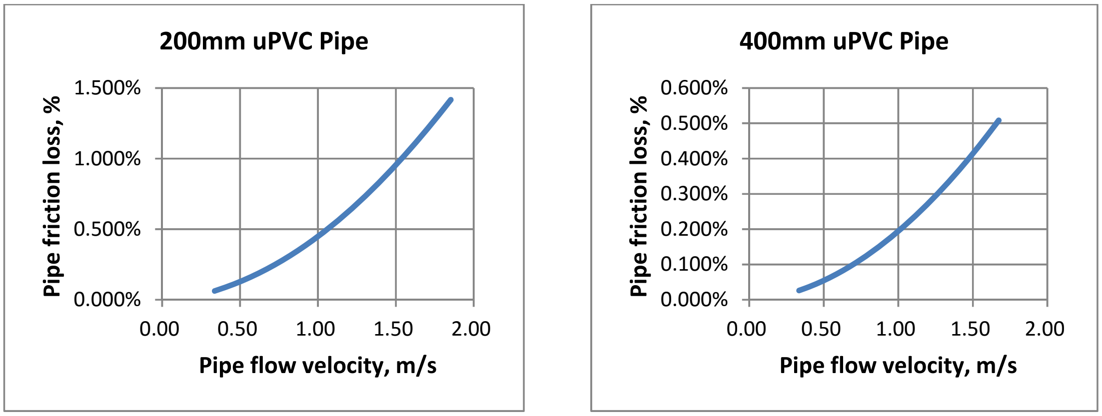
For the same friction loss, 0.3%, pipe flow varies from 24 l/s for a 195 mm (200 mm OD) pipe, to 273 l/s for a 488 mm (500 mm OD) pipe, an increase of about 11.

The ratio of unit costs for these pipes is about 6, (BDT 5,700 / BDT 971)

Note: Calculated using Colebrook - White formula with ks = 0.03 mm

Capital costs are reduced if higher flow velocities, 1.2-1.7 m/s can be adopted. Head losses in pipes (and pipe fittings) are particularly sensitive to pipe flow velocity, see Figure I-4. For a 400 mm uPVC pipe the friction loss is 0.05% for 0.5 m/s flow, but increases to 0.4% for 1.5 m/s flow. Similarly for a 200 mm uPVC pipe the friction loss is 0.12% for 0.5 m/s flow, but increases to 0.96% for 1.5 m/s flow.

Figure I-4: Pipe flows and friction loss for different pipe sizes



Note: Calculated using Colebrook - White formula with ks = 0.03 mm

Adoption of high flow velocities increases pumping head and annual pumping costs, and therefore may result in higher whole life costs. This is illustrated for a typical scheme in the table below, where adopting moderate (0.7-1.0 m/s) pipe flows gave the lowest whole life costs over 25 years.

Table I-6: Whole Life Costs over 25 years

		CAD subproject with:		
		Higher pipe flows	**Modest pipe flows**	**Lower pipe flows**
Capital cost	US$ / ha	600	850	1,300
Pumping cost	US$ / ha	70	47	30
Whole life cost (not discounted)	US$ / ha	2,350	2,025	2,050
Whole life cost (discounted at 4%)	US$ / ha	1,694	1,584	1,769

Recommended measures to reduce whole life costs include:

- Adopting the most direct alignment for the expensive main (large diameter) pipelines, even if this means that many branch spurs are required to convey water to high points in the command area.
- Limiting the length of the main pipelines – conveying water more than about 2.5 km is not practical for LGED buried pipe systems. If necessary the command boundary and area should be limited / reduced.
- Avoiding twinning of pipelines – always adopt a single pipe of suitable diameter. For particularly large flows it may be necessary to adopt a concrete pipe.
- Adopting pipe diameters to give moderate pipe flow velocities of 0.7-0.8 m/s and pumping pressures of 3-5 m for the *usual* (3-month average) discharges. This usually gives the lowest total (capital and pumping) cost over 20-25 years. To enable the system to meet *peak* (1-month) discharge the header tank will have to be sufficiently high to accommodate higher (5-8 m) pressures.

II. Pipeline Design

A. Design Process and Steps

The design of a CAD subproject is facilitated by breaking the design up into a number of steps each of which is done in correct sequence. The design steps are listed below:

i. Layout: fix the boundary of the subproject and alignment of the pipelines. Divide the command area into roughly equal sized hydraulic (rotation) units 80-120 ha in size.
ii. Obtain stakeholder approval to the layout and complete any necessary (additional) topographic survey – eg header tank and other structure surveys and long section surveys along pipeline routes.
iii. Fix the location of (any) flow control / measurement structures in addition to the header tank.
iv. Decide on the number and location of each outlet riser. Note: each outlet is to command 5-15 ha irrigator units and to be spaced at 200-500 m intervals along the pipeline.
v. Adopt the design duties to design the system. The u*sual* (3-month) duty may be used to size and optimise the pipe distribution system, while the *peak* (1-month) duty will be used to determine the height of the header tank and standpipes.
vi. Divide the pipeline into reaches separated by nodes (points). For uPVC pipe systems for which a wide range of pipe diameters is available each reach will usually extend between adjacent riser outlets.
vii. Determine the lengths, net command areas and design discharges along the pipelines for each reach and prepare a Discharge Statement. An initial indication of pipe diameters may be obtained by observing recommended flow velocities of 0.7-0.8 m/s for the *usual* flows.
viii. Make a note of the existing ground level at each node (reach end point) and also (if different) the highest ground level in the command area of the the node outlet.
ix. The minimum pressure at each outlet of shall be 0.5 m above (the highest) ground level in its command area.
x. Allowing for friction losses along the pipeline and through its structures determine the required pipe diameters for the design flows. The calculation starts from the tail (downstream end) of each pipeline and works upstream towards the header tank.
xi. Confirm / identify locations for all structures including: (i) riser outlets; (ii) any flow control / measurement structures; (iii) standpipe air-vents; (iv) standpipe escapes; (v) washouts; and (vi) khal / road crossings.
xii. Determine pressure head at the header tank for the *usual* flow. Also determine the pressure head for the *peak* flow to determine the full height of the header tank and standpipes. For the header tank allow a freeboard of 0.1 m to the calculated peak water level. For the *peak* discharge check that the maximum flow velocity in the pipeline is not exceeded, (1.7 m/s for uPVC pipes).
xiii. Determine pumping heads, suitable pump types and power (motor) requirements.

B. Pipeline and Node Numbering System

The pipeline numbering system should, as far as possible, reflect the rotation units. For example Pipeline 1 to supply Rotation Unit 1 and so on.

Off-taking (branch) pipelines should be numbered from upstream to downstream with the number of the main pipeline as well as the number of the branch. For example Branch 5-1 implies the first branch off-taking from pipeline 5. Similarly 5-1-1 implies the first sub-branch pipeline offtaking from Branch 5-1.

Nodes for outlets and pipe-bends should be denoted by numbers and letters starting from upstream and progressing downstream. Thus 1A is the first node along pipeline 1, while 2B would be the second node along pipeline 2.

C. Pipe Sizing and Pipe Flow Friction Losses

1. Approach

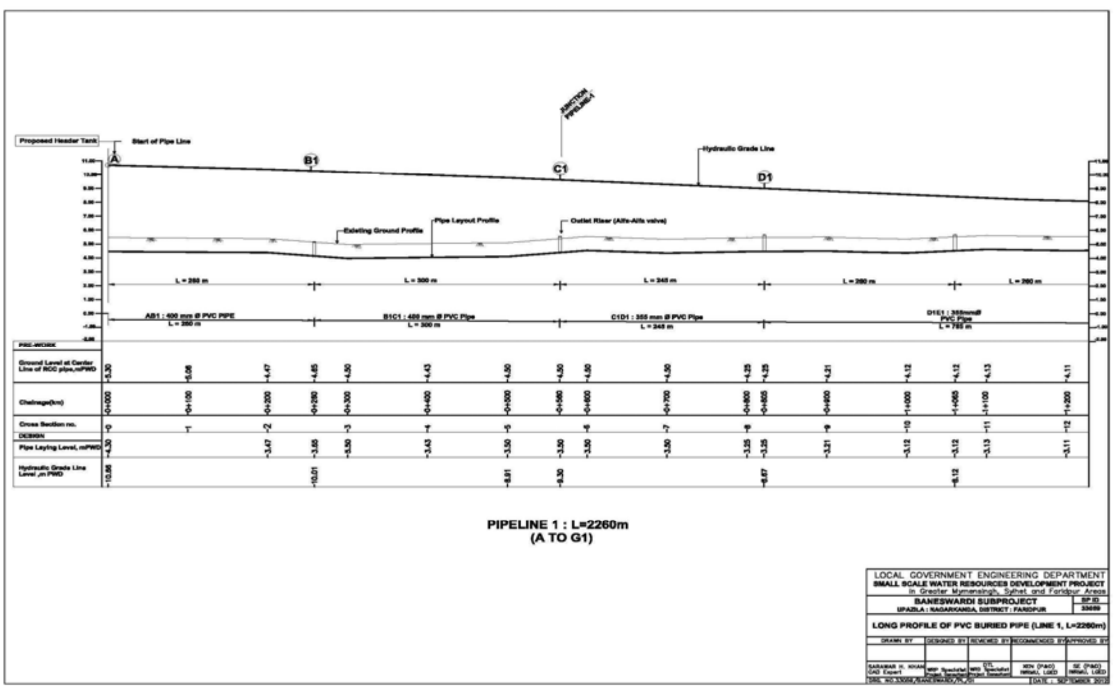
Pipe sizing is the process whereby pipe diameters are adopted for each reach taking into account pipe friction losses and losses due to bends, changes in pipe diameter and off-taking T-junctions to outlets.

This is an iterative process with more than one solution possible. However the aim will be to optimise the selection of pipe diameters so that:

i. Flow velocities are reasonably uniform from reach to reach and do not exceed the maximum allowable velocity for the pipe type.
ii. The design hydraulic grade line ensures command over all off-takes but is not so high that pumping costs will be so large that whole life costs increase. In practice, for the *usual* design discharges the pipe flow velocities are likely to range from 0.7-0.8 m/s, giving a pressure at the header tank of 3-5 m. For the *peak* design discharges check the pipelines to determine the *peak* pressures and required heights of the standpipes and header tank. In practice the hydraulic pressure head should not exceed 6-8 m.
iii. A negative hydraulic head should never develop.

Once head losses are calculated for the reach pipe pressures are determined at each node and the hydraulic grade line is determined working from the tail of the pipeline upstream towards the header tank. During operations pipe pressures decline from a maximum of about 2-6 m at the header tank, depending on flow, to about 0.8 m (min), at the tail / last outlet.

Figure II-1: Long section showing pressure drop along pipeline



A standard design spreadsheet allows the impact of a change in pipe diameter on the hydraulic grade line to be immediately apparent and facilitates the selection of appropriate pipe diameters.

2. Pressure and Velocity Limits

For concrete pipes the maximum flow velocity may be 2.4 m/s, though rather lower velocities are suggested unless rubber gasket seals and spigot & socket joints are adopted. The maximum flow velocity for uPVC pipes should be 1.7 m/s [10]. This helps safeguard the pipe against high surge / water hammer pressures.

A minimum flow velocity of about 0.3 m/s is suggested to avoid sedimentation of the pipelines.

The allowable (working / static) water pressure in the pipeline depends on the class of uPVC pipe (wall thickness) specified. Usually for CAD subprojects developed by LGED a 3.25 bar (32 m) pressure rating will be specified. To protect against surge damage the allowable water pressure shall not exceed 70% of the pressure rating, ie about 2.3 bar (22-23 m head), see Section II-D.

A lower pressure rating is not recommended as damage during transit and handling would be significant. Further it is difficult to manufacture thinner walled pipes as these tend to deform as they are extruded from the die machine.

3. Pipe Friction Losses

a. Darcey-Wiesbach formula

Pipe friction may be calculated by spreadsheet using the Darcey-Weisbach formulae:

$$H_L = f\,(L/D)\,(V^2/2g)$$

where:

L = pipe length (between nodes)
D = pipe diameter
V = pipe flow velocity
G = acceleration due to gravity (9.81 m/s^2)

The spreadsheet includes a fixed value for the Moody friction factor of 0.020 for concrete pipes and 0.0168 for uPVC pipes[11].

These values are appropriate for completely turbulent flow in the pipes. However the flow type and appropriate equation for the friction factor (there are four) depends on the relative pipe roughness (roughness / pipe diameter) and Reynolds number. With reference to the Moody diagram below, fully turbulent flow is above and to the right of the dotted line.

For the smooth uPVC pipes (roughness of 0.0015 mm compared to concrete which has a roughness of about 0.03-3.0 mm) with very low flow velocities (and low Reynolds numbers) the pipe flow may not be turbulent.

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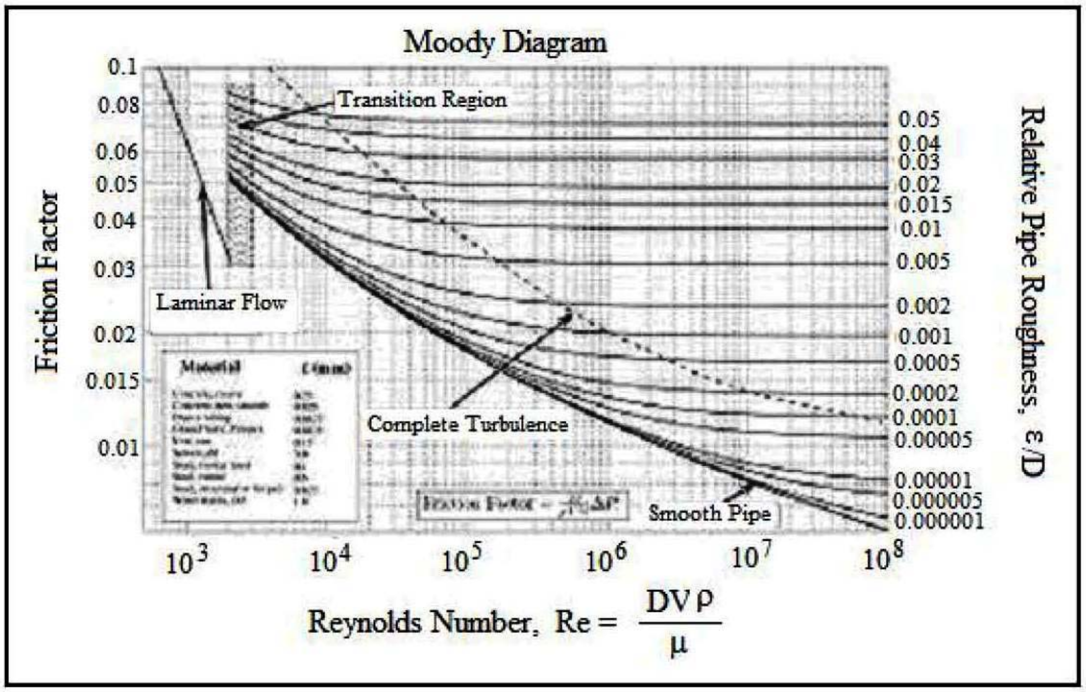
[10] FAO Handbook for Pressurised Irrigation, 2007
[11] Note: in the spreadsheet the formula is rearranged to use 4f values where f is 0.0050 (concrete) and 0.0042 (uPVC)

Figure II-2: Moody Diagram



For uPVC pipes the excel design spreadsheet using Darcy-Weisbach could possibly be amended to include for a check on the flow type, and include for the four different formulae for calculation of the friction factor depending on flow type. However this would be quite complex and is probably not necessary.

b. Colebrook White formula

The Colebrook-White formula is recommended by the Hydraulics Research Centre, Wallingford, UK, and is particularly suited to pipes which are neither totally smooth nor wholly rough. The relationship between velocity, pipe slope, pipe diameter and pipe roughness is as follows[12]:

$$V = -2\sqrt{(2gDS)}\log\left[\frac{k_s}{3.7D} + \frac{2.51\nu}{D\sqrt{(2gDS)}}\right]$$

where:

V = velocity (m/s)
D = diameter (m)
S = hydraulic gradient
ks= pipe effective roughness (m)
g= gravitational acceleration (9.806 m/s^2)
v = kinematic viscosity of fluid (0.00111 at 15^{0}C)

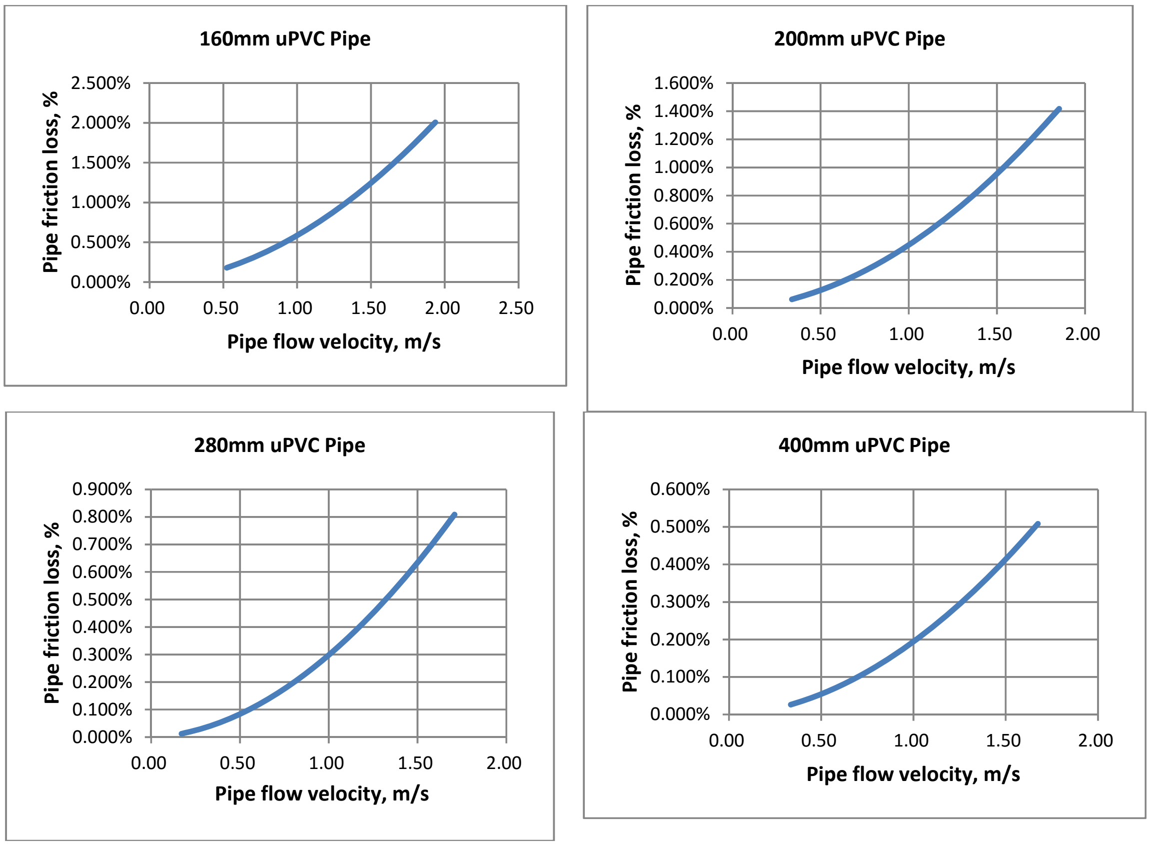
Pipe effective roughness values, ks, for use in the Colebrook-White formula are tabulated below. Friction losses for difference pipe sizes are shown on Figure II-3.

[12] Charts for the Hydraulic Design of channels and pipes, HR Wallingford, 1983

Table II-1: Pipe Roughness, k_s

Material	k_s (mm)			Recommended Maximum Flow Velocity (m/s)
	Good	Normal	Poor	
uPVC (with spigot & socket joints)		0.06		1.5
uPVC (chemically cemented joints)		0.03		
Precast concrete with 'O' ring joints	0.06	0.15	0.60	2.5
Spun precast concrete with 'O' ring joints	0.06	0.13	0.30	
Monolithic concrete construction - steel forms	0.30	0.60	1.5	

Figure II-3: Pipe flows and friction loss



Note: Calculated using Colebrook - White formula with ks = 0.03 mm

4. Losses Due to Bends and Fittings

Losses due to a bend of fitting may be calculated by the product of the velocity head ($V^2/2g$) in the pipeline and the appropriate loss coefficient, C.

Coefficient C values are listed below:

- Entry: 0.50 (sharp), 0.05 (bell).
- Bends: 0.15 (22.5^0); 0.30 (45^0); 0.75 (90^0).
- Tees: 1.20 (sharp); 0.80 (radius).
- Valves: 0.12 (open gate valve).
- Exit: 1.00 (sudden), 0.20 (bell).

In practice highly accurate calculation of headloss is not necessary and in the standard design spreadsheet a fairly conservative approach is adopted whereby the headloss in each reach is calculated as follows:

i. Calculation of the velocity head, $V^2/2g$
ii. Determination of the number of pipe bends / changes in pipe diameter / values etc in the reach.
iii. Calculation of the loss due to pipe bends, etc adopting a coefficient C of 0.75.
iv. Determination of the number of riser outlets and the number of standpipe air valves in the reach.
v. Calculation of the loss due to riser outlets and standpipes.
vi. Calculation of the total fitting and bend losses

The total fitting and bend losses are added to the pipe friction losses to give the total reach head loss.

5. Standard Design Spreadsheet

Use of a standard design "*excel*" spreadsheet facilitates design and choice of pipe diameter, headloss and hydraulic pressure head in each reach working from the tail in an upstream direction to the header tank.

A printout of the spreadsheet used to design a subproject is included as **Appendix D-3**.

D. Surge and Water Hammer Protection

Before discussing the design and provision of protection against pipe burst, pressures due to "surge" and "water hammer" are briefly defined.

1. Surge

Surge is considered to be any transient pressure fluctuation which may occur in pipeline systems at atmospheric pressure. During surge, water flow is characterized as being unsteady, oscillating from one steady state condition to another. Surge is often associated with the entry and exit of air which becomes trapped in the pipe system. This particularly occurs when ever pumping is restarted after a closure.

Surge problems in low-pressure pipelines are usually caused by the sudden and uncontrolled release of entrapped air from the line. The air may have collected at one position during pipe filling or be entrained in the flow at structures. Open pipe systems, where overflow stand-pipes are used suffer more from surge than other pipe systems. If large volumes of air are released a shock wave may be generated. Ways of avoiding surge include:

- Provision of air valves to provide for the controlled release of air; and
- Ensuring that pipe systems remain full of water, which dramatically reduces surge problems.

2. Water hammer

When the kinetic energy of moving water is transformed into pressure energy, a pressure wave is generated that oscillates back and forth in the pipeline. At any point in the pipeline this is registered as a surge in pressure which is known as water hammer. The pressure wave is reflected back on itself when it encounters any free water surface, usually at the air vent standpipe, and becomes superimposed on itself so resulting in the dampening of the surge.

Water hammer usually occurs as a result of the sudden arrest of flow caused by one of the following:

- Sudden valve closure.
- Sudden release of air.
- Sudden stoppage of a pump.

The sudden release of air can be avoided by adequate provision for air release using valves or vents. In the case of sudden pump stoppage or valve closure the surge in pressure can be damaging if not restricted to below certain limits. The hazards include:

- If the total of the initial pressure and the excess pressure developed at water hammer exceeds the maximum permitted pipe pressure, then there is a risk of the rupture of the pipe or a pipe joint.
- If negative pressure results then a pocket of cavitation may be created, causing possible collapse of the pipe wall.
- Cycling positive and negative pressures may lead to acceleration of pipe failure over time, due to pipe fatigue.

For low-pressure uPVC pipe materials, standard specifications (ASAE 5376.1, 1989) detail that:

- The maximum surge pressure should not exceed 30% of the rated pipe pressure - ie about 10 m for the proposed pipes which have a rating pressure of 3.25 bar (32 m);
- The total of maximum operating pressure and pressure surge should not exceed the rated pipe pressure.

For most buried pipe systems in Bangladesh, terrain and pipelines are quite flat, and protection against surge and water hammer is ensured by taking the following measures:

i. Adoption of a steel pipe from the pump to the header tank.
ii. Provision of open standpipes just upstream of every outlet – these release air as well as dampening out any water hammer.
iii. Adoption of open standpipe diameters which are commensurate with the size of the buried pipeline, as tabulated below.

Table II-2: Buried Pipeline and Open Standpipe Diameters (mm)

<table>
<tr><th>Buried uPVC Pipeline Outer Diameter (D_0)</th><th>uPVC Air vent Standpipe Outer Diameter</th><th>Protective Concrete Standpipe Inner Diameter</th></tr>
<tr><td>160</td><td rowspan="2">160</td><td rowspan="7">300
(50 mm thick)</td></tr>
<tr><td>180</td></tr>
<tr><td>200</td><td rowspan="5">200</td></tr>
<tr><td>225</td></tr>
<tr><td>250</td></tr>
<tr><td>280</td></tr>
<tr><td>315</td></tr>
<tr><td>355</td><td rowspan="4">355</td><td rowspan="4">400
(50 mm thick)</td></tr>
<tr><td>400</td></tr>
<tr><td>450</td></tr>
<tr><td>500</td></tr>
</table>

III. CAD Irrigation System Structures

A. Types of Structures

The types and typical numbers of structures associated with a typical irrigation (uPVC) pipe distribution system are described below along with a summary of their function. Sample structure drawings are included as Appendix E.

Table III-1: Description and Function of CAD Irrigation System Structures

Nr	Type of Structure	Nr Required	Description	Function
1	Pump House	0-1	Masonry walls and (depressed) concrete floor to house the required number of motors and pumps. Steel shutter winders and doors, and corrugated iron roofing.	Protection and security of pumping equipment.
2	Header Tank	1	Rectangular reinforced concrete structure with 3 main separate compartments, and with (steel) ladder and operating platforms to provide access to gates / shutters and flow measurement V-notches. Also hand railing and washouts. A cheaper alternative would be to adopt a circular reinforced concrete tank and adopt, if required electronic flow monitoring devices to out let pipes.	To receive discharge from pumps and allow settlement of sediment to removed by flushing / manually. Also to enable flow control and flow measurement to offtaking pipelines. Height to be sufficient to drive design flow through conveyance pipelines.
3	Flow Control Structures	0-3	RC structure with gates / shutters / valves and V-notch weirs	To provide flow control and flow measurement at head of rotation units.
4	Outlets (Risers) for irrigation	30 (typ.)	uPVC pipe offtake from pipeline leading to (concrete/PVC) riser pipe fitted with an alfalfa value. Masonry / concrete distribution box to be located over riser pipe. If lay flat hose connections are are proposed then the walls of the outlet box are about 1.2 m high and steel pipes are set into the walls of the outlet box to which hoses may be attached.	To release irrigation flows from pipeline to 5-15 ha (typ) irrigator units (usually every 200-500 m along pipeline). The type of structure built depends on whether layflat hose conveyance from the structure is requested by farmers, or surface conveyance.
5	Outlets to standpipes	0-10	uPVC pipe offtake with control valve and RC access box leading to steel pipe riser to which 1-2 lay flat hoses may be attached.	To release smaller flows for hose conveyance to irrigate small areas of higher land, ponds, homestead gardens, etc
6	Standpipes (air vents)	30 (typ.)	Vertical uPVC pipe leading off from top of uPVC pipeline at high points and usually just upstream of outlets (risers). Standpipes to comprise uPVC pipe placed within concrete pipes for support / protection.	To ensure pressures within pipeline remains within design limits and to allow air to vent. Top of standpipes to be 0.6 (typ) m above design HGL
7	Escapes (standpipe overflows)	3	Vertical uPVC pipe leading off from top of PVC pipeline key locations and where escape flow	To allow monitoring of pressures in pipeline, feed back to pump operator to increase /

Nr	Type of Structure	Nr Required	Description	Function
			can discharge safely. Small clear piezometric tube to be fitted to allow monitoring of water level (pressure).	decrease pumping flows, and for excess flow to discharge safely into drainage ditch. Top of standpipes to be 0.3 (typ) m above design HGL.
8	Washouts	3	uPVC pipe offtake with control valve and RC access box located at low point(s) in pipelines	To allow periodic flushing and emptying of pipeline for repairs and removal of sediment.

B. Flow Formulae

In this section the flow formulae used for the hydraulic designs of the pipe system structures are presented, focussing on energy / head losses.

1. Energy Loss Equations for Transitions

Head (energy) losses through transitions include for losses between structures / channels and pipes.

The general expressions for transition losses are:

For exit losses: $\delta H_e = C_e (V_2 - V_3)^2 / 2g$

For inlet losses: $\delta H_i = C_i (V_1 - V_2)^2 / 2g$

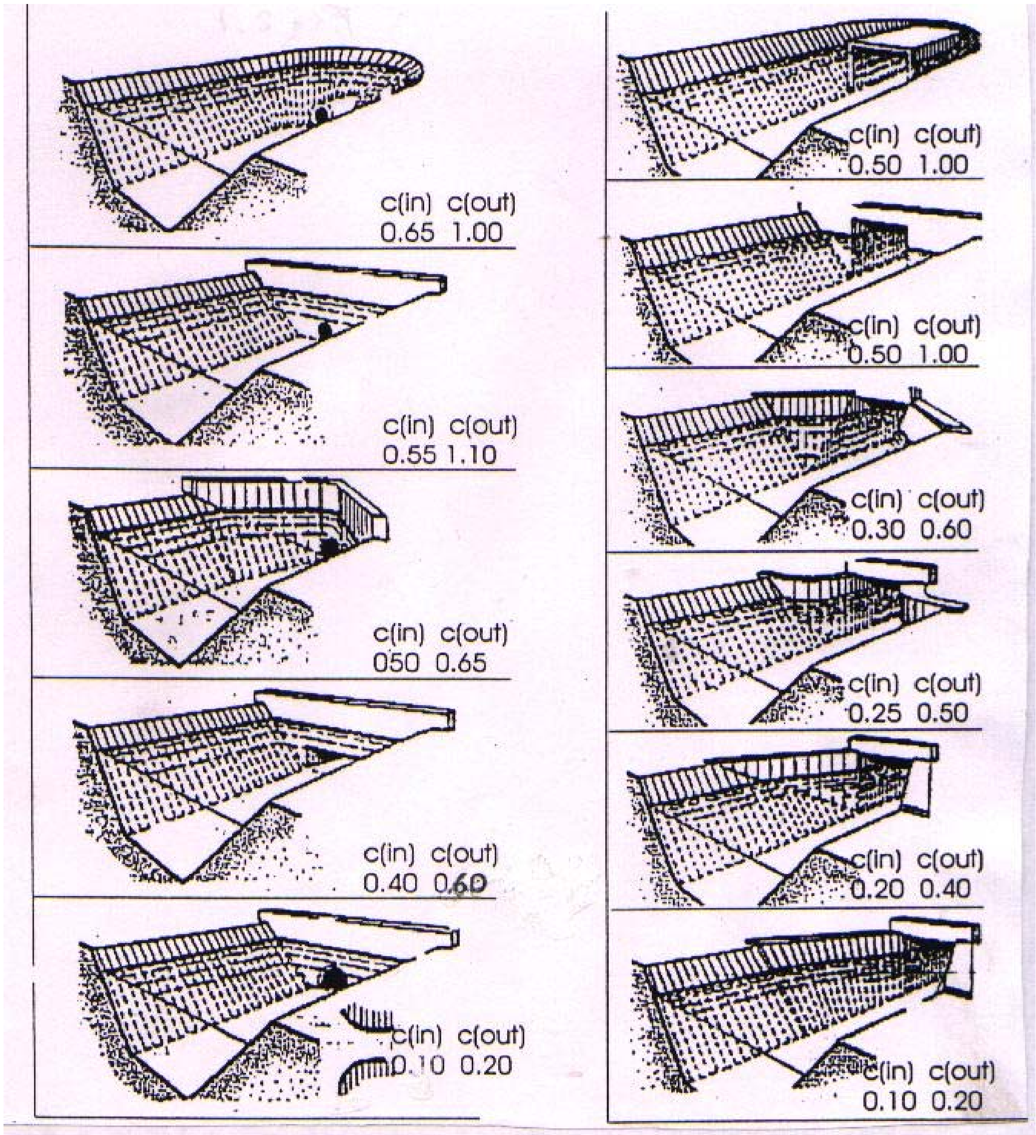
δH_i, δH_e = energy loss through transition [m]
C_i, C_e = coefficient of head loss in transition
V_1 = velocity upstream of transition [m/s]
V_2 = velocity in constriction (pipeline) [m/s]
V_3 = velocity downstream of transition [m/s/]

Values for the head loss coefficients from open channels / structures to and from conduits are tabulated below and shown on **Figure 2.2**. Note: these coefficients apply for Froude numbers of the constricted flow of less than 0.5.

Table III-2: Energy Loss Coefficients for Transitions

Type of Transition	Type of Conduit			
	Circular, Submerged		Rectangular (free water surface)	
	C_i	C_e	C_i	C_e
Conduit protruding from channel slope	0.65	1.00	0.50	1.00
Conduit connected to straight head wall	0.55	1.10	0.50	1.00
Conduit connected to simplified straight line transition	0.50	0.65	0.30	0.60
Conduit connected with rounded ends to straight head wall			0.25	0.50
Conduit connected to simplified straight line transition with vertical walls			0.20	0.40
Conduit connected to transition with round to rectangular 6D long pipe transition (width 2D, height D)	0.40	0.60		
Warped transition			0.10	0.20

Figure III-1: Headloss Coefficients for Pipe – Channel / Structure Transitions



2. Alfalfa Valves

Energy losses through alfalfa valves are calculated using the transition loss formula for exits.

The flow velocity downstream of the transition may be taken as zero, giving:

$$\delta H_e = C_e (V_2)^2 / 2g$$

The head loss through alfalfa valve will be 1.5 to 2.2 times the velocity head through the riser. Adoption of a loss coefficient of 2.0 for alfalfa valves is proposed.

Adopting headloss throiugh the alfalfa valve of about 50 mm gives the following outlet pipe and valve sizes for the likely range of areas/ discharges. Where higher heads are to be dissipated/ flows reduced the alfalfa valve must be partially closed. For areas smaller than about 10 ha, it may be more appropriate to adopt a sluice valve outlet structure.

Table III-3: Irrigator Area and Alfalfa Valve Diameters

Net Irrigation Area for Outlet (ha)	Indicative Peak Flow (l/s)	Offtaking uPVC Outlet Pipe Dia. (mm)	Alfalfa Valve Dia. (inch)	Indicative Flow Velocity (m/s)	Indicative Headloss (mm)
10	11	160	6	0.55	31
15	17	160	6	0.82	69
20	22	200	8	0.70	50
25	28	200	8	0.88	78
30	33	225	8	0.83	70

3. Pipe Orifices

The (gated) pipe offtakes from concrete structures are submerged flow orifices for which discharge is mainly a function of the head loss across the orifice, and the orifice opening as given by the following formula:

$$Q = C_d C_v A (2g(h_1 - h_2))^{0.5}$$

Where:

Q = discharge [m^3/s]
C_d = discharge co-efficient
Cv = velocity co-efficient
A = area of opening (= product of orifice opening "a" and orifice width "b") [m^2]
h_1 = upstream water depth above orifice crest [m]
h_2 = downstream water depth above orifice crest [m]

C_v can usually be taken as 1.0, and adoption of Cd = 0.61, (fully contracted orifice) is suggested.

Note: as an alternative to this equation the transition headloss equation may be used with the appropriate loss coefficient, C.

4. Broad Crested Weirs

For free flow (ie modular) conditions discharge is (approximately) given by:

$$Q = 1.7\ b\ h_1^{1.5}$$

Where:

Q = discharge [m^3/s]
h_1 = upstream depth of flow over the weir crest [m]
b = width of the weir [m]

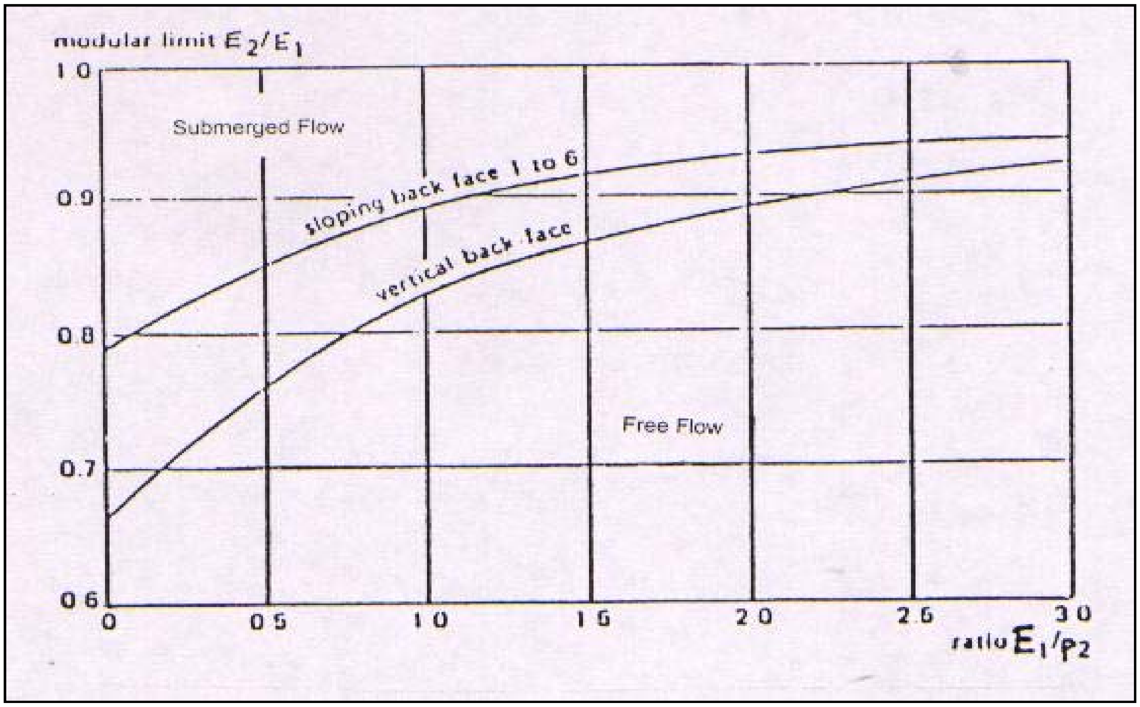
The flow over a weir is modular when it is independent of variations in downstream water level. For this to occur the downstream energy head (E_3), must not rise beyond a certain percentage of the upstream energy head (E_1).

The ratio E_3/E_1 is the "*modular ratio*" and the modular limit is the value of the modular ratio at which flow ceases to be free. Usually flow velocities upstream of the weir, and downstream of the hydraulic jump are similar, and E_3/E_1 may be approximated by h_3/h_1.

The modular limit also depends on the height of the crest above the downstream floor (p_2).

As shown below the modular limit for broad crested weirs with a shallow sloping back (downstream) face varies from 0.79 to 0.94, while for a vertical back face the modular limit varies from 0.67 to 0.92, depending on the value of the ratio (E_1/p_2).

Figure III-2: Modular Limit for Broad Crested Weirs



For submerged (non-modular) flow, the discharge is reduced by multiplication by the applicable reduction factor "f" tabulated below. The reduction factor depends on the modular ratio (E_3/E_1), and on the approaches to the weir.

The values given in this table are applicable to weirs with either a rounded or a sloping upstream face and a sloping downstream face, with slopes 1V:2H or flatter, are from Fane's curve. For weirs with a vertical back (downstream) face, reduction factors are greater, and have been approximated from Chow, 1978, Figure 14-17.

Table III-4: Reduction Factors for Submerged Flow

Modular Ratio E_3/E_1	"f" value for weirs with shallow sloping u/s and d/s faces	"f" value for weirs with a vertical back face
0.80	0.99	0.88
0.90	0.98	0.70
0.95	0.84	0.50
0.96	0.77	-
0.97	0.71	-
0.98	0.61	-

5. V-Notch Weir

For a negligible approach velocity tests on a 90^0 V-notch weir for upstream heads (H_1) varying from 6 to 55 cm resulted in the following equation:

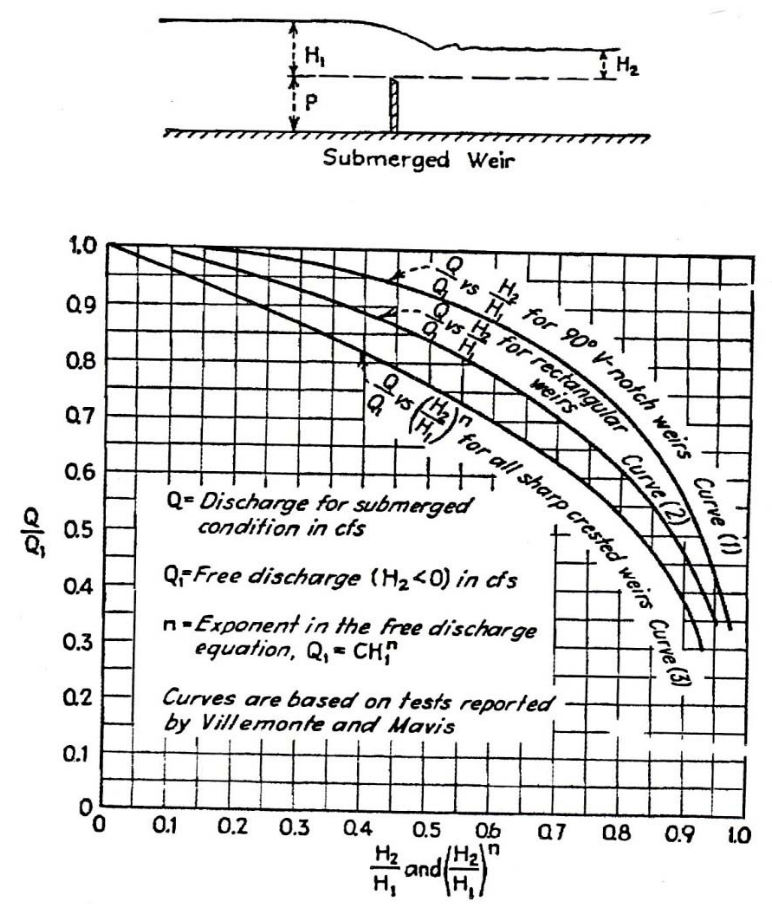
$$Q = 1.34\ H_1^{2.47} \qquad (m^3/s)$$

Where, H_1 = upstream head over the weir crest (m).

If the flow becomes submerged the discharge reduces. For a 90% V-notch weir a 10% loss in discharge occurs if the downstream head (H_2) rises to $0.5H_1$ as shown on the figure below.

Adopting a limit for the downstream head H_2 of 0.5 H_1 (or less) is proposed.

Figure III-3: Head over V-notch weir crest and flow



It is suggested that 90^0 V-notch weirs are incorporated into pipe distribution system structures (for example at header tanks and flow control structures) to allow flows into pipelines to be measured.

Alternatively, it may be appropriate to fit flow measurement / metering devices to the pipelines despite the higher costs, particularly if a record of cumulative flow is required.

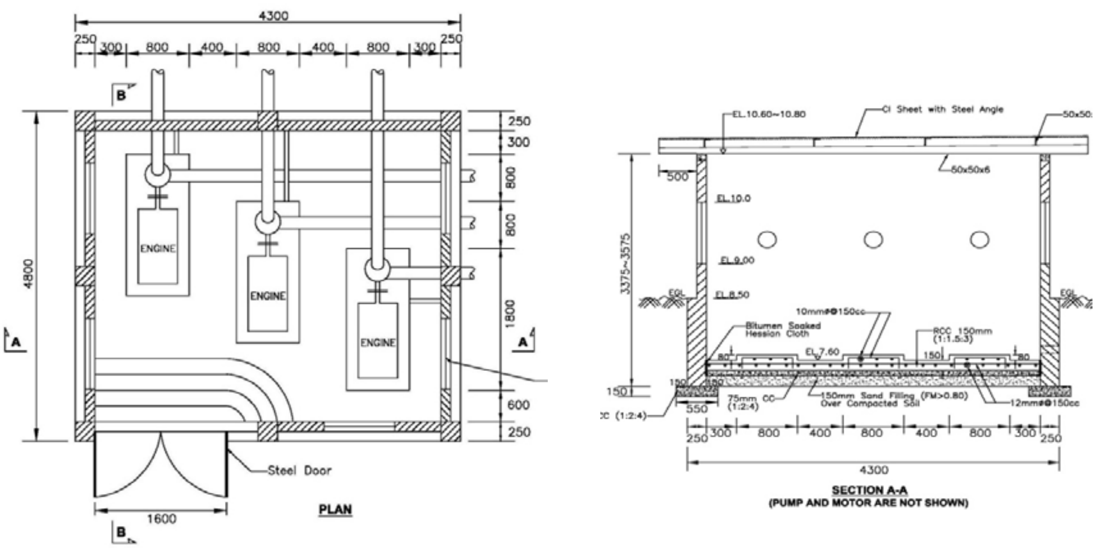
C. Design Features of Pipe System Structures

Sample drawings for pipe system structures are given in **Appendix E** and design features of are discussed below.

1. Pump house and Platform

The pump house will typically have brick masonry walls and a concrete floor. The floor may be depressed below ground level so that the suction head for the pumps does not exceed a practical limit of 5-6 m. It should be sufficiently large to house the required number of motors and pumps. Steel suction and delivery pipework should be arranged to facilitate access to the pumps for operation/ maintenance. For ventilation steel shutter windows and doors are required. The roof may corrugated-iron sheets or a concrete slab. The pump house provides protection and security for pumping equipment.

Figure III-4: Pump House and Platform



For subprojects drawing water from larger rivers it may not be practical to locate pumps inside the pump house, even with a depressed floor, as the pumping suction head could be too high (more than about 4-6 m) in the lean season. In this case usual practice is either to provide a concrete platform on the river bank where the pumps may be placed in the lean season, removed during the monsoon, or to provide a floating platform anchored to the river bank. Unless the river bank is stable any pumping platform should comprise a reinforced concrete slab supported on top of precast concrete / steel sheet piles. Access steps to the platform would facilitate placement/ removal of pumps.

2. Header tank

The height of the tank is determined by the pipeline design and necessary head to supply irrigation water to all the outlet risers. It has to be sufficiently tall to allow the peak (1-month) demand flows to be met. In addition freeboard of 0.2 m may be provided. As usual flows are much lower, to avoid pumping excessive heights and incurring high pumping costs, the discharge pipes from the pump house enter the tank in the bottom half of the tank, see *Figure III-5*.

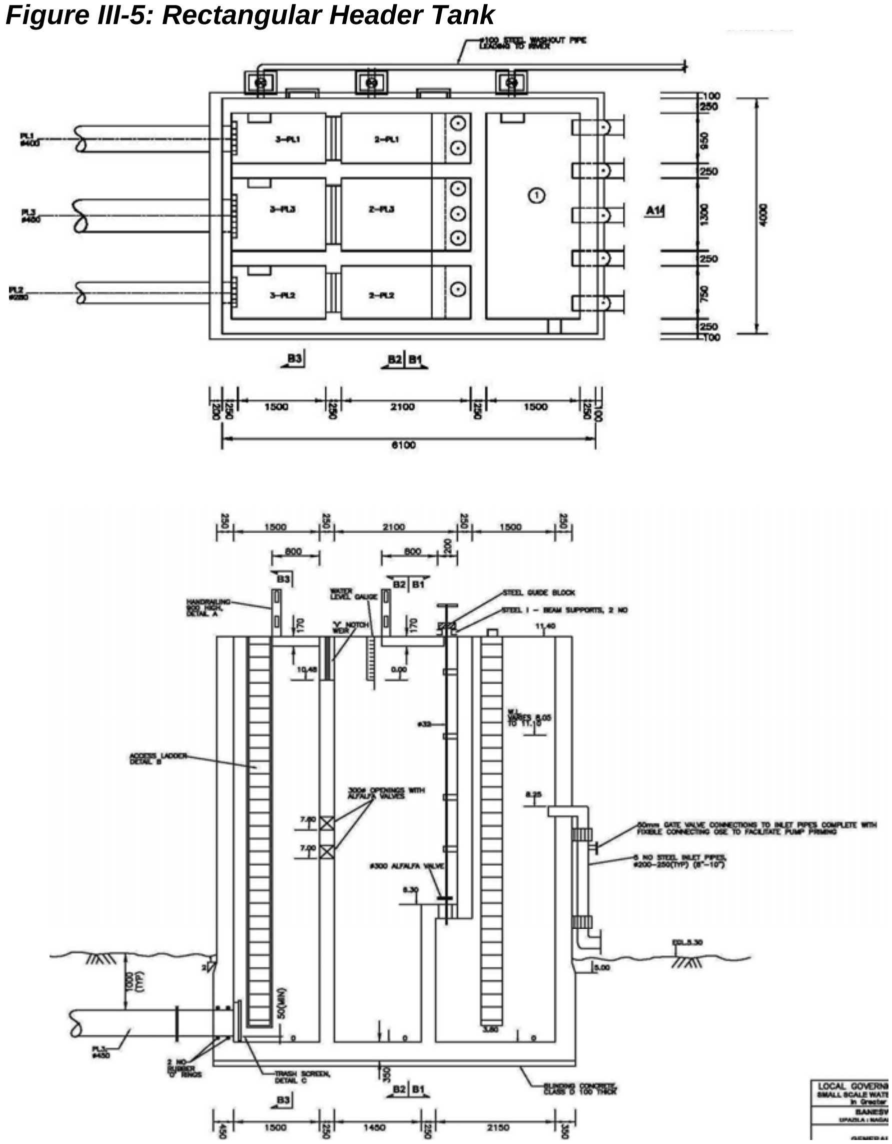
There are three main compartments. The first receives water from the delivery pipes and facilitate settlement of any coarse sediment. Flows into the second compartment are controlled by (8 or 10 inch) alfalfa valves operated from an operating platform. From the second compartment flows may be through orifices into the third compartment, or if these are closed over 90^0 V-notch weirs so that flows may be measured.

The second and third compartments are divided into sub-compartments according to the number of off-taking pipelines.

The number and diameter of alfalfa valves is determined from the design flows, adopting a head loss of 100 mm or less.

Only one V-notch weir will be provided to measure the flows to each off-taking pipeline and their crest levels vary according to the design discharges – the higher the discharge the lower the crest. Sufficient headloss should be allowed so that flow remains free (ie unaffected by the downstream water levels), and is likely to be about 150 mm.

Figure III-5: Rectangular Header Tank



Plan of a typical tank showing compartments. In compartment-1 sediments are settled and flows into compartment-2 controlled by alfalfa valves. Flow measurement by V-notch weir is possible between compartments 2 & 3. Flows enter the 3 main pipelines from compartment-3.

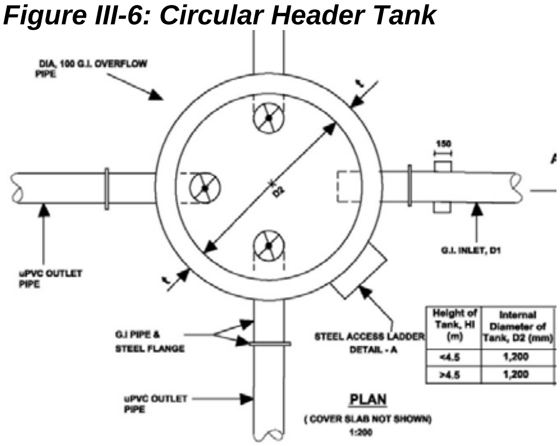
Pumped water from the pump house enters about halfway up the tank.

Flow control is by the alfalfa valves located in compartment-2. The allow flows to be controlled / rotated as required to each off-taking pipeline.

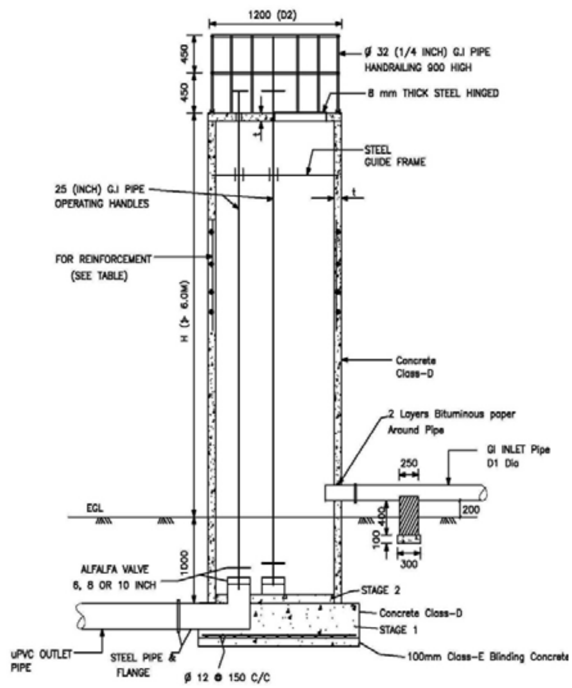
Flow measurement is possible only if the direct connections set in the walls between compartments 2&3 are closed. Flow measurement is suggested whenever new pumps are procured.

The reinforced concrete header tank is a costly structure, and cheaper alternatives may be considered. For example, where pumped coarse sediment is not expected, a cheaper, circular header tank design may be considered[13], see ***Figure III-6***. The internal diameter of a circular header tanks would be about 1,200 mm to allow for inspection/ cleaning. Wall thicknesses would be about: (i) 175 mm for tanks where 3.5<H< 4.5 m; (ii) 200 mm for 4.5<H<5.5 m, and (iii) 225 mm for 5.5<H>6.5 m.

Figure III-6: Circular Header Tank



A circular reinforced concrete header tank would be cheaper than rectangular structures and practical so long as pumping of coarse sediment is not expected.



A further operational improvement may be to adopt flow control by providing sluice / gate valves to each pipeline instead of the alfalfa valves, and flow meters instead of V-notch weirs. However this could increase costs.

3. Flow Control / Measurement Structure

For many subprojects flow control / measurement at the head of each Rotation Unit would be at the header tank. However for the larger subprojects, a pipeline offtaking from the header tank may supply water to two or more Rotation Units, in which case an additional flow control / measurement structure will be needed.

A typical structure could comprise several compartments as shown below. The inlet pipe would discharge into the first compartment, from which flows into second compartment would be controlled by alfalfa valves operated from the top of the tank. Flow measurement to each pipeline would be by a 90^0 V-notch weir set into the partition wall between adjacent compartments.

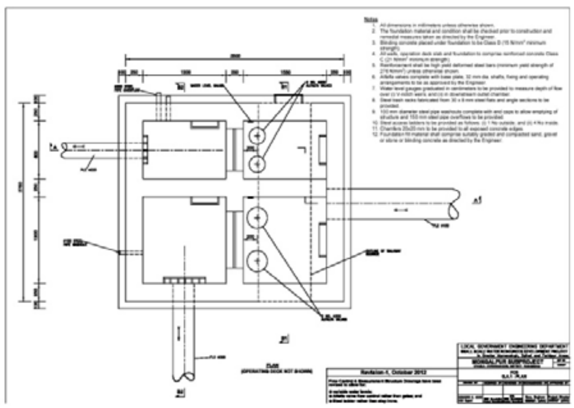
The structure would incorporate the following features: (i) trash racks to prevent trash entering the off-taking pipelines; (ii) an operating platform to access the valve operating handles and V-notch weirs; (iii) access ladders; (iv) small pipe drains set at the floor of the structure to allow cleaning of each compartment; and (v) pipe overflows set at design water level.

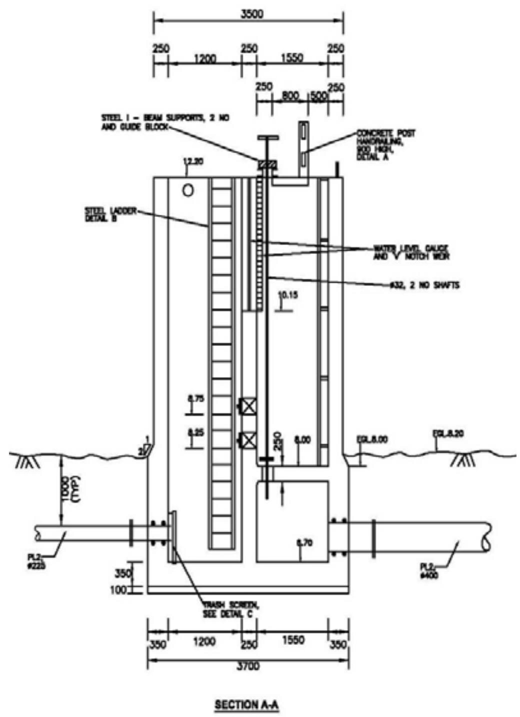
[13] Circular tanks are the norm for smaller irrigation schemes built by the BMDA and BADC.

The height of the reinforced concrete structure is dictated by the pipeline design, specifically the hydraulic pressure head in the off-taking pipelines plus head losses through the structure itself.

If flow measurement was not needed then an alternative would be to provide a gate / sluice valve located within a valve chamber / box at the head of the off-taking pipeline. To protect against surge pressures and allow exit / entry of air a standpipe should be located just upstream of the valve.

Figure III-7: Flow Control / Measurement Structure



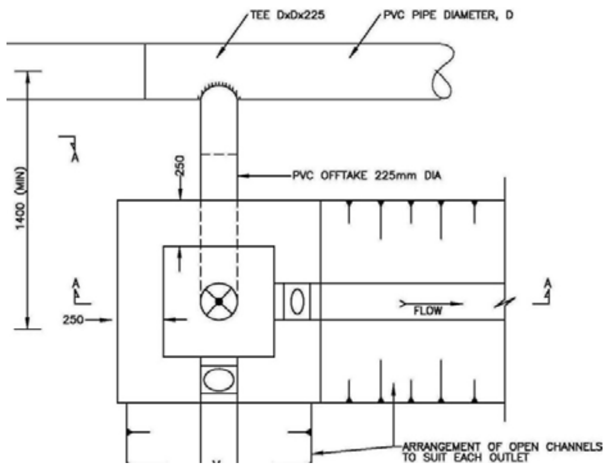


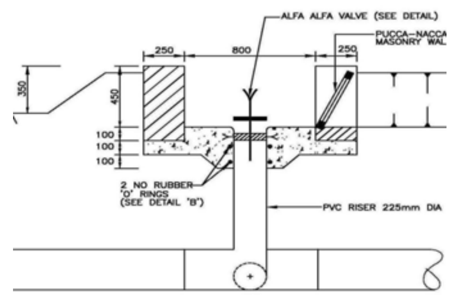
Flow control / measurement structures should be located at the head of each Rotation Unit to facilitate equitable flow distribution, allow flow rotations during periods of relatively low irrigation demand, as well as closure of part of the pipe system for emergency repair / maintenance without closing the whole system.

4. Outlet Risers

Outlets typically comprise am off-taking uPVC pipe leading to riser pipe capped with an alfalfa value. A masonry / concrete distribution box is located over the riser pipe. It is advised, particularly for uPVC pipes, that the outlet box is offset from the main pipeline to avoid damage to the pipeline and allow access to the pipeline in event of repairs being required. To prevent tampering of the alfalfa valve a lockable screen may be provided.

Figure III-8: Outlet Riser supplying Field Channels





Outlet risers release irrigation flows from pipeline to 5-15 ha (typ) Irrigator Units and are usually every 200-500 m along the pipelines

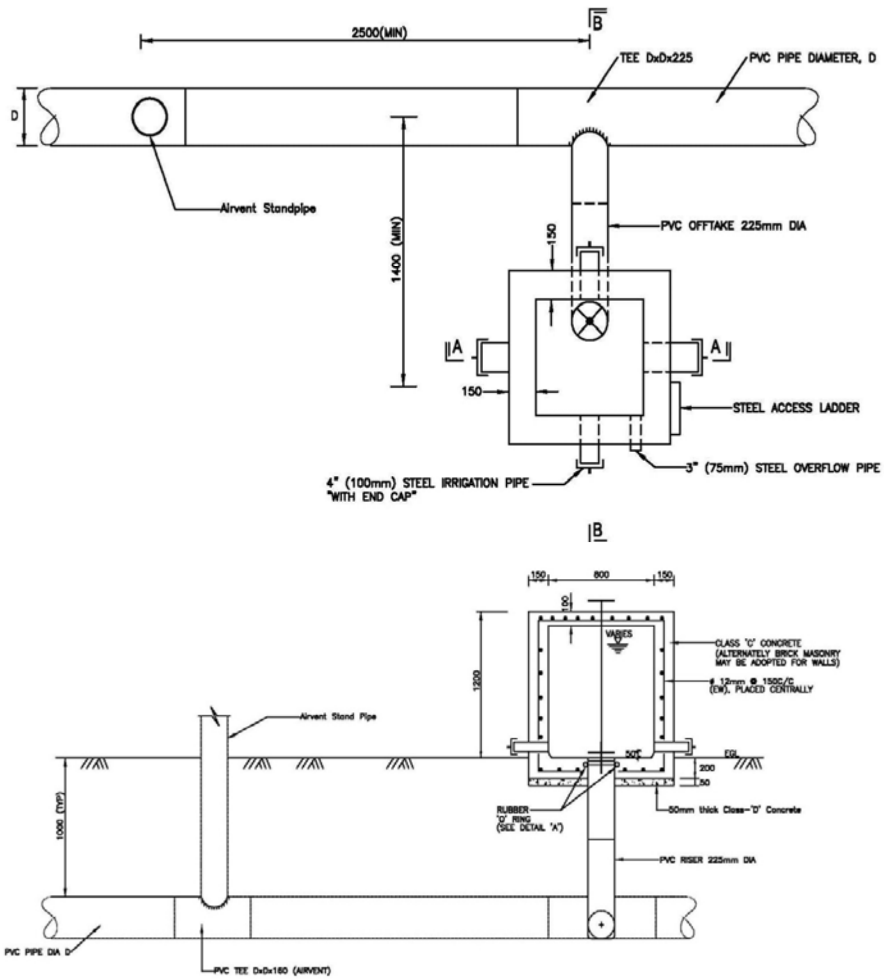
Depending on area of the Irrigator Unit, the offtaking pipeline diameter should vary from 160-225 mm, and the alfalfa valve be either 6 or 8 inch in diameter, see *Table III-3*.

While the T-joint for off-taking pipelines are laid horizontally, the T-joint for standpipes / air vents which are constructed over the pipeline, are laid vertically - as shown in the adjacent picture.

The outlet riser shown on Figure III-8 supplies water to field channels, and the pucca-nuccas built into the walls of the outlet box control flows to the field channels.

An alternative design, shown below is for outlets supplying water for lay-flat hose conveyance to farmers' fields. In this case the outlet box requires high walls - assuming water is to be conveyed less than 100-150 m then 1.2 m high walls are likely to be sufficient.

Figure III-9: Outlet Riser supplying Layflat hose

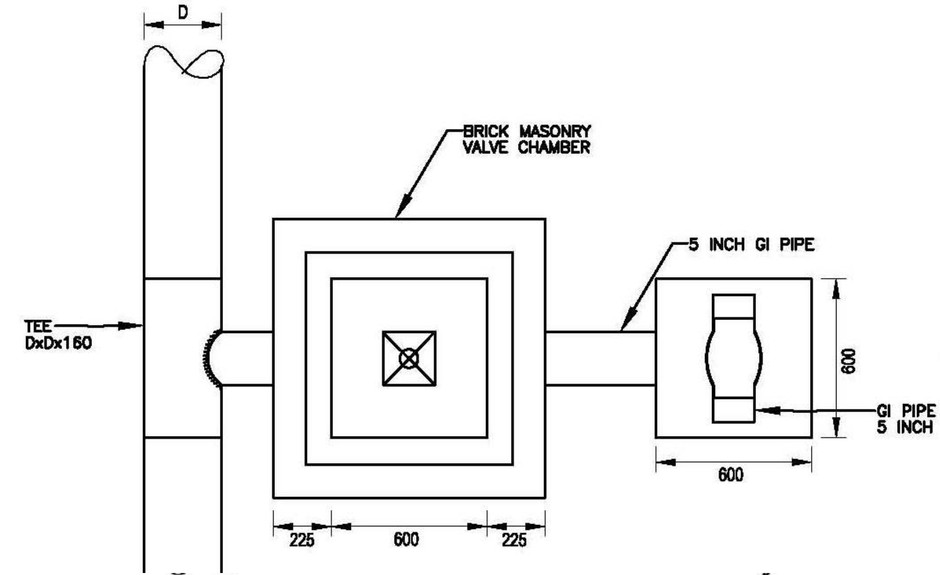


If lay flat hose connections are are proposed then the walls of the outlet box are about 1.2 m high and steel pipes are set into the walls of the outlet box to which hoses may be attached.

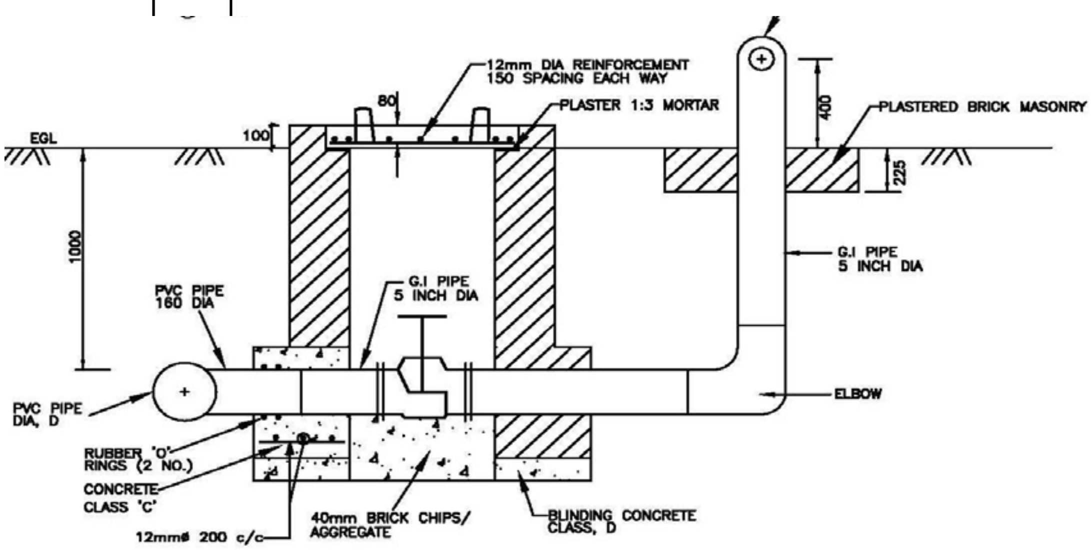
5. Outlets to Standpipes

For smaller areas, less than about 10 ha, or to provide water to fish ponds/ washing, standpipes are suggested. These structures comprise a uPVC pipe offtake with control valve housed in a concrete / masonry chamber leading to a steel pipe riser to which 1-2 lay flat hoses may be attached.

Figure III-10: Outlet to Standpipes



This structure is suited for release of smaller flows for hose conveyance to irrigate small areas of higher land, ponds, homestead gardens, etc



6. Air Vent and Escape Standpipes

Air-vent and escapes are similar structures comprising vertical (uPVC / concrete) standpipes leading from the top of the pipeline as shown on Figure III-11. The main differences between them are as follows:

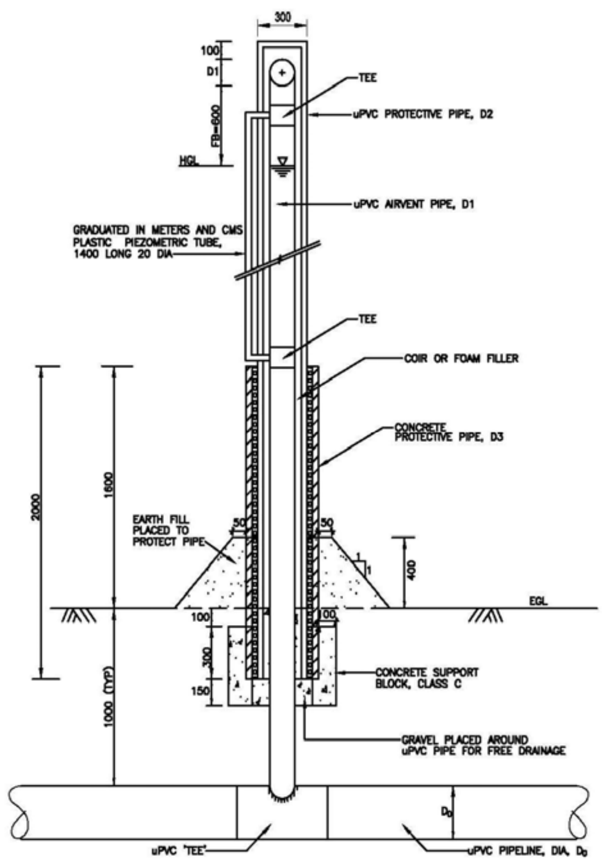
i. Air vents are located at high points and just upstream of every outlet. They ensure that surge / water hammer pressures within the pipeline remain within design limits and allow air to vent. The top of the air vent standpipes is usually 0.6 m above the design hydraulic grade line (pressure head) at the standpipe location.

ii. Escapes are located at a few key locations and allow excess flow to discharge safely into a drainage ditch. The top of escape standpipes is usually set just 0.3 m above the design hydraulic grade line.

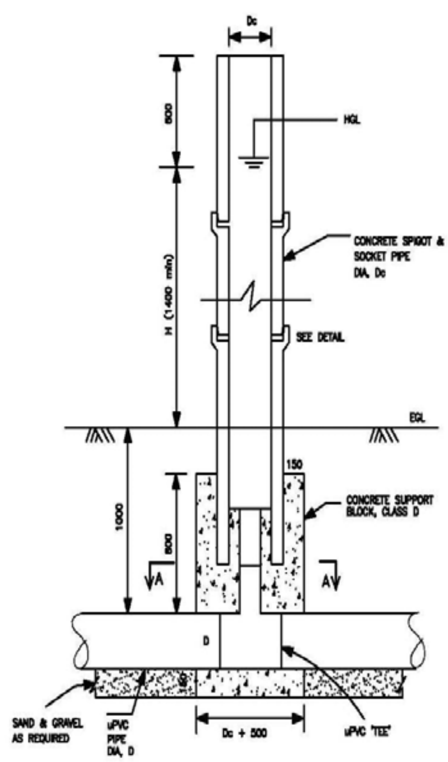
Escape standpipes always have a small clear piezometric tube fixed to the standpipe to allow monitoring of pressures in the pipeline and "*feed back*" to the pump operator to increase supply if pressure is low, and to decrease supply if pressure is too high. The air vents may also have these piezometric tubes if additional monitoring is desired.

These standpipes may comprise just concrete pipes placed on top of the uPVC riser pipe without any way to monitor pressures. If this simple design is adopted then the concrete joints must be sealed carefully and may require periodic re-sealing. However as they rise above ground any leakage is readily apparent. To ensure against leaks the uPVC pipe may be taken to the required height, in which case the concrete / 2nd uPVC pipe surround is purely for protection.

Figure III-11: Standpipe Airvent



Standpipes allow air to vent and control pressures. The top of the standpipes to be 0.6 (typ) m above design pressure in the pipe (HGL). Standpipes may comprise a simple concrete pipe (below) or a uPVC pipe protected by concrete / 2nd uPVC pipe and complete with piezometric tube for pressure monitoring (opposite)



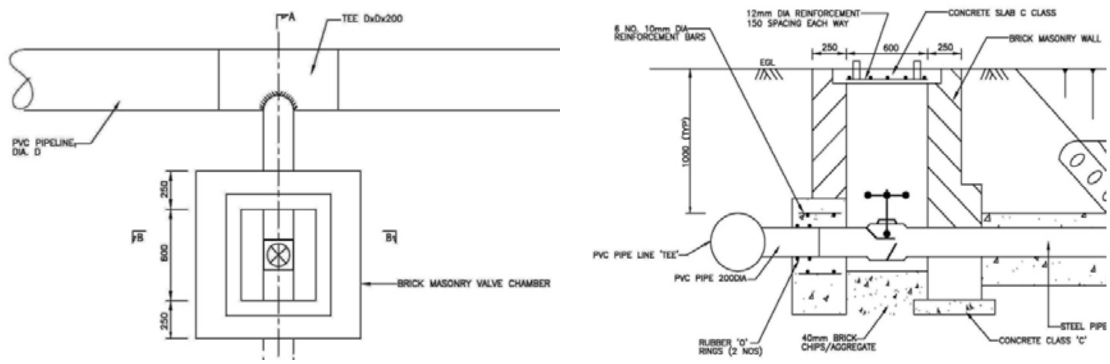
The diameter of the standpipe depends on the parent buried pipe diameter, see ***Table II-2***, while its height will depend on the design pressure in the pipeline. For an upstream control system, the pressure in the pipeline declines from the header tank to the tail. If too much water is supplied water will overtop the standpipes.

For most subprojects the height of the standpipes will probably vary from about 6.0 m at the head to a minimum of 1.6 m at the tail.

7. Washouts

Washouts comprise a side pipe off-take from the parent pipeline fitted with a control (gate) valve and concrete / masonry protective box. They should be located at any particularly low point(s) along the pipelines to to allow periodic flushing and emptying for repairs and removal of sediment.

Figure III-12: Plan and Section of Washout



IV. Pumps, Power Requirements and Accessories

A. Introduction

For each CAD subproject the required design flows, *usual* and *peak*, pumping heads, pump type(s) and power requirements must be determined. In this section the selection of suitable pump sets is discussed and the power and energy required for them. Pump accessories are also described.

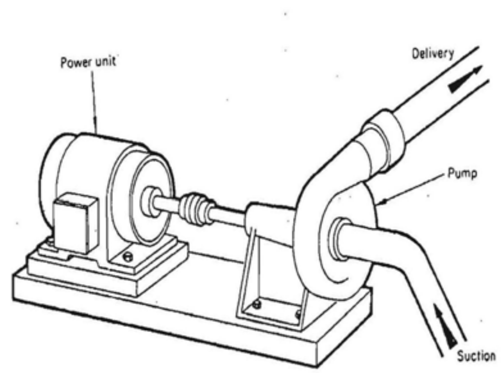
A pump set comprises the following:

The *Pump* itself, usually cast iron – centrifugal pumps up to 8 inch in size are manufactured locally.
Power unit – either an electric motor or a diesel engine – this makes up the major cost of the pump set.
Steel Base frame on which the motor and pump are fixed – usually skid type
Main switch & starter – for electric motors only
Electric connection to mains – for electric motors only
Battery and starter – diesel engines only

Together with associated steel pipes, pipe bends, gate / sluice valves, end (foot)-valve to prevent back flow and pipe screen the pump sets typically make up about 1-2% of the subproject cost, refer Table I-5. Suggested rates for pump sets and associated items are given in **Appendix A-2**.

In Figure IV-1 below a pump set with electric motor, steel pipework from pumps to header tank and a small platform located on a river bank are shown.

Figure IV-1: Pump Sets and associated equipment



Electric motors are more efficient than diesel engines, and electric power attracts a significant subsidy in Bangladesh. For these reasons adoption of electric motors will reduce running costs. However complete reliance on electric motors leaves farmers vulnerable to load shedding and crop losses.

B. Types of Pumps

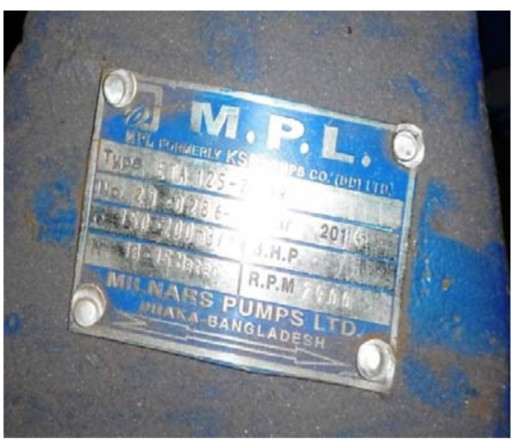
Roto-dynamic pumps fall into the following categories: (i) axial flow pumps – low head and high discharge; (ii) centrifugal pumps – high head and low discharge; and (ii) mixed flow pumps. They are all designed to run at a constant speed and their performance is described by the following characteristics:

- Pumping head and discharge;
- Power Requirement; and
- Efficiency of operation.

Pump labels typically summarize the pump type / size, pumping head and discharge, and operating speed. Indicative power requirement and date of manufacture may also be given. However sometimes labels are misleading, for example a label may state: 400 m^3/hr, 20 m meaning one or the other (ie 200 m^3/s <u>or</u> 20 m of lift), not both.

Two labels for centrifugal pumps manufactured by Milners Pumps Ltd, Bangadesh are shown below. Label A for a 125 mm (5 inch) pump indicates the recommended range of flows and associated heads, ie 150 m^3/hr for 18 m pumping head, and 200 m^3/hr for 15 m head. Label B for a 150 mm (6 inch) pump is less informative, and indicates 5 cusecs (507 m^3/hr) for 9.5 m head. No pump efficiency information is given.

Figure IV-2: Pump Labels



A. Label states:

- *125 mm (5 inch) pump*
- *Flows: 150-200 m^3/hr*
- *Head: 18 – 15 m*
- *BHP: blank*
- *RPM: 2900*

A. Label states:

- *150 mm (6 inch) pump*
- *Flows: 5 cusecs (150-200 m^3/hr*
- *Head: 9.5 m*
- *RPM 1500*

Table IV-1: Discharge Units Conversion

(m^3/s)	(cusecs)	(l/s)	(m3/hr)
0.05	1.77	50.00	180.00
0.06	2.12	60.00	216.00
0.07	2.47	70.00	252.00
0.08	2.82	80.00	288.00
0.09	3.18	90.00	324.00
0.10	3.53	100.00	360.00
0.11	3.88	110.00	396.00
0.12	4.24	120.00	432.00
0.13	4.59	130.00	468.00
0.14	4.94	140.00	504.00
0.15	5.30	150.00	540.00
0.16	5.65	160.00	576.00
0.17	6.00	170.00	612.00
0.18	6.35	180.00	648.00
0.19	6.71	190.00	684.00
0.20	7.06	200.00	720.00

1. Axial flow pumps

Axial Flow Pumps (AFPs) initially spread in East Asia in the 1960s via national programs and village level machinery manufacturers to small farms where surface water needs to be raised 1-4 m. In its most simple form the pump consists of a boat propeller inside a pipe. IRRI improved the impeller blade design in the early 1970s and today there are millions of low cost, improved AFPs in Thailand, China and Vietnam. AFPs currently have very limited use in South Asia.

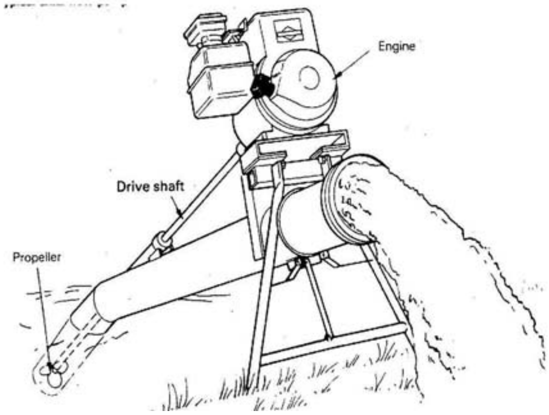
In 2012 CIMMYT, Bangladesh and iDE, Bangladesh and their national partners began manufacturing[14] and testing AFPs in Bangladesh. Testing to determine performance was done by BARI and closely monitored by CIMMYT[15]. Test features and results (June 2013) were as follows:

- Static pumping lifts (negligible friction lift): 1, 2 and 3 m;
- Pump diameters: 4 – 6 inch;
- Diesel engine power: 10 – 14 HP;
- Engine speed: 2,000 – 2,300 rpm;
- Pumping discharge variation: 50-70 l/s at 1.0 m lift to 30-50 l/s at 3.0 m lift; and
- Energy (fuel) efficiency[16]: 80 – 120 m^3 / l at 1.0 m lift to 60-70 m^3/l at 3.0 lift.

The axial flow pumps showed significant efficiency gains over centrifugal pumps, with energy (fuel) savings of 30-50% for a static pumping lift of 1.0 m, reducing to 10-30% for a static lift of 2.0 m. For a static pumping lift of 3.0 m there was negligible energy saving, and above 3.0 m centrifugal pumps are more energy efficient.

[14] Manufacturers of pilot AFPs are: (i) Rahmann Engineeringm Kushtia (6 & 8 inch models); (ii) Hira Engineering Workshop, Dhaka (6 inch); and (iii) the PRAN-RFL Group.
[15] Farm Machinery & Post Harvest Extension Division, Bangladesh Agricultural Research Institute (BARI)
[16] Measured by volume of water pumped in m^3 for each litre of fuel used.

Figure IV-3: Axial Flow Pump



Axial Flow Pumps have been manufactured in Bangladesh since about 2012. They show energy savings of 10-30% for low (<3 m) pumping heads compared to centrifugal pumps. Here the power source is a diesel engine

CIMMYT, Bangladesh consider that the locally manufactured axial flow pumps are still not as energy efficient as ones used in southeast Asia. Catalogue information for axial flow pumps from Thailand gives the following.

Diameter (inch)	***Discharge at 5 m***		***Speed (rpm)***
	(m^3/min)	***l/s***	
5 - 6	3	50	900
7 - 8	7	120	900

One disadvantage of axial flow pumps is their length, typically 4-6 m long, and weight, typically 40-80 kg depending on length and diameter. Unlike a centrifugal pump they are never mounted on the same chassis but may be connected to an engine (dedicated stationary diesel engine or a two-wheel tractor) via rubber V-belts.

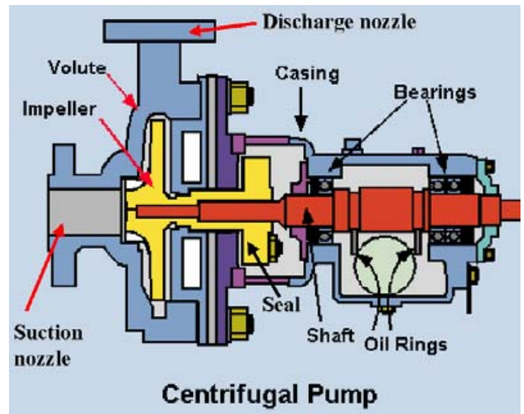
For AFPs there is a large power demand as the pump is starting because there is a column of water and heavy pump impeller to start moving. Once the pump is underway the power demand drops to its usual running level. Starting and shutting down of AFPs should be minimized as much as possible.

For the CAD subprojects pumping heads are likely to exceed 10 m including static lift and friction losses, and axial flow pumps are not suitable.

2. Centrifugal pumps

In Bangladesh centrifugal pumps are widely available and manufactured locally. They are suited to the range of pumping heads required by the CAD subprojects. Pumping characteristics for this type of pump are discussed below.

Figure IV-4: Centrifugal Pumps



C. Pump Performance Curves

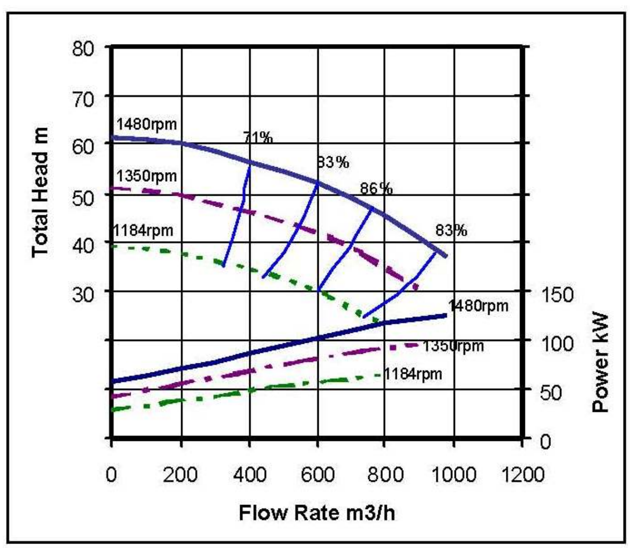
Performance characteristics curves are valid for a certain operating speed. The equations relating the roto-dynamic pump performance parameters of flow (Q), head (H) and power (P) to rotating speed (N) are as follows[17]:

$Q \propto N$

$H \propto N^2$

$P \propto N^3$

The relatively small changes in rotating speed on pump performance (discharge and head) are illustrated on the adjacent figure for a centrifugal pump.



Points of equal efficiency on the curves for the 3 different speeds are joined to make the iso-efficiency lines, showing that pump efficiency remains constant over small changes of speed providing the pump continues to operate at the same position related to its best efficiency point (BEP).

[17] These are collectively known as the Affinity Laws

The affinity laws give a good approximation of how pump performance curves change with speed but in order to obtain the actual performance of the pump in an irrigation system, it has to be matched to the system curve/ required pumping flows and heads, as discussed below.

Note: changing the impeller diameter gives a proportional change in peripheral velocity with flow directly proportional to the impeller diameter D. However for any particular pump it is not possible to change the impeller, at least not without badly affecting efficiency, so pump performance cannot be adjusted this way.

a. Performance Curves for Selected Pumps

Milner Pumps Ltd has a testing facility at their factory in Tongi and pump performance curves are available for their pumps, and are presented here.

The peak efficiency for any pump occurs for a certain single head and discharge and efficiency falls off quite rapidly if the pump is required to pump at different heads. At their optimum operating head and discharge, Milner pumps are 80-83% efficient.

For the six pumps manufactured by Milner's the operating range where pump efficiency is between 70-83% are tabulated below. Data for one larger pump (YANSHAN 250S24) are also give. Performance curves for each pump are included as **Appendix F**.

For the largest Milner pump (F: 150-26 CN), operating against a total head of about 16 m is the most efficient point for operation, and providing the power unit selected can deliver the required power gives a discharge of about 360 m^3/hr. If the head increases, for example due to a decline in the river water level in the lean season, the flow will decrease unless the power delivered by the power unit can be adjusted – easy for diesel motors with a throttle, but less usual for simple / small electric motors. For example, if the head increases to 20 m the flow will decline to 210 m^3/hr and the pump efficiency will drop from 83% to about 70%.

Table IV-2: Pump Models and Operating Heads

Pump ID	Pump Model	Suggested Pipe Size		Range of Flow (m^3/hr)	Range of Total Dynamic Head (m)	Most Efficient Operating Point				
		mm	inch			m	m3/hr	l/s	cusecs	Eff %
A	ETA 80-20	100	4	43 - 111	13.8 - 9	**12**	**84**	23	0.8	80%
B	ETA 100-20	125	5	66-158	12.8 - 8.1	**11**	**120**	33	1.2	80%
C	ETA 125-20	150	6	108 - 288	12.5 - 6.6	**11**	**178**	49	1.7	80%
D	ETA 100-26	125	5	70 - 182	21.5 - 13.7	**19**	**132**	37	1.3	80%
E	ETA 125-26	150	6	117 - 285	22.8 - 15	**20**	**218**	61	2.1	80%
F	ETA 150-26 CN	200	8	212 - 458	20 - 11	**16**	**362**	101	3.6	80%
Yanshan	250 S 24	250	10	250 - 650	29 - 12	**24**	**470**	131	4.6	84%

For subprojects with pumping heads ranging from 6-13 m, Pump Type C is likely to be most suitable, while for higher heads, 11-20 m, Pump Type F is suitable. The Yanshan pump is suitable where even larger heads, from 12-29 m, and higher discharges are required.

Figure IV-5: Pump Performance Curves

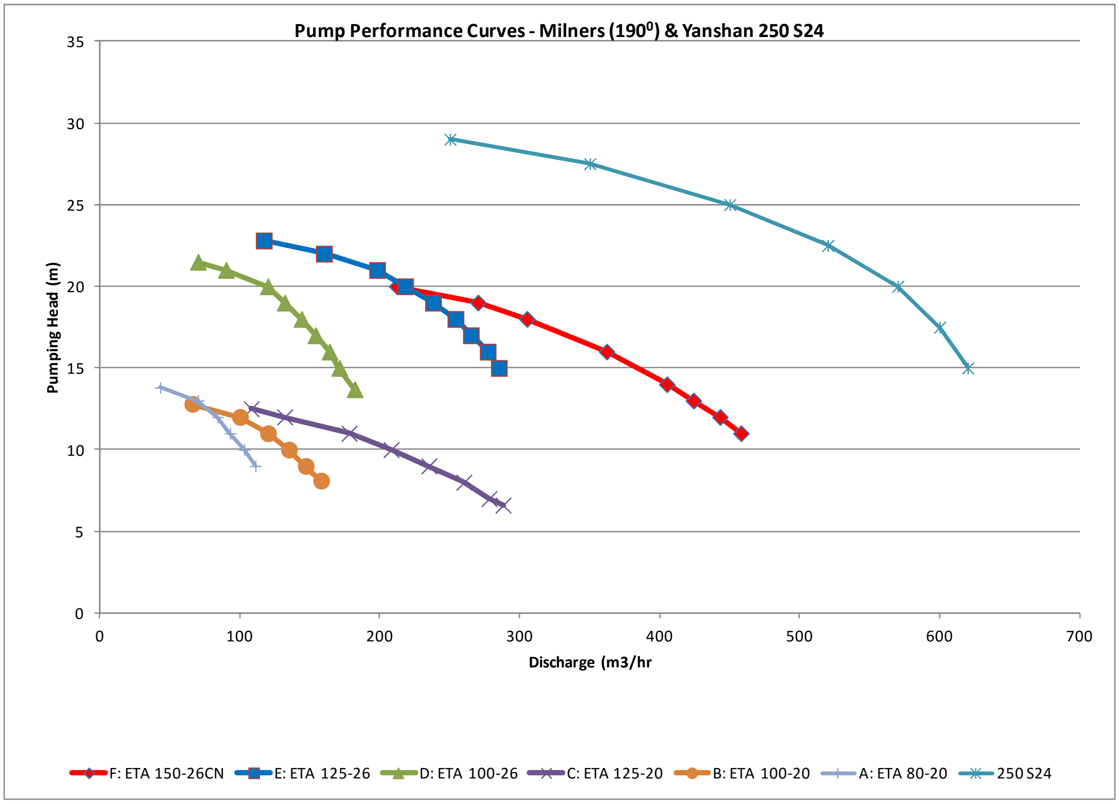
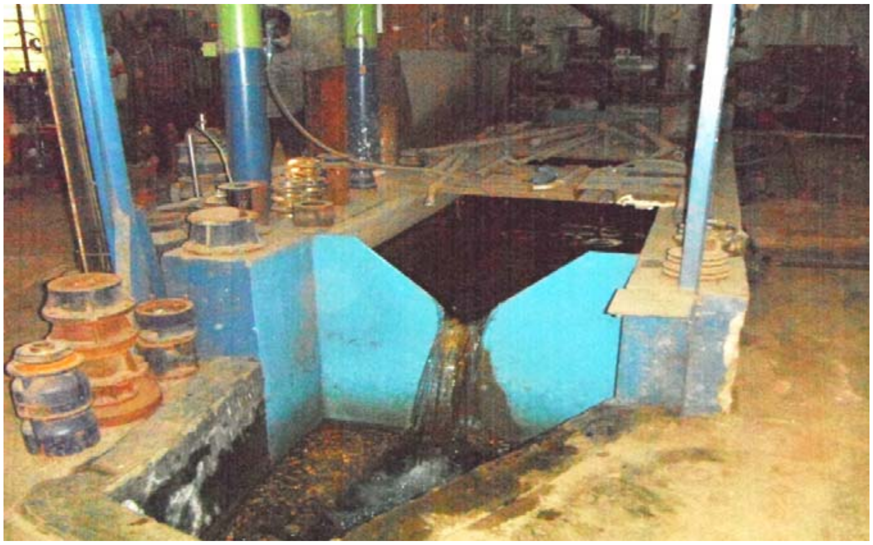


Figure IV-6: Centrifugal Pump Testing, Milnars Factory, Tongi



Testing Pumps at Milnar's Factory (ie measure discharge, head, energy use)

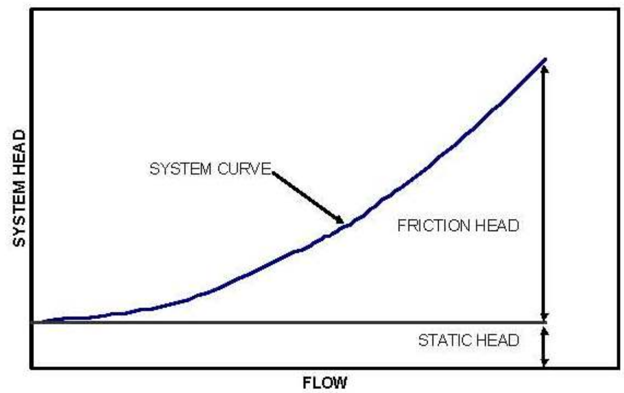
D. System Operating Curves and Energy Efficiency

1. System Operating Curves

For the CAD schemes the pumping equipment (pump and motor) for each system need to cope with variation of both discharge and head depending on crop water requirements and incidence of load shedding. As detailed in Chapter II, the buried pipeline diameter is selected for the *usual* (3-month) duty, but the system accommodates the *maximum* or *peak* (1-month). If there is severe load shedding then at least part of the pumping should be using diesel.

For most of our CAD systems the total (static plus friction) pumping head will be between 4 - 18 m for the *usual* duty, increasing to between 9 – 23 m for the *maximum* duty. ** REF **

Each system has a unique operating curve showing the relationship between head and flow.



Note: the pumping head is comprised of both friction losses in the suction and delivery pipelines as well as the static lift from the khal / river to the header tank.

2. Varying Pump Performance to Minimise Energy Use

As discussed in Chapter II, water requirements vary through the season / year, but sufficient pumping capacity should be provided to meet the *peak* (1-month) demand. Most of the time irrigation demand will be less than this.

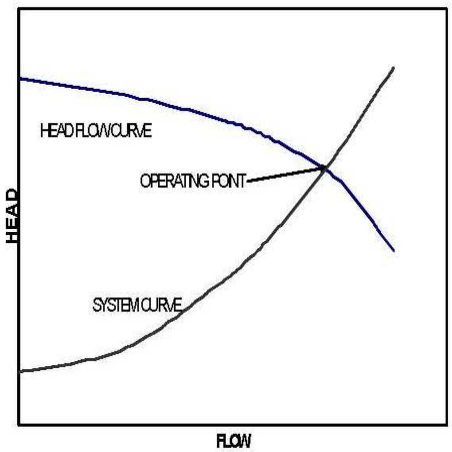
Options to match pumping supply to demand include the following:

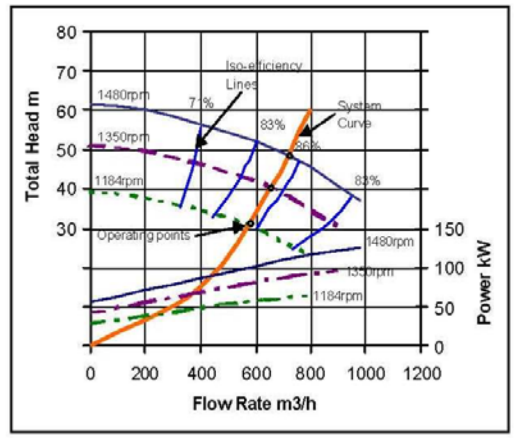
- Option 1: Pumping for only a few hours each day. This is a high energy cost option as pumping head will be at a maximum for the time the pump(s) are operated. For this reason Option 1 is not recommended.
- Option 2: Adjusting pump speed. This is easy to do with diesel pumps and farmers often try to minimise fuel costs by throttling down the engines to reduce speeds. However for electric pumps this is more difficult.
- Option 3: Adoption of several pumps working together (ie in parallel), and using the minimum number of pumps commensurate with irrigation demand.
- Option 4: Adoption of pumps which operate separately – this option will only be attractive if there is a large range of operating heads to be met, and significant efficient gains will result from having separate pumps to meet the usual and peak flows.

a. Pump Control by Adjusting Speed

Figure IV-7, shows a system curve plotted together with the head – flow characteristics of a pump. For a single pump operating at constant speed there is only one operating point. For a variable flow pump, reducing speed moves the intersection point on the system curve along a line of constant efficiency. The operating point of the pump, relative to its best efficiency point, remains constant and the pump continues to operate in its ideal region. The affinity laws are obeyed which means that there is a substantial reduction in power absorbed (energy used) accompanying the reduction in flow and head.

Figure IV-7: System Curve and Variable Speed Pump





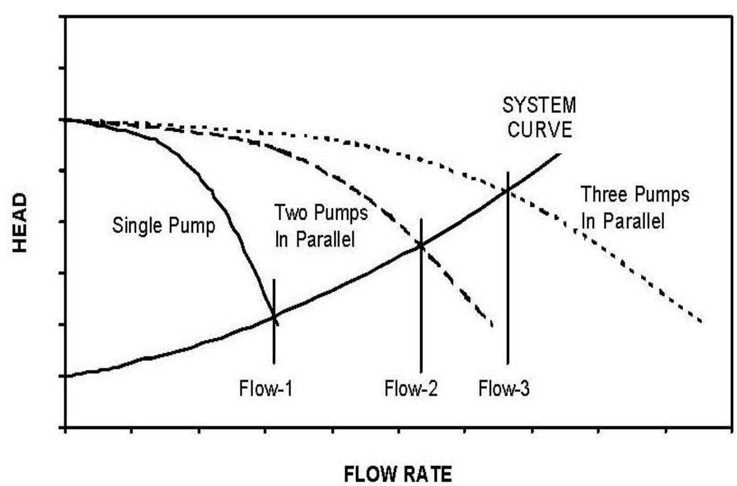
Single Pump (one operating point)

Variable Speed Pump (several operating points)

In addition to energy savings there could be other benefits of lower speed. The hydraulic forces on the impeller, created by the pressure profile inside the pump casing, reduce approximately with the square of speed. These forces are carried by the pump bearings and so reducing speed increases bearing life. In addition, vibration and noise are reduced and seal life is increased providing the duty point remains within the allowable operating range.

b. Multiple Pumps working in Parallel

Installing several pumps working in parallel is an energy efficient method of flow control with variation in flow met by switching on and off the additional pump(s) to meet demand.



The system curve is usually not affected by the number of pumps that are running. For any one CAD system with a combination of static and friction head loss, it can be seen, that the operating point of the pumps on their performance curves moves to a higher head and hence lower flow rate per pump, as more pumps are started. It is also apparent that the flow rate with two pumps running is not double that of a single pump.

It is possible to run pumps of different sizes/ types in parallel providing their closed valve heads are similar (ie overlap). For example, with reference to Figure IV-5 above, pump types D (ETA 100-26) and E (ETA 125-26) would operate well in parallel against heads in the range 14-20 m, but neither are very suited to operate together with pump C (ETA 125-20) which has a closed valve pressure of about 13 m.

For most subprojects, adopting a combination of three or more compatible pumps is likely to be most efficient.

E. Pumping Power Requirements

For a given discharge and head the power required by the pump is given by:

Power (kW) = 9.81 x discharge (m^3/s) x head (m) / pump efficiency

This is sometime expressed as:

Power (kW) = discharge (l/s) x head (m) / 102 x pump efficiency

As noted above, the efficiency of the pumps will be about 70-80% provided that suitable pumps are selected and are operating within their recommended pumping head.

For the range of Milner pumps manufactured in Bangladesh the pumping power requirements for the most efficient operating points (about 80% efficiency) are given below. Data for the large Yanshin pump are also given.

Table IV-3: Pump Model, Most Efficient Operating Point and Power Required

Pump ID	Pump Model	Suggested Pipe Size		Most Efficient Operating Point					Pump power required	
		mm	inch	m	m3/hr	l/s	cusecs	Eff %	kW	HP
A	ETA 80-20	100	4	12	84	23	0.8	80%	3.4	4.6
B	ETA 100-20	125	5	11	120	33	1.2	80%	4.5	6.0
C	ETA 125-20	150	6	11	178	49	1.7	80%	6.7	8.9
D	ETA 100-26	125	5	19	132	37	1.3	80%	8.5	11.4
E	ETA 125-26	150	6	20	218	61	2.1	80%	14.9	19.9
F	ETA 150-26 CN	200	8	16	362	101	3.6	80%	19.7	26.4
Yanshan	250 S 24	250	10	24	470	131	4.6	84%	38.4	51.5

For the largest Milner pump (F: 150-26 CN), the pumping power requirement to deliver 362 m^3/hr (101 l/s; 3.6 cusecs) against a total head of 16 m is about 20 kW, or 27 HP.

For the (10 inch) Yanshan pump, 250 S24 the pumping power required to deliver 470 m^3/hr (131 l/s; 4.6 cusecs) against a total head of 24 m is about 38 kW (52 HP).

1. Diesel Motor

For a diesel motor (engine), its Break Horse Power, BHP (power output) must at least equal the power required by the pump calculated above. However in practice the following considerations are taken into account:

(i) ***Fuel efficiency*** – engine fuel efficiency drops when operated at maximum power and speed (rpm), and also a very low power and speed, with optimum fuel efficiency occurring at a middling power and speed. The pump curves given above are for an operating speed of 1450 – 1500 rpm. Typical diesel engines may operate at speeds from 1000 to 2400 rpm, and a speed of about 1500 is likely to give maximum fuel efficiency. Therefore if the pump power requirement is calculated to be 26 HP, then adopting a diesel engine with a 10-20% higher power output, ie about 30 BHP, is likely to enable higher fuel efficiency.

(ii) ***Service life***: engines for pumping water are likely to be operated continuously for long periods, and service life is increased by operating them at about 80% peak power and speeds.

As a rule of thumb, the power delivered by the engine (its break horse power, BHP) should be 10-20% higher than the pumping power requirement. Adopting 15% gives diesel engine BHP requirements for the range of Milner pumps as tabulated below. For the largest Milner pump (F: 150-26 CN), a 30-32 BHP engine is appropriate. For the Yanshan pump, a 60 BHP engine is needed.

Table IV-4: Diesel Engine Output Power Requirements

Pump ID	Pump Model	Most Efficient Operating Point					Pump power required		Diesel Engine Output Power		Suggest
		m	m3/hr	l/s	cusecs	Eff %	kW	HP	kW	BHP	BHP
A	ETA 80-20	12	84	23	0.8	80%	3.4	4.6	3.9	5.3	5.5
B	ETA 100-20	11	120	33	1.2	80%	4.5	6.0	5.2	6.9	7
C	ETA 125-20	11	178	49	1.7	80%	6.7	8.9	7.7	10.3	10-12
D	ETA 100-26	19	132	37	1.3	80%	8.5	11.4	9.8	13.2	12-15
E	ETA 125-26	20	218	61	2.1	80%	14.9	19.9	17.1	22.9	22-25
F	ETA 150-26 CN	16	362	101	3.6	80%	19.7	26.4	22.7	30.4	30-32
Yanshan	250 S 24	24	470	131	4.6	84%	38.4	51.5	44.2	60.1	60

The energy efficiency of internal combustion engines is typically 15-35%, as most of the energy of the fuel is wasted as heat.

Two pump sets with Type F Milner Pumps, and diesel engines with rated outputs of 28 and 32 BHP, Baneswardi, May 2014

2. Electric Motor

The power output of an electric motor must supply the power required by the pump as calculated in Table IV-3 above.

While the power of diesel engines usually refers to their *output* power, the power for an electric motor typically refers to its rated *input* power, which is the power it can safely take without burn-out.

The rated input power for an electric motor is typically given by:

Pumping power requirement / motor efficiency

The motor power ratings required for the range of Milner pumps is tabulated below for 80% motor efficiencies. For the largest Milner pump (F: 150-26 CN), a 25 kW (33 HP) rated motor is appropriate. For the Yanshan pump a 48 kW (65 HP) electric motor is needed.

Table IV-5: Electric Motor Input Power Requirements

Pump ID	Pump Model	Most Efficient Operating Point					Pump power required		Electric Motor Input Power rating		Suggest
		m	m3/hr	l/s	cusecs	Eff %	kW	HP	kW	HP	HP
A	ETA 80-20	12	84	23	0.8	80%	3.4	4.6	4.3	5.8	6
B	ETA 100-20	11	120	33	1.2	80%	4.5	6.0	5.6	7.5	8
C	ETA 125-20	11	178	49	1.7	80%	6.7	8.9	8.3	11.2	12
D	ETA 100-26	19	132	37	1.3	80%	8.5	11.4	10.7	14.3	14-16
E	ETA 125-26	20	218	61	2.1	80%	14.9	19.9	18.6	24.9	25-26
F	ETA 150-26 CN	16	362	101	3.6	80%	19.7	26.4	24.7	33.0	30-35
Yanshan	250 S 24	24	470	131	4.6	84%	38.4	51.5	48.0	64.4	60-65

The efficiency of electric motors is typically 75-80%, much higher than for internal combustion engines. Most of the wasted energy is in the form of heat.

Pump set with large Milner's Pump and electric motor, Milner's Pump Factory, Tongi June 2014

Control Switch for electric motor June 2014

F. Selection of Suitable Pumps and Motors for CAD Subprojects

The capital cost of pump sets and associated equipment is typically about US$ 15-20/ ha, Table I-5, while seasonal energy costs using subsidized electricity is about US$ 20/ ha (Tk 7 / dc), *Table IV-7*. In other words, the amount spent on energy in a single year is more than the cost of the pump sets. Taking care to select pumps that will be operating efficiently will save farmers a great deal of money.

To allow for varying irrigation demand at least three pump sets are recommended for our CAD subprojects, and in general 3-6 pumps will be provided depending on scheme size, location and crops grown.

High energy efficiency will usually be achieved by adoption of compatible pumps working in parallel to meet the *usual* water demand operations, as well as *peak* water demand and when the header tank will be full.

If the range of operating head is within the design head range for a single pump, then all the pumps may be the same. However it may be that the booster pumps used to meet peak demand are selected as being suitable for higher heads.

For some CAD subprojects where there is a large operating head range, it may be best to adopt lower head pumps to meet usual flows, and higher head pumps to meet peak flows. Where these pumps are not compatible with each other they should be operated separately (not in parallel).

a. Friction Losses

Steel pipe friction and bend losses are given below for the range of pumps considered. For the largest pump (F: 150-26 CN), pumping 362 m^3/hr (101 l/s, 3.6 cusecs), the pipe flow velocity would be 3.2 m/s, and the pipe friction loss would 3.9% (calculated using the Colebrook White equation and for ks =0.03). Losses in a 90^0 bend would be 0.4 m (adopting 0.75 $V^2/2g$).

For a reasonable typical pumping installation comprising 4 bends / fittings and 40 m of pipe, the total friction head loss would be about 3-4 m for *peak* flows, dropping to about half this for *usual* flows.

Table IV-6: Bend and Pipe Friction Losses

Pump ID	Pump Model	Suggested Pipe Size		Most Efficient Operating Point					Pipe flow	90^0 Bend Loss	Pipe Friction loss	Loss for 40 m of pipe
		mm	inch	m	m3/hr	l/s	cusecs	Eff %	m/s	m	%	m
A	ETA 80-20	100	4	12	84	23	0.8	80%	3.0	0.34	7.5%	3.00
B	ETA 100-20	125	5	11	120	33	1.2	80%	2.7	0.28	4.8%	1.92
C	ETA 125-20	150	6	11	178	49	1.7	80%	2.8	0.30	4.1%	1.64
D	ETA 100-26	125	5	19	132	37	1.3	80%	3.0	0.34	6.0%	2.40
E	ETA 125-26	150	6	20	218	61	2.1	80%	3.4	0.45	6.2%	2.48
F	ETA 150-26 CN	200	8	16	362	101	3.6	80%	3.2	0.39	3.9%	1.56
Yanshan	250 S 24	250	10	24	470	131	4.6	84%	2.7	0.27	3.0%	1.20

b. Steps for Pump Selection

To select the required number(s) of suitable pumps the following design steps are suggested:

- From the net irrigation area and crop mix calculate the *peak* and *usual* discharges.

- Determine the system curve for the subproject by:
    - Calculating the water level in the header tank for three different flows, eg peak flow, usual flow and one other. This should be done for the critical (usually longest) pipeline. Thence determine the static pumping head (ie the difference between the lean season river/ khal water level and the water level in the header tank) for each flow. Note: only for the *peak* flow will the header tank be full.
    - Adopt diameter for pipe steel work and determine the friction head loss in the pipe and pipe fittings for each flow. Note: as the number of pumps operated will be reduced for lower flows, the friction loss for the peak flow with all pumps operating may be adopted for all scenarios.
    - Total head for each of the 3 different flows is given by the friction loss plus the static lift.
- Select numbers and types / capacities of pumps to meet head and discharge requirements. Where possible adopt compatible pumps that may be operated in parallel. Clearly specify the numbers and types of pumps to be operated to meet: (i) the *usual* flow and head conditions, and (ii) the *peak* flow and head conditions.

G. Pumping Energy Requirement and Cost

Pumping costs are given by the product of energy used and unit cost of energy.

The energy used is the power required by the motor times the duration the motor is running.

Thus for a given discharge and head the energy required is given by:

$$Energy\ (kWh) = \frac{9.81\ Q\ H\ T}{(e_1\ e_2)}$$

where:

Q is the pumped discharge (m^3/s)
H is the average pumping head (m)
e_1 the pump efficiency (in the order 0.7–0.85)
e_2 the motor driving efficiency (0.7–0.9 for electric motors and 0.1–0.35 for diesel engines).

As indicated in the above equation, pumping efficiencies are given by the product of the efficiencies of: (i) the pump; and (ii) the power unit. The efficiency of the pump is usually about 70-85% provided that a suitable pump is selected and is operating not too far from its optimal pumping head and discharge. The efficiency of the power unit varies from: (i) 70-90% for electric motors; and (ii) 10-35% for internal combustion engines.

Unless improved data are available the following efficiencies are suggested for the calculation of power requirements:

- Pumps: 0.75
- Electric motor: 0.75
- Diesel engine: 0.25

A (spreadsheet) calculation of power requirements is tabulated below for a scheme net irrigation area of 313 ha, a gross water requirements of 826 mm and an average pumping head of about 9 m.

Table IV-7: Power & Energy Requirements

Nr	Item	Electric Pumping	Diesel Pumping	Units
	Water Requirements	429		
1.1	Net Irrigation Requirements	826		mm
1.2	Gross irrigation requirements	826		mm
		8,263		m³/ha
1.3	Average pumping Head	9.0		m
	Pumping Hours			
2.1	Nr of pumping days per season (with staggered planting)	140		days
2.2	Nr of pumping hours per day	20		hours
2.3	Nr of pumping hours per season	2,800		hours
	Irrigation Flows			
3.1	Average flow required per ha	2.95		m³/hr per ha
		0.82		l/s per ha
3.2	Net Irrigation Area	313		Ha
3.3	Flow required for scheme	256		l/s
	Pump & Motor Efficiencies & Power Required			
4.1	Pump efficiency	0.75	0.75	
4.2	Motor efficiency	0.75	0.25	
4.3	Average power required per hectare	0.13	0.26	kW/ha
4.4	Average power required for scheme	40.2	7.8	kW
		54.7	10.6	HP
	Energy Requirements			
5.1	Energy required per ha for the season	360	584	kWh / ha
5.2	Energy required for the season for scheme	112,687	17,531	kWh
	Cost with Electric Pumping			
6.1	Cost of electricity	4.5		BDT / kWh
6.2	Cost of pumping	1,620		BDT per ha
		656		BDT per ac
		6.6		BDT per dc
		20.3		US$ per ha
		2,450		US$ per Mm³
	Cost with Diesel Pumping			
7.1	Fuel consumption rate		0.15	l / kWh
7.2	Fuel consumption / ha for the season		162	l /ha
7.3	Cost of diesel fuel		68	BDT / l
7.4	Cost of pumping		9,181	BDT per ha
			3,715	BDT per ac
			37.2	BDT per dc
			114.8	US$ per ha
			13,900	US$ per Mm³
7.5	Fuel efficiency		61	m³ water / l fuel

These calculations indicate that average power requirements are 40.2 kW (0.13 kW/ha) for electric pumping and 100 kW (0.32 kW/ha) for diesel, and the energy required for the lean season is 360 kWh/ha for electric pumping and 900 kWh/ha for diesel.

A fuel consumption rate for diesel pumps of 0.15 l / kWH is adopted to determine diesel fuel requirements[18].

For the current (2014) energy cost rates, pumping costs for boro are likely to be about US$ 20 / ha and US$ 110 / ha for electric and diesel respectively.

For diesel pumping efficiency may be expressed as the volume of water pumped per unit of fuel used, and is about 60 m^3 of water / l of fuel.

These calculations indicate that pumping with electric pumps is much cheaper than using diesel, about 1/5th of the diesel pumping costs. However to firm up pumping costs, particularly for diesel pumps, additional data / pump testing is required.

H. Pump Accessories

Suction pipes lead from the river / khal to the pumps. These are fitted with a screen and a (flap) foot-valve at the end to: (i) prevent entry of debris or stones that may damage the pump impeller; and (ii) to held water in the pipe and facilitate pump priming at start up. To minimise leakage the flap valve must have a river seal. The suction pipeline should have flanged connections so that they can be removed during the monsoon, and extra pipe lengths added as required in dry years.

From the pumps pressure pipes lead to the header tank. These are usually fitted with: (i) a 1½ -2 inch priming pipe to allow water to be poured into the pipe system and pump at start up; (ii) a ½ inch take off pipe to allow cooling water to be taken off – only required for diesel pumps; and (iii) ideally a gate valve. The gate valve, when fitted, ensures that leakage from the header tank back to the river does not occur and, proving water is retained in the header tank, facilitates pump priming using water from the header tank.

To safely accommodate high pressures that may be generated at pump start up / shut down steel pipes are recommended. If uPVC pipes are used to reduce costs, then they should be thicker walled and able to take a nominal pressure of at least 6 bars. Even so, unless they can be buried, they remain vulnerable to damage and are likely to deteriorate (become brittle) in sunlight. Other accessories include pipe bends and pipe supports.

Screen and foot-valve with flange connection

1½ inch pipe fitted to 8 inch outlet pipe to allow pump priming. ½ inch pipe also fitted for draw off of cooling water for diesel engine

[18] CSIRO report 20/02 – January 2002 reports fuel consumption rates of 0.09 to 0.25 l / kWh

APPENDICES

Appendix A: uPVC Pipe Rates (2014/15)

	Outside Diameter mm	Nominal Wall thickness mm	Internal Diameter mm	All-in Installation Rate (2014) BDT/m
1	160	2.00	156	652
2	180	2.30	175	809
3	200	2.50	195	971
4	225	2.80	219	1,449
5	250	3.10	244	1,542
6	280	3.50	273	1,901
7	315	4.00	307	2,469
8	355	4.40	346	3,113
9	400	5.00	390	3,849
10	450	5.60	439	4,913
11	500	6.20	488	5,700

1. Working Pressure: 3.25 bar (32 m head)
2. Pipe sizes & wall thickness in accordance with ISO-4422 and ISO-4065 for required working pressure - the nominal wall thickness is the minimum diameter
3. Ex-factory rates as quoted by Suppliers in August 2011
4. Total rate is the all-in Installation rate for the uPVC pipeline including placing, connecting and jointing but excluding bedding & trench earthworks (O-ring jointing proposed)
5. In estimating pipe quantity allow for jointing wastage of (say) 3-8% depending on pipe diameter

Appendix A2: Suggested Rates for Pump Sets and Associated Items

S.No	Work description		Rate (2014/15)	
		Unit	BDT	US$
Steel Pipes & Fittings				
6.9.01	Supplying MS pipes of standard thickness including painting with anticorrosive paint, laying in position and true to alignment, fitting, fixing and joining by welding and / or flange connections all complete as per specifications and drawings and as per direction of the Engineer in Charge:			
	- Internal diameter 100 mm (4 inch)	m	2,321	30.14
	- Internal diameter 125 mm (5 inch)	m	2,901	37.67
	- Internal diameter 150 mm (6 inch)	m	**3,442**	44.70
	- Internal diameter 200 mm (8 inch)	m	**4,733**	61.46
	- Internal diameter 250 mm (10 inch)	m	**6,903**	89.65
6.09.08	Supplying and installation of different diameters of Gate Valves used in any pipeline system, including different diameter flange, dresser rubber washer, nut, bolts, gasket, welding, fixing, etc all complete as per drawing, specification and direction of the Engineer in Charge			
0.1	500 mm dia. gate valve (20 inch)	each	124,195	1,612.92
0.2	450 mm dia. gate valve (18 inch)	each	112,000	1,454.55
0.3	400 mm dia. gate valve (16 inch)	each	97,600	1,267.53
0.4	355 mm dia. gate valve (14 inch)	each	72,200	937.66
0.5	315 mm dia. gate valve (12 inch)	each	57,200	742.86
0.6	280 mm dia. gate valve	each		0.00
0.7	250 mm dia. gate valve (10 inch)	each	42,000	545.45
0.8	225 mm dia. gate valve	each		0.00
0.9	200 mm dia. gate valve (8 inch)	each	33,099	429.86
0.10	150 mm dia. gate valve (6 inch)	each	22,500	292.21
0.11	125 mm dia. gate valve	each		0.00
0.12	100 mm dia. gate valve (4 inch)	each	15,500	201.30
6.09.13	Supplying and installation of different diameters of MS perforated Foot Valve including painting with anticorrosion paint, laying in position, fitting, fixing and joining by welding and / or flange connection all complete as per drawing, specification and direction of the Engineer in Charge:			
0.1	- Internal diameter 100 mm (4 inch)	each	3,295	42.80
0.2	- Internal diameter 125 mm (5 inch)	each	4,119	53.49
0.3	- Internal diameter 150 mm (6 inch)	each	4,887	63.47
0.4	- Internal diameter 200 mm (8 inch)	each	**6,717**	87.23
0.5	- Internal diameter 250 mm (10 inch)	each	9,803	127.31
6.09.14	Supplying and installation of different diameters of 90^0 MS Bend including painting with anticorrosion paint, laying in position, fitting, fixing and joining by welding and / or flange connection all complete as per drawing, specification and direction of the Engineer in Charge:			
0.1	- Internal diameter 100 mm (4 inch)	each	2,437	31.64
0.2	- Internal diameter 125 mm (5 inch)	each	3,046	39.56
0.3	- Internal diameter 150 mm (6 inch)	each	3,614	46.93
0.4	- Internal diameter 200 mm (8 inch)	each	**4,748**	61.66
0.5	- Internal diameter 250 mm (10 inch)	each	7,248	94.13
6.09.**	Supplying and installation of different diameters of 45^0 MS Bend including painting with anticorrosion paint, laying in position, fitting, fixing and joining by welding and / or flange connection all complete as per drawing, specification and direction of the Engineer in Charge:			
0.1	- Internal diameter 100 mm (4 inch)	each	2,193	28.48
0.2	- Internal diameter 125 mm (5 inch)	each	2,741	35.60
0.3	- Internal diameter 150 mm (6 inch)	each	3,252	42.24
0.4	- Internal diameter 200 mm (8 inch)	each	**4,273**	55.50
0.5	- Internal diameter 250 mm (10 inch)	each	6,524	84.72

S.No	Work description	Unit	Rate (2014/15) BDT	Rate (2014/15) US$
6.09.**	Supplying and installation of 125mm - 150 mm (5 - 6 inch) ecentric expansion MS pipe joint for the pipe system including painting with anticorrosion paint, laying in position, fitting, fixing and joining by welding and / or flange connection all complete as per direction of the Engineer in Charge	Nr	6,883	89.39
6.09.**	Supplying and installation of 125mm - 200 mm (5 - 8 inch) ecentric expansion MS pipe joint for the pipe system including painting with anticorrosion paint, laying in position, fitting, fixing and joining by welding and / or flange connection all complete as per direction of the Engineer in Charge	Nr	8,519	110.63
6.09.**	Supplying and installation of 150mm - 200 mm (6 - 8 inch) ecentric expansion MS pipe joint for the pipe system including painting with anticorrosion paint, laying in position, fitting, fixing and joining by welding and / or flange connection all complete as per direction of the Engineer in Charge	Nr	**9,465**	122.93
6.09.**	Supplying and installation of 150mm - 250 mm (6 - 10 inch) ecentric expansion MS pipe joint for the pipe system including painting with anticorrosion paint, laying in position, fitting, fixing and joining by welding and / or flange connection all complete as per direction of the Engineer in Charge	Nr	12,426	161.37
6.09.**	Supplying and installation of 200mm - 250 mm (8 - 10 inch) ecentric expansion MS pipe joint for the pipe system including painting with anticorrosion paint, laying in position, fitting, fixing and joining by welding and / or flange connection all complete as per direction of the Engineer in Charge	Nr	13,806	179.30
Pumps with Diesel Engines				
6.13.20	Supply, installation and commissioning of approved pump-set including: (i) Water Pump for rated head and discharge with operating efficiency > 70%, complete with suction and discharge pipe flange connections and priming arrangement; and (ii) a Diesel Engine with rated power complete with self starter and battery; all mounted on (iii) a steel Base-frame. Pump, flanges, pipe-work and steel frame to be painted in accordance with the Specification. Discharge and power requirements as follows:			
0.1	- 3 inch pump: Rated discharge 84 m3/hr, 0.8 cusecs (43 - 111 m3/hr), Rated head 12 m (13.8 - 9.0 m), 3-4 inch flanged connections, 6 HP engine	Nr	51,459	668.30
0.2	- 4 inch pump: Rated discharge 120 m3/hr, 1.2 cusecs (66 - 158 m3/hr), Rated head 11 m (12.8 - 8.1 m), 4-5 inch flanged connections, 7 HP engine	Nr	64,715	840.46
0.3	- 5 inch pump: Rated discharge 178 m3/hr, 1.7 cusecs (108 - 288 m3/hr), Rated head 11 m (12.5 - 6.6 m), 5-6 inch flanged connections, 9 HP engine	Nr	86,275	1,120.46
0.4	- 4 inch pump: Rated discharge 132 m3/hr, 1.3 cusecs (70 - 182 m3/hr), Rated head 19 m (21.5 - 13.7 m), 4-5 inch flanged connections, 12 HP engine	Nr	76,231	990.01
0.5	- 5 inch pump: Rated discharge 218 m3/hr, 2.1 cusecs (117 - 285 m3/hr), Rated head 20 m (22.8 - 15 m), 5-6 inch flanged connections, 20 HP engine	Nr	101,636	1,319.95
0.6	- 6 inch pump: Rated discharge 362 m3/hr, 3.6 cusecs (212 - 458 m3/hr), Rated head 16 m (20 - 11 m), 6-8 inch flanged connections, 27 HP engine	Nr	139,056	1,805.92
0.7	- 10 inch pump: Rated discharge 470 m3/hr, 4.6 cusecs (250 - 650 m3/hr), Rated head 24 m (29 - 12 m), 10 inch flanged connections, 52 HP engine	Nr	265,197	3,444.11

S.No	Work description		Rate (2014/15)	
		Unit	BDT	US$
Pumps with Electric Motors				
6.13.21	Supply, installation and commissioning of pump-set including: (i) Water Pump for rated head and discharge with operating efficiency > 70%, complete with suction and discharge pipe flange connections and priming arrangement; and (ii) AC 3-phase, 50 Hz, 380 $\pm$5% Voltage squirrel cage Electric Motor; (iii) Starter enclosed within metal box and ensuring adequate protection to motor against overload and with 3-phase volt and amp meter and neon indicators; (iv) Capacitor Bank to keep power factor on 0.95 and installed inside Starter Box; (v) Switch Fuse Unit (Main Switch) with indicator lamps suitable for outside use and complete with housing; (vi) a steel Base-frame for Pump and Motor. Pump, flanges, pipe-work and steel frame to be painted in accordance with the Specification. Discharge and power requirements as follows:			
0.1	- 3 inch pump, Rated discharge 84 m3/hr, 0.8 cusecs (43 - 111 m3/hr), Rated head 12 m (13.8 - 9.0 m), 3-4 inch flanged connections, 4.3 kW (5.8 HP) min. power rating	Nr	100,078	1,299.71
0.2	- 4 inch pump, Rated discharge 120 m3/hr, 1.2 cusecs (66 - 158 m3/hr), Rated head 11 m (12.8 - 8.1 m), 4-5 inch flanged connections, 5.6 kW (7.6 HP) min. power rating	Nr	126,590	1,644.02
0.3	- 5 inch pump, Rated discharge 178 m3/hr, 1.7 cusecs (108 - 288 m3/hr), Rated head 11 m (12.5 - 6.6 m), 5-6 inch flanged connections, 8.3 kW (11.3 HP) min. power rating	Nr	169,709	2,204.02
0.4	- 4 inch pump, Rated discharge 132 m3/hr, 1.3 cusecs (70 - 182 m3/hr), Rated head 19 m (21.5 - 13.7 m), 4-5 inch flanged connections, 10.7 kW (14.5 HP) min. power rating	Nr	150,063	1,948.87
0.5	- 5 inch pump, Rated discharge 218 m3/hr, 2.1 cusecs (117 - 285 m3/hr), Rated head 20 m (22.8 - 15 m), 5-6 inch flanged connections, 18.6 kW (25.2 HP) min. power rating	Nr	225,874	2,933.43
0.6	- 6 inch pump, Rated discharge 362 m3/hr, 3.6 cusecs (212 - 458 m3/hr), Rated head 16 m (20 - 11 m), 6-8 inch flanged connections, 24.7 kW (33.5 HP) min. power rating	Nr	285,536	3,708.26
0.7	- 10 inch pump, Rated discharge 470 m3/hr, 4.6 cusecs (250 - 650 m3/hr), Rated head 24 m (29 - 12 m), 10 inch flanged connections, 48 kW (65.3 HP) min. power rating	Nr	454,107	5,897.49
Electric Power Connection				
8.08.4	Supplying all materials as per requirement of power development board for service connection from PDB pole to the desired structure and any other charges (eg. Security deposit, connection fee, meter installation, testing fee) required by the power development board for supply of power through underground cable / overhead line, etc, complete as per direction of the Engineer in Charge	LS (PS)	(450,000)	(5,844.16)

Appendix B: Climate Data and Crop Water Requirements

Appendix B1: Description of FAO Programmes for CWR Calculation

CLIMWAT is a climatic database to be used in combination with the computer program CROPWAT and allows the calculation of crop water requirements, irrigation supply and irrigation scheduling for various crops for a range of climate stations worldwide.

CLIMWAT 2.0 for CROPWAT is a joint publication of the Water Development and Management Unit and the Climate Change and Bio-energy Unit of FAO. It offers observed agro-climatic data of over 5000 stations worldwide.

CLIMWAT provides long-term monthly mean values of seven climatic parameters, namely:

i. Mean daily maximum temperature in °C
ii. Mean daily minimum temperature in °C
iii. Mean relative humidity in %
iv. Mean wind speed in km/day
v. Mean sunshine hours per day
vi. Mean solar radiation in MJ/m2/day
vii. Monthly rainfall in mm/month
viii. Monthly effective rainfall in mm/month
ix. Reference evapotranspiration calculated with the Penman-Monteith method in mm/day.

The data can be extracted for a single or multiple stations in the format suitable for their use in CROPWAT. Two files are created for each selected station. The first file contains long-term monthly rainfall data [mm/month]. Additionally, effective rainfall is also included calculated and included in the same file. The second file consists of long-term monthly averages for the seven climatic parameters listed above. This file also contains the coordinates and altitude of the location.

All station information is drawn from the database of the Agromet Group of FAO.

All variables, except potential evapotranspiration, are direct observations or conversions of observations. Original data coming from a large number of meteorological stations as included in CLIMWAT, could not be uniform. For example, humidity and radiation can be expressed through different variables. With respect to humidity, data can be provided as relative humidity, dew point temperature or water vapour pressure. These three variables can be uniquely converted into each other if the mean temperature is known. However, if humidity is measured and provided in more than one of these variables, the actual numbers would not necessarily be in line. In this case it is necessary to decide which variable to use. When compiling CLIMWAT, it was decided to use water vapour pressure as a core variable and only where it is not available, use dew point temperature and relative humidity. However, there is a risk that the provided value of vapour pressure is higher than the one that is possible to obtain, given the mean temperature. The original databases were crosschecked for this possible inconsistency and one of the other variables was used in the few cases where it occurred.

The same problem arises with radiation. Instead of the solar energy flux at the surface often only sunshine hours or sunshine fraction are recorded, both of which though can be converted to radiation. In order to calculate evapotranspiration using the Penman-Monteith method, both radiation and sunshine fraction are necessary. To keep both these values in agreement the observed radiation was used as base variable and the sunshine fraction was estimated from it. When only the sunshine fraction (or hours) has been observed it was used to estimate radiation. If both (fraction and radiation) are observed radiation was preferred.

As a result, the provided relative humidity and sunshine hours are often deduced from observations of vapour pressure and radiation, even if the former are observed. The procedure, however, ensures that the different expressions are coherent.

In compiling the data, an effort was made to cover the period 1971 - 2000, but when data for this period were not available, any recent series that ends after 1975 and that has at least 15 years of data have been included. Some of the series are "broken", but they nevertheless have at least 15 years of data (e.g. 1961-70 and 1992-2000).

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO. CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions.

All calculation procedures used in CROPWAT 8.0 are based on the two FAO publications of the Irrigation and Drainage Series, namely, No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements" and No. 33 titled "Yield response to water".

As a starting point, and only to be used when local data are not available, CROPWAT 8.0 includes standard crop and soil data. When local data are available, these data files can be easily modified or new ones can be created. Likewise, if local climatic data are not available, these can be obtained for over 5,000 stations worldwide from CLIMWAT, the associated climatic database. The development of irrigation schedules in CROPWAT 8.0 is based on a daily soil-water balance using various user-defined options for water supply and irrigation management conditions. Scheme water supply is calculated according to the cropping pattern defined by the user, which can include up to 20 crops.

CROPWAT 8.0 is a Windows program based on the previous DOS versions. Apart from a completely redesigned user interface, CROPWAT 8.0 for Windows includes a host of updated and new features, including:

i. Monthly, decade and daily input of climatic data for calculation of reference evapotranspiration (ETo).
ii. Backward compatibility to allow use of data from the CLIMWAT database.
iii. Possibility to estimate climatic data in the absence of measured values.
iv. Decade and daily calculation of crop water requirements based on updated calculation algorithms including adjustment of crop-coefficient values.
v. Calculation of crop water requirements and irrigation scheduling for paddy & upland rice, using a newly developed procedure to calculate water requirements including the land preparation period.
vi. Interactive user adjustable irrigation schedules.
vii. Daily soil water balance output tables.
viii. Easy saving and retrieval of sessions and of user-defined irrigation schedules.
ix. Graphical presentations of input data, crop water requirements and irrigation schedules.
x. Easy import/export of data and graphics through clipboard or ASCII text files.
xi. Extensive printing routines, supporting all windows-based printers.
xii. Context-sensitive help system.
xiii. Multilingual interface and help system: English, Spanish, French and Russian.

CROPWAT 8.0 for Windows was developed using Visual Delphi 4.0 and runs on the following Windows platforms: 95/98/ME/2000/NT/XP and Vista.

Appendix B2: Average Monthly Climate & Rainfall Data for 13 Districts

Barisal

Rainfall (mm)	Average	Dry	Wet
Jan	3.8	3.3	4.3
Feb	22.3	19.2	25.1
March	47.5	40.9	53.4
April	94.4	81.2	106.0
May	221.3	190.2	248.5
June	429.7	369.4	482.5
July	421.9	362.7	473.8
Aug	356.4	306.4	400.2
Sept	293.9	252.6	330.0
Oct	183.7	158.0	206.3
Nov	39.5	34.0	44.4
Dec	5.9	5.0	6.6
Annual	2,120	1,823	2,381

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	11.8	25.5	79	74	8.1
Feb.	14.9	28.3	76	81	8.1
Mar.	20.1	31.3	75	103	8.3
Apr.	23.6	32.3	80	158	8.2
May	24.7	33.0	83	173	6.8
Jun.	25.6	31.6	88	163	4.3
Jul.	25.5	30.9	90	148	4.2
Aug.	25.6	31.0	89	133	4.5
Sep.	25.3	30.5	88	111	5.2
Oct.	23.6	31.5	86	70	7.2
Nov.	18.9	29.5	83	68	7.9
Dec.	13.4	26.5	80	76	8.0
Average	21.1	30.2	83	113	6.7

Chittagong

Rainfall (mm)	Average	Dry	Wet
Jan	16.5	13.9	18.8
Feb	34.6	29.1	39.4
March	78.2	65.8	89.0
April	168.2	141.4	191.4
May	350.1	294.3	398.5
June	615.2	517.1	700.1
July	844.8	710.1	961.5
Aug	526.9	442.9	599.7
Sept	323.3	271.7	367.9
Oct	223.8	188.1	254.7
Nov	71.5	60.1	81.4
Dec	6.0	5.1	6.8
Annual	3,259	2,739	3,709

Month	Min Temp ^0C	Max Temp ^0C	Humidity %	Wind km/day	Sunshine hours
Jan.	13.5	25.3	72	110	8.6
Feb.	16.2	28.2	70	146	8.9
Mar.	20.3	30.8	74	233	8.7
Apr.	22.8	30.9	75	350	8.5
May	24.7	32.3	79	344	7.1
Jun.	25.2	31.5	84	411	4.1
Jul.	24.4	29.9	83	426	4.3
Aug.	25.1	31.2	86	378	5.1
Sep.	24.2	30.7	84	257	6.4
Oct.	23.9	31.5	82	140	7.4
Nov.	19.6	28.9	76	96	8.1
Dec.	15.0	26.1	73	94	8.2
Average	21.2	29.8	78	249	7.1

Comilla

Rainfall (mm)	Average	Dry	Wet
Jan	7.0	5.4	8.3
Feb	22.5	17.5	26.8
March	57.7	45.0	68.9
April	151.0	117.6	180.2
May	351.1	273.5	419.1
June	381.4	297.1	455.3
July	450.6	351.0	537.8
Aug	315.7	245.9	376.8
Sept	271.5	211.5	324.0
Oct	151.9	118.3	181.3
Nov	33.5	26.1	39.9
Dec	8.7	6.8	10.4
Annual	2,202	1,715	2,629

Month	Min Temp ^0C	Max Temp ^0C	Humidity %	Wind km/day	Sunshine hours
Jan.	11.4	23.8	74	55	7.4
Feb.	14.8	26.9	73	74	7.8
Mar.	19.6	31.0	75	132	8.1
Apr.	22.1	31.3	80	211	7.7
May	24.2	32.4	82	204	6.7
Jun.	25.3	31.5	85	225	4.8
Jul.	25.5	30.9	87	226	4.5
Aug.	25.4	31.4	86	193	5.2
Sep.	25.2	31.7	85	129	5.6
Oct.	23.5	31.4	83	67	6.8
Nov.	18.7	29.6	79	46	7.7
Dec.	12.5	24.9	76	45	7.7
Average	20.7	29.7	80	134	6.7

Cox's Bazar

Rainfall (mm)	Average	Dry	Wet
Jan	6.1	5.3	6.8
Feb	22.4	19.4	25.0
March	28.0	24.2	31.3
April	106.6	92.2	119.1
May	288.5	249.7	322.5
June	874.6	756.8	977.7
July	894.2	773.8	999.7
Aug	777.2	672.6	868.9
Sept	484.7	419.4	541.9
Oct	337.4	291.9	377.2
Nov	110.1	95.3	123.1
Dec	6.1	5.3	6.8
Annual	3,936	3,406	4,400

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	15.0	26.7	71	131	9.3
Feb.	17.1	28.6	71	142	9.3
Mar.	20.7	31.0	75	160	9.1
Apr.	24.0	31.3	78	185	8.8
May	25.1	32.4	80	208	7.5
Jun.	25.2	30.7	87	236	4.1
Jul.	24.4	29.2	89	245	3.5
Aug.	25.0	30.3	88	211	4.8
Sep.	24.3	30.1	86	149	5.9
Oct.	23.6	30.7	82	106	7.4
Nov.	20.4	29.2	77	103	8.5
Dec.	15.6	25.9	73	108	8.8
Average	21.7	29.7	80	165	7.2

Dhaka

Rainfall (mm)	Average	Dry	Wet
Jan	5.0	4.0	5.8
Feb	22.0	17.8	25.6
March	63.9	51.7	74.6
April	140.4	113.6	163.9
May	271.8	219.9	317.2
June	356.0	288.0	415.5
July	395.0	319.6	461.1
Aug	301.5	243.9	351.9
Sept	369.7	299.1	431.5
Oct	177.5	143.6	207.2
Nov	31.8	25.8	37.2
Dec	14.6	11.8	17.1
Annual	2,149	1,739	2,508

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	12.7	25.2	70	48	7.7
Feb.	15.6	28.1	64	65	8.3
Mar.	20.3	32.3	62	110	8.4
Apr.	23.6	33.7	72	179	8.2
May	24.5	32.9	78	177	7.1
Jun.	26.1	32.1	84	192	5.1
Jul.	24.6	30.5	85	190	4.3
Aug.	26.2	31.6	84	161	5.3
Sep.	25.8	31.8	84	107	5.3
Oct.	23.8	31.5	80	59	7.1
Nov.	19.2	29.5	74	37	7.8
Dec.	13.7	25.6	73	35	7.9
Average	21.3	30.4	76	113	6.9

Faridpur

Rainfall (mm)	Average	Dry	Wet
Jan	6.1	5.1	7.0
Feb	19.8	16.6	22.6
March	49.5	41.5	56.5
April	110.8	92.9	126.5
May	238.0	199.5	271.6
June	321.7	269.7	367.2
July	348.7	292.3	398.0
Aug	303.4	254.4	346.3
Sept	284.7	238.7	325.0
Oct	153.7	128.9	175.5
Nov	34.3	28.7	39.1
Dec	10.3	8.6	11.7
Annual	1880.9	1577.0	2147.1

Month	Min Temp ^0C	Max Temp ^0C	Humidity %	Wind km/day	Sunshine hours
Jan.	12.1	24.4	73	59	7.5
Feb.	14.6	27.7	68	68	8.1
Mar.	19.3	32.4	63	110	8.0
Apr.	23.0	34.2	69	186	8.1
May	24.1	33.4	77	177	7.1
Jun.	25.5	32.1	83	162	4.9
Jul.	25.7	31.4	82	163	4.3
Aug.	26.0	31.5	83	147	4.9
Sep.	25.7	31.7	86	115	4.9
Oct.	23.9	31.4	82	68	7.1
Nov.	19.2	29.0	78	50	7.8
Dec.	13.7	25.6	77	51	7.8
Average	21.1	30.4	77	113	6.7

Jessore

Rainfall (mm)	Average	Dry	Wet
Jan	12.3	10.7	13.8
Feb	24.4	21.1	27.3
March	47.5	41.1	53.0
April	79.6	68.9	88.9
May	197.1	170.6	220.3
June	327.0	283.0	365.5
July	359.3	310.9	401.6
Aug	279.7	242.0	312.6
Sept	275.0	238.0	307.4
Oct	144.0	124.6	160.9
Nov	32.9	28.5	36.8
Dec	10.8	9.4	12.1
Annual	1789.4	1548.7	2000.3

Month	Min Temp ^0C	Max Temp ^0C	Humidity %	Wind km/day	Sunshine hours
Jan.	11.3	25.4	73	65	7.3
Feb.	14.4	28.5	69	95	7.8
Mar.	19.5	33.2	65	173	7.9
Apr.	23.6	35.7	69	318	8.1
May	24.9	35.1	76	320	7.3
Jun.	25.8	33.3	84	279	4.8
Jul.	25.9	32.2	87	245	3.9
Aug.	25.9	32.2	87	225	4.6
Sep.	25.4	32.5	86	176	4.8
Oct.	23.2	32.3	82	88	6.7
Nov.	17.9	30.0	77	61	7.4
Dec.	12.4	26.5	75	51	7.2
Average	20.8	31.4	77	175	6.5

Madaripur

Rainfall (mm)	Average	Dry	Wet
Jan	5.8	4.7	6.7
Feb	22.7	18.5	26.4
March	55.6	45.2	64.7
April	131.1	106.6	152.5
May	258.4	210.1	300.7
June	374.8	304.8	436.1
July	378.0	307.4	439.9
Aug	310.8	252.8	361.7
Sept	265.2	215.7	308.6
Oct	157.1	127.8	182.8
Nov	45.8	37.2	53.2
Dec	6.6	5.4	7.7
Annual	2012.0	1636.1	2341.2

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	12.1	25.4	73	38	6.0
Feb.	13.6	28.4	69	45	6.8
Mar.	19.0	32.6	66	72	7.0
Apr.	21.2	34.1	73	113	6.8
May	22.3	33.6	78	107	5.6
Jun.	24.7	32.4	84	100	3.6
Jul.	24.7	31.8	86	105	3.2
Aug.	23.0	30.7	84	98	3.6
Sep.	23.6	31.0	83	66	4.0
Oct.	22.8	30.9	79	41	5.7
Nov.	18.5	28.8	75	29	6.4
Dec.	13.3	25.7	74	30	5.9
Average	19.9	30.4	77	70	5.4

Maijdee / Noakhali

Rainfall (mm)	Average	Dry	Wet
Jan	6.1	5.2	6.8
Feb	39.4	33.8	44.2
March	75.4	64.8	84.6
April	154.6	132.9	173.5
May	376.0	323.3	422.2
June	629.6	541.3	706.9
July	759.1	652.7	852.4
Aug	632.9	544.1	710.6
Sept	431.2	370.7	484.1
Oct	216.5	186.1	243.1
Nov	43.7	37.6	49.1
Dec	7.8	6.7	8.8
Annual	3372.2	2899.2	3786.3

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	13.5	23.7	73	31	7.6
Feb.	15.7	26.9	74	48	8.0
Mar.	19.9	31.3	74	77	8.0
Apr.	22.6	32.4	76	129	7.4
May	23.9	32.3	81	127	6.6
Jun.	23.9	31.1	83	154	3.9
Jul.	25.4	30.2	88	148	4.4
Aug.	25.4	30.5	87	133	5.1
Sep.	25.5	31.1	86	92	5.1
Oct.	24.4	31.1	82	48	6.8
Nov.	20.5	29.2	78	40	7.6
Dec.	15.6	26.2	78	29	7.9
Average	21.4	29.7	80	88	6.5

Mymensingh

Rainfall (mm)	Average	Dry	Wet
Jan	5.7	4.6	6.6
Feb	20.6	16.7	24.0
March	32.7	26.6	38.1
April	143.0	116.1	166.6
May	351.5	285.2	409.5
June	433.2	351.6	504.8
July	528.3	428.8	615.5
Aug	394.3	320.0	459.3
Sept	392.4	318.4	457.1
Oct	232.9	189.0	271.3
Nov	17.7	14.3	20.6
Dec	10.8	8.8	12.6
Annual	2563.0	2080.0	2986.0

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	11.8	24.6	73	54	6.6
Feb.	14.2	27.2	67	74	7.4
Mar.	18.0	31.0	66	110	7.4
Apr.	21.8	32.3	73	169	7.1
May	22.9	31.5	80	171	6.1
Jun.	25.0	31.5	85	171	4.1
Jul.	25.3	31.2	86	158	3.6
Aug.	25.4	31.8	85	140	4.4
Sep.	24.9	31.5	85	110	4.2
Oct.	23.0	31.4	82	68	6.6
Nov.	18.2	29.5	77	46	7.8
Dec.	13.2	26.2	75	40	7.2
Average	20.3	30.0	78	109	6.0

Rajshahi

Rainfall (mm)	Average	Dry	Wet
Jan	3.1	2.5	3.6
Feb	11.8	9.6	13.8
March	23.4	19.0	27.3
April	48.2	39.2	56.1
May	129.8	105.4	151.1
June	235.6	191.4	274.3
July	304.6	247.5	354.7
Aug	231.9	188.4	270.0
Sept	256.6	208.4	298.8
Oct	108.2	87.9	125.9
Nov	12.1	9.8	14.1
Dec	9.7	7.9	11.3
Annual	1375.0	1117.0	1601.0

Month	Min Temp ^0C	Max Temp ^0C	Humidity %	Wind km/day	Sunshine hours
Jan.	10.4	24.4	74	74	7.2
Feb.	13.2	27.7	67	81	8.2
Mar.	17.7	33.2	59	103	8.5
Apr.	22.9	36.2	62	158	8.4
May	24.3	34.9	74	173	7.5
Jun.	25.8	33.5	83	163	5.6
Jul.	26.0	32.2	87	148	4.5
Aug.	26.1	32.4	86	133	5.1
Sep.	25.5	32.3	85	111	5.4
Oct.	23.2	31.7	81	70	7.4
Nov.	17.8	29.3	77	68	8.1
Dec.	12.7	25.8	75	76	7.7
Average	20.5	31.1	76	113	7.0

Rangpur

Rainfall (mm)	Average	Dry	Wet
Jan	8.9	7.2	10.5
Feb	10.7	8.6	12.5
March	32.4	26.0	38.0
April	106.6	85.6	125.1
May	271.7	218.0	318.7
June	452.5	363.1	530.8
July	500.9	401.9	587.5
Aug	350.2	281.0	410.8
Sept	383.2	307.5	449.5
Oct	184.3	147.9	216.2
Nov	9.0	7.2	10.5
Dec	7.6	6.1	8.9
Annual	2318.0	1860.0	2719.1

Month	Min Temp ^0C	Max Temp ^0C	Humidity %	Wind km/day	Sunshine hours
Jan.	10.6	23.3	82	53	6.8
Feb.	12.7	26.1	76	71	7.8
Mar.	16.1	30.3	68	113	8.0
Apr.	20.7	32.2	73	153	7.4
May	22.9	32.1	81	131	6.6
Jun.	25.0	32.0	85	128	5.1
Jul.	25.7	31.7	84	124	4.3
Aug.	25.3	30.9	85	115	5.2
Sep.	25.1	31.4	87	95	5.2
Oct.	22.4	30.8	85	70	7.3
Nov.	17.4	28.6	79	69	8.3
Dec.	12.7	25.3	82	53	7.5
Average	19.7	29.6	81	98	6.6

Sylhet

Rainfall (mm)	Average	Dry	Wet
Jan	7.4	6.5	8.3
Feb	37.1	32.2	41.3
March	151.7	131.7	169.1
April	409.1	355.3	456.2
May	592.3	514.4	660.5
June	842.8	732.0	939.9
July	839.9	729.4	936.6
Aug	650.5	565.0	725.5
Sept	623.7	541.7	695.5
Oct	226.0	196.3	252.0
Nov	29.0	25.2	32.3
Dec	13.3	11.6	14.8
Annual	4422.7	3841.2	4932.0

Month	Min Temp ^{0}C	Max Temp ^{0}C	Humidity %	Wind km/day	Sunshine hours
Jan.	13.1	25.2	71	92	7.9
Feb.	14.5	27.2	67	116	8.2
Mar.	18.3	30.4	67	145	7.8
Apr.	20.4	30.8	76	143	6.8
May	22.1	30.9	81	127	5.7
Jun.	23.1	31.0	84	113	3.8
Jul.	24.3	30.9	88	105	3.5
Aug.	24.4	31.6	87	92	4.4
Sep.	23.8	31.1	87	77	4.7
Oct.	22.0	30.9	83	76	7.1
Nov.	18.1	29.2	77	86	8.3
Dec.	13.9	26.4	72	88	8.4
Average	19.8	29.6	78	105	6.4

Appendix B3: Crop Water Requirements and Design Duties for 13 Districts

Barisal

Description	Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall							
Nov	mm/month	0	0	0	0	0	0
Dec	mm/month	121	18	0	0	14	11
Jan	mm/month	164	162	54	32	138	114
Feb	mm/month	80	128	65	66	116	103
March	mm/month	108	105	88	102	103	101
April	mm/month	78	89	12	25	75	61
May	mm/month	8	18	0	0	14	11
Totals	**mm**	559	520	219	225	**460**	**401**
Peak net duty (based on peak month)	mm/d	5.29	5.23	2.84	3.29	4.79	4.36
	l/s/ha	0.61	0.60	0.33	0.38	0.55	0.50
Peak net duty (based on peak 3-month period)	mm/d	4.06	4.39	2.30	2.22	3.96	3.54
	l/s/ha	0.47	0.51	0.27	0.26	0.46	0.41
ratio duties 3-months / 1 month		0.77	0.84	0.81	0.68	0.83	0.81
Efficiencies, Duties & Water Requirements							
At Field boundary							
Field irrigation efficiency (weighted)	%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)	mm/d	6.2	6.8	4.2	4.0	6.3	5.8
	l/s/ha	0.72	0.78	0.48	0.47	0.73	0.67
Total water requirement at field level	**mm**	**860**	**800**	**398**	**409**	**731**	**657**
At Pumping Point at Head of System							
Conveyance efficiency (pipe outlet to field	%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)	mm/d	7.8	8.4	5.2	5.1	7.9	7.2
	l/s/ha	0.90	0.98	0.61	0.58	0.91	0.84
Total water requirement at pipe outlet	mm	1,075	1,000	498	511	913	821
Conveyance efficiency (HT to pipe outlet)	%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point	mm	**1,075**	**1,000**	**498**	**511**	**913**	**821**

Chittagong

Description	Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall							
Nov	mm/month	0	0	0	0	0	0
Dec	mm/month	125	19	0	0	15	11
Jan	mm/month	164	160	51	27	136	112
Feb	mm/month	90	136	72	75	124	111
March	mm/month	111	110	90	107	108	105
April	mm/month	65	77	9	17	64	51
May	mm/month	8	20	0	0	16	12
Totals	**mm**	563	522	222	226	**462**	**403**
Peak net duty (based on peak month)	mm/d	5.29	5.2	2.9	3.4	4.8	4.4
	l/s/ha	0.61	0.60	0.34	0.39	0.55	0.51
Peak net duty (based on peak 3-month period)	mm/d	4.21	4.51	2.37	2.32	4.08	3.64
	l/s/ha	0.49	0.52	0.27	0.27	0.47	0.42
ratio duties 3-months / 1 month		0.80	0.87	0.82	0.68	0.85	0.83
Efficiencies, Duties & Water Requirements							
At Field boundary							
Field irrigation efficiency (weighted)	%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)	mm/d	6.5	6.9	4.3	4.2	6.5	6.0
	l/s/ha	0.75	0.80	0.50	0.49	0.75	0.69
Total water requirement at field level	**mm**	**866**	**803**	**404**	**411**	**734**	**660**
At Pumping Point at Head of System							
Conveyance efficiency (pipe outlet to field	%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)	mm/d	8.1	8.7	5.4	5.3	8.1	7.5
	l/s/ha	0.94	1.00	0.62	0.61	0.94	0.86
Total water requirement at pipe outlet	mm	1,083	1,004	505	514	917	825
Conveyance efficiency (HT to pipe outlet)	%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point	mm	**1,083**	**1,004**	**505**	**514**	**917**	**825**

Comilla

Description	Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall							
Nov	mm/month	0	0	0	0	0	0
Dec	mm/month	114	16	0	0	13	10
Jan	mm/month	151	152	46	27	129	106
Feb	mm/month	76	123	62	64	111	99
March	mm/month	103	102	85	99	100	98
April	mm/month	53	63	8	15	53	42
May	mm/month	2	6	0	0	5	4
Totals	**mm**	499	462	201	205	**410**	**358**
Peak net duty (based on peak month)	mm/d	4.87	4.90	2.74	3.19	4.52	4.13
	l/s/ha	0.56	0.57	0.32	0.37	0.52	0.48
Peak net duty (based on peak 3-month period)	mm/d	3.79	4.19	2.14	2.11	3.78	3.36
	l/s/ha	0.44	0.48	0.25	0.24	0.44	0.39
ratio duties 3-months / 1 month		0.78	0.85	0.78	0.66	0.84	0.81
Efficiencies, Duties & Water Requirements							
At Field boundary							
Field irrigation efficiency (weighted)	%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)	mm/d	5.8	6.4	3.9	3.8	6.0	5.5
	l/s/ha	0.67	0.75	0.45	0.44	0.69	0.64
Total water requirement at field level	**mm**	**768**	**711**	**365**	**373**	**651**	**588**
At Pumping Point at Head of System							
Conveyance efficiency (pipe outlet to field	%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)	mm/d	7.3	8.1	4.9	4.8	7.5	6.9
	l/s/ha	0.84	0.93	0.56	0.56	0.87	0.80
Total water requirement at pipe outlet	mm	960	888	457	466	814	734
Conveyance efficiency (HT to pipe outlet)	%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point	mm	**960**	**888**	**457**	**466**	**814**	**734**

Cox's Bazar

Description	Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall							
Nov	mm/month	0	0	0	0	0	0
Dec	mm/month	128	20	0	0	16	12
Jan	mm/month	182	173	67	40	149	125
Feb	mm/month	102	151	83	85	138	124
March	mm/month	139	137	118	133	135	132
April	mm/month	80	91	13	25	77	62
May	mm/month	7	16	0	0	13	10
Totals	**mm**	638	588	281	283	**527**	**466**
Peak net duty (based on peak month)	mm/d	5.87	5.58	3.81	4.29	5.27	4.97
	l/s/ha	0.68	0.65	0.44	0.50	0.61	0.57
Peak net duty (based on peak 3-month period)	mm/d	4.70	5.12	2.98	2.87	4.68	4.24
	l/s/ha	0.54	0.59	0.34	0.33	0.54	0.49
ratio duties 3-months / 1 month		0.80	0.92	0.78	0.67	0.89	0.85
Efficiencies, Duties & Water Requirements							
At Field boundary							
Field irrigation efficiency (weighted)	%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)	mm/d	7.2	7.9	5.4	5.2	7.4	7.0
	l/s/ha	0.84	0.91	0.63	0.60	0.86	0.80
Total water requirement at field level	**mm**	**982**	**905**	**511**	**515**	**836**	**763**
At Pumping Point at Head of System							
Conveyance efficiency (pipe outlet to field	%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)	mm/d	9.0	9.9	6.8	6.5	9.3	8.7
	l/s/ha	1.05	1.14	0.78	0.75	1.08	1.01
Total water requirement at pipe outlet	mm	1,227	1,131	639	643	1,045	954
Conveyance efficiency (HT to pipe outlet)	%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point	mm	**1,227**	**1,131**	**639**	**643**	**1,045**	**954**

Dhaka

Description		Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall								
	Nov	mm/month	0	0	0	0	0	0
	Dec	mm/month	89	16	0	0	13	10
	Jan	mm/month	156	156	49	29	133	109
	Feb	mm/month	81	129	66	68	117	104
	March	mm/month	108	107	89	104	105	103
	April	mm/month	73	86	11	20	72	58
	May	mm/month	7	19	0	0	15	11
	Totals	**mm**	514	513	215	221	**454**	**395**
Peak net duty (based on peak month)		mm/d	5.03	5.03	2.87	3.35	4.65	4.26
		l/s/ha	0.58	0.58	0.33	0.39	0.54	0.49
Peak net duty (based on peak 3-month period)		mm/d	3.83	4.36	2.27	2.23	3.93	3.51
		l/s/ha	0.44	0.50	0.26	0.26	0.46	0.41
ratio duties 3-months / 1 month			0.76	0.87	0.79	0.67	0.85	0.82
Efficiencies, Duties & Water Requirements								
At Field boundary								
Field irrigation efficiency (weighted)		%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)		mm/d	5.9	6.7	4.1	4.1	6.2	5.8
		l/s/ha	0.68	0.78	0.48	0.47	0.72	0.67
Total water requirement at field level		**mm**	**791**	**789**	**391**	**402**	**721**	**648**
At Pumping Point at Head of System								
Conveyance efficiency (pipe outlet to field		%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)		mm/d	7.4	8.4	5.2	5.1	7.8	7.2
		l/s/ha	0.85	0.97	0.60	0.59	0.90	0.83
Total water requirement at pipe outlet		mm	988	987	489	502	901	809
Conveyance efficiency (HT to pipe outlet)		%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point		mm	**988**	**987**	**489**	**502**	**901**	**809**

Faridpur

Description	Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall							
Nov	mm/month	0	0	0	0	0	0
Dec	mm/month	102	16	0	0	13	10
Jan	mm/month	154	154	48	28	131	108
Feb	mm/month	80	128	66	68	116	104
March	mm/month	115	114	96	111	112	110
April	mm/month	91	105	13	28	88	71
May	mm/month	11	27	0	0	22	16
Totals	**mm**	553	544	223	235	**481**	**418**
Peak net duty (based on peak month)	mm/d	4.97	4.97	3.10	3.58	4.64	4.32
	l/s/ha	0.57	0.57	0.36	0.41	0.54	0.50
Peak net duty (based on peak 3-month period)	mm/d	3.88	4.40	2.33	2.30	3.98	3.57
	l/s/ha	0.45	0.51	0.27	0.27	0.46	0.41
ratio duties 3-months / 1 month		0.78	0.89	0.75	0.64	0.86	0.83
Efficiencies, Duties & Water Requirements							
At Field boundary							
Field irrigation efficiency (weighted)	%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)	mm/d	6.0	6.8	4.2	4.2	6.3	5.8
	l/s/ha	0.69	0.78	0.49	0.48	0.73	0.68
Total water requirement at field level	**mm**	**851**	**837**	**405**	**427**	**763**	**685**
At Pumping Point at Head of System							
Conveyance efficiency (pipe outlet to field	%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)	mm/d	7.5	8.5	5.3	5.2	7.9	7.3
	l/s/ha	0.86	0.98	0.61	0.61	0.91	0.85
Total water requirement at pipe outlet	mm	1,063	1,046	507	534	954	857
Conveyance efficiency (HT to pipe outlet)	%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point	mm	**1,063**	**1,046**	**507**	**534**	**954**	**857**

Jessore

Description	Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall							
Nov	mm/month	0	0	0	0	0	0
Dec	mm/month	91	16	0	0	13	10
Jan	mm/month	123	119	44	24	102	85
Feb	mm/month	83	130	68	71	118	106
March	mm/month	135	135	114	131	133	130
April	mm/month	138	159	20	53	135	110
May	mm/month	27	61	0	0	49	37
Totals	**mm**	597	620	246	279	549	477
Peak net duty (based on peak month)	mm/d	4.6	5.3	3.7	4.2	5.0	4.8
	l/s/ha	0.53	0.61	0.43	0.49	0.58	0.55
Peak net duty (based on peak 3-month period)	mm/d	4.00	4.76	2.51	2.51	4.32	3.89
	l/s/ha	0.46	0.52	0.36	0.41	0.49	0.47
ratio duties 3-months / 1 month		0.87	0.90	0.68	0.59	0.86	0.82
Efficiencies, Duties & Water Requirements							
At Field boundary							
Field irrigation efficiency (weighted)	%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)	mm/d	6.2	7.3	4.6	4.6	6.9	6.4
	l/s/ha	0.71	0.85	0.53	0.53	0.79	0.74
Total water requirement at field level	**mm**	**918**	**954**	**447**	**507**	**871**	**782**
At Pumping Point at Head of System							
Conveyance efficiency (pipe outlet to field	%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)	mm/d	7.7	9.2	5.7	5.7	8.6	8.0
	l/s/ha	0.89	1.06	0.66	0.66	0.99	0.92
Total water requirement at pipe outlet	mm	1,148	1,192	559	634	1,088	977
Conveyance efficiency (HT to pipe outlet)	%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point	mm	**1,148**	**1,192**	**559**	**634**	**1,088**	**977**

Madaripur

Description	Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall							
Nov	mm/month	0	0	0	0	0	0
Dec	mm/month	100	16	0	0	13	10
Jan	mm/month	130	126	43	26	108	89
Feb	mm/month	69	98	55	57	90	81
March	mm/month	94	92	76	89	90	88
April	mm/month	58	68	9	16	57	46
May	mm/month	3	7	0	0	6	4
Totals	**mm**	454	407	183	188	**363**	**318**
Peak net duty (based on peak month)	mm/d	4.19	4.06	2.45	2.87	3.78	3.50
	l/s/ha	0.49	0.47	0.28	0.33	0.44	0.41
Peak net duty (based on peak 3-month period)	mm/d	3.32	3.51	1.93	1.91	3.19	2.88
	l/s/ha	0.38	0.41	0.22	0.22	0.37	0.33
ratio duties 3-months / 1 month		0.79	0.86	0.79	0.67	0.84	0.82
Efficiencies, Duties & Water Requirements							
At Field boundary							
Field irrigation efficiency (weighted)	%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)	mm/d	5.1	5.4	3.5	3.5	5.1	4.7
	l/s/ha	0.59	0.63	0.41	0.40	0.59	0.55
Total water requirement at field level	**mm**	**698**	**626**	**333**	**342**	**576**	**522**
At Pumping Point at Head of System							
Conveyance efficiency (pipe outlet to field	%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)	mm/d	6.4	6.8	4.4	4.3	6.3	5.9
	l/s/ha	0.74	0.78	0.51	0.50	0.73	0.68
Total water requirement at pipe outlet	mm	873	783	416	427	720	652
Conveyance efficiency (HT to pipe outlet)	%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point	mm	**873**	**783**	**416**	**427**	**720**	**652**

Maijdee / Noakhali

Description	Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall							
Nov	mm/month	0	0	0	0	0	0
Dec	mm/month	117	17	0	0	14	10
Jan	mm/month	145	143	46	27	122	100
Feb	mm/month	59	89	45	47	80	72
March	mm/month	79	79	63	76	77	75
April	mm/month	40	49	6	10	41	33
May	mm/month	1	2	0	0	2	1
Totals	**mm**	**441**	**379**	**160**	**160**	**335**	**291**
Peak net duty (based on peak month)	mm/d	4.68	4.61	2.03	2.45	4.14	3.66
	l/s/ha	0.54	0.53	0.24	0.28	0.48	0.42
Peak net duty (based on peak 3-month period)	mm/d	3.57	3.46	1.71	1.67	3.10	2.75
	l/s/ha	0.41	0.40	0.20	0.19	0.36	0.32
ratio duties 3-months / 1 month		0.76	0.75	0.84	0.68	0.75	0.75
Efficiencies, Duties & Water Requirements							
At Field boundary							
Field irrigation efficiency (weighted)	%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)	mm/d	5.5	5.3	3.1	3.0	4.9	4.5
	l/s/ha	0.64	0.62	0.36	0.35	0.57	0.52
Total water requirement at field level	**mm**	**678**	**583**	**291**	**291**	**532**	**478**
At Pumping Point at Head of System							
Conveyance efficiency (pipe outlet to field	%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)	mm/d	6.9	6.6	3.9	3.8	6.2	5.6
	l/s/ha	0.79	0.77	0.45	0.44	0.71	0.65
Total water requirement at pipe outlet	mm	848	729	364	364	665	597
Conveyance efficiency (HT to pipe outlet)	%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point	mm	**848**	**729**	**364**	**364**	**665**	**597**

Mymensingh

Description		Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall								
	Nov	mm/month	1	0	0	0	0	0
	Dec	mm/month	88	15	0	0	12	9
	Jan	mm/month	139	138	45	26	118	97
	Feb	mm/month	75	112	62	64	102	92
	March	mm/month	116	115	98	112	113	111
	April	mm/month	58	68	9	17	57	46
	May	mm/month	1	4	0	0	3	2
	Totals	**mm**	478	452	214	219	**405**	**358**
Peak net duty (based on peak month)		mm/d	4.48	4.45	3.16	3.61	4.24	4.03
		l/s/ha	0.52	0.52	0.37	0.42	0.49	0.47
Peak net duty (based on peak 3-month period)		mm/d	3.67	4.06	2.28	2.24	3.70	3.34
		l/s/ha	0.42	0.47	0.26	0.26	0.43	0.39
ratio duties 3-months / 1 month			0.82	0.91	0.72	0.62	0.87	0.83
Efficiencies, Duties & Water Requirements								
At Field boundary								
Field irrigation efficiency (weighted)		%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)		mm/d	5.6	6.2	4.1	4.1	5.9	5.5
		l/s/ha	0.65	0.72	0.48	0.47	0.68	0.63
Total water requirement at field level		**mm**	**735**	**695**	**389**	**398**	**643**	**587**
At Pumping Point at Head of System								
Conveyance efficiency (pipe outlet to field		%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)		mm/d	7.1	7.8	5.2	5.1	7.3	6.8
		l/s/ha	0.82	0.90	0.60	0.59	0.85	0.79
Total water requirement at pipe outlet		mm	919	869	486	498	803	733
Conveyance efficiency (HT to pipe outlet)		%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point		mm	**919**	**869**	**486**	**498**	**803**	**733**

Rajshahi

Description		Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall								
	Nov	mm/month	1	0	0	0	0	0
	Dec	mm/month	115	16	0	0	13	10
	Jan	mm/month	154	155	49	30	132	109
	Feb	mm/month	88	136	74	76	124	112
	March	mm/month	140	139	120	136	137	135
	April	mm/month	142	162	21	60	138	113
	May	mm/month	33	75	0	0	60	45
	Totals	**mm**	**673**	**683**	**264**	**302**	**603**	**523**
Peak net duty (based on peak month)		mm/d	4.97	5.00	3.87	4.39	4.83	4.65
		l/s/ha	0.57	0.52	0.36	0.41	0.49	0.47
Peak net duty (based on peak 3-month period)		mm/d	4.24	4.91	2.70	3.06	4.48	4.04
		l/s/ha	0.49	0.52	0.36	0.41	0.49	0.47
ratio duties 3-months / 1 month			0.85	0.98	0.70	0.70	0.93	0.87
Efficiencies, Duties & Water Requirements								
At Field boundary								
Field irrigation efficiency (weighted)		%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)		mm/d	6.5	7.6	4.9	5.6	7.1	6.6
		l/s/ha	0.76	0.87	0.57	0.64	0.82	0.77
Total water requirement at field level		**mm**	**1035**	**1051**	**480**	**549**	**957**	**857**
At Pumping Point at Head of System								
Conveyance efficiency (pipe outlet to field		%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)		mm/d	8.2	9.4	6.1	6.9	8.9	8.3
		l/s/ha	0.94	1.09	0.71	0.80	1.03	0.96
Total water requirement at pipe outlet		mm	1294	1313	600	686	1196	1072
Conveyance efficiency (HT to pipe outlet)		%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point		mm	**1,294**	**1,313**	**600**	**686**	**1,196**	**1,072**

Rangpur

Description		Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall								
	Nov	mm/month	1	0	0	0	0	0
	Dec	mm/month	89	15	0	0	12	9
	Jan	mm/month	114	112	39	22	96	79
	Feb	mm/month	78	126	65	67	114	102
	March	mm/month	115	114	98	111	112	110
	April	mm/month	75	87	12	23	73	59
	May	mm/month	4	10	0	0	8	6
	Totals	**mm**	476	464	214	223	**415**	**366**
Peak net duty (based on peak month)		mm/d	3.7	4.5	3.1	3.6	4.3	4.0
		l/s/ha	0.43	0.52	0.36	0.41	0.49	0.47
Peak net duty (based on peak 3-month period)		mm/d	3.41	3.91	2.24	2.22	3.58	3.24
		l/s/ha	0.39	0.52	0.36	0.41	0.49	0.47
ratio duties 3-months / 1 month			0.92	0.87	0.72	0.62	0.84	0.80
Efficiencies, Duties & Water Requirements								
At Field boundary								
Field irrigation efficiency (weighted)		%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)		mm/d	5.2	6.0	4.1	4.0	5.7	5.3
		l/s/ha	0.61	0.70	0.47	0.47	0.66	0.61
Total water requirement at field level		**mm**	**732**	**714**	**389**	**405**	**659**	**600**
At Pumping Point at Head of System								
Conveyance efficiency (pipe outlet to field)		%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)		mm/d	6.6	7.5	5.1	5.1	7.1	6.6
		l/s/ha	0.76	0.87	0.59	0.58	0.82	0.77
Total water requirement at pipe outlet		mm	915	892	486	507	823	750
Conveyance efficiency (HT to pipe outlet)		%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point		mm	**915**	**892**	**486**	**507**	**823**	**750**

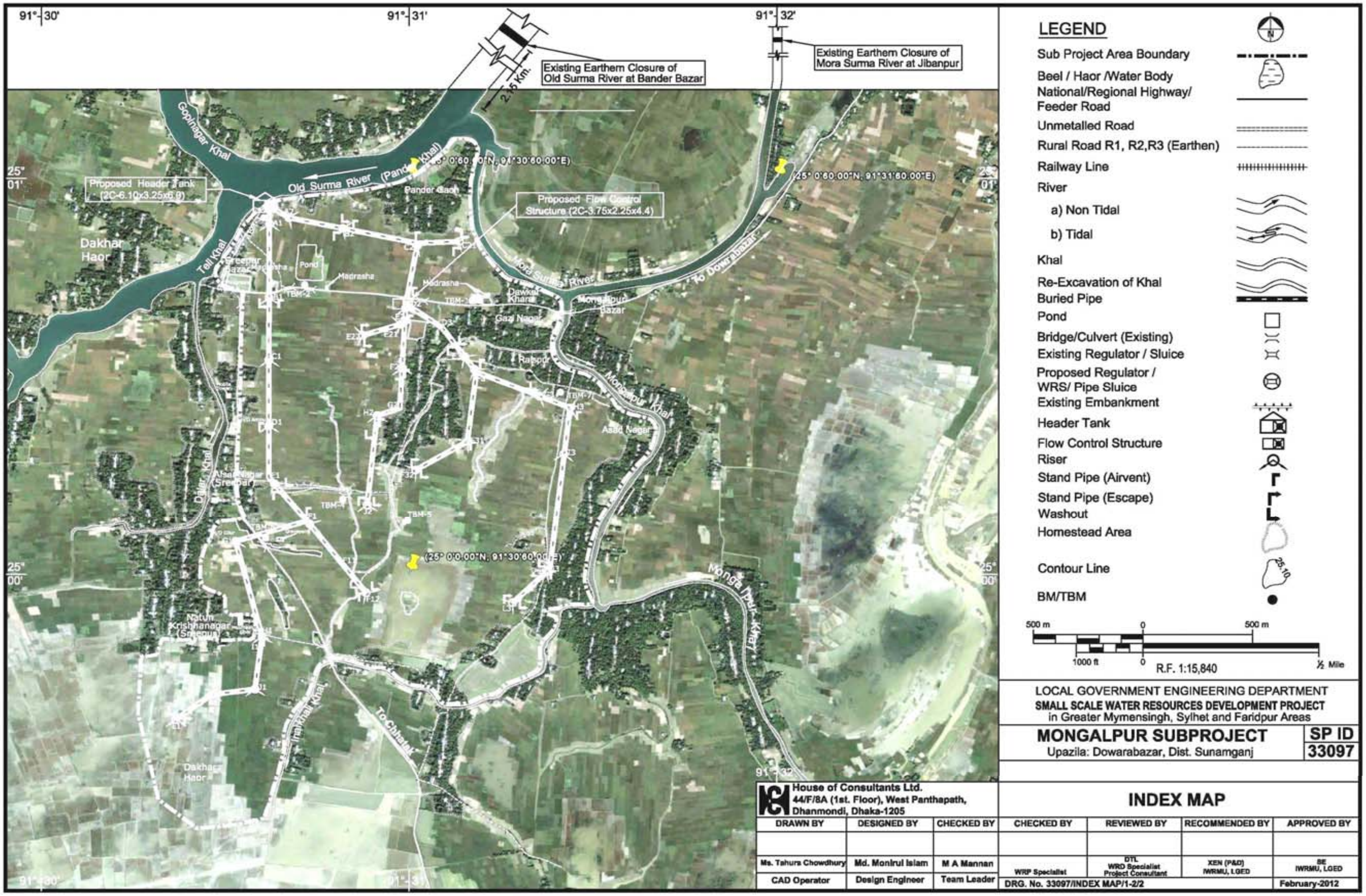
Sylhet

Description		Units	100% Rice: Early Planting (Dec to Feb)	100% Rice: Late Planting (Jan to Feb)	100% Vegetables	100% Pulses	10% Vegetables; 10% Pulses & 80% Rice	20% Vegetables; 20% Pulses & 60% Rice
Net irrigation requirements incl. land preparation & effective rainfall								
	Nov	mm/month	0	0	0	0	0	0
	Dec	mm/month	103	16	0	0	13	10
	Jan	mm/month	161	159	52	30	135	112
	Feb	mm/month	73	120	57	59	108	95
	March	mm/month	45	43	26	40	41	39
	April	mm/month	1	1	0	0	1	1
	May	mm/month	0	0	0	0	0	0
	Totals	**mm**	383	339	135	129	**298**	**256**
Peak net duty (based on peak month)		mm/d	5.19	5.13	2.04	2.11	4.52	3.91
		l/s/ha	0.60	0.59	0.24	0.24	0.52	0.45
Peak net duty (based on peak 3-month period)		mm/d	3.74	3.58	1.50	1.43	3.16	2.73
		l/s/ha	0.43	0.41	0.17	0.17	0.37	0.32
ratio duties 3-months / 1 month			0.72	0.70	0.74	0.68	0.70	0.70
Efficiencies, Duties & Water Requirements								
At Field boundary								
Field irrigation efficiency (weighted)		%	65%	65%	55%	55%	63%	61%
Peak field irrigation duty (based on 3 month period)		mm/d	5.8	5.5	2.7	2.6	5.0	4.5
		l/s/ha	0.67	0.64	0.32	0.30	0.58	0.52
Total water requirement at field level		**mm**	**589**	**522**	**245**	**235**	**472**	**420**
At Pumping Point at Head of System								
Conveyance efficiency (pipe outlet to field		%	80%	80%	80%	80%	80%	80%
Peak duty for at pipe outlet (based on 3 month period)		mm/d	7.2	6.9	3.4	3.3	6.3	5.6
		l/s/ha	0.83	0.80	0.39	0.38	0.72	0.65
Total water requirement at pipe outlet		mm	737	652	307	293	590	525
Conveyance efficiency (HT to pipe outlet)		%	100%	100%	100%	100%	100%	100%
Total water requirement at pumping point		mm	**737**	**652**	**307**	**293**	**590**	**525**

Appendix C

Sample Layouts

SP 33097 Mongalpur, Dowrabazar, Sunamganj


Existing Earthern Closure of Old Surma River at Bander Bazar
Existing Earthern Closure of Mora Surma River at Jibanpur
2.5 Km.
Proposed Header Tank (2C-6.10x3.25x6.0)
Proposed Flow Control Structure (2C-3.75x2.25x4.4)
Old Surma River (Pander Khal)
Gopinagar Khal
Dakhar Haor
Teli Khal
Mora Surma River
Mongalpur Khal
To Dowarabazar
To Chhatak
Pander Gaon
Madrasha
Pond
Gazi Nagar
Raipur
Asad Nagar
Mongalpur Bazar
Natun Krishnanagar (Sreegour)
Dakhar Haor
(25° 0'60.00"N, 91°31'60.00"E)
(25° 0'0.00"N, 91°30'60.00"E)
91° 30'
91° 31'
91° 32'
25° 01'
25° 00'
LEGEND
Sub Project Area Boundary
Beel / Haor /Water Body
National/Regional Highway/ Feeder Road
Unmetalled Road
Rural Road R1, R2,R3 (Earthen)
Railway Line
River
a) Non Tidal
b) Tidal
Khal
Re-Excavation of Khal
Buried Pipe
Pond
Bridge/Culvert (Existing)
Existing Regulator / Sluice
Proposed Regulator / WRS/ Pipe Sluice
Existing Embankment
Header Tank
Flow Control Structure
Riser
Stand Pipe (Airvent)
Stand Pipe (Escape)
Washout
Homestead Area
Contour Line
BM/TBM
500 m
0
500 m
1000 ft
R.F. 1:15,840
½ Mile
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas
MONGALPUR SUBPROJECT
SP ID 33097
Upazila: Dowarabazar, Dist. Sunamganj
House of Consultants Ltd.
44/F/8A (1st. Floor), West Panthapath, Dhanmondi, Dhaka-1205
INDEX MAP
DRAWN BY
DESIGNED BY
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CAD Operator
Design Engineer
Team Leader
DRG. No. 33097/INDEX MAP/1-2/2
February-2012

Appendix D

Sample Design Calculations for a CAD Subproject

SP 33097 Mongalpur

Appendix D1: Number of Rotation and Irrigator Units
Appendix D2: Command Areas, Design Flows & Minimum Pipe Diameters
Appendix D3: Buried Pipe Loss Calculation for Pipeline-1
Appendix D4: Head losses in Header Tank and in Flow Control Tank

Appendix D1

Number of Rotation and Irrigator Units

Name of SP : Mongalpur Subproject
Up : Dowrabazar
Dist : Sunamganj

Item	Units	Quantity	Remarks
Gross Area	ha	**401**	
Net Irrigable Area	ha	**313**	
Crop Water Requirements	l/s/ha	**0.65**	
Efficiency d/s of outlet	%	**80.0%**	
Water Requirements at Outlet	l/s/ha	0.81	
Number of Rotation Units	Nr	**3**	Select to give 80-120 ha Rotation Units
Net Irrigable Area of Rotation Units (avg)	ha	104.3	
Number of Outlets (risers) ie Irrigator Units	Nr	**30**	Select to give 5-15 ha Irrigator Units, and generally every 200-500 m along pipe line
Net Irrigable Area of Irrigator Units (avg)	ha	10.4	
Nr of standpipes	Nr	15	Adopt about 50% of nr of riser outlets
Number of benefitting HHs	Nr	**704**	
Number of HH per Rotation Units	Nr	235	
Number of HH per Irrigator Units	Nr	23	
Rotation flows (avg)	l/s	85	
Irrigator flows (avg)	l/s	8	

Appendix D2

Command Areas, Design Flows & Minimum Pipe Diameters

Command Areas, Design Flows & Minimum Pipe Diameters Associated with Maximum PipeFlow
Name of SP : Mongalpur Subproject
Up : Dowrabazar
Dist : Sunamganj

Available PVC pipe sizes outer diameter (mm): 160, 180, 200, 225, 250, 280, 315, 355,400, 450 & 500
Max flow velocity is 1.5 m/s for PVC pipes. Typical max is 1.2 m/s
Pipe thickness for 3.25 bar working pressure

Pipeline-1

Sl No	Pipeline Reach	Length	RD	EL	Command Area (cumulative)	Design Duty		Irrigation Efficiency d/s of Outlet	Design Discharge, Q	Pipe Flow Velocity		Pipe diameters		Suggested Pipe Thickness & Diameter (mm)		
										Typ	Max	Typ	Min			
		m	m	m	ha	cfs/acre	l/s/ha	%	m3/s	m/s	m/s	mm	mm	External Dia	Thickless	Internal Dia
1	KL	200	2,990	6.60	15	0.0093	0.65	80	0.012	1.20	1.50	114	102	160	2.00	156
2	JK	200	2,790	7.00	30	0.0093	0.65	80	0.024	1.20	1.50	161	144	160	2.00	156
3	IJ	200	2,590	7.10	45	0.0093	0.65	80	0.037	1.20	1.50	197	176	200	2.50	195
4	HI	50	2,390	8.25	45	0.0093	0.65	80	0.037	1.20	1.50	197	176	200	2.50	195
5	GH	460	2,340	8.30	56	0.0093	0.65	80	0.046	1.20	1.50	220	197	225	2.80	219
6	FG	340	1,880	8.26	71	0.0093	0.65	80	0.058	1.20	1.50	248	221	250	3.10	244
7	EF	270	1,540	8.05	97	0.0093	0.65	80	0.079	1.20	1.50	289	259	315	4.00	307
8	DE	240	1,270	7.55	105	0.0093	0.65	80	0.085	1.20	1.50	301	269	315	4.00	307
9	CD	310	1,030	8.20	118	0.0093	0.65	80	0.096	1.20	1.50	319	285	355	4.40	346
10	BC	290	720	7.30	129	0.0093	0.65	80	0.105	1.20	1.50	334	298	355	4.40	346
11	AB	350	430	7.21	139	0.0093	0.65	80	0.113	1.20	1.50	346	310	355	4.40	346
12	HT-A	80	80	8.50	147	0.0093	0.65	80	0.120	1.20	1.50	356	319	400	5.00	390
		2,990		8.45												

Pipeline-2

Sl No	Pipeline Reach	Length	RD	EL	Command Area (cumulative)	Design Duty		Irrigation Efficiency d/s of Outlet	Design Discharge, Q	Pipe Flow Velocity		Pipe diameters		Suggested Pipe Thickness & Diameter (mm)		
										Typ	Max	Typ	Min			
		m	m	m	ha	cfs/acre	l/s/ha	%	m3/s	m/s	m/s	mm	mm	External Dia	Thickless	Internal Dia
1	IJ	320	2,015	7.60	6	0.0093	0.65	80	0.005	1.20	1.50	72	64	160	2.00	156
2	HI	100	1,695	7.51	6	0.0093	0.65	80	0.005	1.20	1.50	72	64	160	2.00	156
3	GH	110	1,595	7.55	14	0.0093	0.65	80	0.011	1.20	1.50	110	98	160	2.00	156
4	FG	190	1,485	7.80	14	0.0093	0.65	80	0.011	1.20	1.50	110	98	160	2.00	156
5	EF	210	1,295	8.20	22	0.0093	0.65	80	0.018	1.20	1.50	138	123	160	2.00	156
6	DE	90	1,085	8.70	38	0.0093	0.65	80	0.031	1.20	1.50	181	162	200	2.50	195
7	CD	290	995	8.17	133	0.0093	0.65	80	0.108	1.20	1.50	339	303	355	4.40	346
8	BC	350	705	8.55	145	0.0093	0.65	80	0.118	1.20	1.50	354	316	400	5.00	390
9	AB	250	355	7.68	158	0.0093	0.65	80	0.129	1.20	1.50	369	330	450	5.60	439
10	HT-A	105	105	8.05	166	0.0093	0.65	80	0.135	1.20	1.50	378	339	450	5.60	439
		2,015		8.45												

Pipeline-3

Sl No	Pipeline Reach	Length	RD	EL	Command Area (cumulative)	Design Duty		Irrigation Efficiency d/s of Outlet	Design Discharge, Q	Pipe Flow Velocity		Pipe diameters		Suggested Pipe Thickness & Diameter (mm)		
										Typ	Max	Typ	Min			
		m	m	m	ha	cfs/acre	l/s/ha	%	m3/s	m/s	m/s	mm	mm	External Dia	Thickless	Internal Dia
1	KL	150	1,910	7.42	14	0.0093	0.65	80	0.011	1.20	1.50	110	98	160	2.00	156
2	JK	80	1,760	8.30	14	0.0093	0.65	80	0.011	1.20	1.50	110	98	160	2.00	156
3	IJ	540	1,680	8.00	28	0.0093	0.65	80	0.023	1.20	1.50	155	139	180	2.30	175
4	HI	220	1,140	8.20	44	0.0093	0.65	80	0.036	1.20	1.50	195	174	200	2.50	195
5	GH	150	920	8.68	52	0.0093	0.65	80	0.042	1.20	1.50	212	189	225	2.80	219
6	FG	310	770	8.35	60	0.0093	0.65	80	0.049	1.20	1.50	228	204	280	3.50	273
7	EF	90	460	8.32	90	0.0093	0.65	80	0.073	1.20	1.50	279	249	280	3.50	273
8	DE	170	370	8.30	92	0.0093	0.65	80	0.075	1.20	1.50	282	252	355	4.40	346
9	D2-D3	200	200	9.17	92	0.0093	0.65	80	0.075	1.20	1.50	282	252	355	4.40	346
		1,910		8.17												

Branch 1-1

Sl No	Pipeline Reach	Length	RD	EL	Command Area (cumulative)	Design Duty		Irrigation Efficiency d/s of Outlet	Design Discharge, Q	Pipe Flow Velocity		Pipe diameters		Suggested Pipe Thickness & Diameter (mm)		
										Typ	Max	Typ	Min			
		m	m	m	ha	cfs/acre	l/s/ha	%	m3/s	m/s	m/s	mm	mm	External Dia	Thickless	Internal Dia
1	F11-F12	180	430	7.68	12	0.0093	0.65	80	0.010	1.20	1.50	102	91	160	2.00	156
2	F1-F11	250	250	7.90	12	0.0093	0.65	80	0.010	1.20	1.50	102	91	160	2.00	156
		430		8.05												

Branch 2-1

Sl No	Pipeline Reach	Length	RD	EL	Command Area (cumulative)	Design Duty		Irrigation Efficiency d/s of Outlet	Design Discharge, Q	Pipe Flow Velocity		Pipe diameters		Suggested Pipe Thickness & Diameter (mm)		
										Typ	Max	Typ	Min			
		m	m	m	ha	cfs/acre	l/s/ha	%	m3/s	m/s	m/s	mm	mm	External Dia	Thickless	Internal Dia
1	C2-C21	190	190	8.45	6	0.0093	0.65	80	0.005	1.20	1.50	72	64	160	2.00	156
		190		8.55												

Branch 2-2

Sl No	Pipeline Reach	Length	RD	EL	Command Area (cumulative)	Design Duty		Irrigation Efficiency d/s of Outlet	Design Discharge, Q	Pipe Flow Velocity		Pipe diameters		Suggested Pipe Thickness & Diameter (mm)		
										Typ	Max	Typ	Min			
		m	m	m	ha	cfs/acre	l/s/ha	%	m3/s	m/s	m/s	mm	mm	External Dia	Thickless	Internal Dia
1	E21-E22	100	200	7.93	9	0.0093	0.65	80	0.007	1.20	1.50	88	79	160	2.00	156
2	E2-E21	100	100	7.91	9	0.0093	0.65	80	0.007	1.20	1.50	88	79	160	2.00	156
		200		8.70												

Branch 3-1

Sl No	Pipeline Reach	Length	RD	EL	Command Area (cumulative)	Design Duty		Irrigation Efficiency d/s of Outlet	Design Discharge, Q	Pipe Flow Velocity		Pipe diameters		Suggested Pipe Thickness & Diameter (mm)		
										Typ	Max	Typ	Min			
		m	m	m	ha	cfs/acre	l/s/ha	%	m3/s	m/s	m/s	mm	mm	External Dia	Thickless	Internal Dia
1	F31-F32	270	600	7.40	15	0.0093	0.65	80	0.012	1.20	1.50	114	102	160	2.00	156
2	F3-F31	330	330	7.85	21	0.0093	0.65	80	0.017	1.20	1.50	135	120	160	2.00	156
		600		8.32												

Pumping Plant and Power Requirements

Total discharge at peak demand (for boro paddy - see note below)	0.254	m3/s	80% efficiency		
	8.979	cusecs			
Nr of pumps	**5**	Nr	(Notes: (i) not less than the nr of Rotation units; (ii) no standby pump)		
Pump discharage	51	l/s per pump			
	1.80	cusecs/pump			
Adopted pump capacity	57	l/s per pump			
	2.01	cusecs/pump			
	205	m3/hr per pump			
	902	USG/m per pump		1 USG =	3.8 ltr
Pump spare capacity	12%		(Note: adopt 10-20%)	1 USG =	0.83 UKG
Top of header tank	**14.45**	m			
EGL at header tank / near river (ie where pump to be located)	**8.50**	m			
River level during dry season (ie Dec - March)	**3.60**	m	(refer feasibility report: note data not too reliable)		
Total Static Head	10.85	m			
Suction Head	4.90	m	Note: recommended limit: 2-3 m		
Allowance for friction losses (pipe and fittings)	**0.50**	m	(Note: distance maybe about 50 m)		
Total Pumping Head	11.35	m			
Adopted power unit efficiency	**0.80**		Note: electric unit: 75-85%)		
Adopted pump efficiency	**0.60**		Note: 40 - 80%		
Overall efficiency	0.48				
Power Demand per pump (for adopted pump capacity)	13.2	kW	Power (kW) = 9.81 x discharge (m3/s) x head (m) / overall efficiency		
	18.0	HP (1 kW= 1.36 HP)			
Total Peak Power Demand for SP	66.1	kW			
	89.9	HP (1 kW= 1.36 HP)			

Note: 24/7 pumping at peak demand period is assumed. However electical power shortages mean that pumping may only be possible during night hours. If 100% rice cropping occurs in the SP area and if peak demand occurs over the whole command area simultaneously then the pipe system and pumps cannot meet crop water demand by only pumping at night. In practice: (i) some vegetables / wheat etc may be cropped; and (ii) transplanting of boro rice is usually staggered reducing peak water demand. None-the-less water shortage may occur due to non-availability of power in which case the WMCA may have to arrange hire / purchase of a generator for day time use over the peak water demand period.

Appendix D3

Buried Pipe Loss Calculation for Pipeline-1

Buried Pipe Loss Calculation for Pipeline -1

Name of SP : Mongalpur Subproject
Up : Dowrabazar
Dist : Sunamganj

For concrete pipe adopt f = 0.0050
For PVC pipe adopt f = 0.0042

Available PVC pipe sizes outer diameter (mm): 160, 180, 200, 225, 250, 280, 315, 355,400, 450 & 500

Hydraulic Grade Line : HT-A-B-C-D-E-F-G-H-I-J-K-L

L		**Chainage**		2,990.0				
Length	**KL**		200	m				
Ground EL			6.60	m PWD				
Command			0.80	m	(0.5 plus 0.3 m req'd - min)			
Top of pipeline			5.60	m PWD				
Hydraulic Grade Line El			**7.40**	m PWD				
Freeboard for standpipes			0.60	m				
El of top of standpipes			8.00	m PWD				
Diameter of Pipe (external)			160	mm	hf = (2*f*l*v^2)/(g*d)			
Diameter of Pipe (internal)			156	mm	f =	0.0042		
Design Discharge			0.012	m3/sec	v =	0.63	m/s	
Pipe Friction Loss			0.43		hf =	**0.433**	m	
Velocity head, v2/sg			0.02	m				
Nr of pipe bends / changes in pipe diameter / values etc			1.00	Nr				
Loss due to pipe bends / change in pipe diameter/ control values, etc			0.02	m	Adopt loss coefficient, K, of 0.8			
Estimated nr of riser outlets			1.43	Nr				
Nr of riser / outlets			2.00	Nr				
Nr of standpipes			1.00	Nr				
Loss per riser / standpipe			0.01	m	Adopt loss coefficient, K, of 0.6			
Losses due to risers / standpipes			0.04	m				
Total fitting / bend etc losses			**0.05**	m				
Hydraulic Grade Line El at K			**7.88**	m PWD				

K		**Chainage**		2,790.0				
Length	**JK**		200	m				
Ground EL			7.00	m PWD				
Command			0.88	m	(0.5 plus 0.3 m req'd - min)			
Top of pipeline			6.00	m PWD				
Hydraulic Grade Line El			**7.88**	m PWD				
Freeboard for standpipes			0.60	m				
El of top of standpipes			8.48	m PWD				
Diameter of Pipe (external)			200	mm	hf = (2*f*l*v^2)/(g*d)			
Diameter of Pipe (internal)			195	mm	f =	0.0042		
Design Discharge			0.024	m3/sec	v =	0.80	m/s	
Pipe Friction Loss			0.57		hf =	**0.567**	m	
Velocity head, v2/sg			0.03	m				
Nr of pipe bends / changes in pipe diameter / values etc			1.00	Nr				
Loss due to pipe bends / change in pipe diameter/ control values, etc			0.03	m	Adopt loss coefficient, K, of 0.8			
Estimated nr of riser outlets			1.43	Nr				
Nr of riser / outlets			2.00	Nr				
Nr of standpipes			1.00	Nr				
Loss per riser / standpipe			0.02	m	Adopt loss coefficient, K, of 0.6			
Losses due to risers / standpipes			0.06	m				
Total fitting / bend etc losses			**0.09**	m				
Hydraulic Grade Line El at J			**8.54**	m PWD				

J	**Chainage**	2,590.0		
Length	**IJ**	200	m	
Ground EL		7.10	m PWD	
Command		1.44	m	(0.5 plus 0.3 m req'd - min)
Top of pipeline		6.10	m PWD	
Hydraulic Grade Line El		**8.54**	m PWD	
Freeboard for standpipes		0.60	m	
El of top of standpipes		9.14	m PWD	
Diameter of Pipe (external)		250	mm	hf = (2*f*l*v^2)/(g*d)
Diameter of Pipe (internal)		244	mm	f = 0.0042
Design Discharge		0.037	m3/sec	v = 0.79 m/s
Pipe Friction Loss		0.44		hf = **0.439** m
Velocity head, v2/sg		0.03	m	
Nr of pipe bends / changes in pipe diameter / values etc		1.00	Nr	
Loss due to pipe bends / change in pipe diameter/ control values, etc		0.03	m	Adopt loss coefficient, K, of 0.8
Estimated nr of riser outlets		1.43	Nr	
Nr of riser / outlets		2.00	Nr	
Nr of standpipes		1.00	Nr	
Loss per riser / standpipe		0.02	m	Adopt loss coefficient, K, of 0.6
Losses due to risers / standpipes		0.06	m	
Total fitting / bend etc losses		**0.08**	m	
Hydraulic Grade Line El at I		**9.06**	m PWD	

I	**Chainage**	2,390.0		
Length	**HI**	50	m	
Ground EL		8.25	m PWD	
Command		**0.81**	m	(0.5 plus 0.3 m req'd)
Top of pipeline		7.25	m PWD	
Hydraulic Grade Line El		**9.06**	m PWD	
Freeboard for standpipes		0.60	m	
El of top of standpipes		9.66	m PWD	
Diameter of Pipe (external)		250	mm	hf = (2*f*l*v^2)/(g*d)
Diameter of Pipe (internal)		244	mm	f = 0.0042
Design Discharge		0.037	m3/sec	v = 0.79 m/s
Pipe Friction Loss		0.11		hf = **0.110** m
Velocity head, v2/sg		0.03	m	
Nr of pipe bends / changes in pipe diameter / values etc		1.00	Nr	
Loss due to pipe bends / change in pipe diameter/ control values, etc		0.03	m	Adopt loss coefficient, K, of 0.8
Estimated nr of riser outlets		0.36	Nr	
Nr of riser / outlets		2.00	Nr	
Nr of standpipes		1.00	Nr	
Loss per riser / standpipe		0.02	m	Adopt loss coefficient, K, of 0.6
Losses due to risers / standpipes		0.06	m	
Total fitting / bend etc losses		**0.08**	m	
Hydraulic Grade Line El at H		**9.25**	m PWD	

H		**Chainage**	2,340.0				
Length	**GH**	460	m				
Ground EL		8.30	m PWD				
Command		**0.95**	m	(0.5 plus 0.3 m req'd)			
Top of pipeline		7.30	m PWD				
Hydraulic Grade Line El		**9.25**	m PWD				
Freeboard for standpipes (min)		0.30	m				
El of top of standpipes (min)		9.55	m PWD				
Diameter of Pipe (external)		280	mm		hf = (2*f*l*v^2)/(g*d)		
Diameter of Pipe (internal)		273	mm		f =	0.0042	
Design Discharge		0.046	m3/sec		v =	0.79	m/s
Pipe Friction Loss		0.89			hf =	**0.891**	m
Velocity head, v2/sg		0.03	m				
Nr of pipe bends / changes in pipe diameter / values etc		1.00	Nr				
Loss due to pipe bends / change in pipe diameter/ control values, etc		0.03	m	Adopt loss coefficient, K, of 0.8			
Estimated nr of riser outlets		3.29	Nr				
Nr of riser / outlets		3.00	Nr				
Nr of standpipes		1.00	Nr				
Loss per riser / standpipe		0.02	m	Adopt loss coefficient, K, of 0.6			
Losses due to risers / standpipes		0.08	m				
Total fitting / bend etc losses		**0.10**	m				
Hydraulic Grade Line El at G		**10.24**	m PWD				

G		**Chainage**	1,880.0				
Length	**FG**	340	m				
Ground EL		8.26	m PWD				
Command		**1.98**	m	(0.5 plus 0.3 m req'd)			
Top of pipeline		7.26	m PWD				
Hydraulic Grade Line El		**10.24**	m PWD				
Freeboard for standpipes (min)		0.30	m				
El of top of standpipes (min)		10.54	m PWD				
Diameter of Pipe (external)		315	mm		hf = (2*f*l*v^2)/(g*d)		
Diameter of Pipe (internal)		307	mm		f =	0.0042	
Design Discharge		0.058	m3/sec		v =	0.78	m/s
Pipe Friction Loss		0.58			hf =	**0.582**	m
Velocity head, v2/sg		0.03	m				
Nr of pipe bends / changes in pipe diameter / values etc		1.00	Nr				
Loss due to pipe bends / change in pipe diameter/ control values, etc		0.03	m	Adopt loss coefficient, K, of 0.8			
Estimated nr of riser outlets		2.43	Nr				
Nr of riser / outlets		2.00	Nr				
Nr of standpipes		0.00	Nr				
Loss per riser / standpipe		0.02	m	Adopt loss coefficient, K, of 0.6			
Losses due to risers / standpipes		0.04	m				
Total fitting / bend etc losses		**0.06**	m				
Hydraulic Grade Line El at F		**10.89**	m PWD				

F		Chainage	1,540.0				
Length	**EF**	270	m				
Ground EL		8.05	m PWD				
Command		**2.84**	m	(0.5 plus 0.3 m req'd)			
Top of pipeline		7.05	m PWD				
Hydraulic Grade Line El		**10.89**	m PWD				
Freeboard for standpipes (min)		0.30	m				
El of top of standpipes (min)		11.19	m PWD				
Diameter of Pipe (external)		355	mm		hf = (2*f*l*v^2)/(g*d)		
Diameter of Pipe (internal)		346	mm		f =	0.0042	
Design Discharge		0.079	m3/sec		v =	0.84	m/s
Pipe Friction Loss		0.47			hf =	**0.472**	m
Velocity head, v2/sg		0.04	m				
Nr of pipe bends / changes in pipe diameter / values etc		0.00	Nr				
Loss due to pipe bends / change in pipe diameter/ control values, etc		0.00	m	Adopt loss coefficient, K, of 0.8			
Estimated nr of riser outlets		1.93	Nr				
Nr of riser / outlets		2.00	Nr				
Nr of standpipes		1.00	Nr				
Loss per riser / standpipe		0.02	m	Adopt loss coefficient, K, of 0.6			
Losses due to risers / standpipes		0.06	m				
Total fitting / bend etc losses		**0.06**	m				
Hydraulic Grade Line El at E		**11.43**	m PWD				

E		Chainage	1,270.0				
Length	**DE**	240	m				
Ground EL		7.55	m PWD				
Command		**3.88**	m	(0.5 plus 0.3 m req'd)			
Top of pipeline		6.55	m PWD				
Hydraulic Grade Line El		**11.43**	m PWD				
Freeboard for standpipes		0.60	m				
El of top of standpipes		12.03	m PWD				
Diameter of Pipe (external)		355	mm		hf = (2*f*l*v^2)/(g*d)		
Diameter of Pipe (internal)		346	mm		f =	0.0042	
Design Discharge		0.085	m3/sec		v =	0.90	m/s
Pipe Friction Loss		0.49			hf =	**0.485**	m
Velocity head, v2/sg		0.04	m				
Nr of pipe bends / changes in pipe diameter / values etc		1.00	Nr				
Loss due to pipe bends / change in pipe diameter/ control values, etc		0.03	m	Adopt loss coefficient, K, of 0.8			
Estimated nr of riser outlets		1.71	Nr				
Nr of riser / outlets		2.00	Nr				
Nr of standpipes		1.00	Nr				
Loss per riser / standpipe		0.03	m	Adopt loss coefficient, K, of 0.6			
Losses due to risers / standpipes		0.08	m				
Total fitting / bend etc losses		**0.11**	m				
Hydraulic Grade Line El at D		**12.02**	m PWD				

D		**Chainage**	1,030.0				
Length	**CD**		310	m			
Ground EL			8.20	m PWD			
Command			**3.82**	m	(0.5 plus 0.3 m req'd)		
Top of pipeline			7.20	m PWD			
Hydraulic Grade Line El			**12.02**	m PWD			
Freeboard for standpipes			0.60	m			
El of top of standpipes			12.62	m PWD			
Diameter of Pipe (external)			400	mm	hf =	(2*f*l*v^2)/(g*d)	
Diameter of Pipe (internal)			390	mm	f =	0.0042	
Design Discharge			0.096	m3/sec	v =	0.80	m/s
Pipe Friction Loss			0.44		hf =	**0.440**	m
Velocity head, v2/sg			0.03	m			
Nr of pipe bends / changes in pipe diameter / values etc			1.00	Nr			
Loss due to pipe bends / change in pipe diameter/ control values, etc			0.03	m	Adopt loss coefficient, K, of 0.8		
Estimated nr of riser outlets			2.21	Nr			
Nr of riser / outlets			2.00	Nr			
Nr of standpipes			1.00	Nr			
Loss per riser / standpipe			0.02	m	Adopt loss coefficient, K, of 0.6		
Losses due to risers / standpipes			0.06	m			
Total fitting / bend etc losses			**0.09**	m			
Hydraulic Grade Line El at C			**12.55**	m PWD			

C		**Chainage**	720.0				
Length	**BC**		290	m			
Ground EL			7.30	m PWD			
Command			**5.25**	m	(0.5 plus 0.3 m req'd)		
Top of pipeline			6.30	m PWD			
Hydraulic Grade Line El			**12.55**	m PWD			
Freeboard for standpipes			0.60	m			
El of top of standpipes			13.15	m PWD			
Diameter of Pipe (external)			450	mm	hf =	(2*f*l*v^2)/(g*d)	
Diameter of Pipe (internal)			439	mm	f =	0.0042	
Design Discharge			0.105	m3/sec	v =	0.69	m/s
Pipe Friction Loss			0.27		hf =	**0.272**	m
Velocity head, v2/sg			0.02	m			
Nr of pipe bends / changes in pipe diameter / values etc			1.00	Nr			
Loss due to pipe bends / change in pipe diameter/ control values, etc			0.02	m	Adopt loss coefficient, K, of 0.8		
Estimated nr of riser outlets			2.07	Nr			
Nr of riser / outlets			2.00	Nr			
Nr of standpipes			1.00	Nr			
Loss per riser / standpipe			0.01	m	Adopt loss coefficient, K, of 0.6		
Losses due to risers / standpipes			0.04	m			
Total fitting / bend etc losses			**0.06**	m			
Hydraulic Grade Line El at B			**12.88**	m PWD			

B		Chainage	430.0				
Length	**AB**		350	m			
Ground EL			7.21	m PWD			
Command			**5.67**	m	(0.5 plus 0.3 m req'd)		
Top of pipeline			6.21	m PWD			
Hydraulic Grade Line El			**12.88**	m PWD			
Freeboard for standpipes			0.60	m			
El of top of standpipes			13.48	m PWD			
Diameter of Pipe (external)	E to F		450	mm	hf = (2*f*l*v^2)/(g*d)		
Diameter of Pipe (internal)			439	mm	f =	0.0042	
Design Discharge			0.113	m3/sec	v =	0.75	m/s
Pipe Friction Loss			0.38		hf =	**0.380**	m
Velocity head, v2/sg			0.03 m				
Nr of pipe bends / changes in pipe diameter / values etc			1.00 Nr				
Loss due to pipe bends / change in pipe diameter/ control values, etc			0.02 m		Adopt loss coefficient, K, of 0.8		
Estimated nr of riser outlets			2.50 Nr				
Nr of riser / outlets			2.00 Nr				
Nr of standpipes			1.00 Nr				
Loss per riser / standpipe			0.02 m		Adopt loss coefficient, K, of 0.6		
Losses due to risers / standpipes			0.05 m				
Total fitting / bend etc losses			**0.07** m				
Hydraulic Grade Line El at A			**13.34**	m PWD			

A		Chainage	80.0				
Length	**HT-A**		80	m			
Ground EL			8.50	m PWD			
Command			**4.84**	m	(0.5 plus 0.3 m req'd)		
Top of pipeline			7.50	m PWD			
Hydraulic Grade Line El			13.34	m PWD			
Freeboard for standpipes			0.60	m			
El of top of standpipes			13.94	m PWD			
Diameter of Pipe (external)			450	mm	hf = (2*f*l*v^2)/(g*d)		
Diameter of Pipe (internal)			439	mm	f =	0.0042	
Design Discharge			0.12	m3/sec	v =	0.79	m/s
Pipe Friction Loss			0.10		hf =	**0.098**	m
Velocity head, v2/sg			0.03 m				
Nr of pipe bends / changes in pipe diameter / values etc			1.00 Nr				
Loss due to pipe bends / change in pipe diameter/ control values, etc			0.03 m		Adopt loss coefficient, K, of 0.8		
Estimated nr of riser outlets			0.57 Nr				
Nr of riser / outlets			1.00 Nr				
Nr of standpipes			0.00 Nr				
Loss per riser / standpipe			0.02 m		Adopt loss coefficient, K, of 0.6		
Losses due to risers / standpipes			0.02 m				
Total fitting / bend etc losses			**0.04** m				
Hydraulic Grade Line El at HT			**13.48**	m PWD			

HT		Chainage	0.0		
Ground EL			8.45	m PWD	
Command			**5.03**	m	
Top of pipeline			7.45	m PWD	
Hydraulic Grade Line El			13.48	m PWD	Check also pipeline 2
Freeboard for Header tank			0.60	m	
El of top of header tank			14.08	m PWD	
Height of Tank			5.63		

Appendix D4

Head losses in Header Tank and in Flow Control Tank

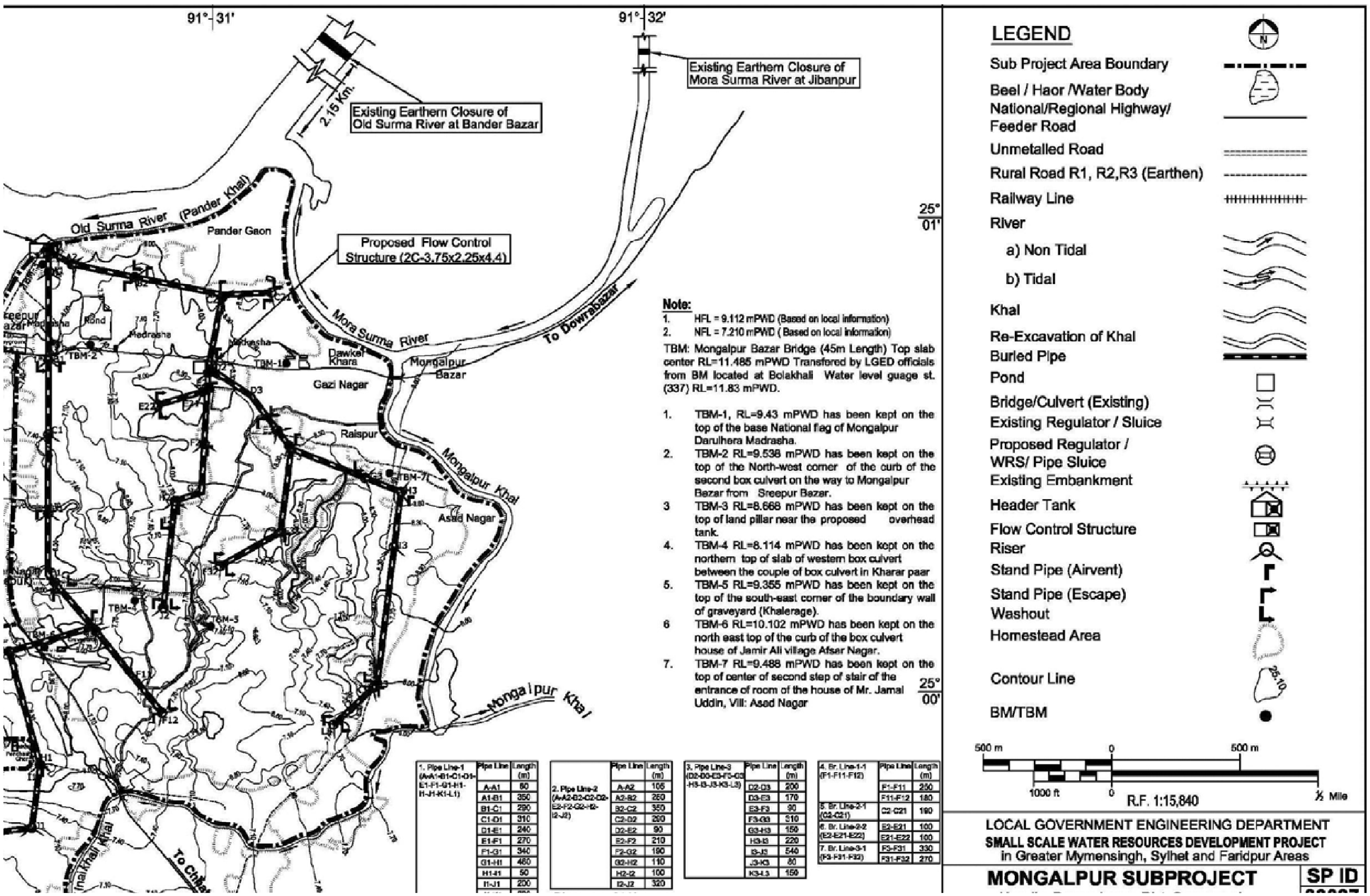
Appendix E

Sample Drawings of a CAD Subproject

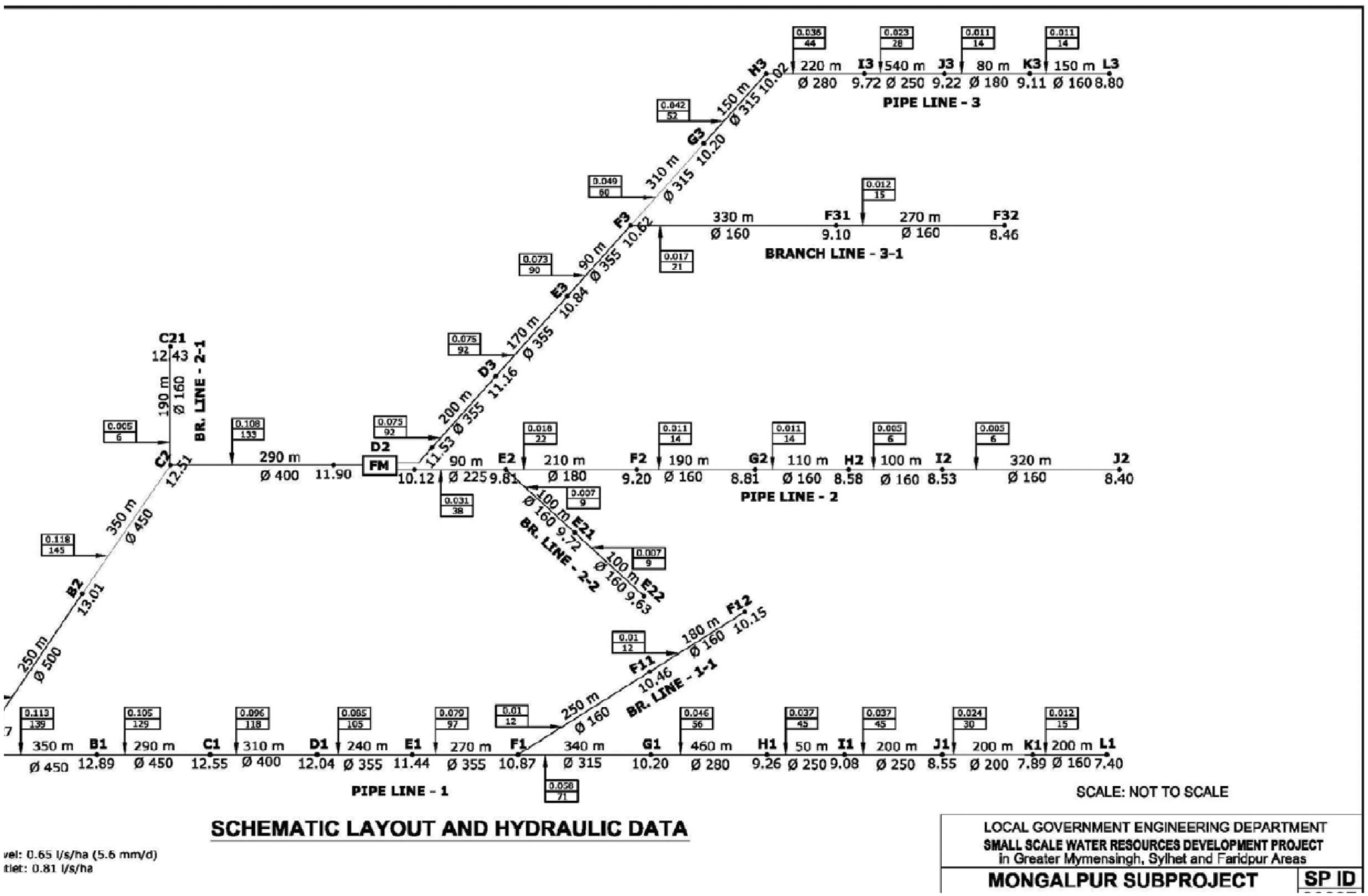
SP 33097 Mongalpur

Appendix E1: Index Map, Schematic Layout and Layout Drawing
Appendix E2: Pump House
Appendix E3: Header Tank
Appendix E4: Flow Control Tank
Appendix E5: Long Profile for Main Pipelines
Appendix E6: Standard Drawings

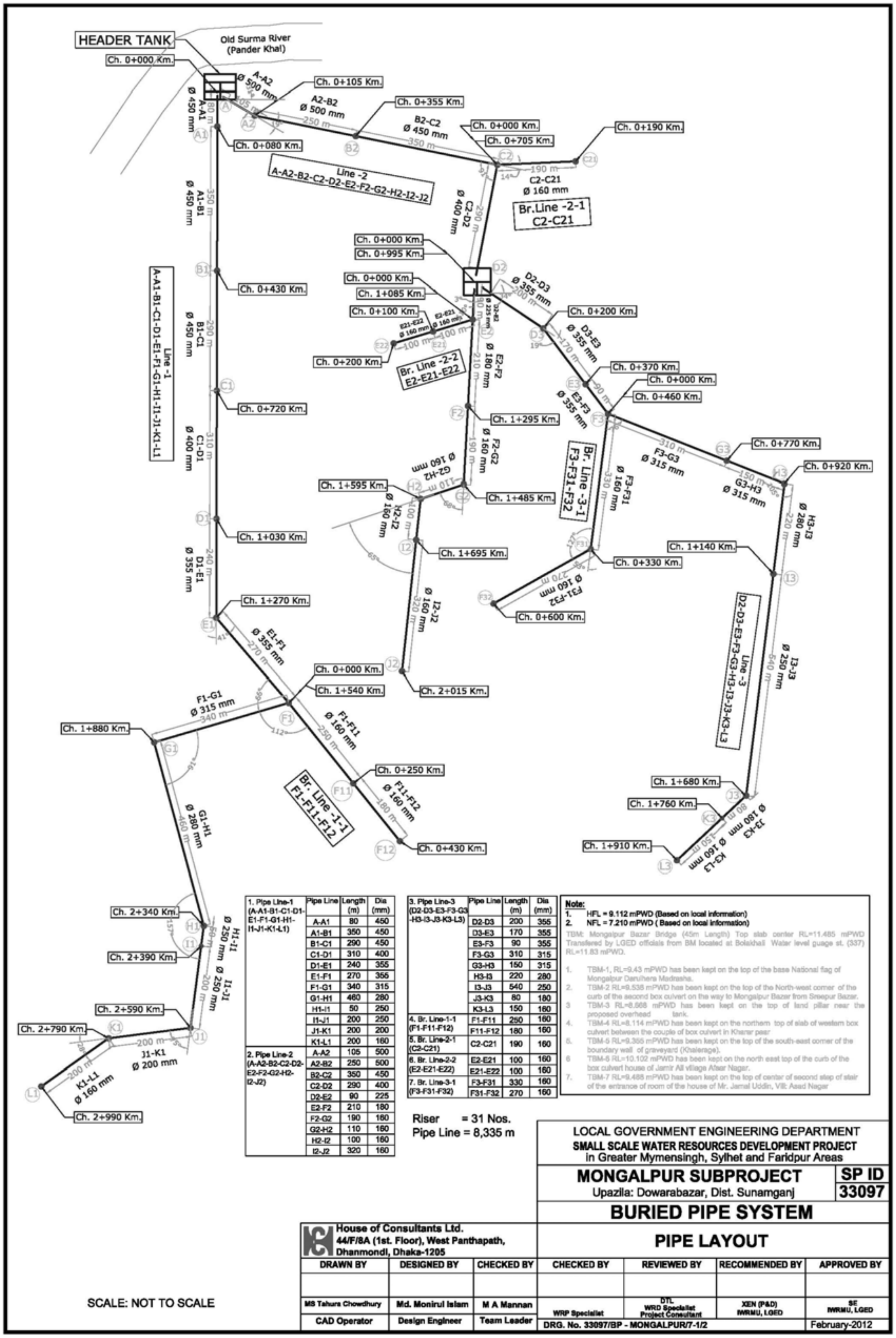
Appendix E1: Index Map



Appendix E1: Schematic Layout and Hydraulic Data



Appendix E1: Pipe Layout Drawing



	Pipe Line	Length (m)	Dia (mm)
1. Pipe Line-1 (A-A1-B1-C1-D1-E1-F1-G1-H1-I1-J1-K1-L1)	A-A1	80	450
	A1-B1	350	450
	B1-C1	290	450
	C1-D1	310	400
	D1-E1	240	355
	E1-F1	270	355
	F1-G1	340	315
	G1-H1	460	280
	H1-I1	50	250
	I1-J1	200	250
	J1-K1	200	200
	K1-L1	200	160
2. Pipe Line-2 (A-A2-B2-C2-D2-E2-F2-G2-H2-I2-J2)	A-A2	105	500
	A2-B2	250	500
	B2-C2	350	450
	C2-D2	290	400
	D2-E2	90	225
	E2-F2	210	180
	F2-G2	190	160
	G2-H2	110	160
	H2-I2	100	160
	I2-J2	320	160

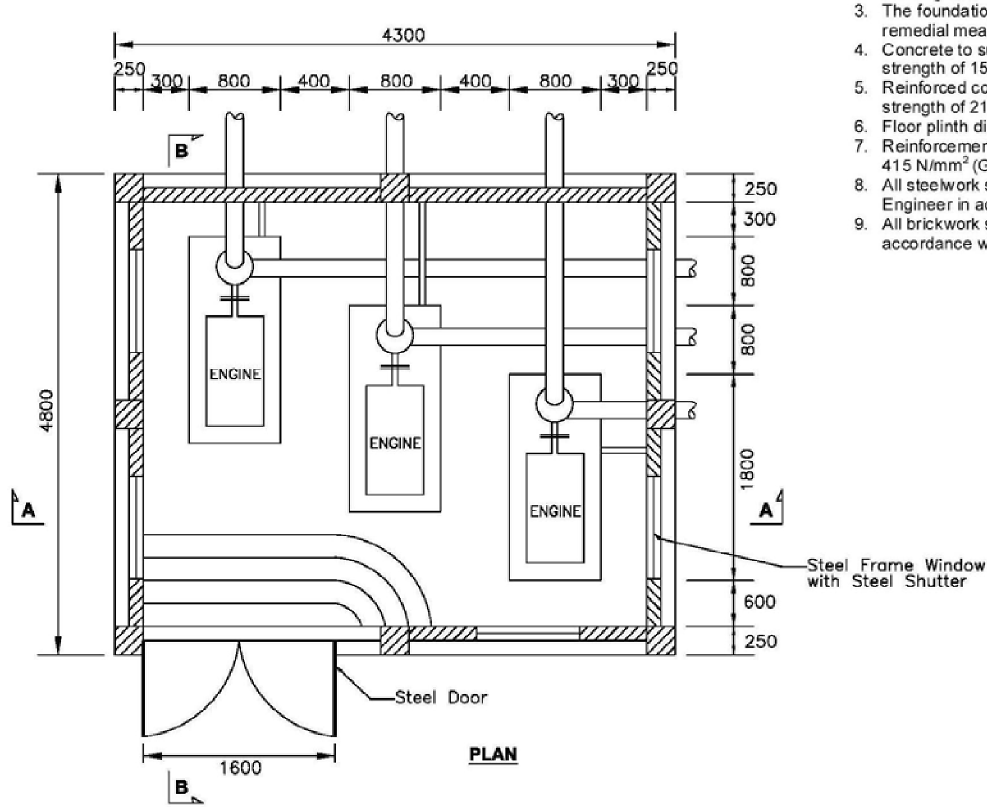
	Pipe Line	Length (m)	Dia (mm)
3. Pipe Line-3 (D2-D3-E3-F3-G3-H3-I3-J3-K3-L3)	D2-D3	200	355
	D3-E3	170	355
	E3-F3	90	355
	F3-G3	310	315
	G3-H3	150	315
	H3-I3	220	280
	I3-J3	540	250
	J3-K3	80	180
	K3-L3	150	160
4. Br. Line-1-1 (F1-F11-F12)	F1-F11	250	160
	F11-F12	180	160
5. Br. Line-2-1 (C2-C21)	C2-C21	190	160
6. Br. Line-2-2 (E2-E21-E22)	E2-E21	100	160
	E21-E22	100	160
7. Br. Line-3-1 (F3-F31-F32)	F3-F31	330	160
	F31-F32	270	160

Note:
1. HFL = 9.112 mPWD (Based on local information)
2. NFL = 7.210 mPWD (Based on local information)

TBM: Mongalpur Bazar Bridge (45m Length) Top slab center RL=11.485 mPWD Transfered by LGED officials from BM located at Bolakhali Water level guage st. (337) RL=11.83 mPWD.

1. TBM-1, RL=9.43 mPWD has been kept on the top of the base National flag of Mongalpur Darulhera Madrasha.
2. TBM-2 RL=9.538 mPWD has been kept on the top of the North-west corner of the curb of the second box culvert on the way to Mongalpur Bazar from Sreepur Bazar.
3. TBM-3 RL=8.668 mPWD has been kept on the top of land pillar near the proposed overhead tank.
4. TBM-4 RL=8.114 mPWD has been kept on the northern top of slab of western box culvert between the couple of box culvert in Kharar pear
5. TBM-5 RL=9.355 mPWD has been kept on the top of the south-east corner of the boundary wall of graveyard (Khalerage).
6. TBM-6 RL=10.102 mPWD has been kept on the north east top of the curb of the box culvert house of Jamir Ali village Afsar Nagar.
7. TBM-7 RL=9.488 mPWD has been kept on the top of center of second step of stair of the entrance of room of the house of Mr. Jamal Uddin, Vill: Asad Nagar

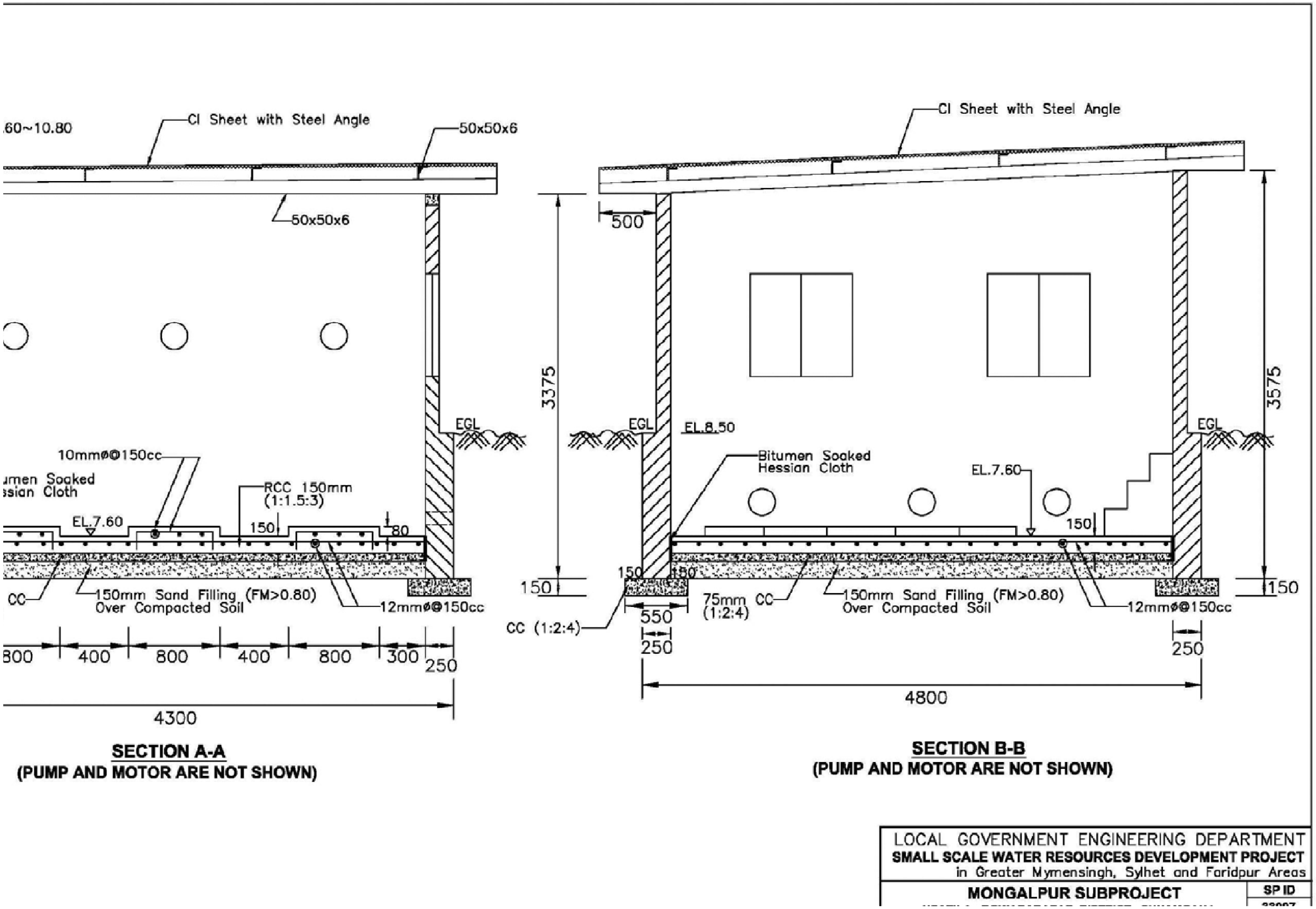
Appendix E2: Pump House



Notes :

1. All dimensions are in millimeters unless otherwise shown.
2. The orientation and exact layout of each Pump House shall be confirmed on Site by the Engineer.
3. The foundation material and condition shall be checked prior to construction and remedial measures taken as directed by the Engineer.
4. Concrete to support brick masonry walls shall have minimum 28-day crushing strength of 150 kg/cm^2 (15 N/mm^2): suggested mix proportions 1:2:4.
5. Reinforced concrete for floor and pump plinths shall have minimum 28-day crushing strength of 210 kg/cm^2 (21 N/mm^2): suggested mix proportions 1:1.5:3.
6. Floor plinth dimensions shall be confirmed before casting.
7. Reinforcement shall be high strength deformed steel bars minimum yield strength of 415 N/mm^2 (Grade 60) unless otherwise shown.
8. All steelwork shall be fabricated and painted or galvanized as shown / directed by the Engineer in accordance with the Specification.
9. All brickwork shall be pointed / plastered and painted as directed by the Engineer in accordance with the Specification.

LOCAL GOVERNMENT ENGINEERING DEPARTMENT **SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT** in Greater Mymensingh, Sylhet and Faridpur Areas				
MONGALPUR SUBPROJECT **UPAZILA : DOWARABAZAR, DISTRICT : SUNAMGANJ**				**SP ID** **33097**
PUMP HOUSE PLAN				
DRAWN BY	DESIGNED BY	REVIEWED BY	RECOMMENDED BY	APPROVED BY
SARAWAR H. KHAN CAD Expert	WRP Specialist Project Consultant	DTL WRD Specialist Project Consultant	Exec. Engineer SSWRDP, (JICA)	Project Director SSWRDP (JICA)
DRG. NO.33097/PUMP-MONGALPUR-02				JUNE 2014


.60~10.80
CI Sheet with Steel Angle
50x50x6
50x50x6
10mmø@150cc
umen Soaked
ssian Cloth
EL.7.60
RCC 150mm
(1:1.5:3)
150
80
EGL
CC
150mm Sand Filling (FM>0.80)
Over Compacted Soil
12mmø@150cc
800
400
800
400
800
300
250
4300
SECTION A-A
(PUMP AND MOTOR ARE NOT SHOWN)
CI Sheet with Steel Angle
500
3375
3575
EGL
EL.8.50
EGL
Bitumen Soaked
Hessian Cloth
EL.7.60
150
150
150
150
150
CC (1:2:4)
550
250
75mm CC
(1:2:4)
150mm Sand Filling (FM>0.80)
Over Compacted Soil
12mmø@150cc
250
4800
SECTION B-B
(PUMP AND MOTOR ARE NOT SHOWN)
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas
MONGALPUR SUBPROJECT
SP ID

Appendix E3: Header Tank Drawings

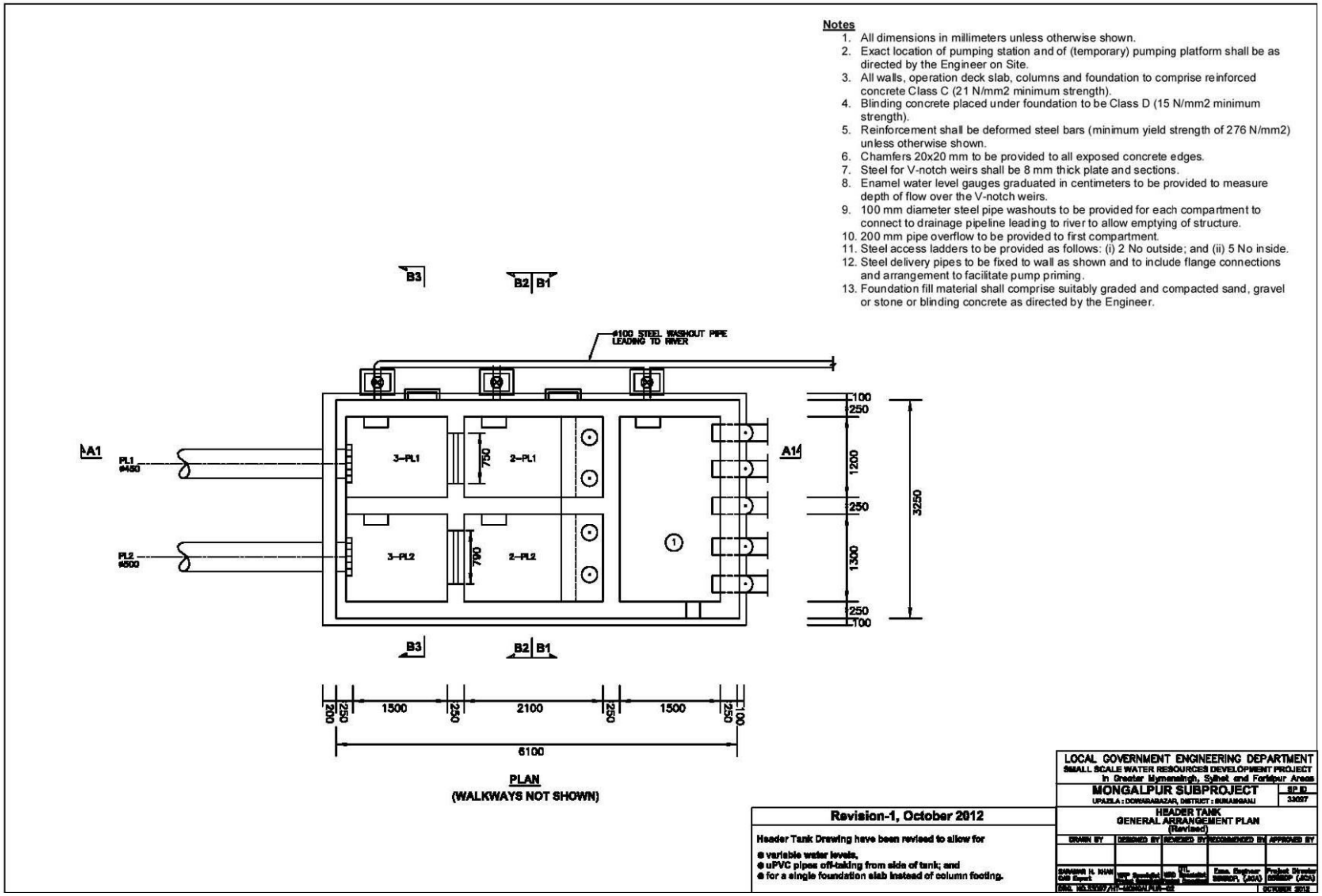


Exhibit G6-I

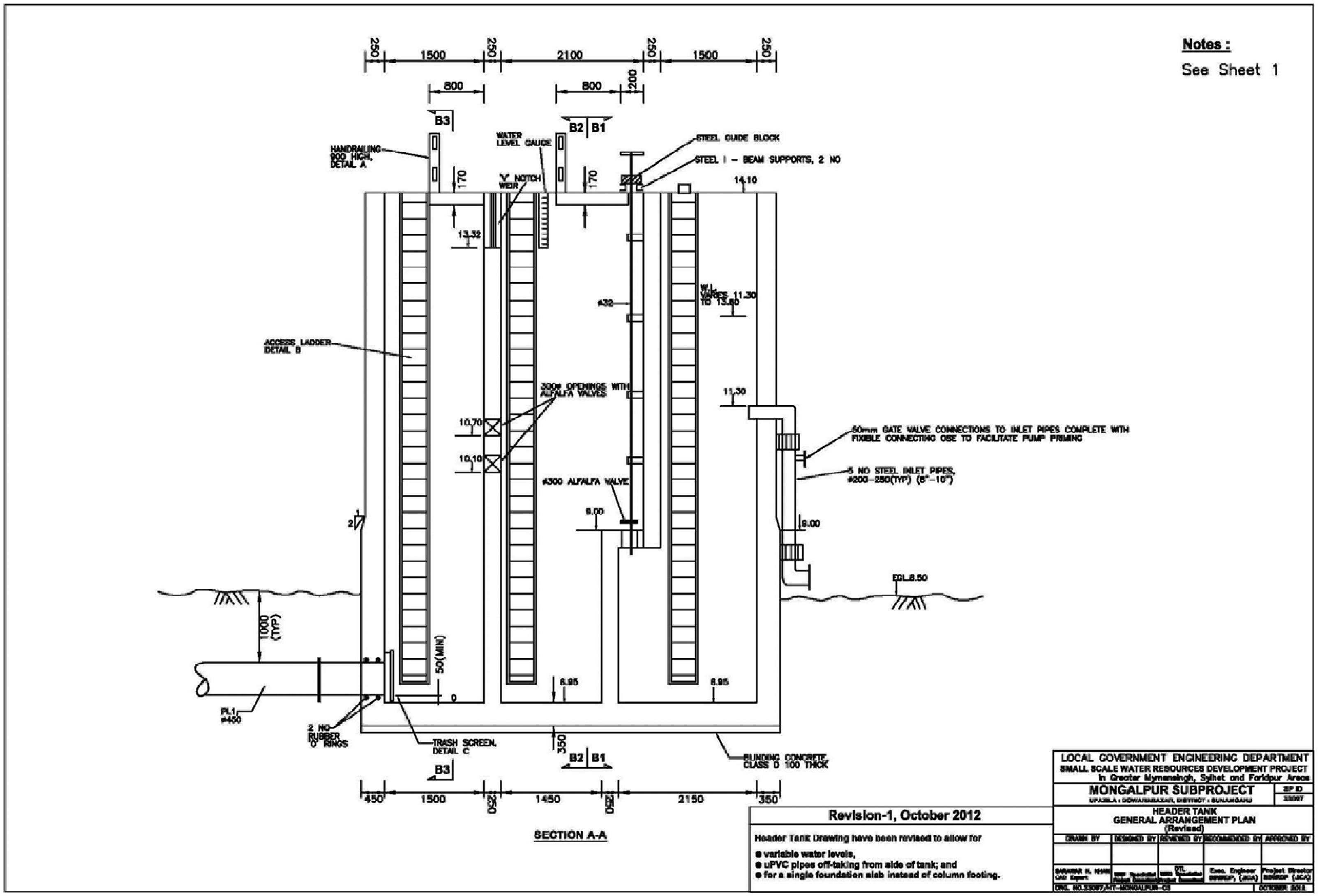
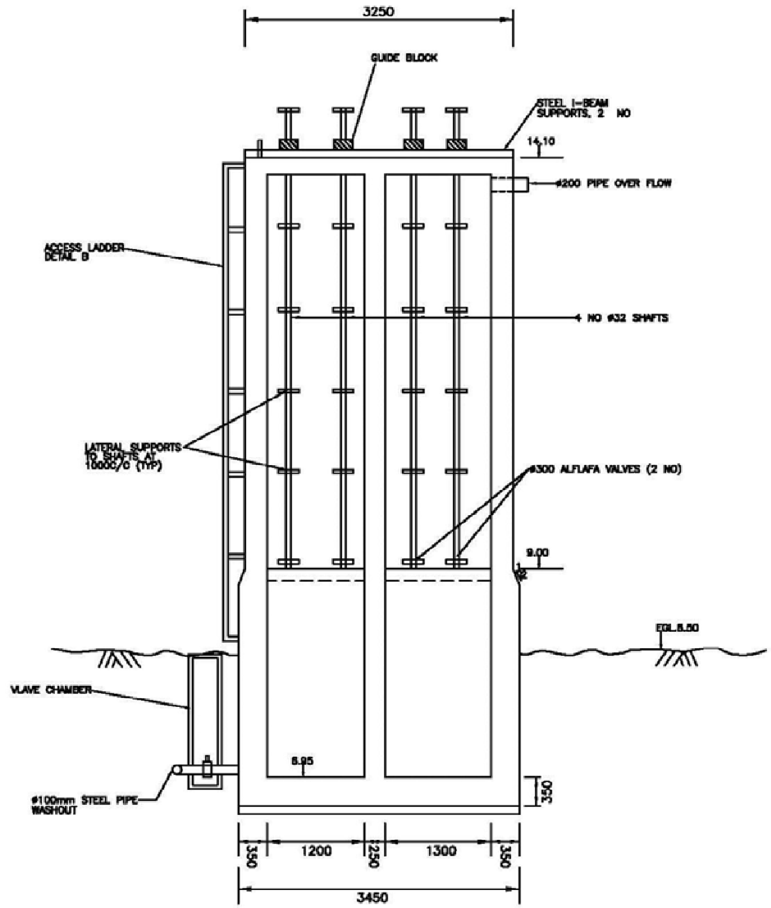

Notes :
See Sheet 1
250
1500
2100
800
200
B3
B2 B1
HANDRAILING 900 HIGH, DETAIL A
WATER LEVEL GAUCE
'V' NOTCH WEIR
STEEL GUIDE BLOCK
STEEL I - BEAM SUPPORTS, 2 NO
170
14.10
13.32
W.L. VARIES 11.30 TO 13.60
ACCESS LADDER DETAIL B
300ø OPENINGS WITH ALFALFA VALVES
11.30
10.70
10.10
ø300 ALFALFA VALVE
50mm GATE VALVE CONNECTIONS TO INLET PIPES COMPLETE WITH FIXIBLE CONNECTING OSE TO FACILITATE PUMP PRIMING
5 NO STEEL INLET PIPES, ø200-250(TYP) (8"-10")
9.00
EGL.8.50
1000 (TYP)
50(MIN)
6.95
PL1 ø450
2 NO RUBBER 'O' RINGS
TRASH SCREEN, DETAIL C
350
BLINDING CONCRETE CLASS D 100 THICK
450
1450
2150
SECTION A-A
Revision-1, October 2012
Header Tank Drawing have been revised to allow for
● variable water levels,
● uPVC pipes off-taking from side of tank; and
● for a single foundation slab instead of column footing.
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
In Greater Mymensingh, Sylhet and Faridpur Areas
MONGALPUR SUBPROJECT
HEADER TANK
GENERAL ARRANGEMENT PLAN
(Revised)
DRAWN BY
DESIGNED BY
REVIEWED BY
RECOMMENDED BY
APPROVED BY

Exhibit G6-I

Notes :
See Sheet 1



SECTION B1-B1

Revision-1, October 2012

Header Tank Drawing have been revised to allow for

- variable water levels,
- uPVC pipes off-taking from side of tank; and
- for a single foundation slab instead of column footing.

LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
In Greater Mymensingh, Sylhet and Faridpur Areas

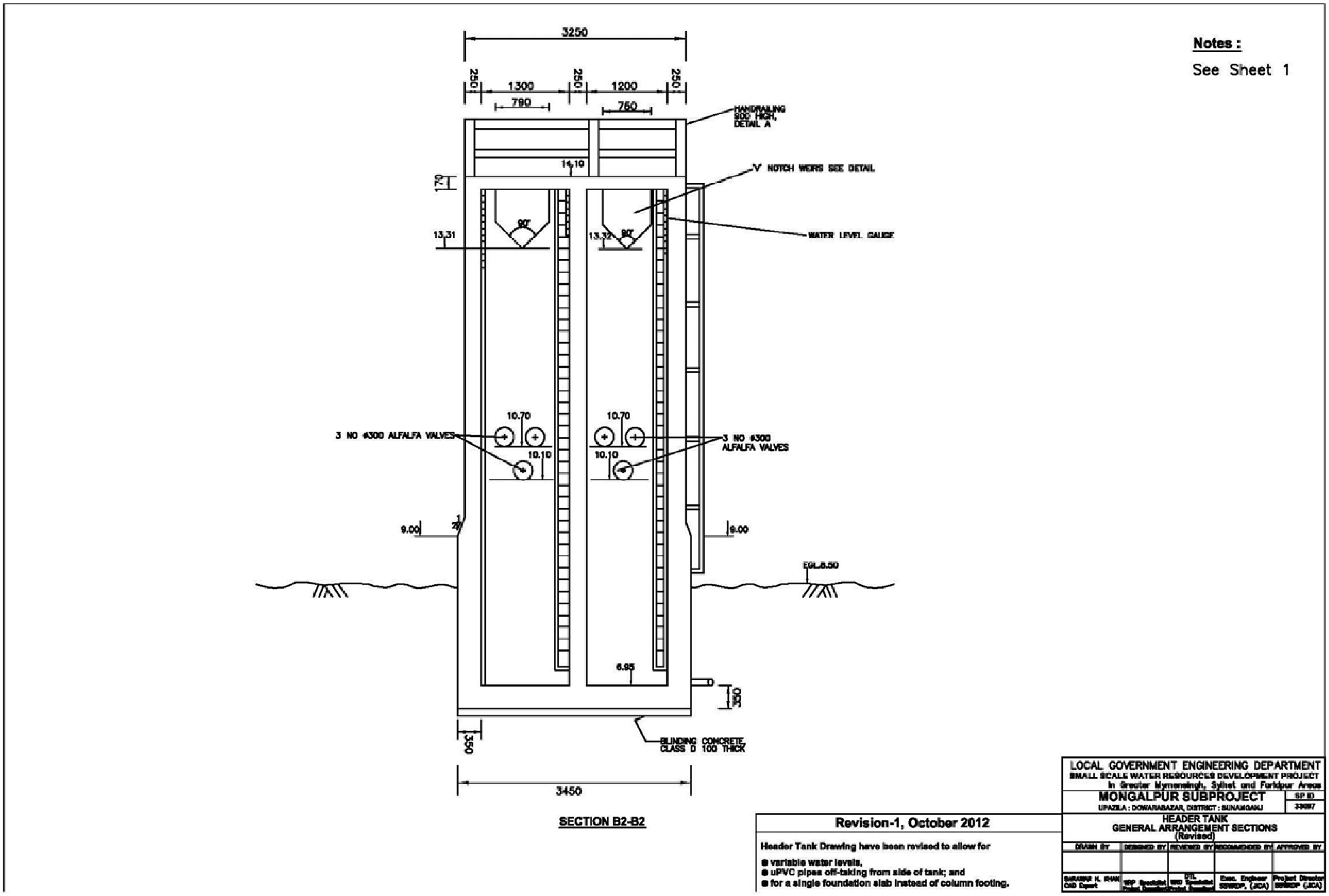
MONGALPUR SUBPROJECT | SP ID

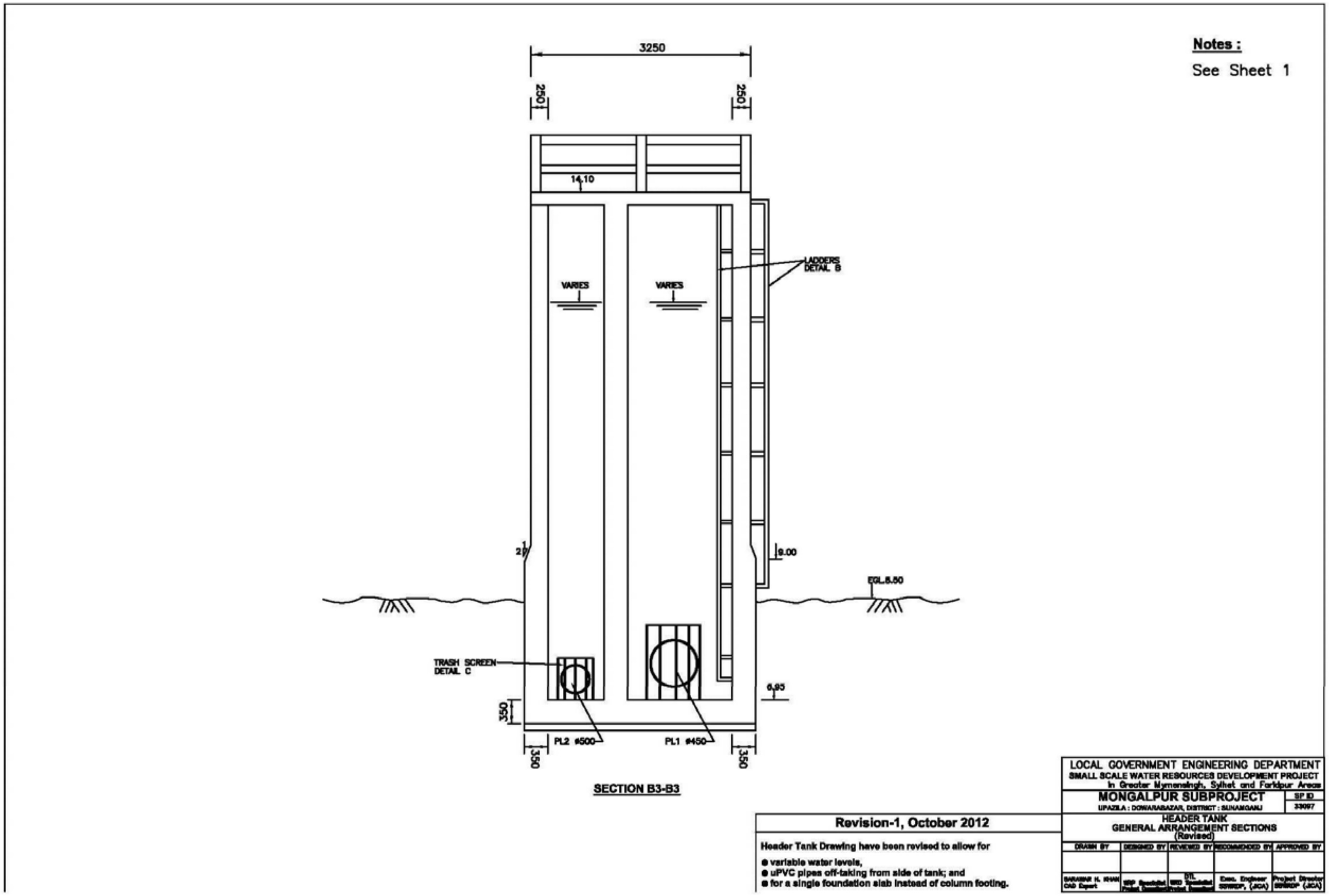
HEADER TANK
GENERAL ARRANGEMENT SECTIONS
(Revised)

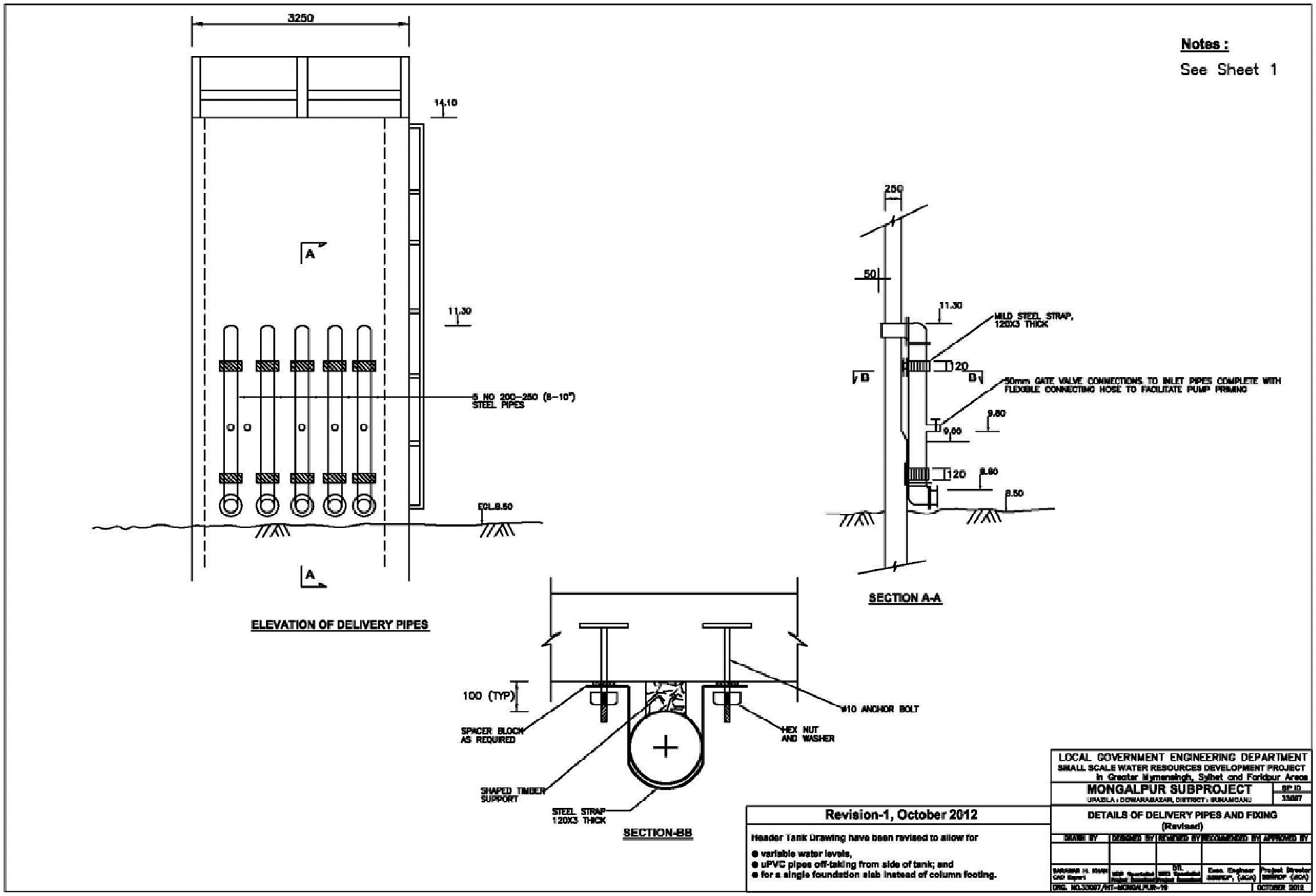
DRAWN BY	DESIGNED BY	REVIEWED BY	RECOMMENDED BY	APPROVED BY
CAD Expert			Exec. Engineer SSWRDP, (JICA)	Project Director SSWRDP (JICA)

OCTOBER 2012

Exhibit G6-L


3250
250
1300
250
1200
250
790
750
HANDRAILING 900 HIGH, DETAIL A
14.10
V NOTCH WEIRS SEE DETAIL
170
90°
13.31
13.32
WATER LEVEL GAUGE
10.70
10.70
3 NO ø300 ALFALFA VALVES
3 NO ø300 ALFALFA VALVES
10.10
10.10
9.00
9.00
EGL 8.50
6.95
350
350
BLINDING CONCRETE CLASS D 100 THICK
3450
SECTION B2-B2
Notes :
See Sheet 1
Revision-1, October 2012
Header Tank Drawing have been revised to allow for
● variable water levels,
● uPVC pipes off-taking from side of tank; and
● for a single foundation slab instead of column footing.
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
In Greater Mymensingh, Sylhet and Faridpur Areas
MONGALPUR SUBPROJECT
SP ID
HEADER TANK
GENERAL ARRANGEMENT SECTIONS
(Revised)
DRAWN BY
DESIGNED BY
REVIEWED BY
RECOMMENDED BY
APPROVED BY
CAD Expert
Exec. Engineer
Project Director


3250
250
250
14.10
VARIES
VARIES
LADDERS DETAIL B
9.00
EGL.8.50
TRASH SCREEN DETAIL C
6.95
350
PL2 ø500
PL1 ø450
350
350
SECTION B3-B3
Notes :
See Sheet 1
Revision-1, October 2012
Header Tank Drawing have been revised to allow for
● variable water levels,
● uPVC pipes off-taking from side of tank; and
● for a single foundation slab instead of column footing.
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
In Greater Mymensingh, Sylhet and Faridpur Areas
MONGALPUR SUBPROJECT
UPAZILA : DOWARABAZAR, DISTRICT : SUNAMGANJ
SP ID
33097
HEADER TANK
GENERAL ARRANGEMENT SECTIONS
(Revised)
DRAWN BY
DESIGNED BY
REVIEWED BY
RECOMMENDED BY
APPROVED BY


3250
14.10
11.30
EGL 8.50
5 NO 200-250 (8-10") STEEL PIPES
A
ELEVATION OF DELIVERY PIPES
Notes :
See Sheet 1
250
50
MILD STEEL STRAP, 120X3 THICK
20
B
50mm GATE VALVE CONNECTIONS TO INLET PIPES COMPLETE WITH FLEXIBLE CONNECTING HOSE TO FACILITATE PUMP PRIMING
9.80
9.00
8.80
8.50
SECTION A-A
100 (TYP)
SPACER BLOCK AS REQUIRED
SHAPED TIMBER SUPPORT
STEEL STRAP 120X3 THICK
ø10 ANCHOR BOLT
HEX NUT AND WASHER
SECTION-BB
Revision-1, October 2012
Header Tank Drawing have been revised to allow for
● variable water levels,
● uPVC pipes off-taking from side of tank; and
● for a single foundation slab instead of column footing.
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas
MONGALPUR SUBPROJECT
SP ID
DETAILS OF DELIVERY PIPES AND FIXING
(Revised)
DRAWN BY
DESIGNED BY
REVIEWED BY
RECOMMENDED BY
APPROVED BY
CAD Expert
Exec. Engineer
Project Director

Appendix E4: Flow Control Tank

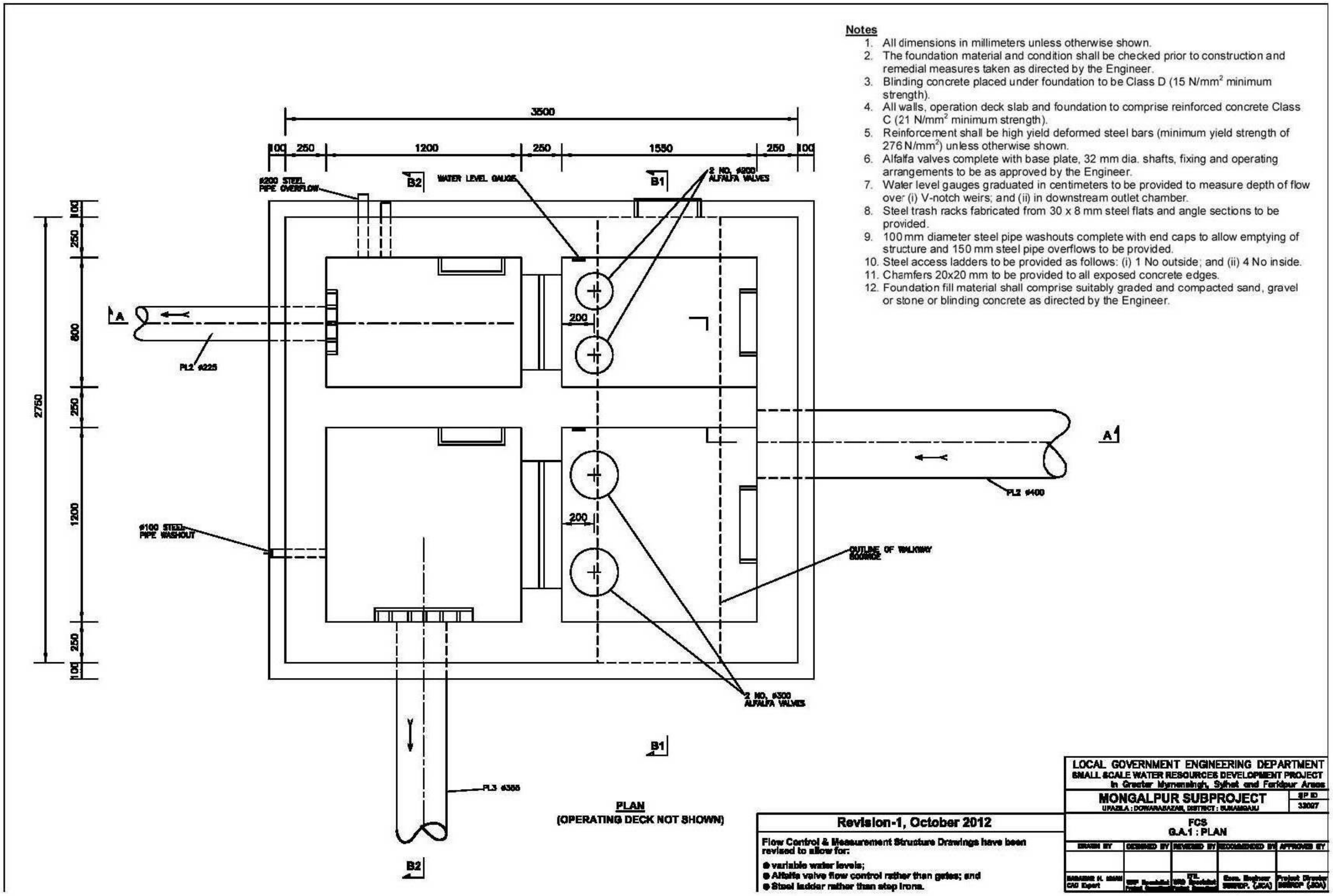
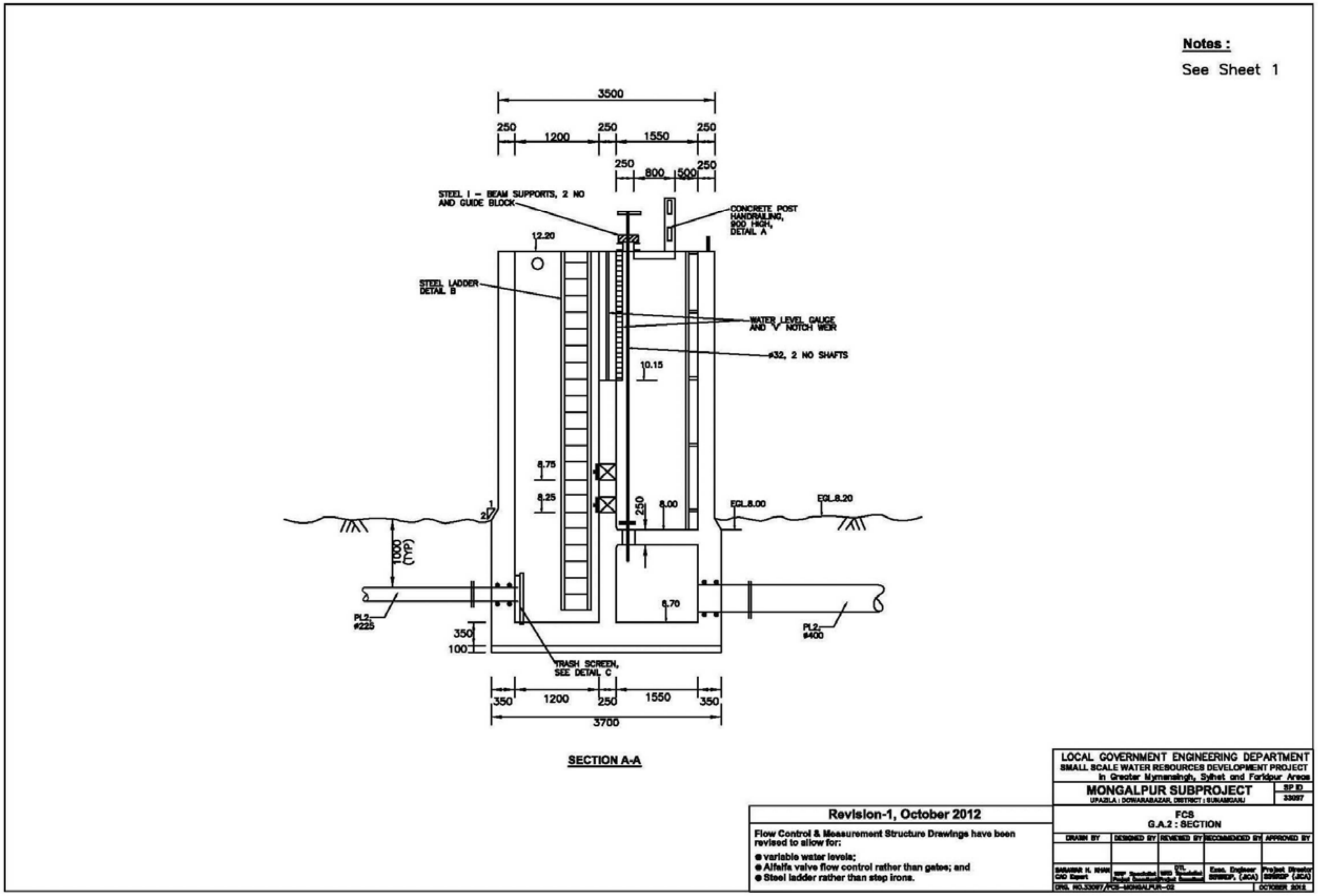
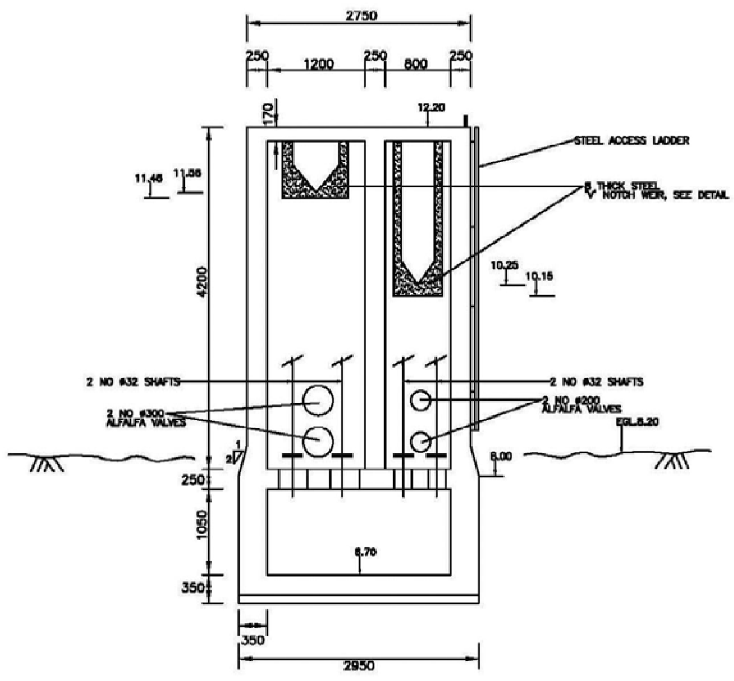


Exhibit G6-L


Notes :
See Sheet 1
3500
250
1200
250
1550
250
250
800
500
250
STEEL I - BEAM SUPPORTS, 2 NO AND GUIDE BLOCK
CONCRETE POST HANDRAILING, 900 HIGH, DETAIL A
12.20
STEEL LADDER DETAIL B
WATER LEVEL GAUGE AND 'V' NOTCH WEIR
ø32, 2 NO SHAFTS
10.15
8.75
8.25
250
8.00
EGL.8.00
EGL.8.20
1000 (TYP)
8.70
PL2, ø225
PL2, ø400
350
100
TRASH SCREEN, SEE DETAIL C
350
1200
250
1550
350
3700
SECTION A-A
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas
MONGALPUR SUBPROJECT
SP ID
FCS
G.A.2 : SECTION
DRAWN BY
DESIGNED BY
REVIEWED BY
RECOMMENDED BY
APPROVED BY
Exec. Engineer SSWRDP, (JICA)
Project Director SSWRDP (JICA)
Revision-1, October 2012
Flow Control & Measurement Structure Drawings have been revised to allow for:
● variable water levels;
● Alfalfa valve flow control rather than gates; and
● Steel ladder rather than step irons.

Notes :

See Sheet 1



SECTION B1-B1

LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas

MONGALPUR SUBPROJECT

SP ID 33097

FCS
G.A.3 : SECTION

DRAWN BY | DESIGNED BY | REVIEWED BY | RECOMMENDED BY | APPROVED BY

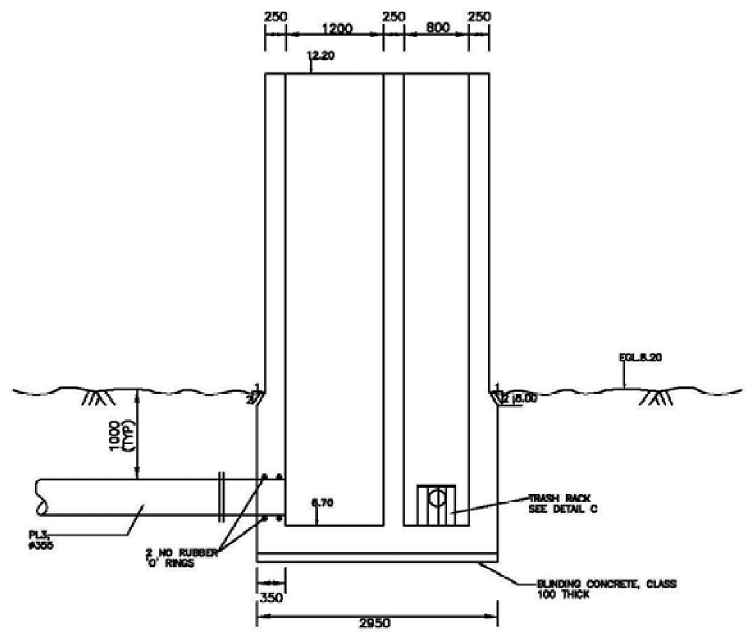
Revision-1, October 2012

Flow Control & Measurement Structure Drawings have been revised to allow for:

- variable water levels;
- Alfalfa valve flow control rather than gates; and
- Steel ladder rather than step irons.

Notes :

See Sheet 1



SECTION B2-B2

Revision-1, October 2012

Flow Control & Measurement Structure Drawings have been revised to allow for:

- variable water levels;
- Alfalfa valve flow control rather than gates; and
- Steel ladder rather than step irons.

LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas

MONGALPUR SUBPROJECT
UPAZILA : DOWARABAZAR, DISTRICT : SUNAMGANJ

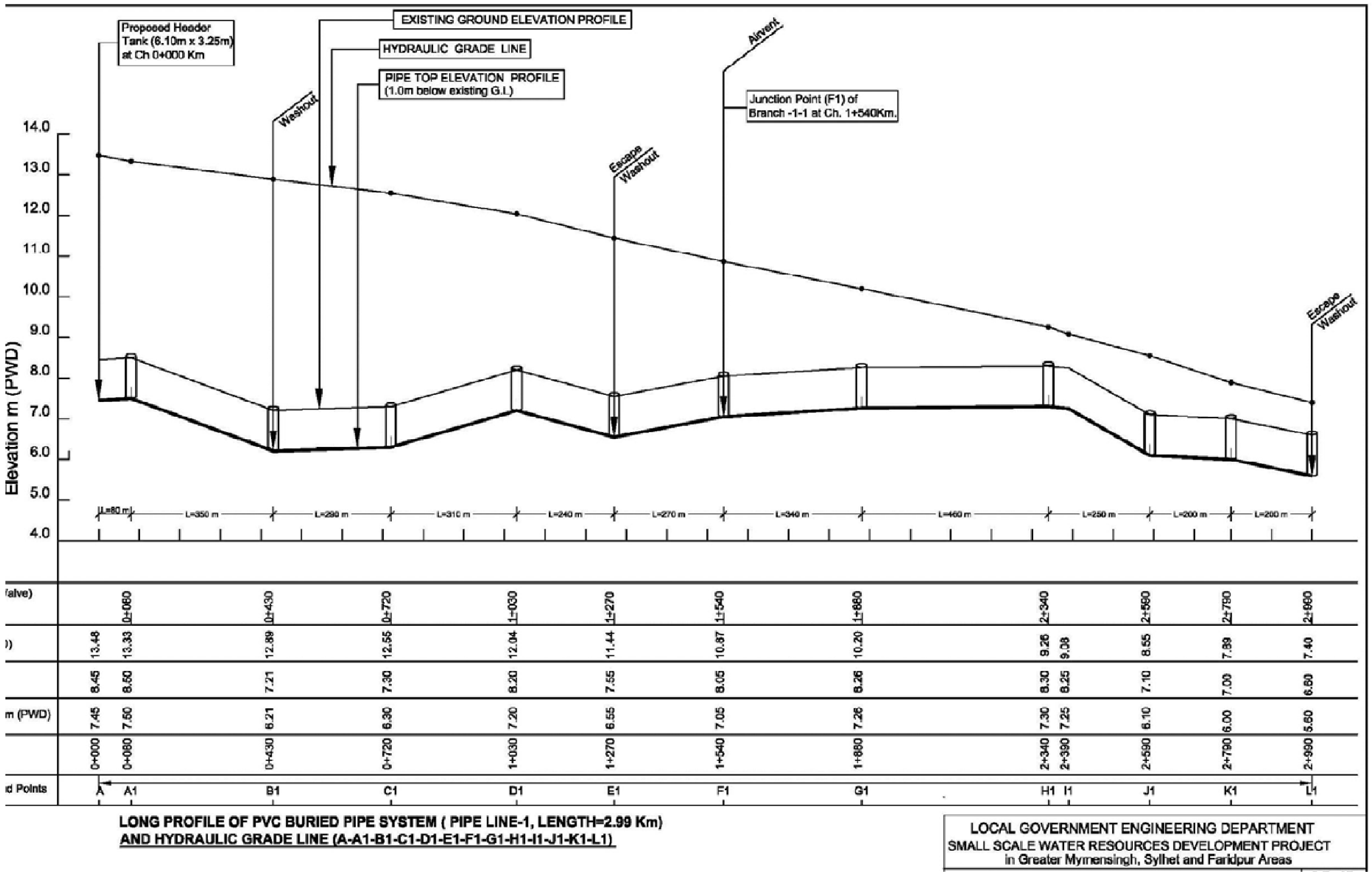
SP ID 33097

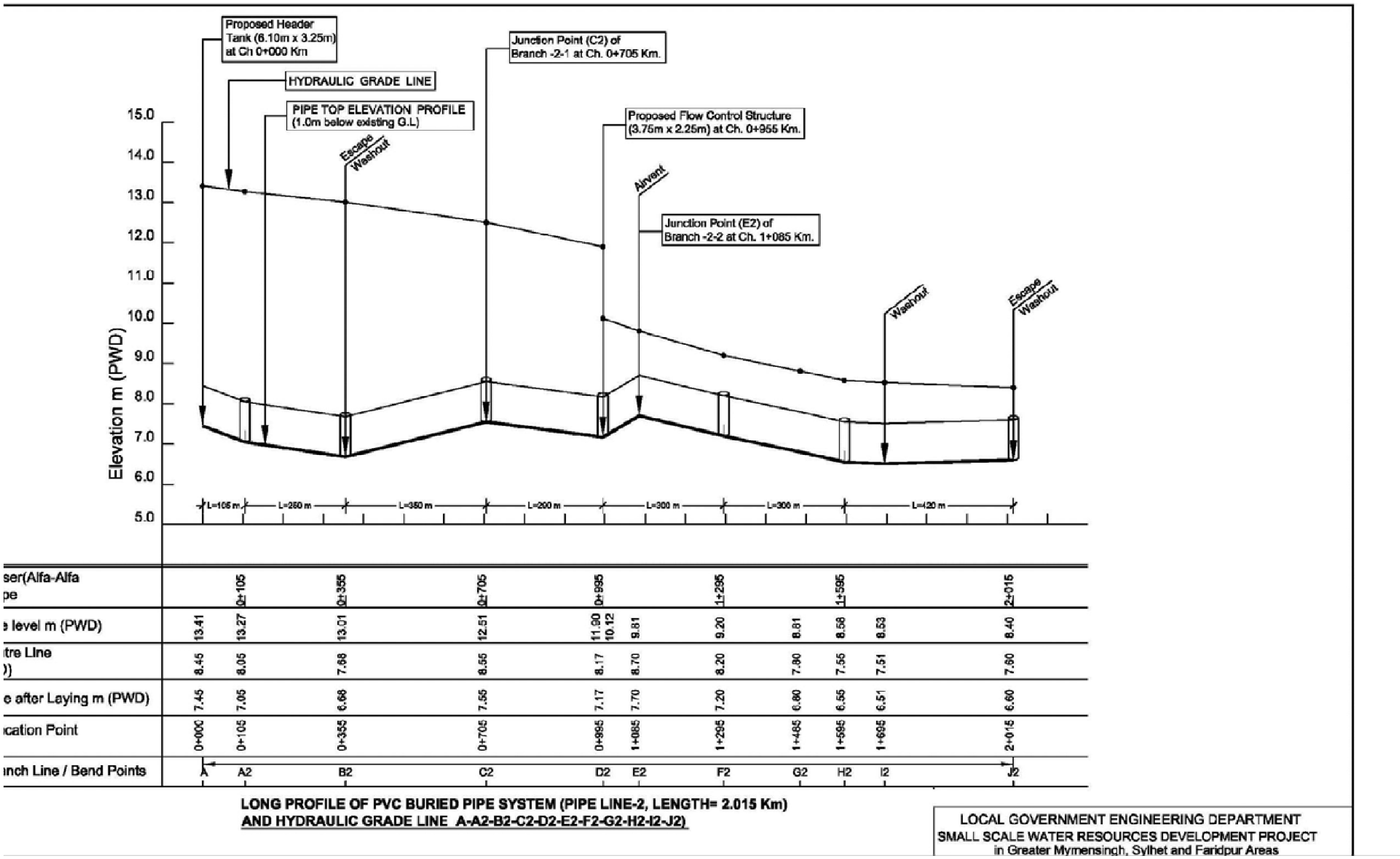
FCS
G.A.4 : SECTION

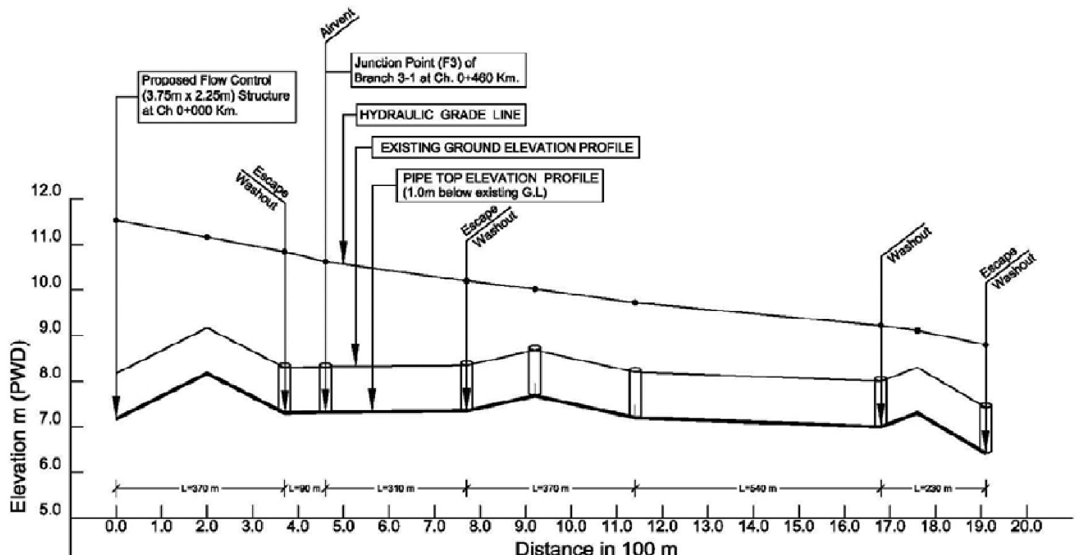
DRAWN BY	DESIGNED BY	REVIEWED BY	RECOMMENDED BY	APPROVED BY
GAO Expert			Exec. Engineer SSWRDP, (JICA)	Project Director SSWRDP (JICA)

DRG. NO.33097/FCS-MONGALPUR-04 | OCTOBER 2012

Appendix E5: Long Profile for Main Pipelines



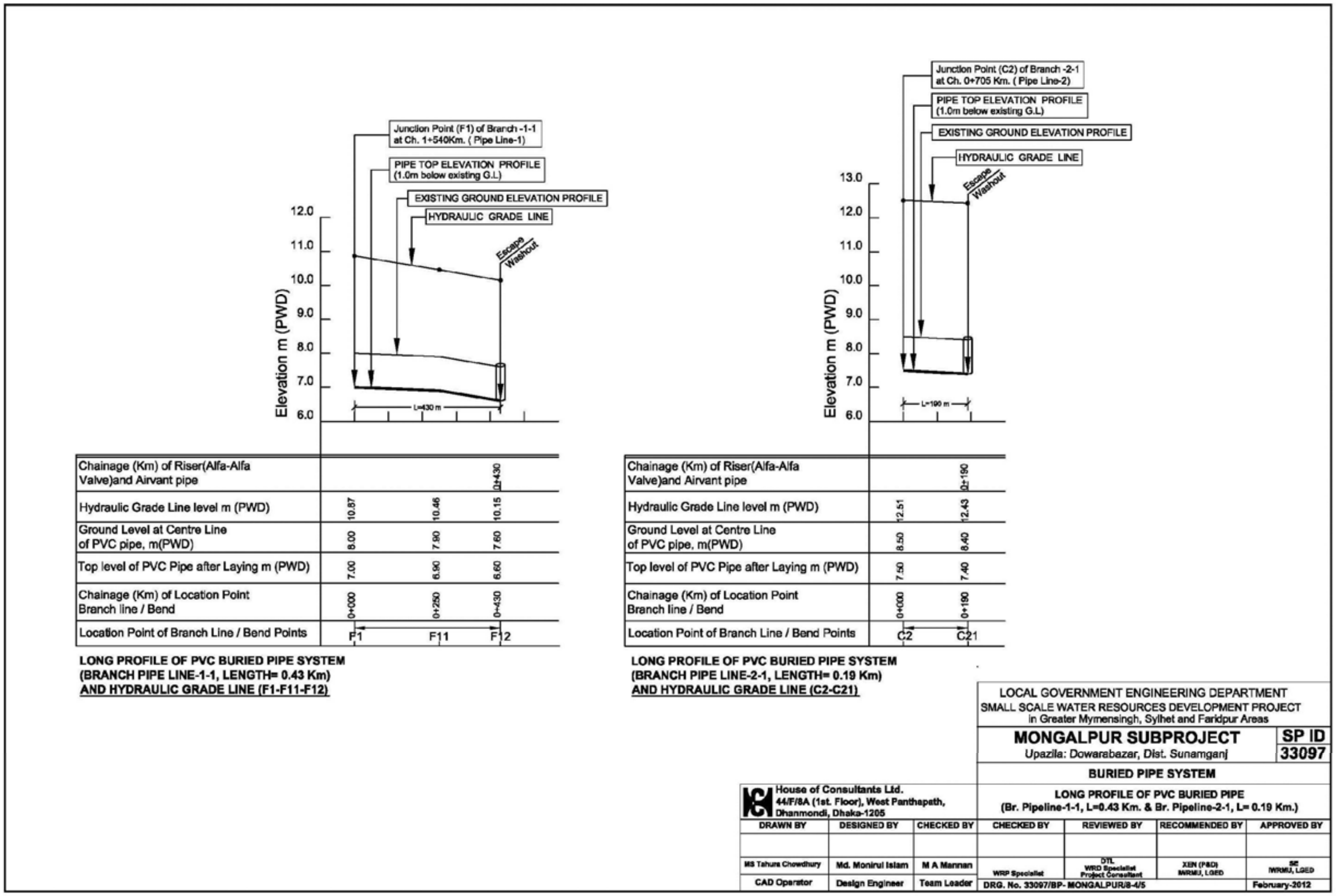

Proposed Header Tank (6.10m x 3.25m) at Ch 0+000 Km
HYDRAULIC GRADE LINE
PIPE TOP ELEVATION PROFILE (1.0m below existing G.L)
Junction Point (C2) of Branch -2-1 at Ch. 0+705 Km.
Proposed Flow Control Structure (3.75m x 2.25m) at Ch. 0+955 Km.
Junction Point (E2) of Branch -2-2 at Ch. 1+085 Km.
Escape Washout
Airvent
Washout
Elevation m (PWD)
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
L=105 m
L=250 m
L=350 m
L=200 m
L=300 m
L=300 m
L=420 m
level m (PWD)
after Laying m (PWD)
cation Point
nch Line / Bend Points
A
A2
B2
C2
D2
E2
F2
G2
H2
I2
J2
LONG PROFILE OF PVC BURIED PIPE SYSTEM (PIPE LINE-2, LENGTH= 2.015 Km)
AND HYDRAULIC GRADE LINE A-A2-B2-C2-D2-E2-F2-G2-H2-I2-J2)
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas



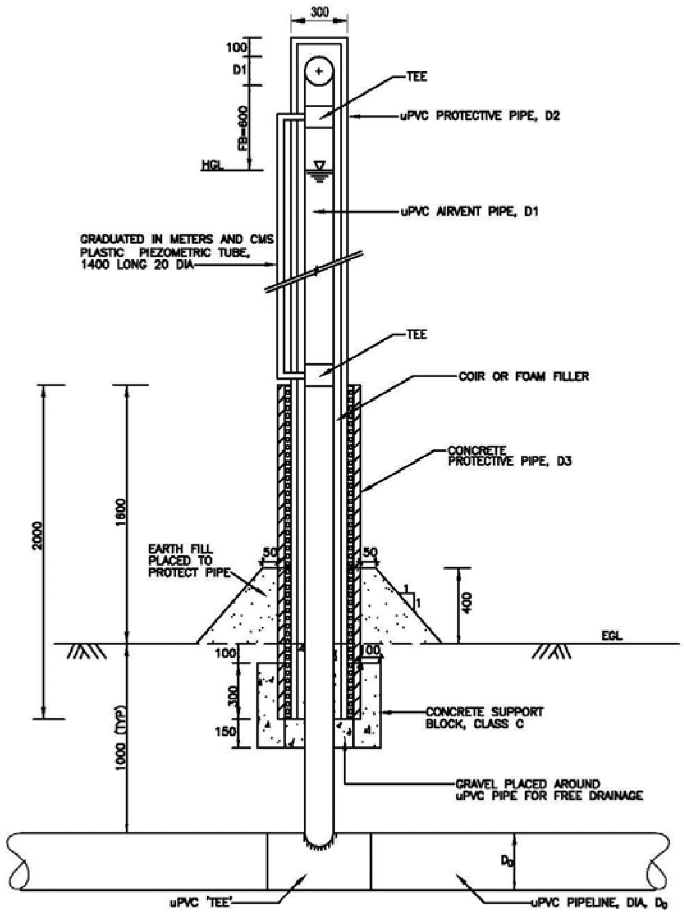
e (Km) of Riser(Alfa-Alfa d Airvant pipe			0+370	0+460	0+770	0+920	1+140	1+680		1+910
c Grade Line level m (PWD)	11.53	11.16	10.84	10.62	10.20	10.02	9.72	9.22	9.11	8.80
Level at Centre Line ipe, m(PWD)	8.17	9.17	8.30	8.32	8.35	8.68	8.20	8.00	8.30	7.42
l of PVC Pipe after Laying m (PWD)	7.17	8.17	7.30	7.32	7.35	7.68	7.20	7.00	7.30	6.42
e (Km) of Location Point ne / Bend	0+000	0+200	0+370	0+460	0+770	0+920	1+140	1+680	1+760	1+910
Point of Branch Line / Bend Points	D2	D3	E3	F3	G3	H3	I3	J3	K3	L3

LONG PROFILE OF PVC BURIED PIPE SYSTEM (PIPE LINE-3, LENGTH= 1.91 Km)
AND HYDRAULIC GRADE LINE (D2-D3-E3-F3-G3-H3-I3-J3-K3-L3)

LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas


Junction Point (F1) of Branch -1-1 at Ch. 1+540Km. (Pipe Line-1)
PIPE TOP ELEVATION PROFILE (1.0m below existing G.L)
EXISTING GROUND ELEVATION PROFILE
HYDRAULIC GRADE LINE
Escape Washout
Elevation m (PWD)
L=430 m
Chainage (Km) of Riser(Alfa-Alfa Valve)and Airvant pipe
Hydraulic Grade Line level m (PWD)
Ground Level at Centre Line of PVC pipe, m(PWD)
Top level of PVC Pipe after Laying m (PWD)
Chainage (Km) of Location Point Branch line / Bend
Location Point of Branch Line / Bend Points
0+430
10.87 10.46 10.15
8.00 7.90 7.60
7.00 6.90 6.60
0+000 0+250 0+430
F1 F11 F12
LONG PROFILE OF PVC BURIED PIPE SYSTEM (BRANCH PIPE LINE-1-1, LENGTH= 0.43 Km) AND HYDRAULIC GRADE LINE (F1-F11-F12)
Junction Point (C2) of Branch -2-1 at Ch. 0+705 Km. (Pipe Line-2)
PIPE TOP ELEVATION PROFILE (1.0m below existing G.L)
EXISTING GROUND ELEVATION PROFILE
HYDRAULIC GRADE LINE
Escape Washout
Elevation m (PWD)
L=190 m
0+190
12.51 12.43
8.50 8.40
7.50 7.40
0+000 0+190
C2 C21
LONG PROFILE OF PVC BURIED PIPE SYSTEM (BRANCH PIPE LINE-2-1, LENGTH= 0.19 Km) AND HYDRAULIC GRADE LINE (C2-C21)
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas
MONGALPUR SUBPROJECT
Upazila: Dowarabazar, Dist. Sunamganj
SP ID 33097
BURIED PIPE SYSTEM
LONG PROFILE OF PVC BURIED PIPE
(Br. Pipeline-1-1, L=0.43 Km. & Br. Pipeline-2-1, L= 0.19 Km.)
House of Consultants Ltd.
44/F/8A (1st. Floor), West Panthapath, Dhanmondi, Dhaka-1205
DRAWN BY
DESIGNED BY
CHECKED BY
CHECKED BY
REVIEWED BY
RECOMMENDED BY
APPROVED BY
MS Tahura Chowdhury
Md. Monirul Islam
M A Mannan
CAD Operator
Design Engineer
Team Leader
WRP Specialist
DTL WRD Specialist Project Consultant
XEN (P&D) IWRMU, LGED
SE IWRMU, LGED
DRG. No. 33097/BP- MONGALPUR/8-4/5
February-2012

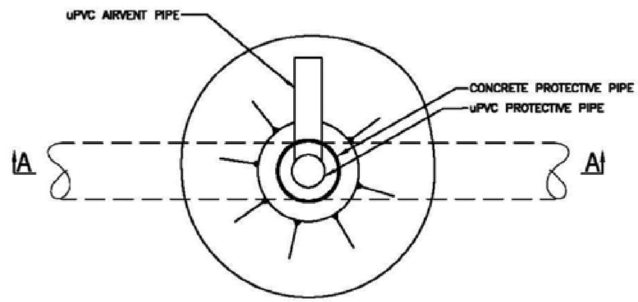
Appendix E6: Standard Drawings (Standpipe Airvent)



SECTION A-A

Notes :

1. All dimensions in millimeters unless otherwise shown.
2. Exact location of Standpipes Air-vents to be decided on Site but typically at intervals of 200 – 500 m and just upstream of any outlet valves to control surge pressures.
3. All uPVC pipes to be in accordance with ISO-4065 and ISO-4422
4. uPVC distribution pipeline to comprise pipes with design working pressure of 3.25 bar. while uPVC pipe used for protection against sunlight to have working pressure of 6.3 bar.
5. Air-vent pipe diameters to be 160 –250 mm as tabulated.
6. Concrete (spun) pipes to be placed around base of uPVC protective standpipes for additional protection.
7. Holes to be made in protective pipes as required for plastic piezometric tube, and for air vent overflow.
8. Minimum concrete strengths to be: (i) 21 N/mm2 for Class C, and 15 N/mm2 for Class D.
9. Reinforcement shall be high yield deformed steel bars (minimum yield strength of 276 N/mm2) unless otherwise shown.

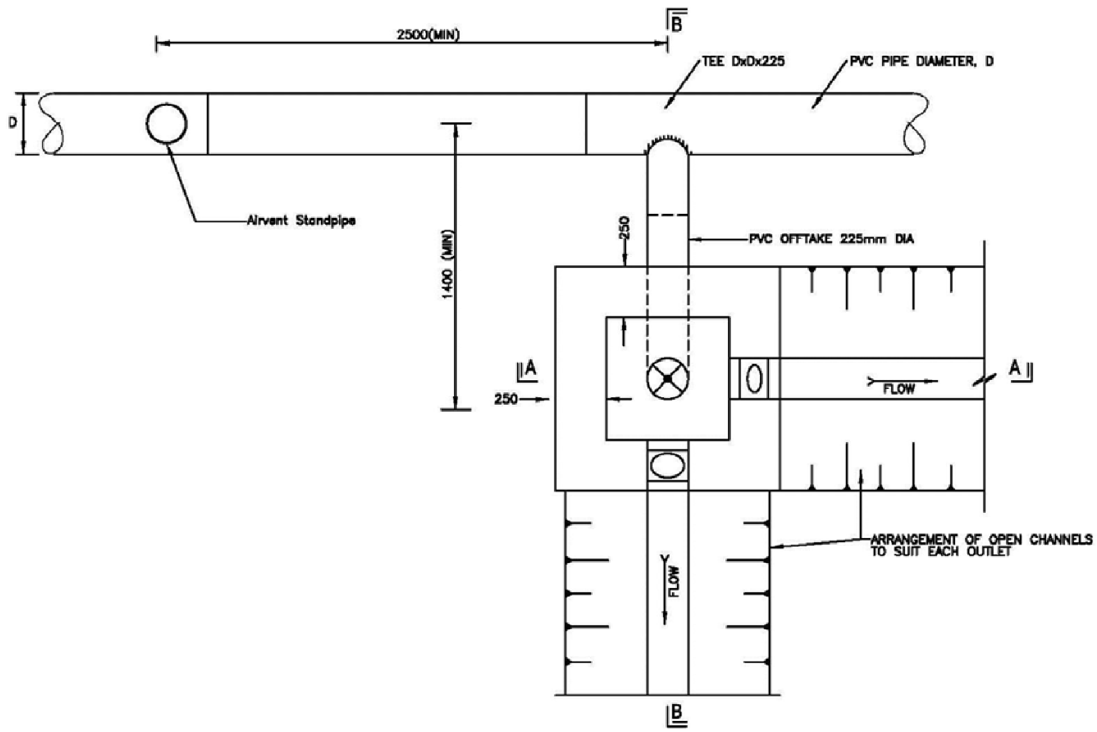


PLAN

Buried uPVC Pipeline Outer Diameter (D_0) (mm)	uPVC Air Vent Outer Diameter (D_1) (mm)	uPVC Protective Pipe Outer Diameter (D_2) (mm)	Concrete Protective Pipe Inner Diameter (D_3) (mm)
160	160	180	300 mm (50 mm thick)
180			
200	200	225	
225			
250			
280			
315			
355	355	380	400 mm (50 mm thick)
400			
450			
500			

LOCAL GOVERNMENT ENGINEERING DEPARTMENT SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT in Greater Mymensingh, Sylhet and Faridpur Areas				
CAD SUBPROJECTS				SP ID
STANDPIPE FOR AIRVENT FROM PVC PIPE				
DRAWN BY	DESIGNED BY	REVIEWED BY	RECOMMENDED BY	APPROVED BY

Appendix E6: Standard Drawings (Discharge Box for Surface Irrigation)



PLAN
SCALE : 1 : 20

Notes :

1. All dimensions in millimeters unless otherwise shown.
2. All uPVC pipes to be in accordance with ISO–4065 and ISO–4422.
3. uPVC distribution pipes to comprise pipeline with design working pressure of 3.25 bar.
4. Exact location of Outlets to be decided on Site.
5. Number and orientation of pucca–nuccas to be decided on Site.
   open channels to out each outlet.
6. Minimum concrete strengths to be: (i) 21 N/mm2 for Class C, and 15 N/mm2 for Class D.
   for Class D.
7. Reinforcement shall be high yield deformed steel bars (minimum yield strength of 276 N/mm2) unless otherwise shown.
8. Lockable grill to prevent tampering to be provided as ordered by the Engineer on Site.

LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
In Greater Mymensingh, Sylhet and Faridpur Areas

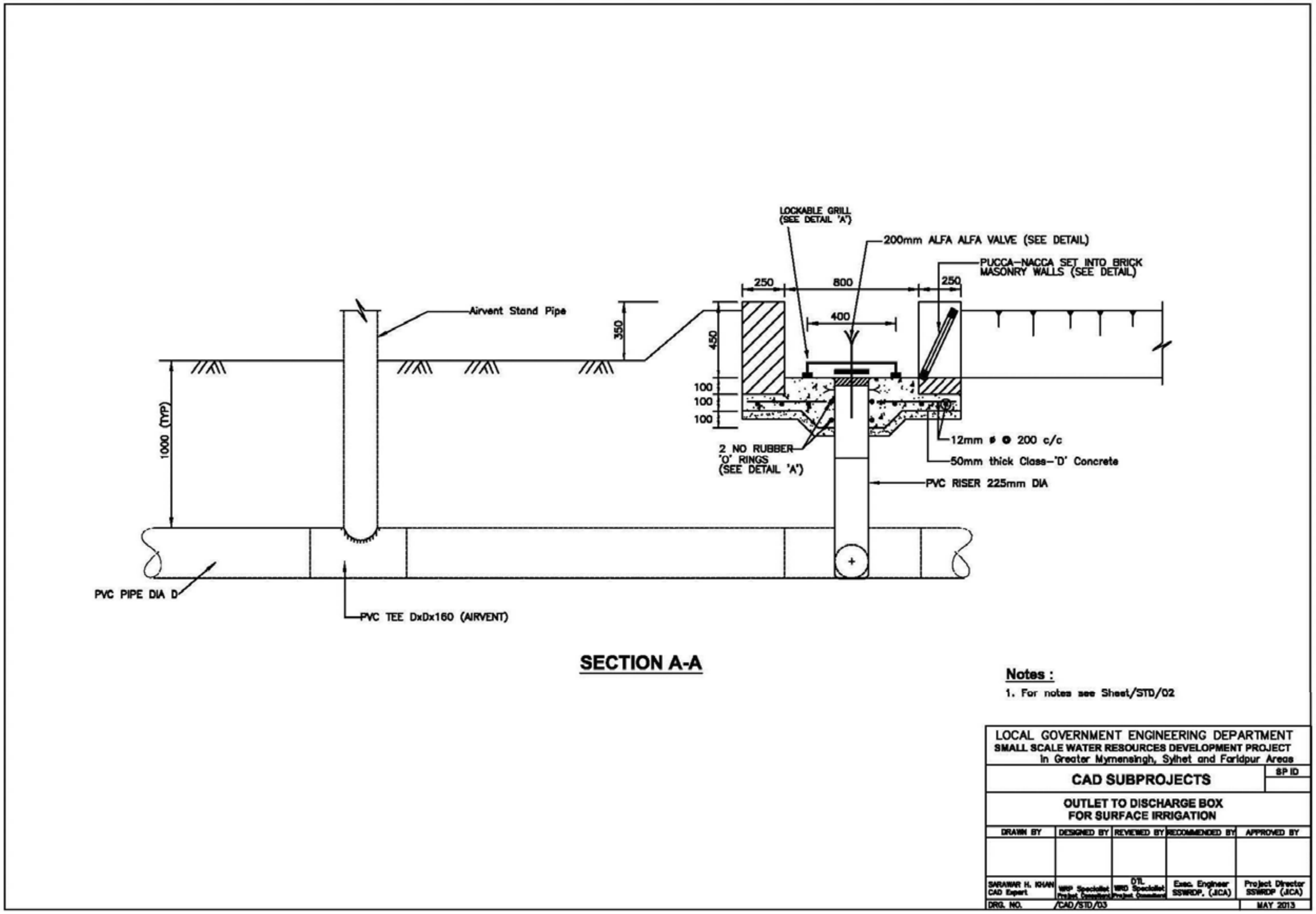
CAD SUBPROJECTS | SP ID

OUTLET TO DISCHARGE BOX FOR SURFACE IRRIGATION

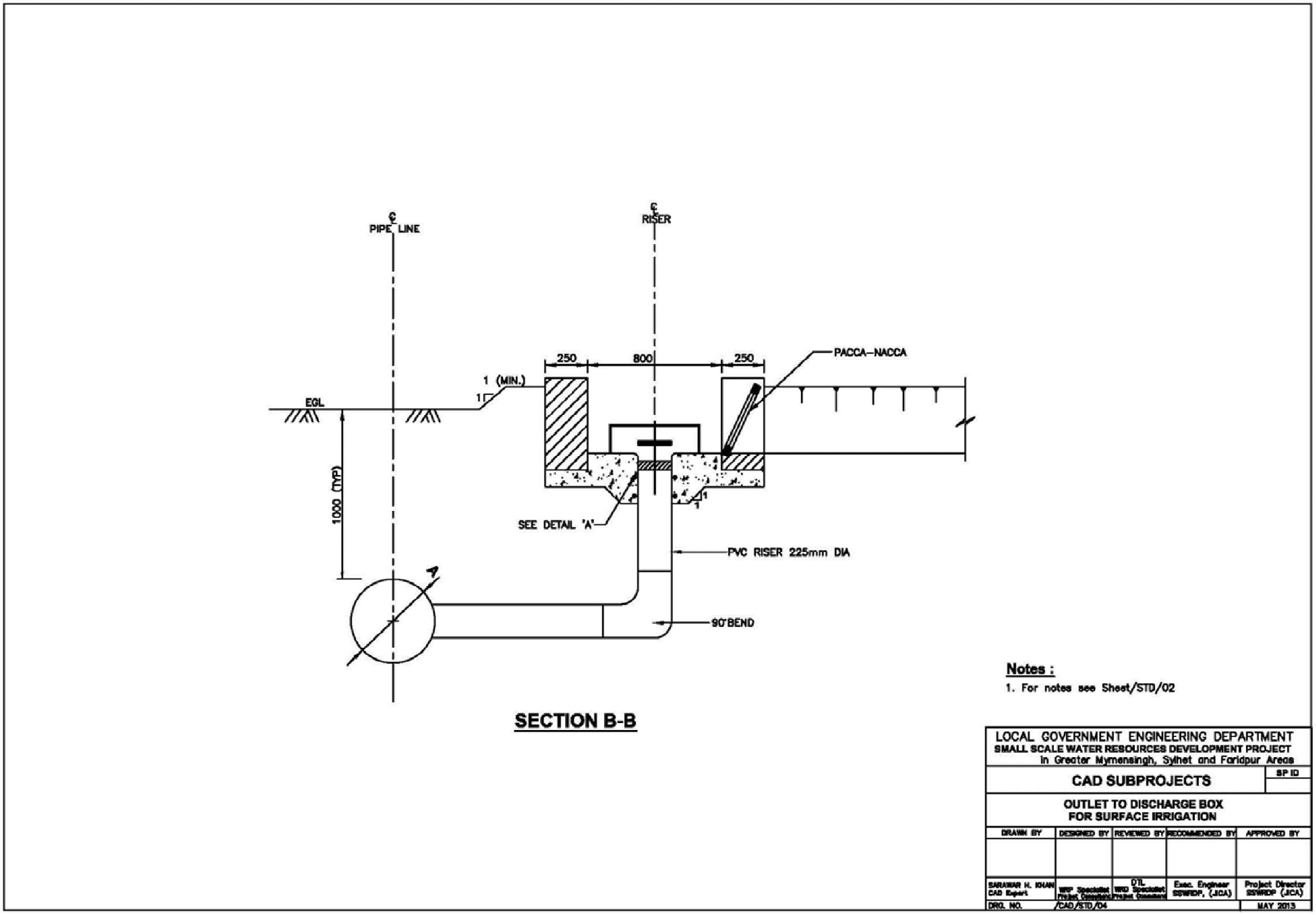
DRAWN BY	DESIGNED BY	REVIEWED BY	RECOMMENDED BY	APPROVED BY
SARAWAR H. KHAN CAD Expert	WRP Specialist	DTL WRD Specialist	Exec. Engineer SSWRDP, (JICA)	Project Director SSWRDP (JICA)

DRG. NO. /CAD/STD/02 — MAY 2013

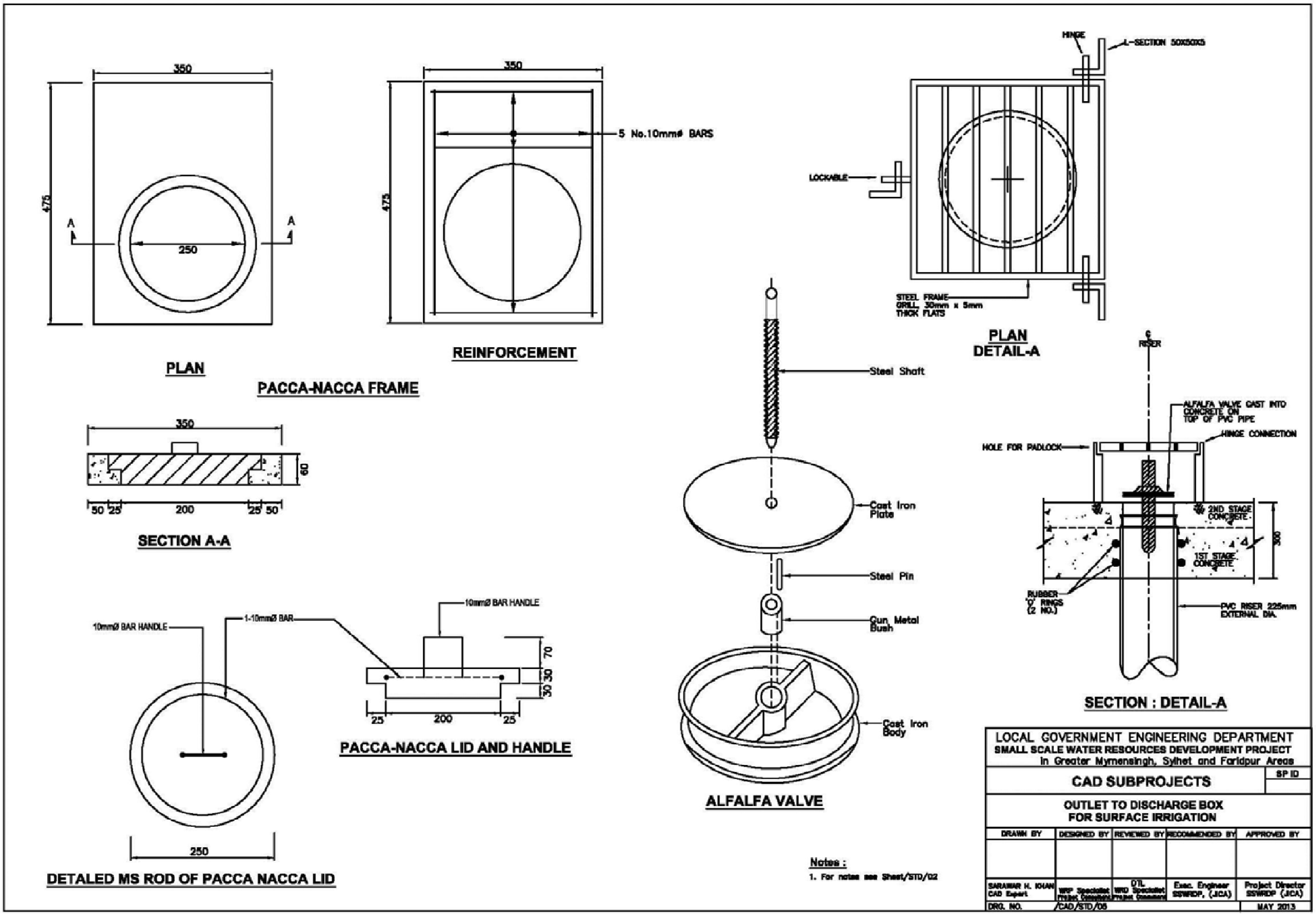
Appendix E6: Standard Drawings (Discharge Box for Surface Irrigation)



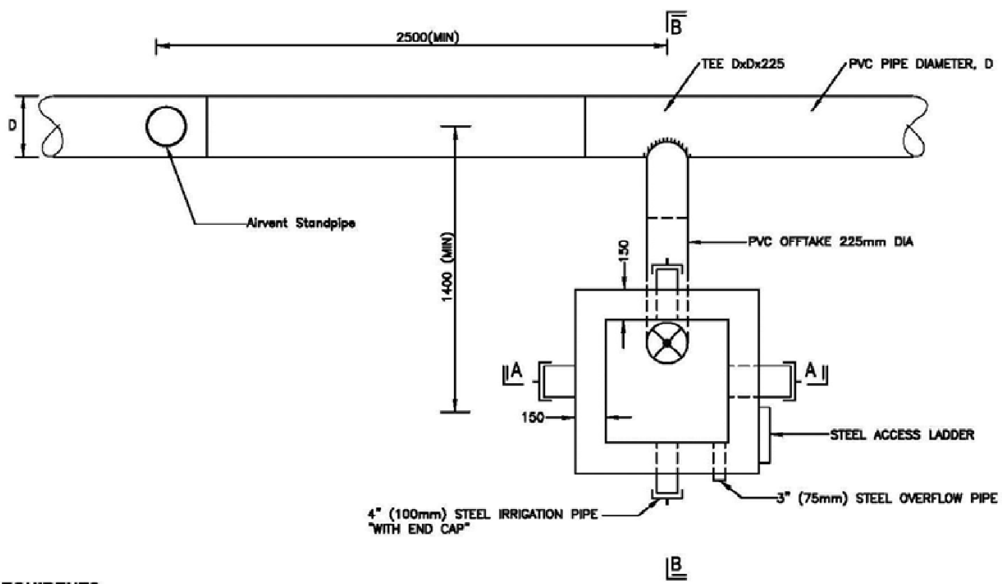
Appendix E6: Standard Drawings (Discharge Box for Surface Irrigation)



Appendix E6: Standard Drawings (Discharge Box for Surface Irrigation)



Appendix E6: Standard Drawings (Discharge Box for Hose Irrigation)



PLAN

STEEL OUTLET PIPE REQUIRENTS

NET IRRIGATION AREA (HA)	MIN. NR OF OUTLET REQUIREDS		
	DIA 3"	DIA 4"	DIA 5"
< 5 HA	2	1	N/A
5-10 HA	4	2	1
10-15 HA	N/R	3	2

N/R-NOT RECOMMENDED

Notes :

1. All dimensions in millimeters unless otherwise shown.
2. All uPVC pipes to be in accordance with ISO–4065 and ISO–4422.
3. uPVC distribution pipeline to comprise pipe with design working pressure of 3.25 bar.
4. Exact location of Outlets to be decided on Site.
5. Diameter and number of steel pipe outlet from discharge box to depend on area to be irrigated as tabulated.
6. Brick masonry may be used for walls instead of concrete if approved by the Engineering. Brick masonry plastered with 1:3 cement mortar.
7. Minimum concrete strengths to be: (i) 21 N/mm2 for Class C, and 15 N/mm2 for Class D.
8. Reinforcement shall be high yield deformed steel bars (minimum yield strength of 276 N/mm2) unless otherwise shown.

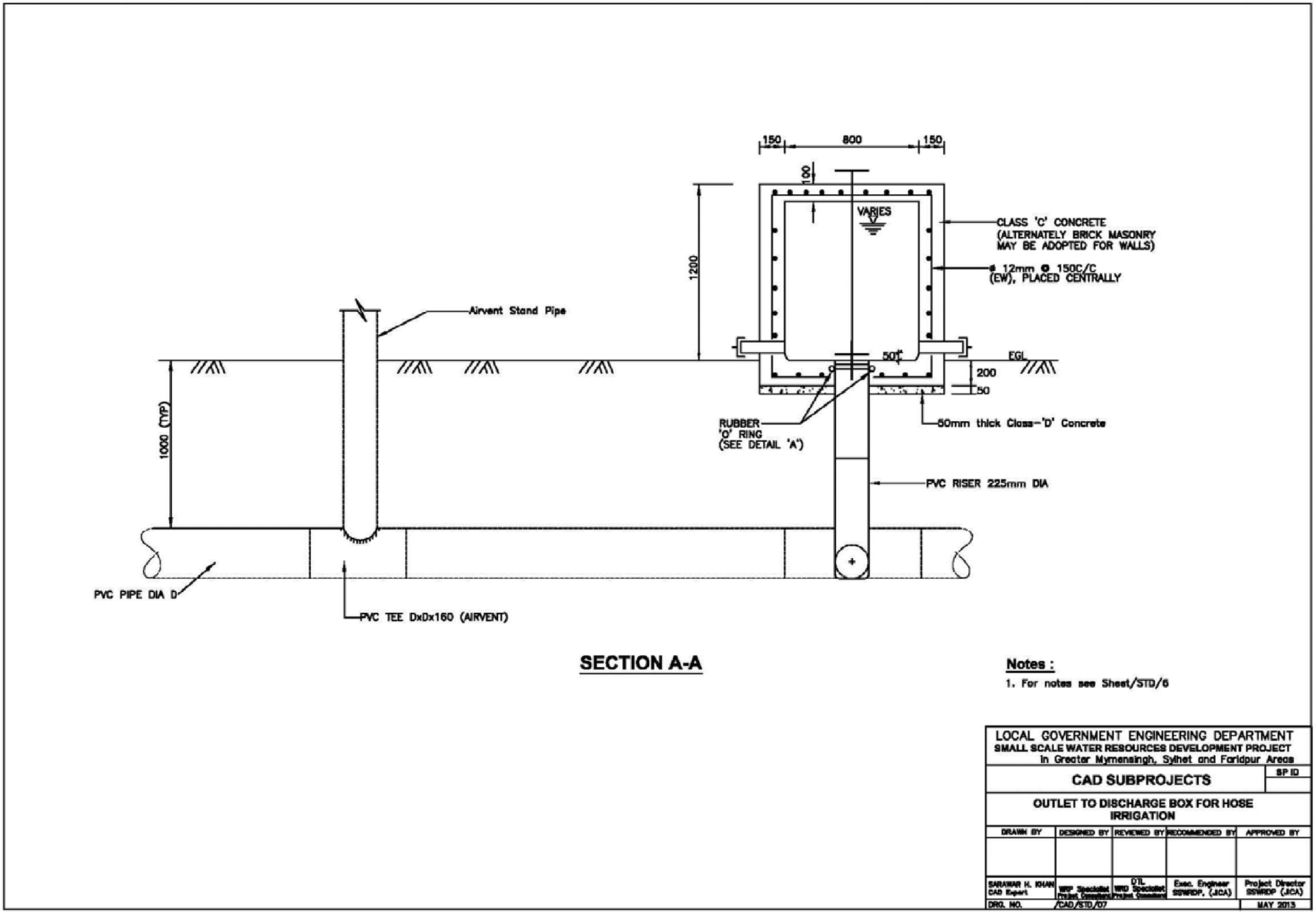
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
In Greater Mymensingh, Sylhet and Faridpur Areas

CAD SUBPROJECTS | SP ID

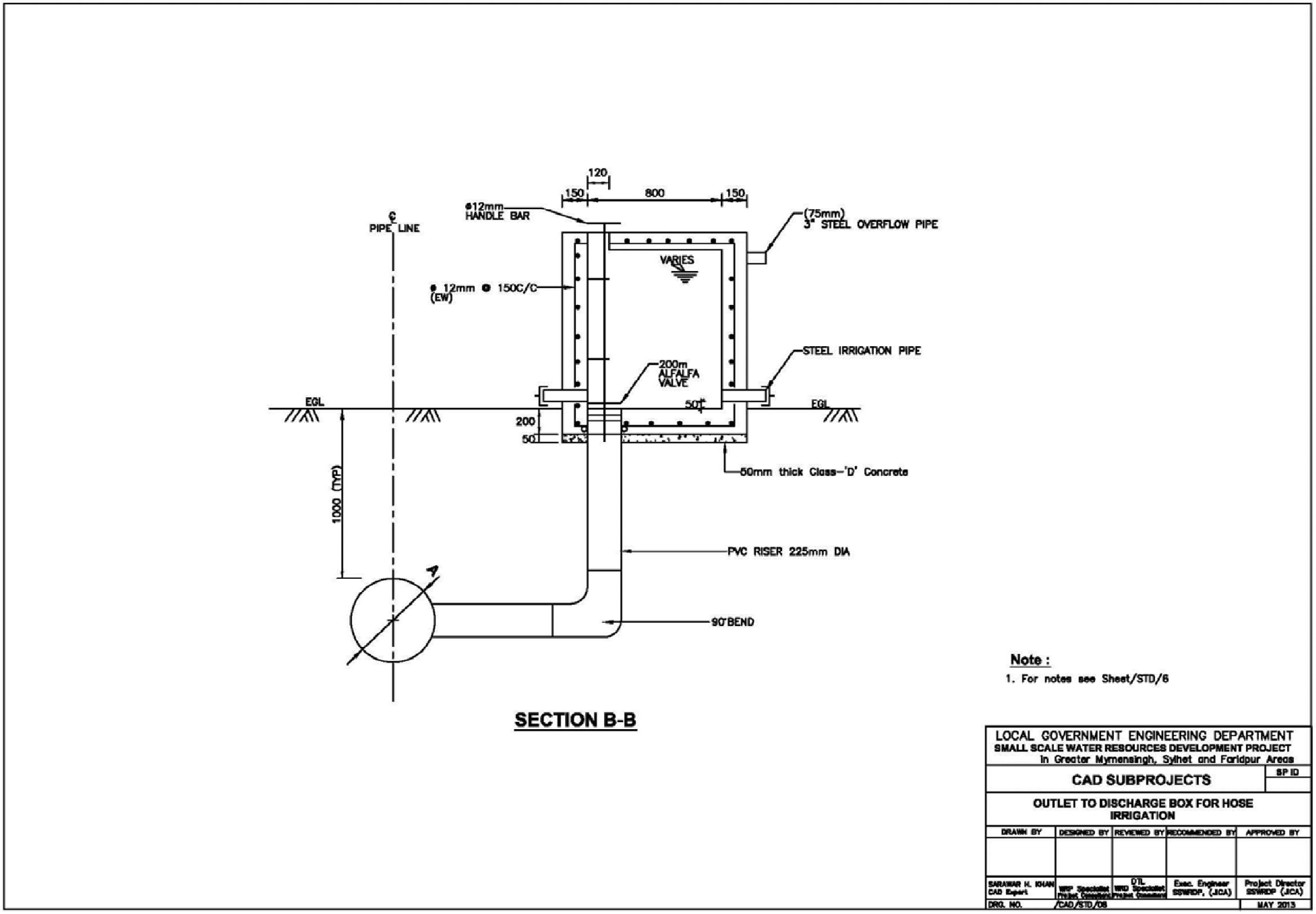
OUTLET TO DISCHARGE BOX FOR HOSE IRRIGATION

DRAWN BY	DESIGNED BY	REVIEWED BY	RECOMMENDED BY	APPROVED BY
SARAWAR H. KHAN CAD Expert	WRP Specialist	OTL WRD Specialist	Exec. Engineer SSWRDP, (JICA)	Project Director SSWRDP (JICA)
DRG. NO.	/CAD/STD/08			MAY 2013

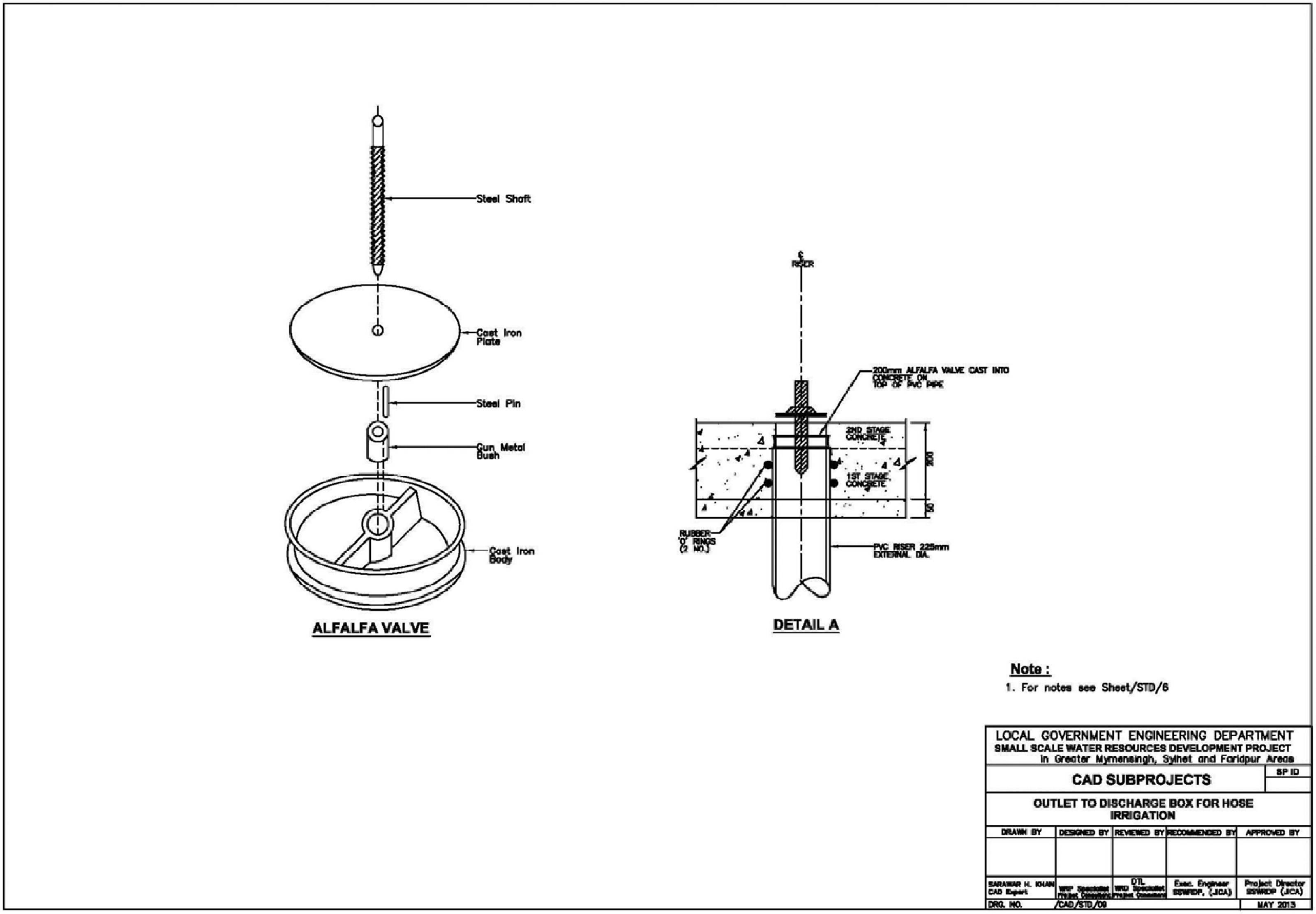
Appendix E6: Standard Drawings (Discharge Box for Hose Irrigation)



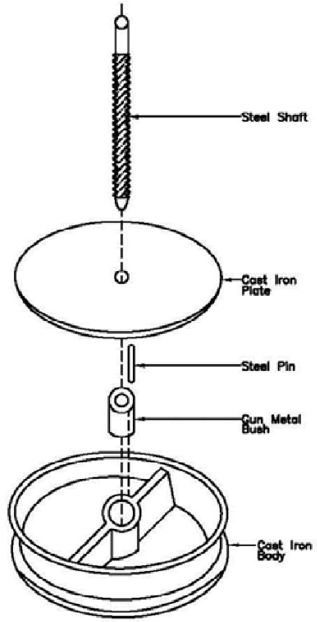
Appendix E6: Standard Drawings (Discharge Box for Hose Irrigation)



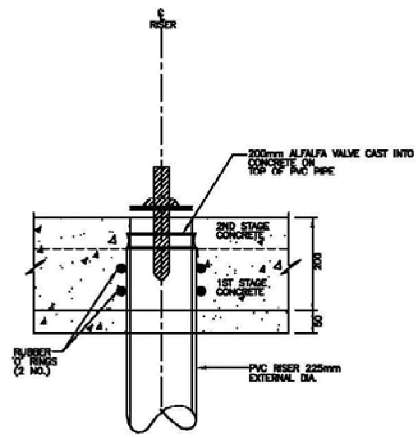
Appendix E6: Standard Drawings (Discharge Box for Hose Irrigation)



Appendix E6: Standard Drawings (Discharge Box for Hose Irrigation)



ALFALFA VALVE



DETAIL A

Note :

1. For notes see Sheet/STD/6

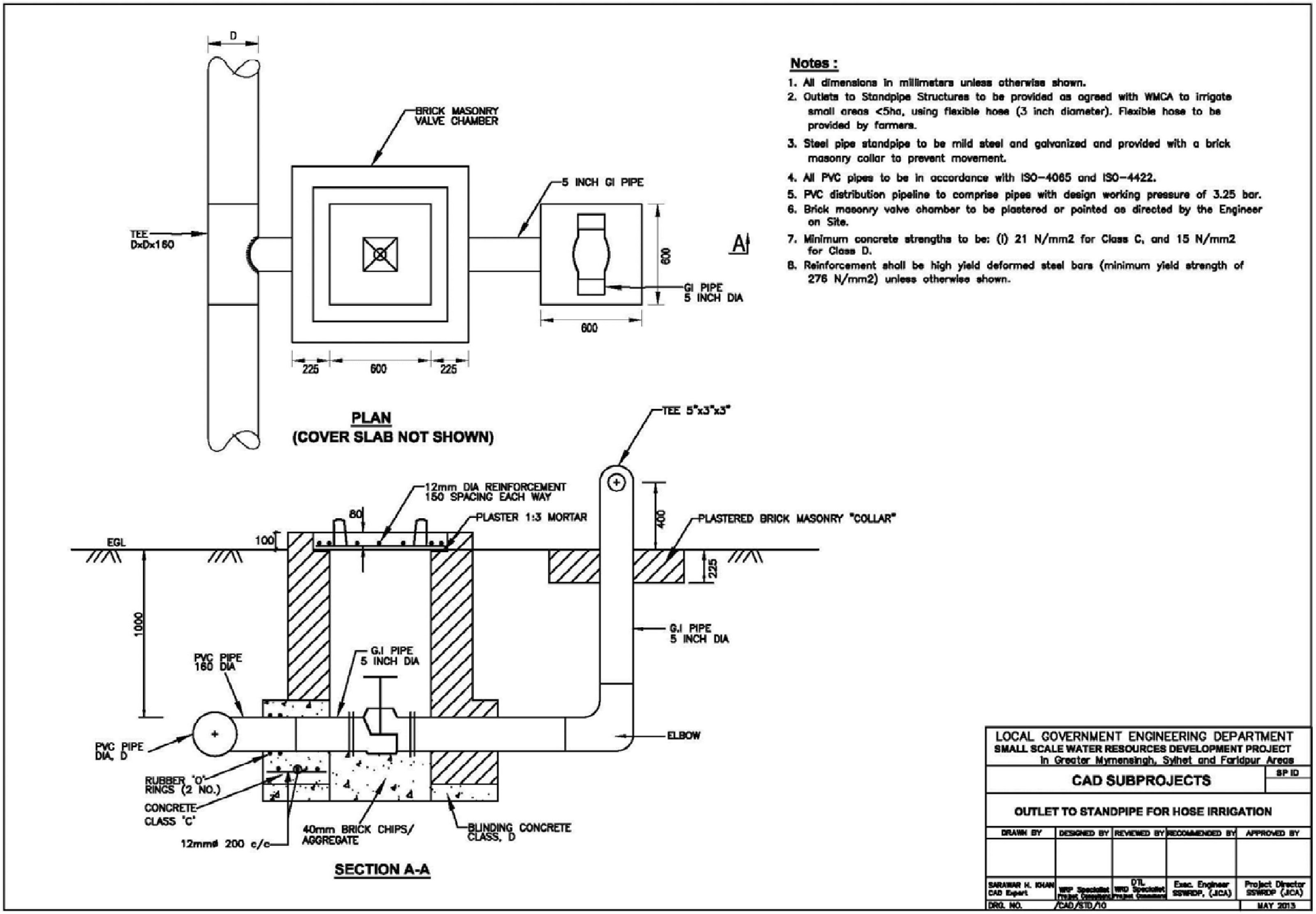
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas

CAD SUBPROJECTS | SP ID

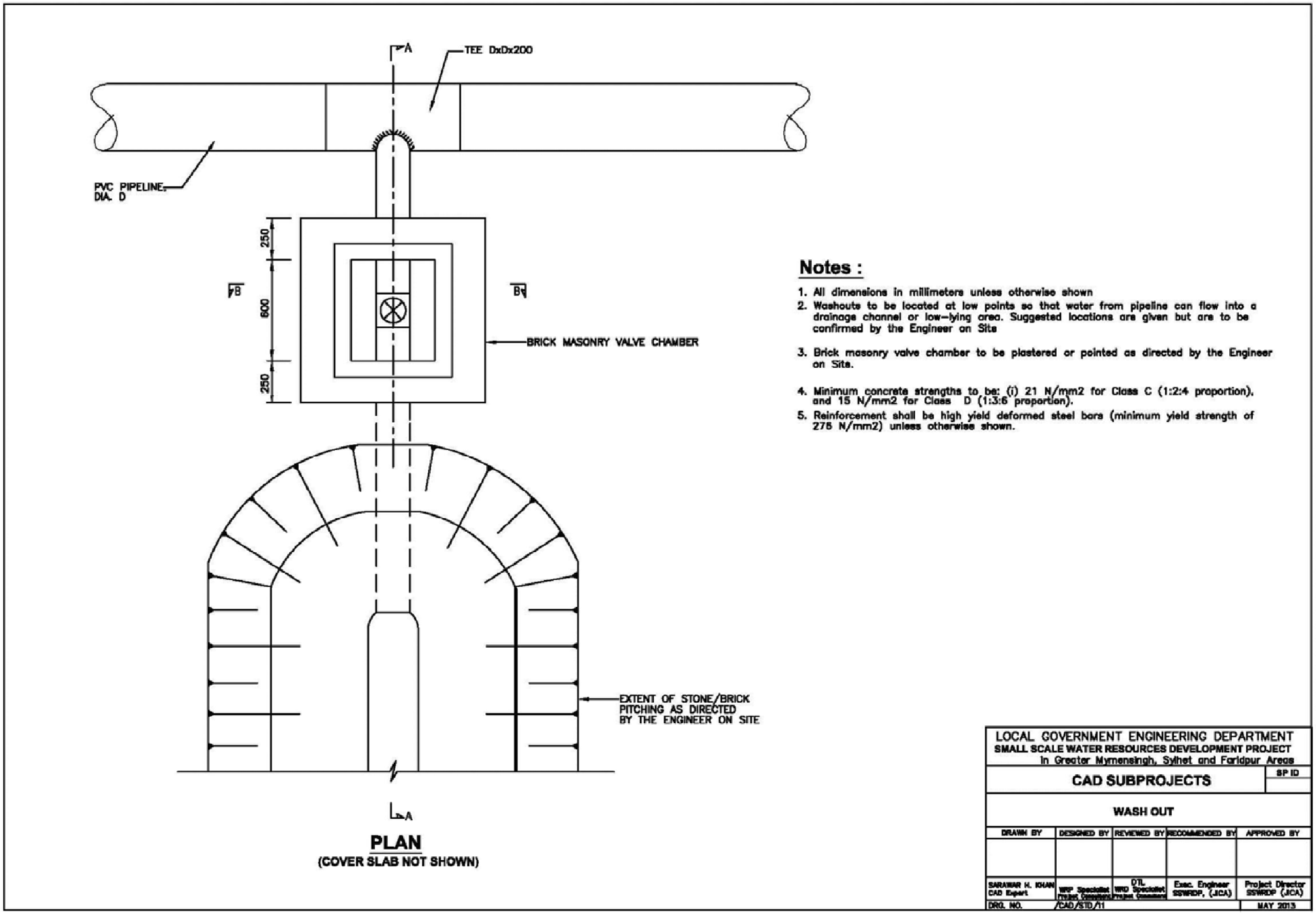
OUTLET TO DISCHARGE BOX FOR HOSE IRRIGATION

DRAWN BY	DESIGNED BY	REVIEWED BY	RECOMMENDED BY	APPROVED BY
SARAWAR H. KHAN CAD Expert	WRP Specialist Project Consultant	DTL WRD Specialist Project Consultant	Exec. Engineer SSWRDP, (JICA)	Project Director SSWRDP (JICA)
DRG. NO.	/CAD/STD/09			MAY 2013

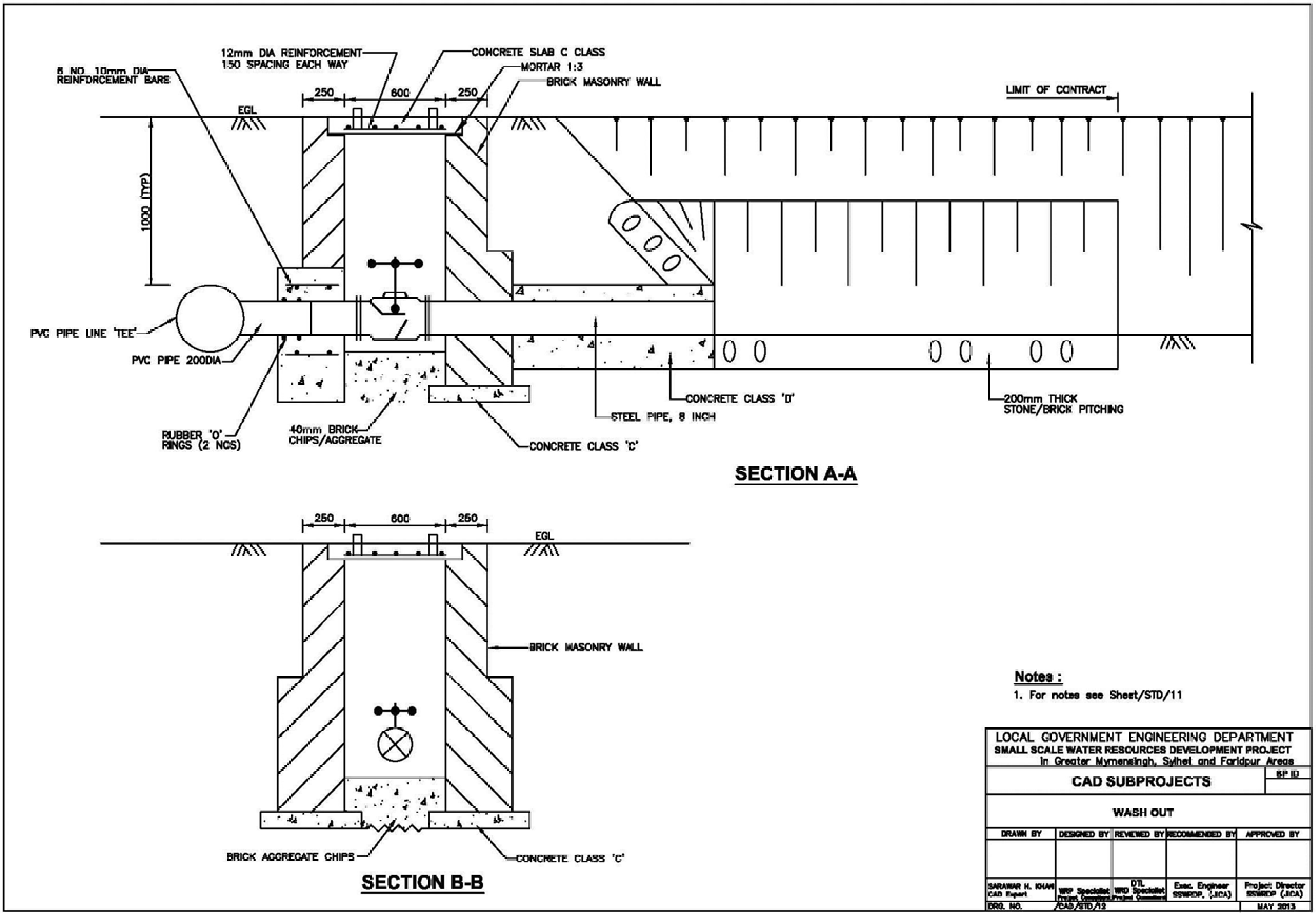
Appendix E6: Standard Drawings (Standpipe for Hose Irrigation)



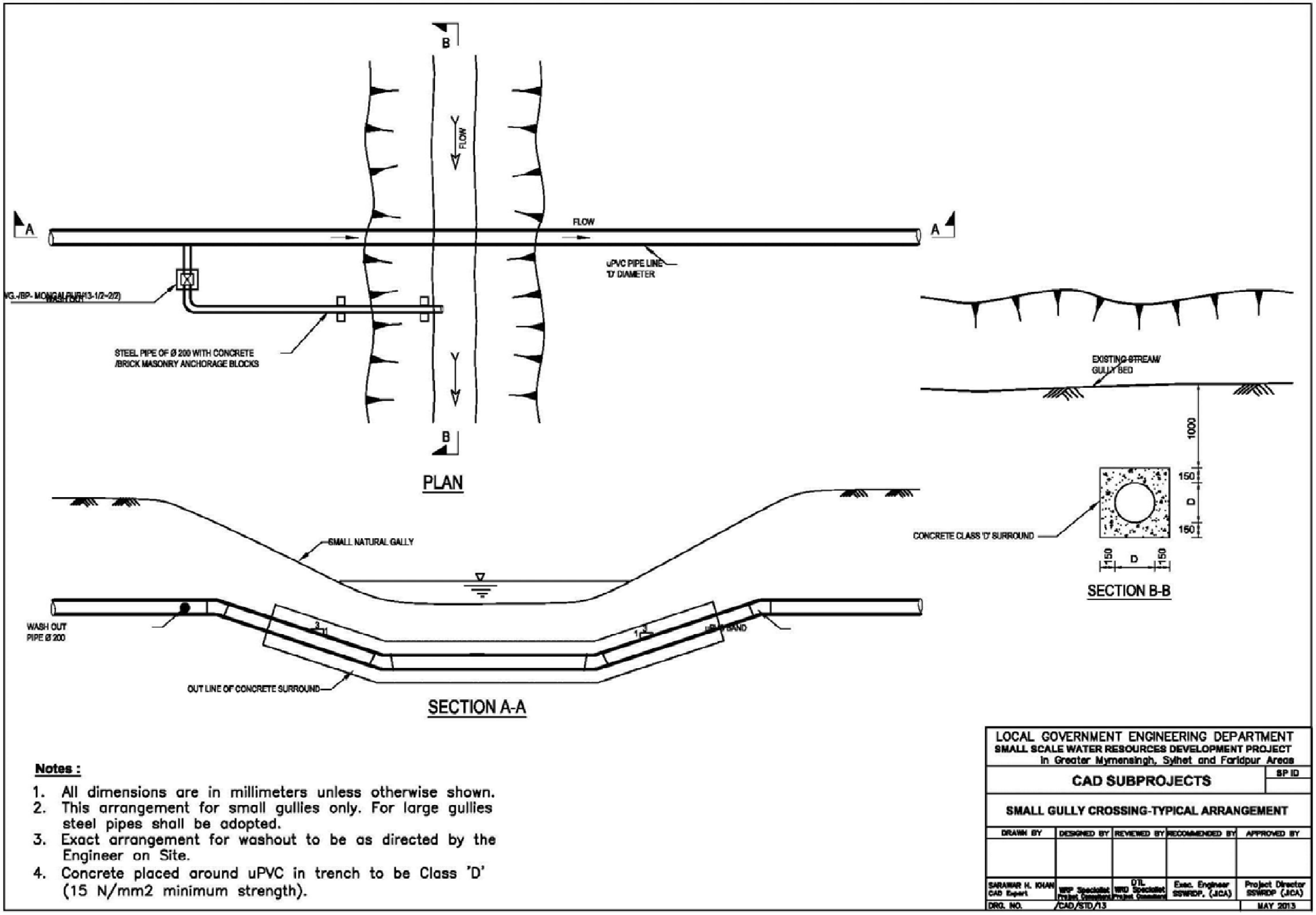
Appendix E6: Standard Drawings (Wash Out)



Appendix E6: Standard Drawings (Wash Out)



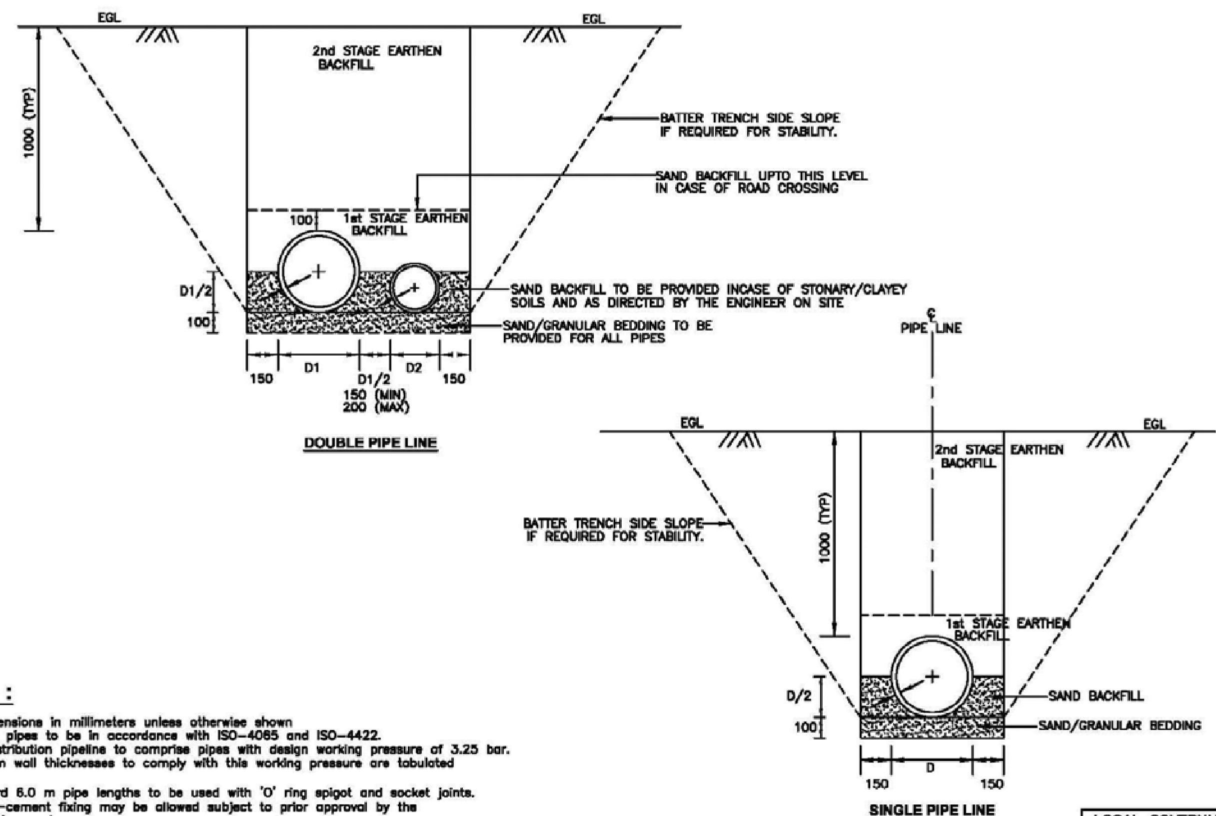
Appendix E6: Standard Drawings (Small Gully Crossing – Typical Arrangement)



Notes :

1. All dimensions are in millimeters unless otherwise shown.
2. This arrangement for small gullies only. For large gullies steel pipes shall be adopted.
3. Exact arrangement for washout to be as directed by the Engineer on Site.
4. Concrete placed around uPVC in trench to be Class 'D' (15 N/mm2 minimum strength).

Appendix E6: Standard Drawings (Conveyance Pipeline Trench Construction)



Notes :

1. All dimensions in millimeters unless otherwise shown
2. All PVC pipes to be in accordance with ISO–4065 and ISO–4422.
3. PVC distribution pipeline to comprise pipes with design working pressure of 3.25 bar. Minimum wall thicknesses to comply with this working pressure are tabulated
4. Standard 6.0 m pipe lengths to be used with 'O' ring spigot and socket joints. Solvent–cement fixing may be allowed subject to prior approval by the supervising engineer
5. The excavated trenches shall have a uniform grade and free of clods, stones and rock and standing water.
6. Testing of the pipeline for leakage and proper functioning shall be carried out before backfilling of trenches.
7. Earthen backfill shall comprise compacted earthen material free from stones / rocks larger than 15 mm in diameter (1st stage) and 75mm (2nd stage) First stage backfill around the pipe shall be placed and compacted by hand.
8. Pipeline sections that pass: (i) under roads; and / or (ii) through drainage alignments shall be provided with a concrete surround to prevent damage and / or floatation.
9. Concrete (thrust blocks) shall be placed on the outer side of bends etc to prevent movement of the pipe all as per the specification.

LOCAL GOVERNMENT ENGINEERING DEPARTMENT
SMALL SCALE WATER RESOURCES DEVELOPMENT PROJECT
in Greater Mymensingh, Sylhet and Faridpur Areas

CAD SUBPROJECTS	SP ID

CONVEYANCE PIPE LINE TRENCH CONSTRUCTION

DRAWN BY	DESIGNED BY	REVIEWED BY	RECOMMENDED BY	APPROVED BY
SARAWAR H. KHAN CAD Expert	WRP Specialist Project Consultant	D/TL WRD Specialist Project Consultant	Exec. Engineer SSWRDP, (JICA)	Project Director SSWRDP (JICA)
DRG. NO.	/CAD/STD/14			MAY 2013

Appendix F

Pumping Characteristics for Selected Pumps

Pump Curve for Milner Pump: A: ETA 80-20

Pump Curve for Milner Pump: B: ETA 100-20

Pump Curve for Milner Pump: C: ETA 125-20

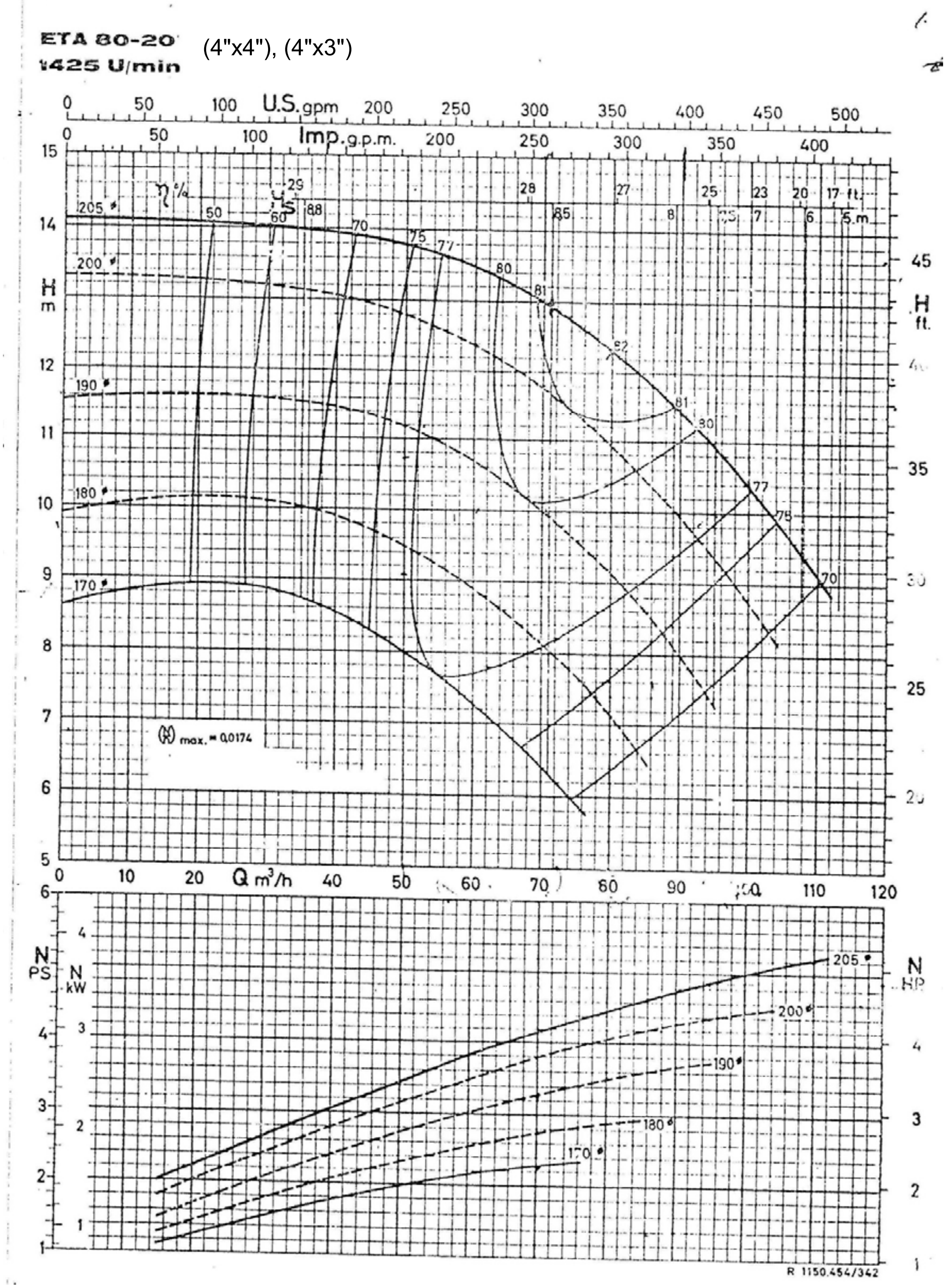
Pump Curve for Milner Pump: D: ETA 100-26

Pump Curve for Milner Pump: E: ETA 125-26

Pump Curve for Milner Pump: F: ETA 150-26

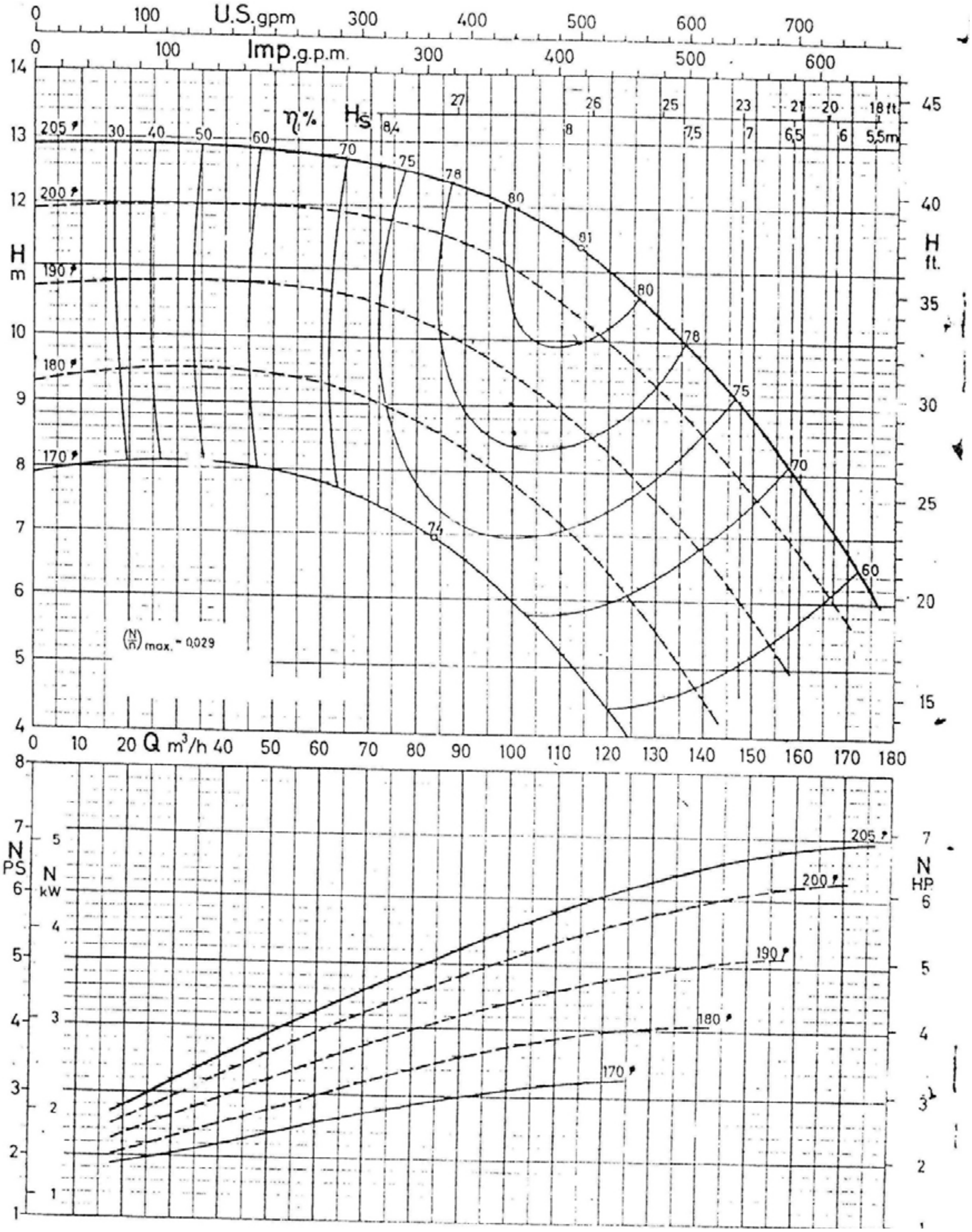
Pump Curve for Yanshan Pump: 250 S24

Pump Curve for Milner Pump: A: ETA 80-20

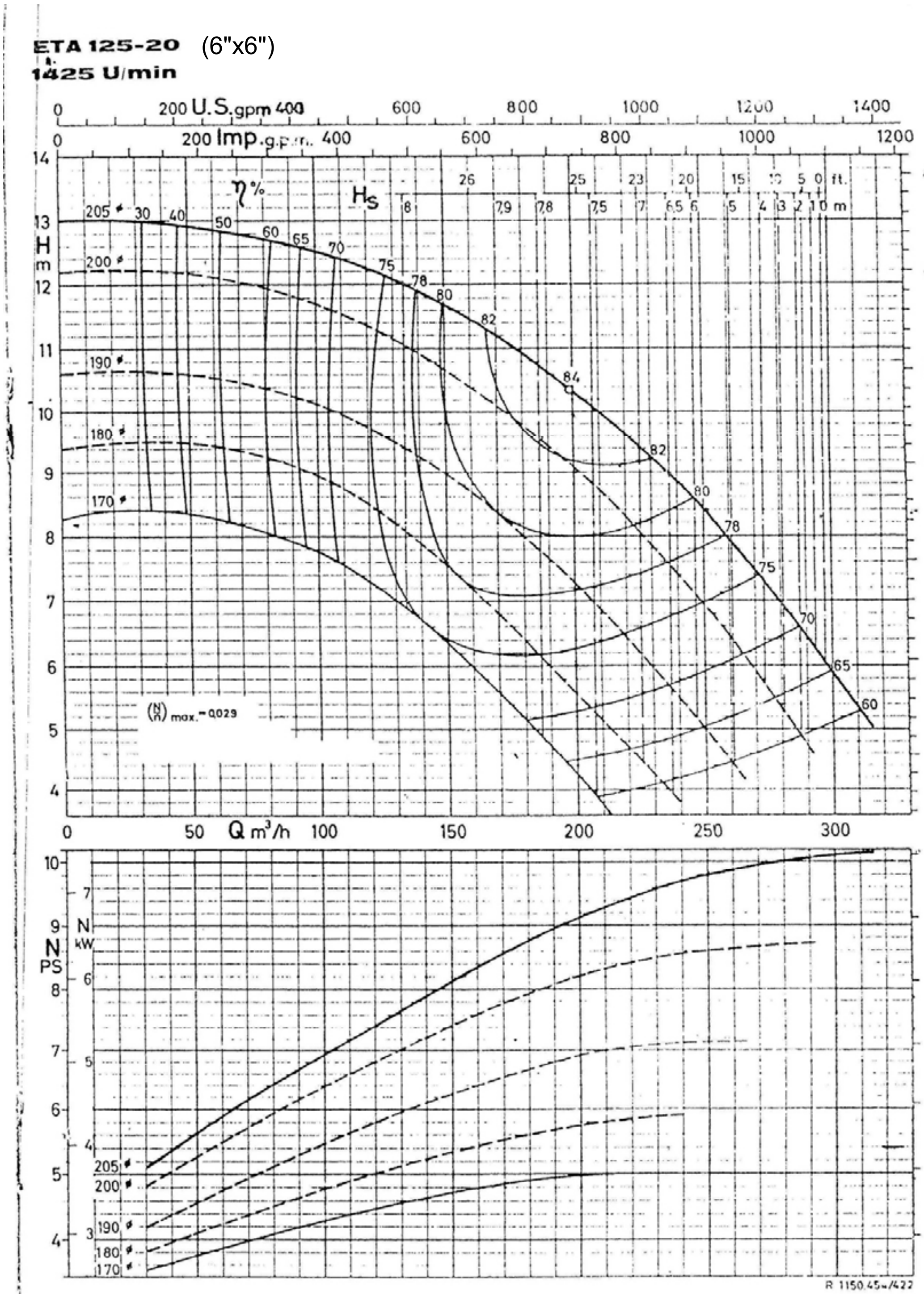


Pump Curve for Milner Pump: B: ETA 100-20

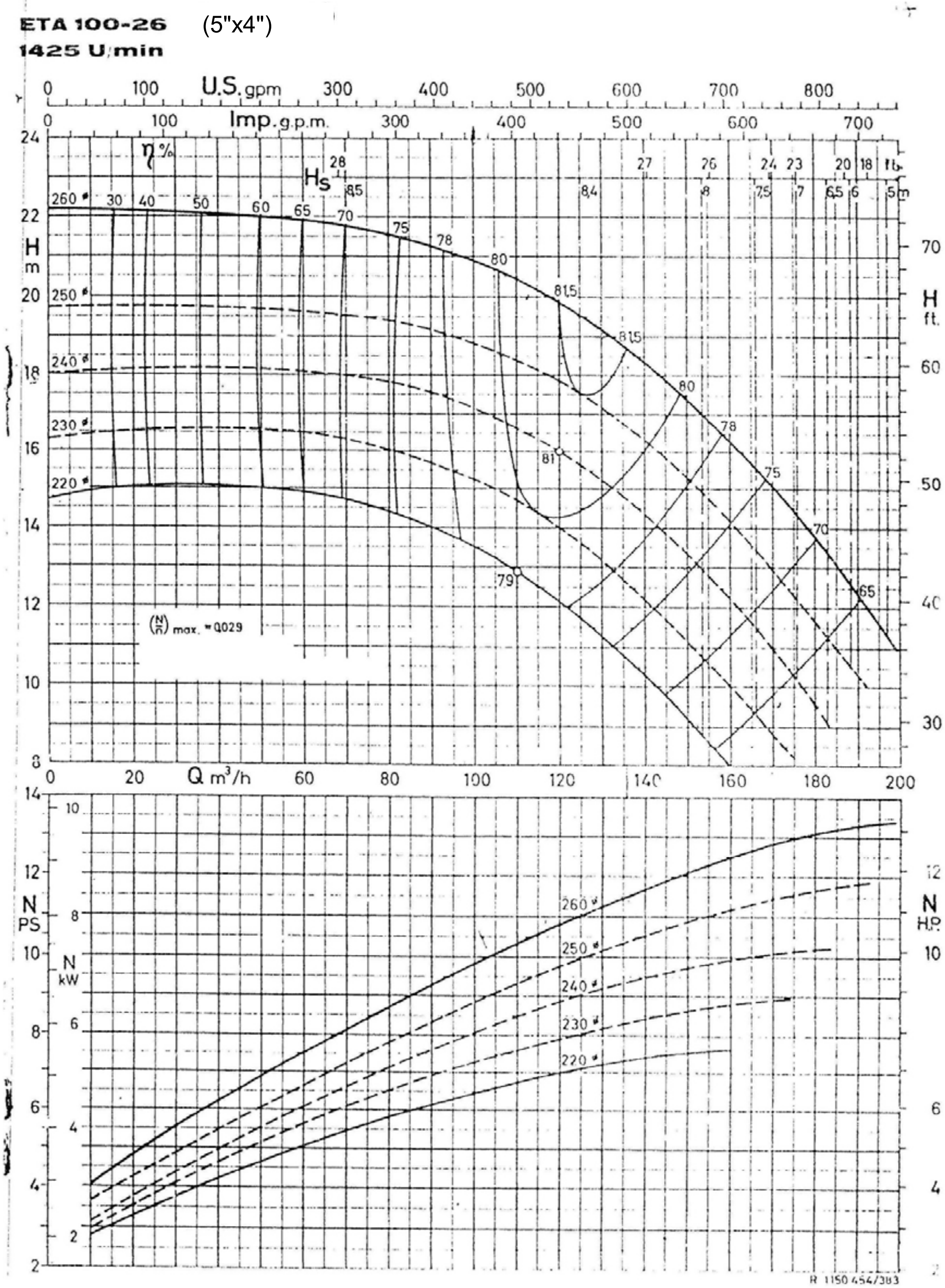
ETA 100-20 (5"x5")
1425 U/min



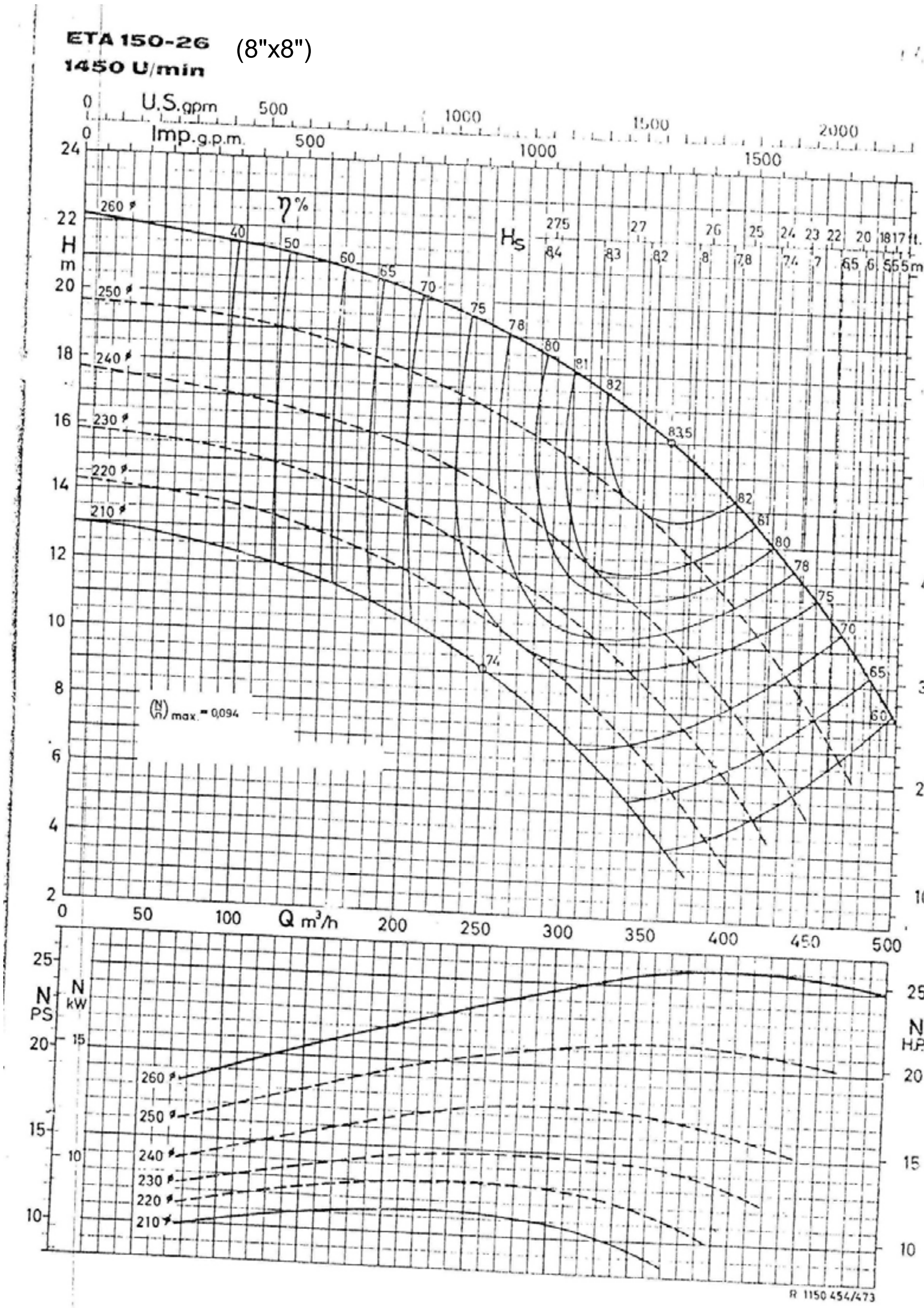
Pump Curve for Milner Pump: C: ETA 125-20



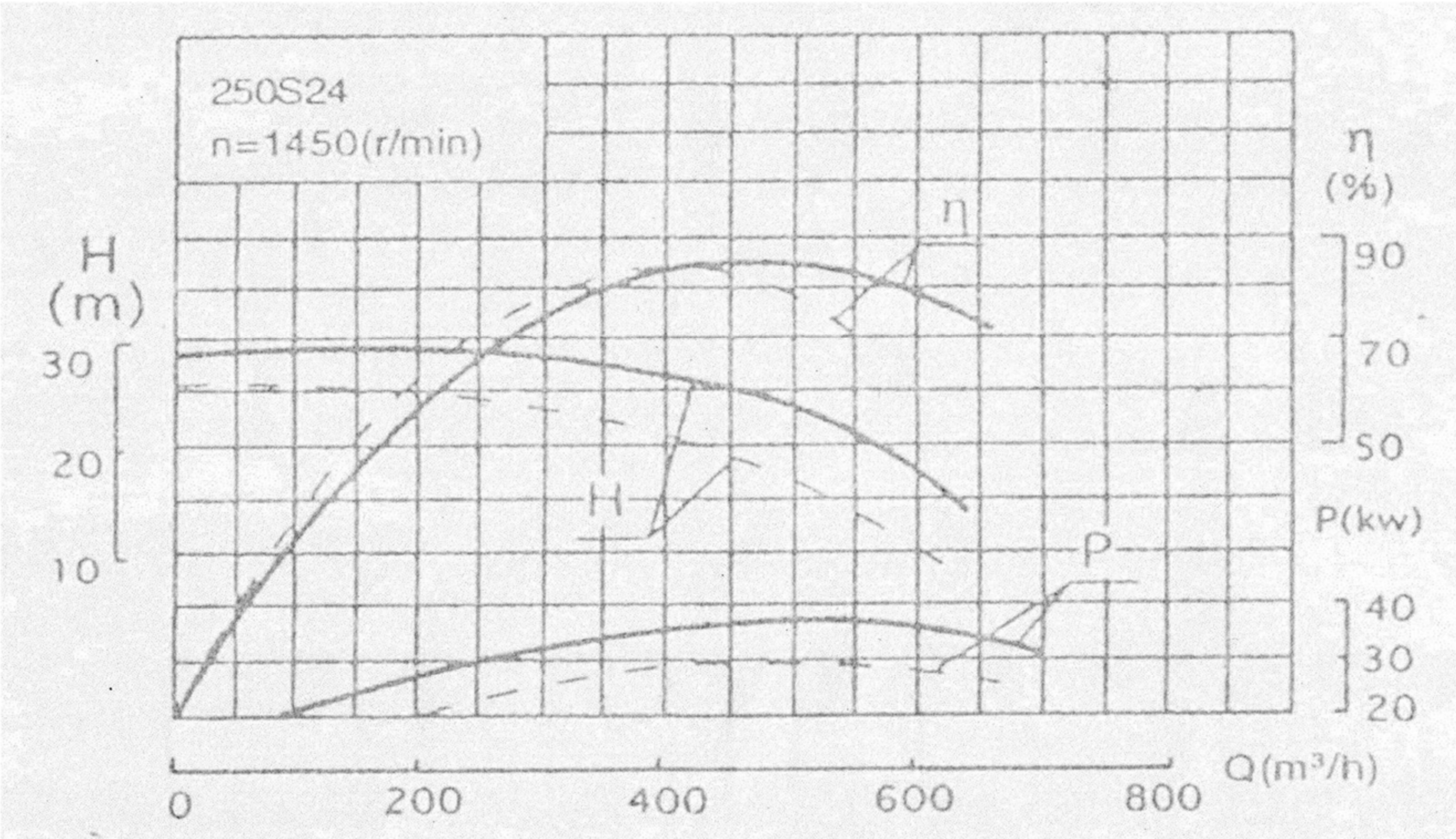
Pump Curve for Milner Pump: D: ETA 100-26



Pump Curve for Milner Pump: F: ETA 150-26



Pump Curve for Yanshan Pump: 250 S24 (10 inch)



Appendix G

Sample Specification for uPVC Pipe Distribution System

Sample Specification for uPVC Pipe Distribution System

1. Introduction

This part of the Specification covers the conveyance pipe system works including: (i) pipe sizes, wall thickness and material specification; (ii) pipe storage and handling; (iii) pipeline layout and location of structures; (iv) trench construction; (v) pipe placement and jointing; (vi) structure connections; (vii) thrust control; and (viii) pipeline testing and backfill.

Works for pipeline system structures, including as applicable, control structures, riser outlets; standpipe air-vents, standpipe escapes and washouts are covered by the General Specifications.

2. uPVC Pipes and Fittings Appearance and Sizes

2.1 Appearance

When viewed without magnification the internal and external surfaces of the pipes and fittings shall be smooth, clean and free from scoring, cavities and other surface defects. The material shall not contain visible impurities. The ends of the pipes and fittings shall be clean and square to their axes. The colour of the pipes and fittings shall be grey.

2.2 Pipe and Fitting Sizes and Wall Thickness

The base material from which the uPVC pipes are produced shall be un-plasticised Polyvinyl Chloride (PVC"u") with additives as necessary for manufacture in accordance with ISO 4065: 1996(E).

All fittings having sockets shall comply with ISO 727-1985 and shall be compatible with the pipes supplied.

Wall thicknesses of uPVC pipes and pipe fittings shall be commensurate with a working pressure rating of 3.25 bar (32 m head). Required wall thickness shall be determined in accordance with ISO 4065: 1996(E), having a SDR value of 81 (equivalent to PN 3.25)

The pipes shall have one end socket and one end spigot (plain). The spigot end shall be chamfered to facilitate insertion into the socket of the adjacent pipeline / fitting. The socket shall be machine made.

The length of the pipes shall be 6.0 m including socket. Pipe diameters and wall thickness are tabulated below for the range of pipes and pipe fittings likely to be used.

uPVC Pipes Diameters and Wall Thicknesses

Nr	External Diameter (mm)	Nominal Wall thickness (mm)	Internal Diameter (mm)	Length (m)
1	160	2.00	156	6.00
2	180	2.30	175	6.00
3	200	2.50	195	6.00
4	225	2.80	219	6.00
5	250	3.10	244	6.00
6	280	3.50	273	6.00
7	315	4.00	307	6.00
8	355	4.40	346	6.00
9	400	5.00	390	6.00
10	450	5.60	439	6.00
11	500	6.20	488	6.00
12	560	7.00	546	6.00

uPVC Tee Dimensions and Wall Thicknesses

Nr	Dimensions - External Diameter (mm)	Nominal Wall thickness (mm)	Length (m)
1	Tee 160 x 160 x 160	2.50	1.47
2	Tee 180 x 180 x 180	2.80	1.47
3	Tee 200 x 200 x 200	3.20	1.47
4	Tee 225 x 255 x 255	3.50	1.47
5	Tee 250 x 250 x 250	3.90	1.47
6	Tee 280 x 280 x 280	4.40	1.47
7	Tee 315 x 315 x 315	4.90	1.47
8	Tee 355 x 355 x 355	5.60	1.98
9	Tee 400 x 400 x 400	6.30	2.29
10	Tee 450 x 450 x 450	7.00	2.67
11	Tee 500 x 500 x 500	7.80	2.67

uPVC Bend Dimensions and Wall Thicknesses

Nr	Dimensions - External Diameter (mm)	Nominal Wall thickness (mm)	Length (m)
1	Bend 160	2.50	1.52
2	Bend 180	2.80	1.52
3	Bend 200	3.20	1.52
4	Bend 225	3.50	1.52
5	Bend 250	3.90	1.52
6	Bend 280	4.40	1.52
7	Bend 315	4.90	1.52
8	Bend 355	5.60	1.52
9	Bend 400	6.30	1.98
10	Bend 450	7.00	1.98
11	Bend 500	7.80	1.98

uPVC End Caps Dimensions and Wall Thicknesses

Nr	Dimensions - External Diameter (mm)	Nominal Wall thickness (mm)	Length (m)
1	End cap 160	2.00	0.56
2	End cap 180	2.30	0.56
3	End cap 200	2.50	0.56
4	End cap 220	2.80	0.56
5	End cap 250	3.10	0.56
6	End cap 280	3.50	0.56
7	End cap 315	4.00	1.42
8	End cap 355	4.40	1.42
9	End cap 400	5.00	1.42
10	End cap 450	5.60	1.42
11	End cap 500	6.20	1.42

3 Pipe Testing and Marking

3.1 Pipe Testing

The following tests shall be conducted for uPVC pipes on representative samples of each diameter of pipe required. Testing shall be carried out in any reputable laboratory as required by the Engineer.

Dimensions: The thickness of the pipes and pipe fittings shall not be less than the nominal thicknesses tabulated, and shall not exceed the nominal thickness by more than 15%.

Short Term Hydrostatic Test: For a temperature of 200C and a test pressure of 9.5 bar the pipes shall not fail within a period of 1.0 hrs.

Heat Reversion Test: The longitudinal reversion value in accordance with the test requirements of ISO 2505 shall not be greater than 5%.

Impact Strength: Impact strength at 200C shall satisfy ISO 3127.

Resistance to Acetone: A short length of pipe shall be immersed in acetone vertically to a depth of at least 25 mm at room temperature for 2 hours shall not show any attack on the surface of the test piece. Fattening and / or swelling of the pipe shall not be deemed to constitute failure.

Specific Gravity: The specific gravity of the pipe material shall be within 1.35 to 1.45.

3.2 Pipe Marking

Pipes shall be permanently marked at intervals no greater than 2.0 m. The marking shall include the following information:

- Manufacturers name or trademark
- Nominal outside diameter
- Pipe material (uPVC)
- Standard (ISO 4065: SDR 81)
- Date (and time) of manufacture
- LGED
- Not for sale

3.3 Fitting Marking

The marking of fittings shall include the following information:

- Manufacturers name or trademark
- Sizes
- Fitting material (uPVC)
- Standard (ISO 727)
- Date (and time) of manufacture
- LGED
- Not for sale

4 Pipe Handling and Storage

4.1 Receiving Pipes and Fittings

All pipes and pipe fittings received on Site shall be visually inspected for damage which may have occurred during transit. Ends shall be checked for any cracks or splits or other damage. The pipes shall also be checked for any severe deformation which could later cause jointing problems.

Any damaged pipes and fittings should be returned to the place of manufacture / procurement and will be not be accepted in the permanent works.

4.2 Handling

The pipes and fittings should be handled with reasonable care. They are relatively light and must not be thrown around and / or dropped from any height.

Pipes and fittings should not be dragged / pushed / dropped from a truck bed. Loose pipes may be rolled down on a timber support but care must be taken that they do not fall on each other or on any hard or uneven surface.

4.3 Storage

Pipes should be stored on level ground which is dry and free from sharp objects. Different pipe sizes should be stored separately.

The pipes and fittings shall be protected from the sun.

Pipes should be continuously supported along its length. If this is not possible the spacing of supports should not exceed 1.0 m.

Pipes shall not be stacked to a height in excess of 2 m, or 6 layers, whichever is the lesser.

5 Pipeline Layout and Location of Structures

The contractor shall confirm the pipeline layout and lengths of each size of pipe required under the contract by setting out the pipeline(s) prior to trench excavation, marking all pipe bends and structure locations with marker flags. The marker flags shall be at least 1.6m in height.

The locations of riser outlets shall be discussed and confirmed by the outlet farmers represented by the the Organizing or Management Committee of the WMCA, all as directed by the Engineer-in-Charge.

6 Trench Construction

The trench shall be excavated to a depth to ensure cover to the top (crown) of the pipe of typically 1.0 m, and at least 0.8 m. The trench grade (longitudinal slope) shall be as shown on the drawings or as otherwise directed by the Engineer-in-Charge, so as to provide uniform slopes between pipeline structures.

The trench below the top of the pipe shall be only wide enough to permit the pipe to be easily placed and joined, and to allow for initial backfill material to be uniformly placed under the haunches and along the side of the pipe. The usual trench width shall be D + 0.3 m where D is the pipe outside diameter.

Where stable conditions exist trench side slopes shall be vertical subject to safety considerations. Where necessary for side slope stability, trenches may be excavated with sloping sides. Where working conditions and / or right-of-way restricts width, the sides of the trench shall be shored using timber boards braced across the trench.

The trench bottom shall be uniform so that the pipe is fully supported without “bridging”. Clods, stones and uneven spots that can damage the pipe or cause non-uniform support shall be removed. A small layer of bedding material (sand) may be spread over the bottom of the trench to facilitate uniform support to the pipe.

Where rocks, stones or uneven material are encountered, the trench bottom shall be cut 100 mm below the required grade, and backfilled with bedding material (sand).

Excavated material shall be placed along one side the trench, allowing easy access from the other side for placement of pipes prior to laying.

The excavated trenches shall be fenced / marked off as directed by the Engineer-in-Charge to prevent people / animals falling into the trench.

Where ground water is encountered it shall be kept below the formation level of the pipes to be joined by pumping, side drainage trench construction, placement of sand in the trench bottom and any other measures as directed by the Engineer-in-Charge.

7 Pipe Placement and Joining

Small holes shall be excavated for the socket ends of the pipes to permit the pipe body to be uniformly supported along its whole length. Pipe laying may start from any structure location and shall proceed in a downstream direction.

Pipes shall be carefully placed in the excavated trench for joining after removal of all foreign matter or dirt. Prior to joining the connecting surfaces of the spigot and socket shall be cleaned with a rag or brush.

The pipe socket (bell end) should be aligned downstream. Ensure that the rubber gasket (ie “O” ring) is placed correctly in the socket and that lubricant is applied to the spigot of the adjacent downstream pipe. The spigot should be smoothly chamfered – if necessary any minor irregularities may be filed off.

The two pipes should be carefully aligned and the spigot of the downstream pipe inserted into the socket (bell end) of the upstream pipe applying firm pressure, either by hand or using a “bar and block” assembly. A small twisting motion may be useful for smaller pipe diameters. Care should be taken to avoid over entry of the spigot into the socket.

Pipes shall be cut by a method which provides a clean square profile with splitting of damage to the pipe wall. Cut spigot ends shall be chamfered.

8 Structure Connections

Minor settlement of rigid structures will not usually cause shear breakage of the uPVC pipe, and the pipes may be placed directly into concrete structures. As uPVC pipe will not bond with concrete water seal is provided by two “0” ring rubber gaskets placed 100 mm apart in the wall of the structure.

To minimize differential settlement initial pipe backfill within 1 m of the structure shall comprise sand. Further to accommodate any differential settlement, rubber “O” ring pipe joints shall be provided to all pipelines within 1 m of the structure.

9 Thrust Control

Thrust control (joint restraint) is required to prevent pipe movement and damage at the following locations: (i) changes in pipe direction (eg tees, bends, elbows, etc); (ii) change in pipe size; (iii) dead ends (end caps). Thrust control shall comprise Class D concrete placed between the pipe and the (vertical) side of the excavated trench to resist movement.

10 Initial and Final Backfill

10.1 Initial Backfill

Initial backfill shall be by hand and shall comprise soil or sand that is free from stones larger than 15 mm in diameter. At the time of placement the moisture content of the material shall be such good compaction can be achieved. Initial backfill shall not be carried out during wet weather.

Initial backfill shall be placed under and around the pipe and to provide 50 mm cover to the pipe top (crown). Initial backfill shall be compacted firmly to provide adequate lateral support to the pipe and prevent movement. Compaction shall be carried out using a steel plate or other approved rammer at least 12 kg in weight in 100 mm thick compacted layers.

Pipeline testing and commissioning shall be carried out after initial backfilling of the pipeline trench, but before final backfill unless otherwise approved / directed by the Engineer-in-Charge.

Grounds for carrying out final backfill prior to testing may include: (i) a real and identified risk of pipe floatation; (ii) safety hazard – particularly near settlements; (iii) blocking of right of way, etc.

10.2 Final Backfill

Final backfill may be by hand or machine.

Final backfill material shall be free from large stones and other debris larger than 75 mm in diameter. The material shall be placed and spread in approximately uniform layers to fully fill the trench. Final backfill shall be placed and compacted by iron rammer in 250 mm thick compacted layers.

10.3 Concrete Backfill

To ensure against floatation and / or scour and exposure of the pipeline where it crosses natural drainage lines, the initial backfill material may comprise concrete Class D placed and compacted under and around the pipe and to a depth of 100 mm over the top of the pipe.

Concrete backfill shall also be used where the pipeline crosses under road embankments.

11 Pipeline Testing and Commissioning

The pipeline shall be tested for leakage and to ensure that design flows are supplied to all outlets along the pipeline before final backfilling. As part of the commissioning process, in additional to checking of flows at each outlet, water levels in the standpipes shall be measured and adequacy of freeboard confirmed at the design flows.

The reasons for any instances of inadequate freeboard shall be reported to the concerned authorities / design engineers and the cause determined (eg foreign material left in pipeline, inaccurate measurement of pipe length, wrong pipe diameter used, etc). Following identification of the causes remedial measures / actions shall be taken as ordered by the Engineer-in-Charge.

If for reasons of safety and / or cropping necessity, (parts) of the pipeline are fully backfilled prior to testing and system commissioning then the Contractor shall re-excavate selected parts of the pipeline, and any areas where surface wetness is observed, to expose the joints and check for any leakage as ordered by the Engineer-in-Charge.

Any leaks or damaged pipes / pipe seals shall be repaired and the pipeline retested.

12 Pumping Plant, Transformer and Electrical Connection

12.1 General

The following may be provided under the CAD subproject contracts subject to instruction by the Engineer-in-Charge, and in accordance with the requirements of the Power Development Board:

- Pumping plant and associated pipeline and fittings
- Transformer and Electrical installation
- Electrical transmission line

12.2 Pumping Plant and associated pipeline and fittings

The number, pumping discharge and pumping head of the required pumps, as well as indicative power requirements are indicated as appropriate in **Section 7: Particular Specifications** and in **Section 9: Bill of Quantities**.

Any electric motor(s) provided shall have the following: (ii) AC 3-phase, 50 Hz, 380 +5% Voltage squirrel cage; (ii) Starter enclosed within metal box and ensuring adequate protection to motor against overload and with 3-phase volt and amp meter and neon indicators; (iii) Capacitor Bank to keep power factor on 0.95 and installed inside Starter Box; (iv) Switch Fuse Unit (Main Switch) with indicator lamps suitable for outside use and complete with housing; (v) a steel Base-frame which shall have lug-holes to allow for bolting to a concrete plinth. The pump set and steel frame shall be painted with anti-corrosion paint.

Any diesel engine(s) provided shall have the required rated power and shall be provided complete with self starter and battery, all mounted on a steel Base-frame. The base-frame shall have lug-holes to allow for bolting to a concrete plinth. The pump set and steel frame shall be painted with anti-corrosion paint.

Pipes, Valves and Associated Fittings

Mild steel galvanized / painted steel suction and delivery pipes shall be provided for each of the pumps sets (pump & motor) complete with bolted flange/ welded connections, bends and arrangement to facilitate pump priming. The pipelines shall be of sufficient length to allow water to be pumped during the lean season from the river / khal to the header tank / discharge box. The diameter of the steel pipes shall not be less than the pump size. Unless otherwise directed by the Engineer gate valves shall be provided in each of the delivery pipelines leading from the pump. These shall be fixed with bolted flange connections to allow for replacement as necessary. MS perforated foot valves galvanized / painted with anticorrosion paint shall be provided to the end of the suction pipes.

Number and Model of Pump Sets and Associated Pipes and Fittings

To allow for varying irrigation (crop) demand during the lean season at least three pump sets are recommended for the CAD subprojects, and in general 3-6 pumps will be provided depending on scheme size, location and crops grown.

12.3 Transformer and Electrical Installation

A complete electrical installation shall be provided for operation of the pumping plant. Since night time operation is envisaged a 65 Watt tubular fluorescent light or similar approved shall be provided, as well as electrical meter, power sockets, switchboard and pumping plant transformer all as required. Theses shall be located at / near the pumping / header tank site as directed by the Engineer-in-Charge.

The switchboard, electrical meter, power sockets and lighting shall be wall mounted, for water proofed construction and with protective cover(s) for security and water proofing, unless located inside a building that may or may not be available on Site.

All cables shall be adequately supported and present a neat appearance. Cables shall be fixed using proper cable cleats or saddles.
The wall mounted switchboard shall receive power from the transformer and distribute it to the pumping plant.

12.4 Electrical Transmission Line

The contractor shall supply and install an overhead electric cable connection complete with supporting poles from the existing electrical distribution system to the pumping plant transformer.

12.5 Testing and Commissioning of Electrical Equipment

The Contractor shall test and commission the electrical equipment along with the pumping plant whether sourced under this contract or some other arrangement all in accordance with requirements of the Power Development Board and as directed by the Engineer-in-Charge.

Appendix H

Selected Photographs

Production of spun concrete pipes
(SP 31001, Rouha, Mymensingh)

Spun concrete pipes – curing
SP 31001 Rouha, Mymensingh

Placed concrete pipes with mortared joints
SP 31001 Rouha, Mymensingh

Pressure Testing of concrete pipes
(in SSWRD this is not carried out)

Elevated concrete pipe aqueduct
(Orissa, India)

Leakage from joints of buried concrete pipeline

Storage of uPVC pipes
SP 35161 Noyemullah Khal, Habiganj

Manufacture of uPVC Pipes
RFL Factory, Bangladesh

T-placed on pipe for airvent standpipe
SP33059 Baneswardi, Faridpur

Backfill to uPVC Pipe
SP 33097 Mongalpur, Sunamganj

Airvent standpipe about 5 m high
(near to head of system)
SP 33044 Bajra Panai, Faridpur

Airvent standpipe about 1.4 m high
(at tail of system)
SP 33044 Bajra Panai, Faridpur

Standpipe airvent which is not suffiently high and venting water
SP 33096 Saherber Gaon, Sunamganj

Piezomentric tube not yet fixed to airvent standpipe
SP 33096 Saherber Gaon, Sunamganj

Outlet riser box with alfalfa valve for flow control
SP 25288 Dariapur, Chapai Nawabganj

Flow from pucca-nucca / outlet riser box during system testing
SP 33096 Saherber Gaon, Sunamganj

Outlet box arrangement with pucca-nucca to control flow to field channels
SP 25240 Chara Para, Unmesh, Mymensingh

Locked cover to prevent tampering with alfalfa valve
SP 25240 Chara Para, Unmesh, Mymensingh

Cast Iron Alfalfa Valve

Steel pipe with flange to connect to uPVC pipe
SP33059 Baneswardi, Faridpur

Factory mande connection between flanged steel and uPVC pipes
SP 41008 Goshinga, Gazipur

Gate valves for on / off flow control may be used instead of alfalfa valves built into flow control structures
SP 41008, Goshinga, Gazipur

Header Tank under construction
SP 33096 Saherber Gaon, Sunamganj

Completed Header Tank
SP 33096 Saherber Gaon, Sunamganj

Access ladder arrangement to top of Header Tank, SP 25288 Dariapur, Chapai Nawabganj

Handles to open / close valves from top of tank, SP 33096 Saherber Gaon, Sunamganj

Flow measurement V-notch weir between compartments 2 & 3, SP 33096 Saherber Gaon, Sunamganj

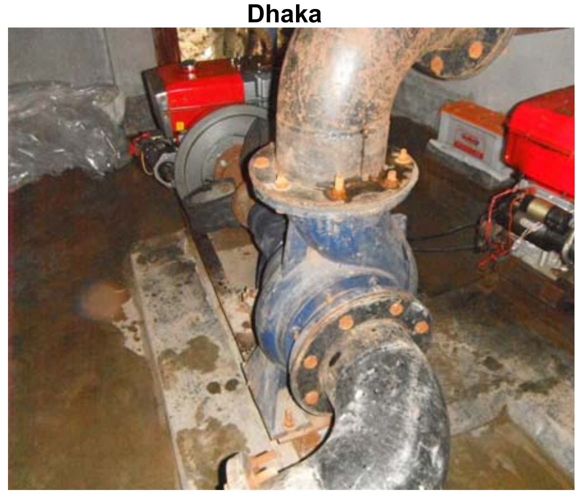
Operating Platform on top of Header Tank, SP 33096 Saherber Gaon, Sunamganj

Pump house and header tank
SP 33044 Bajra Panail, Faridpur

Operating Platform
SP33059 Baneswardi, Faridpur

2 diesel motors & pumps installed in pump house, SP33059 Baneswardi, Faridpur

Electric motor and pump mounted on steel frame / skid, Milner Pump Foundry, Tongi, Dhaka



Diesel Pump set arrangement
Baneswardi Pump House

Screen (& Foot valve) at end of Suction Pipe

Gate (Sluice) Valve